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MASTER DRAINAGE PLAN
WESTERN DEVELOPMENT LANDS
VILLAGE OF RICHMOND

FOR

WESTERN DEVELOPMENT LANDS LANDOWNERS

CITY OF OTTAWA

PROJECT NO.: 17-977

OCTOBER 11, 2019 – REV 5

EXECUTIVE SUMMARY / OUTLINE

This Master Drainage Plan (MDP) has been prepared as requested by City of Ottawa staff to reflect the updates to the ***Sewer Design Guidelines*** regarding the level of service for the minor system. The following is an executive summary or outline of the history of the MDP for the Western Development Lands to provide details of what has been updated.

History

The November 2012 stormwater management report presented facility treatment types, locations, and provided a recommended stormwater facility solution for the subject lands. The final November 2013 stormwater management report expanded upon the previously recommended solution. Furthermore, the November 2013 report outlined various storm conveyance alternatives and presented a detailed review of the recommended conveyance solution. The November 2013 report was finalized for the Western Development Lands on behalf of Richmond Village (South) Limited, which will now be referred to as the Richmond Village Development Corporation (RVDC). The historical information in the November 2013 has been included in this updated MDP for reference but remains unchanged. The information in the final report was approved through the Ontario Municipal Board (OMB) per the decision dated June 23, 2014.

The objective of this updated report is to provide sufficient detail with respect to the stormwater management system including minor and major system conveyance and stormwater facilities to support the Mattamy (Jock River) Limited draft plan of subdivision application and is also applicable to other entities within the Western Development Lands area. The revisions have been made to reflect the following updated information since 2014, primarily the updates to the ***Sewer Design Guidelines***. Where applicable, historical documents, which remain relevant, are referenced and contained in the appendices.

Section 1.0 - Introduction and Approvals

As development has proceeded with the RVDC Lands, which were draft approved in 2015, with Phase 1 currently under construction and Phase 2 in detailed design stage, several approvals are in place with respect to the City of Ottawa, MECP, RVCA and DFO. Additional approvals are required for future works from all agencies.

Note that Section 1.3 Study Process is historical information relating to the approval of the MDP and remains unchanged. Section 1.4 Public and Agency Consultation provides reference to the previously coordinated summary of meeting results; however, it is noted that this is historical and subsequently replaced by the OMB decision. Section 1.5 is included to reference the OMB Decision of June 23, 2014.

Section 2.0 - Guidelines, Previous Studies and Reports

This section has been updated to reflect the up to date studies, guidelines and reports. Notably, the references to the City of Ottawa ***Sewer Design Guidelines*** Technical Bulletins.

Section 3.0 – Existing Conditions

Geotechnical conditions have been updated to reflect the updated information available since the 2007 Jacques Whitford Report was produced for the Western Development Lands. Mattamy and Caivan have retained Paterson Group and Golder Associates, respectively, to prepare supplemental geotechnical investigations for their land holdings. The Jacques Whitford report is included as it provides historical recommendations as well as preliminary recommendations for lands that have not yet proceeded with planning applications.

Where there is new information, existing floodplain has been updated. Notably, Mattamy has received a new permit to place fill behind and existing berm between the Jock River and Ottawa Street.

An update has been made to Section 3.3 Geomorphology to explain the status of the realignment of the existing Van Gaal Drain, which is approved and has gone through the Drainage Act process.

Section 3.4 Pre-Development Drainage Conditions remains unchanged.

Section 3.5 Hydrogeology has been updated to reflect the current groundwater monitoring and reporting on-site.

Section 4.0 - SWM Servicing

This MDP section was included in the updated report for historical reference; however, no changes were made. The comparison of options was used to form the SWM servicing alternative which was selected.

Section 5.0 - Evaluation Storm Conveyance Systems

This MDP section was included in the updated report for historical reference; however, no changes were made. The comparison of options was used to form the SWM servicing alternative which was selected.

Section 6.0 - Stormwater Conveyance

Updates to this section have been made to reflect the updates to the ***Sewer Design Guidelines***, which was the reason why the MDP update was initiated by the City of Ottawa. Updates have been made to reflect the following changes:

- Technical Bulletin ISTB-2019-02 dated July 8, 2019 regarding the use of sump pumps;
- Technical Bulletin PIEDTB-2016-01 dated September 6, 2016 regarding the updated sizing for the minor system (i.e. 2-year for local streets, 5-year for collector streets and 10-year for arterial roads);

Section 6.4 Hydraulic Grade Line analysis was updated to reflect the latest design of the site, incorporating the latest detailed design and preliminary design. It is presented in a memo for the overall Western Development Lands by JFSA with the latest analysis.

Further, this section has been updated for two additional items:

- To reflect small revisions in the drainage split between Pond 1 and 2 as per the figures below; and
- To reflect optimized design, where sump pumps are eliminated for areas south of Ottawa Street and foundations are drained by gravity

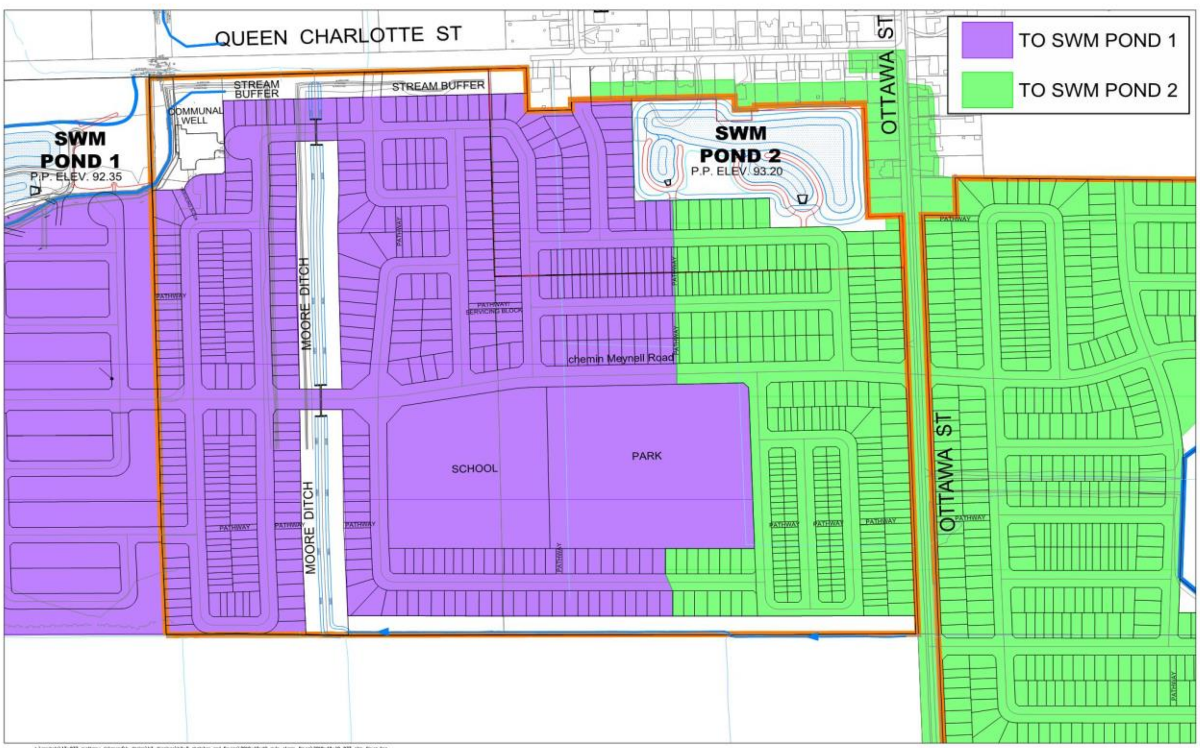

Figure above shows the Pond 1 and 2 Drainage Split in the Western Development Lands per the November 2013 MDP

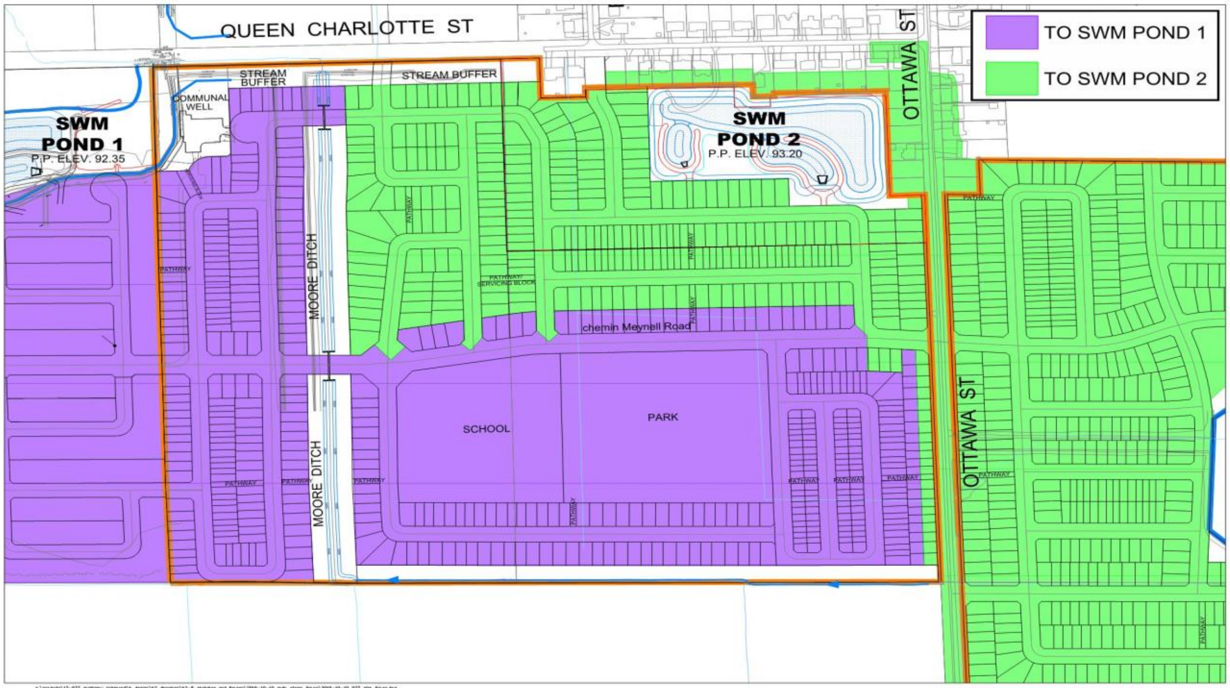

Figure above shows the New Proposed Pond 1 and 2 Drainage Split in the Western Development Lands

Section 6.5 Moore Tributary has been added to the report to describe some design elements of the Realignment of the Moore Tributary. Further details will be worked on at the time of detailed design.

Section 7.0 - Stormwater Management Facilities

This section has been updated as design has progressed on the stormwater management facilities since the MDP was approved. Pond 1 has advanced to detailed design and approvals and has been constructed to an interim condition. The final approval of the ultimate condition for Pond 1 is well underway. The information included regarding the Pond 1 design and associated works reflects what was contained in the detailed design reports. Although still preliminary, Pond 2 has an updated configuration; therefore, updated preliminary analysis has been included in this updated section.

Section 8.0 - Water Budget

As there were not any updated guidelines for Water Budget, this section has not been updated. The analysis has indicated the average annual infiltration over the drainage area is expected to be 58.4% less under proposed conditions. This was approved in the MDP and should remain the target of comparison moving forward.

Section 9.0 - Conclusions and Recommendations

All appropriate conclusions and recommendations per the preceding sections have been updated in this section.

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CITY OF OTTAWA
OCTOBER 11, 2019 – REV 5
PROJECT NO.: 17-977

1.0 INTRODUCTION

Mattamy (Jock River) Limited has retained David Schaeffer Engineering Ltd. (DSEL) to update a stormwater management report in support of their application for draft plan of subdivision. This document supports updates to all of the land holdings within the Western Development Lands (Mattamy, Caivan, Green and Laffin Lands).

This study constitutes a resubmission of previously submitted work and addresses the City of Ottawa comment that the Master Drainage Plan (MDP) be updated to reflect the updates to the ***Sewer Design Guidelines***. The City and Agency comments received to date are summarized in ***Appendix A***.

The November 2012 stormwater management report presented facility treatment types, locations, and provided a recommended stormwater facility solution for the subject lands. The final November 2013 stormwater management report expanded upon the previously recommended solution. Furthermore, the November 2013 report outlined various storm conveyance alternatives and presented a detailed review of the recommended conveyance solution. The November 2013 report was finalized for the Western Development Lands on behalf of Richmond Village (South) Limited, which will now be referred to as the Richmond Village Development Corporation (RVDC).

The objective of this updated report is to provide sufficient detail with respect to the stormwater management system including minor and major system conveyance and stormwater facilities to support the Mattamy (Jock River) Limited draft plan of subdivision application and is also applicable to other entities within the Western Development Lands area.

Adjacent to the Mattamy (Jock River) Limited lands, the RVDC Lands comprise part of the overall Master Drainage Plan. The RVDC Lands were draft approved in 2015, with Phase 1 currently under construction and Phase 2 in detailed design stage.

The Green and Laffin Lands do not yet have any active planning applications.

A Community Information Session, Status of the Village of Richmond Western Development Lands occurred on Wednesday, May 8th, 2019 at the Richmond Memorial

Community Centre to provide a status update of planning applications within the Western Development Lands. The notice is enclosed in ***Appendix A*** for reference.

1.1 Site Context

The Village of Richmond is located within the City of Ottawa planning boundary and is approximately 10 km south of Stittsville and 12 km west of Manotick, as illustrated on ***Figure 1***.

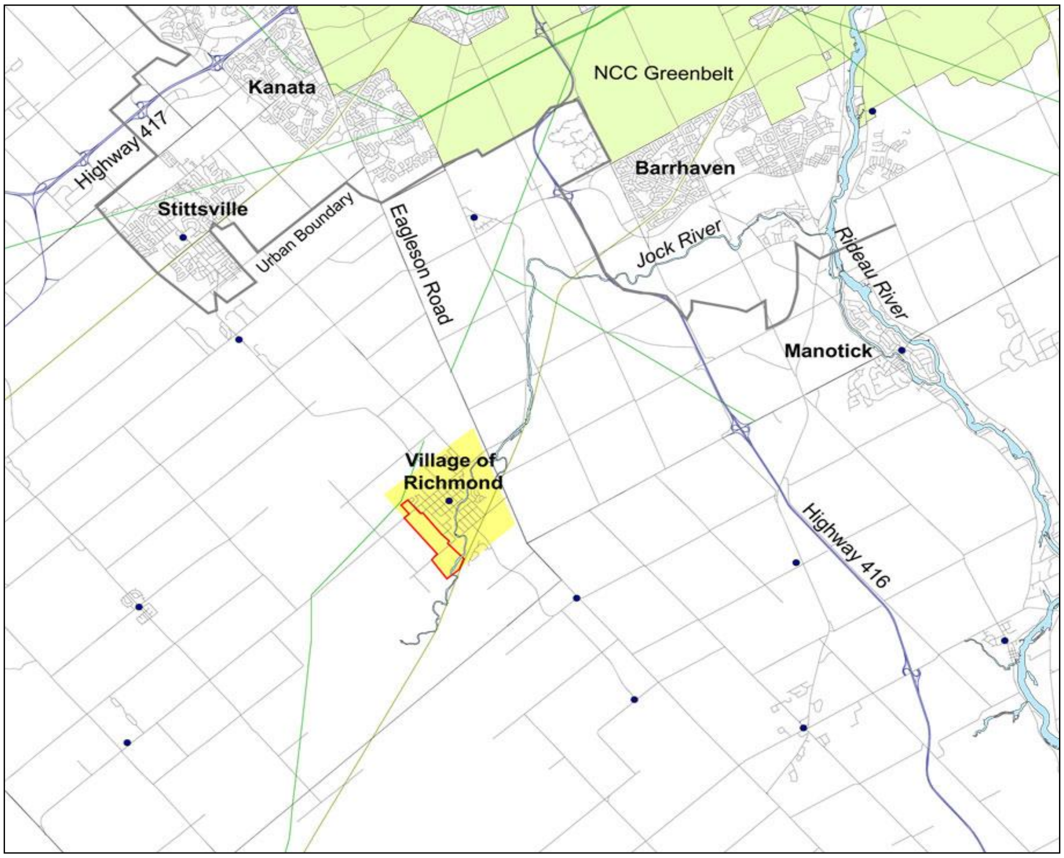

Figure 1: Location of the Village of Richmond

The subject lands lie along the western perimeter of Village of Richmond planning boundary. The subject land extends north of Perth Street and south of Perth Street to the Jock River, as illustrated on ***Figure 2***. The northern portion of the subject site (RVDC lands) is currently under construction and the southern portion consists of agricultural lands and lands formerly used for agricultural purposes. The southern portion of the site is relatively flat with slopes ranging from 0.1% to 0.5%.

The majority of the subject lands are within the Van Gaal sub-watershed which is a tributary to the Jock River. The sub-watershed area is approximately 1,115 ha and is mostly undeveloped, consisting of wooded, wetlands, and agricultural lands fallow, and row crop areas.

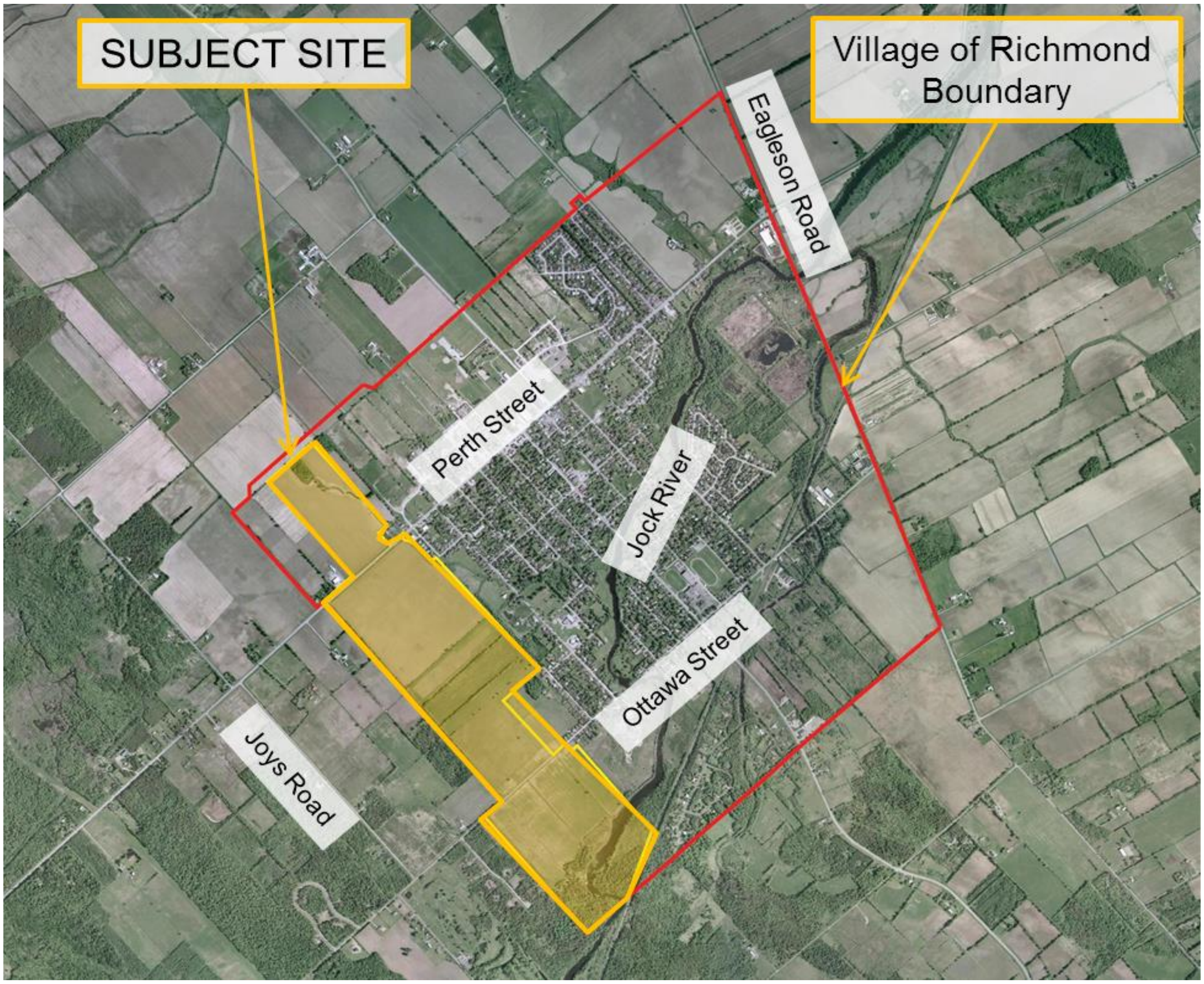

Figure 2: Site Context

1.2 Required Permits / Approvals

Developments within the Western Development Lands are subject to permits and approvals summarized in the following sections.

1.2.1 City of Ottawa

The City of Ottawa is required to approve the engineering design drawings and reports for the subdivisions within the Western Development Lands. The City of Ottawa must review and sign off on the design and forward to the Ministry of the Environment, Conservation and Parks (MECP) for their transfer of review program.

To date, Phase 1 of the RVDC lands has been reviewed by the City and commence work notifications for sewers, watermains, grading and utilities have been issued. Underground servicing and road construction up to base course asphalt is complete and home construction started in 2018.

1.2.2 Ministry of the Environment, Conservation and Parks

The MECP is required to review the engineering design and issue Environmental Compliance Approvals (ECA) for Sanitary and Storm Sewers and Stormwater Management.

The subdivisions will not require an Environmental Compliance Approval (ECA) for watermains. The City will review the watermains on behalf of the MECP.

The MECP will also be required to issue an approval for any proposed temporary sedimentation systems such as on-site ditches and / or temporary sediment ponds. To allow dewatering of the subject site, a Permit to take Water (PTTW) may be required.

The following ECAs have been issued for the Western Development Lands:

- Western Development Lands – Interim SWM Pond 1 and Relocation of Arbuckle Municipal Drain (ECA #1060-AY8JK4, May 30, 2018)
- 6350 Perth Street – Martin Street Sanitary Trunk Sewer (ECA #5426-A5PMR, January 6, 2016)
- Caivan Communities Richmond Phase 1 – Sanitary and Storm Sewers (ECA # 9297-AV9KAL, January 25, 2018)
- Permit To Take Water – Richmond Village Development Corporation (8563-ABNQ5G, August 10, 2016)

Copies of the above approvals are enclosed in ***Appendix A***.

1.2.3 Rideau Valley Conservation Authority (RVCA)

Concurrent with the City and MECP approvals, approvals are required from the Rideau Valley Conservation Authority as it relates to Ontario Regulation 174/06 "The Development, Interference with Wetlands and Alterations to Shorelines and Watercourses" for the ditch creation(s), alteration(s) and / or enclosure(s).

The following RVCA permits have been issued for the Western Development Lands:

- Construction of SWM Pond 1, located partially in Regulatory Floodplain of Jock River and Arbuckle Municipal Drain (Permit #RV5-22/16T, October 8, 2016)

- Placement of Fill between Berm and Ottawa Street West within the Floodplain (Permit # RV5-2219, June 14, 2019)
- Renewed Permit for Construction of Two Storm Pond Outlets to the Arbuckle Drain (Permit # RV5-27/18, September 27, 2018)
- Installation of a new box culvert at Fortune Street at the Arbuckle Drain (Permit #RV5-19/16T, October 13, 2016)
- Open cut installation of sanitary and storm sewer crossings of the Arbuckle Drain and pond spillway (Permit #RV5-20/16, July 7, 2016)
- Construction of SWM Pond 1 from its existing interim size to its ultimate footprint within the floodplain of the Arbuckle Municipal Drain (Permit #RV5-4619, October 1, 2019)

Copies of the above permits are enclosed in ***Appendix A***.

There are two floodplain amendments being proposed to support the proposed development area. Additional information regarding the proposed amendments is discussed under ***Section 3.2***.

1.2.4 Department of Fisheries and Oceans (DFO)

Regarding the infilling and re-alignment of the Van Gaal Drain north of Perth street, the DFO and RVCA have visited the subject site and agreed that the overall risks to fish were low and therefore the proposed work would be subject to a Level 2 RVCA review. Kilgour has prepared a letter on the Van Gaal Realignment proposal which states that the project will present a low risk to fish and will result in fishery enhancements. Confirmation of Kilgour's recommendations will be required from the DFO. Refer to ***Appendix A*** which contains a JFSA memo summarizing the history of the fisheries review of the Van Gaal Drain.

Self-assessment will be required to confirm that work related to the development associated with the WDL in the vicinity of the Arbuckle Drain and Moore Branch will not harm any fish habitat.

1.3 Study Process

The Municipal Class Environmental Assessment is an approved provincial planning and design procedure developed to ensure that the potential social, economic, and natural environmental effects are considered in undertaking certain projects. The approach is provided in the Municipal Engineers Association Municipal Class Environmental Assessment document prepared in October 2000 and amended in 2007, 2011 and 2015. The Class EA planning process is a self-directed process (by the proponent), which represents an acceptable procedure for municipalities to carry out individual assessments for most municipal water and wastewater projects in Ontario. The Class EA deals with various aspects of municipal servicing projects (water and wastewater), including:

- Maintenance and operational activities
- Reconstruction and modification of existing supply sources/treatment facilities and distribution/collection systems
- Construction of facilities

Since water and wastewater projects undertaken by municipalities vary in their environmental impact, projects are further classified in terms of schedules:

Schedule A (Pre-Approved Activities) projects are limited in scale, have minimal adverse environmental effects and include a number of municipal maintenance and operational activities. These projects are pre-approved and may proceed to implementation without following the Class EA planning process. Schedule A projects generally include normal or emergency operational and maintenance activities.

Schedule A+ (Pre-Approved Activities with Public Advisory) projects are similar to Schedule A projects but include projects where it is appropriate to inform the public of the municipal infrastructure project(s) being constructed or implemented in their area.

Schedule B projects have the potential for some adverse environmental effects. The proponent is required to undertake a screening process, involving mandatory contact with directly affected public and relevant review agencies, to ensure that they are aware of the project and that their concerns are addressed. If there are no outstanding concerns, then the proponent may proceed to implementation. Schedule B projects generally include improvements and minor expansions to existing facilities.

Schedule C projects have the potential for significant environmental effects and must proceed under the full planning and documentation procedures specified in the Class EA document. Schedule C projects require that an Environmental Study Report be prepared and filed for review by the public and review agencies. Schedule C projects generally include the construction of new facilities and major expansions to existing facilities.

Note: *There is an appeal mechanism for Schedule B and Schedule C projects – members of the public, interest groups and/or review agencies may request the Minister or delegate to require a proponent to comply with Part II of the EA Act before proceeding with the undertaking (the Minister or delegate will determine if this is necessary). Schedule A and*

Schedule A+ projects are pre-approved and there is no ability for the public to request a Part II Order (public comments on these projects should be directed to local municipal councils).

The selection of the applicable schedule is determined for certain projects by the environmental impact and other projects are determined to fall within a schedule based on cost.

RVDC was the proponent and was the lead of the Stormwater Management and Drainage Plan report. As such, the lead proponent shall be subject to the terms and conditions of this Class EA.

There are a number of stormwater project types identified as wastewater projects under Schedule "A', "A+" and "B" projects, including those that are intended to:

<u>Schedule A</u>

1. Construction of stormwater management facilities which are required as a condition of approval on a consent, site plan, plan of subdivision or condominium which will come into effect under the Planning Act prior to the construction of the facility.

2. Any project which would otherwise be subject to this Class EA and has fulfilled the requirements outlined in Section A.2.9 of this Class EA and for which the relevant Planning Act documents have been approved or have come into effect under the Planning Act, R.S.O. 1990, Chapter P.13, as amended.

<u>Schedule A+</u>

1. Establish, extend, or enlarge a sewage collection system and all necessary works to connect the system to an existing sewage or natural drainage outlet, provided all such facilities are in either an existing road allowances or an existing utility corridor, including the use of Trenchless Technology for water crossings.

<u>Schedule B</u>

2. Establish new stormwater retention/detention ponds and appurtenances or infiltration systems including outfalls to receiving water body.

3. Enclose a watercourse in a storm sewer.

Section A.1.3 of the Class EA document discusses the application of the EA Act for private sector development. Projects undertaken by the private sector developers which are designated as an undertaking to which the Ontario EA Act applies (i.e. Schedule C project that are servicing residential developments – see Ontario Regulation 345/93) are subject to all requirements of this Class EA document.

The potential stormwater management projects to support the RVDC development are Schedule A, A+ and B projects. As this is a private sector lead exercise, subject to Planning Approval with no identified Schedule C undertakings, the projects fall under Schedule A undertaking. However, the Class EA document encourages municipalities to consider requiring developers to fully consider appropriate alternatives even if the project is exempt under Ontario Regulation 345/93.

In this regard, Mattamy's Stormwater Management and Drainage Plan considered alternatives and followed Phases 1 and 2 of the Class EA process in order to determine the preferred stormwater scheme for the Richmond Western Development lands. There was no formal filing of the document under the Class EA provisions. However, the document had gone through a public process as a supporting study of the Official Plan Amendment application.

1.4 Public and Agency Consultation

Numerous public and agency consultations took place between April 2008 and present. The Stormwater Management Report submitted by DSEL for the Mattamy Richmond Lands in March 2010 summarizes the meeting results and times under sub-section 1.3. This previous summary is provided in ***Appendix A*** for ease of reference.

The Stormwater Management Report was submitted as supporting documentation for the Planning Act application. The public will have an opportunity to review the documentation through the City of Ottawa Development Application Review process and the public may submit appeals / objection to the Ontario Municipal Board regarding the Planning Act application. The Stormwater Management Report has been conducted in general accordance with the steps/phases as outlined in the Municipal Class EA Process.

1.5 Ontario Municipal Board (OMB) Decision

The proponents of the Western Development Lands at the time appealed to the Ontario Municipal Board in 2014. An agreement was reached regarding the change of zoning from Development Reserve 1 (DR1) to Village Residential Second Density, Village Residential Third Density, Open Space and Floodplain overlay to permit a proposed plan of subdivision. A copy of the OMB Decision dated June 23, 2014 is enclosed in ***Appendix A***.

2.0 GUIDELINES, PREVIOUS STUDIES, AND REPORTS

2.1 Existing Studies, Guidelines, and Reports

The following studies were utilized in the preparation of this report.

- **Ottawa Sewer Design Guidelines**
  City of Ottawa, October 2012.
  (Sewer Design Guidelines)
  - **Technical Bulletin ISDTB-2014-01**
    City of Ottawa, February 5, 2014
    (ITSB-2014-01)
  - **Technical Bulletin PIEDTB-2016-01**
    City of Ottawa, September 6, 2016
    (PIEDTB-2016-01)
  - **Technical Bulletin ISTB-2018-01**
    City of Ottawa, March 21, 2018
    (ISTB-2018-01)
  - **Technical Bulletin ISTB-2019-02**
    City of Ottawa, July 8, 2019
    (ISTB-2019-02)
- **Stormwater Planning and Design Manual**
  Ministry of the Environment, Conservation and Parks, March 2003.
  (SWMPDM)
- **Ontario Building Code Compendium**
  Ministry of Municipal Affairs and Housing Building Development Branch, January 1, 2010 Update.
  (OBC)
- **Hydrology Report – Jock River Flood Risk Mapping**
  Rideau Valley Conservation Authority, July 2004.
- **Hydraulics Report – Jock River Flood Risk Mapping**
  Rideau Valley Conservation Authority, November 2004.
- **Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond**
  Rideau Valley Conservation Authority, November 2009.

- **Stormwater Management and Drainage Plan for the Mattamy Richmond Lands**
  DSEL, JFSA, AECOM, and Kilgour & Associates Ltd., March 2010.
  (March 2010 SWM Report)

- **Village of Richmond Community Design Plan**
  City of Ottawa, July 2010.
  (CDP)

- **Preliminary Geotechnical Investigation Report**
  Jacques Whitford, June 22, 2007.
  (Geotechnical Study)

- **Supplemental Geotechnical Investigation, PG4683-2**
  Paterson Group, May 15, 2019.
  (Supplemental Geotechnical Study)

- **Design Brief for Stormwater Management Pond 1, Western Development Lands, Richmond**
  JF Sabourin and Associates Inc. and David Schaeffer Engineering Limited, September 2019.
  (Ultimate Pond 1 Design Brief)

- **Design Brief for Caivan Communities Richmond Phase 1, Richmond Village Development Corporation**
  DSEL, November 28, 2017.
  (Caivan Phase 1 Design Brief)

- **Design Brief for Fox Run Subdivision Richmond – Phase 2 (South), Richmond Village Development Corporation**
  DSEL, May 31, 2019.
  (Caivan Phase 2 South Design Brief)

- **Design Brief for Fox Run Subdivision Richmond – Phase 2 (North), Richmond Village Development Corporation**
  DSEL, September 5, 2019.
  (Caivan Phase 2 North Design Brief)

- **Functional Servicing Report for Richmond Village Mattamy Homes**
  DSEL, June 27, 2019.
  (Mattamy FSR)

3.0 EXISTING CONDITIONS

3.1 Geotechnical

Jacques Whitford carried out a Geotechnical Investigation of the subject property in June 2007. The report is included in ***Appendix B***. The following summarizes the results of their investigation:

North of Perth Street, the soils consist of a thick deposit of clay overlying a till deposit overlying inferred bedrock. Bedrock is anticipated at depths in excess of 6 m below ground surface to the north of Perth Street and becoming shallower to the south of Perth Street.

Between Perth and Ottawa Street the soils consist of a thin deposit of clay overlying a sandy silt deposit over a till deposit over inferred bedrock. Bedrock is anticipated at depths between 3 m to 4 m below ground surface.

South of Ottawa Street the soils consist of a deposit sandy silt over a till deposit over inferred bedrock. Bedrock is anticipated at depths ranging from greater than 4 m to less than 1 m below ground surface.

A compressible deposit of clay was encountered within the northern section of the site. Due to the compressible nature of the clay, grade raises over sections of the site should be restricted to minimize total settlements. ***Table 1*** summarizes the preliminary grade raise restrictions for the site. ***Drawing 1 – Constraints Plan*** depicts the grade raise constraint areas proposed by Jacques Whitford in 2007. Some areas of development have updated grade raise restrictions as new reports were completed as described below.

Table 1
Summary of Maximum Grade Raise Constraints

Site Area	Maximum Grade Raise Above Existing Site Grades
PIN 0062, 0061; North of Perth Street	1.0 m
PIN 0285, 0286; Parcel to the south of Perth Street	1.5 m
PIN 0287; Parcel north of Ottawa Street	2.0 m
PIN 0714, 0746, 0047, 0075; Parcels north and south of Ottawa Street	4.0 m

As development has proceeded since 2007, updated geotechnical reports have been prepared for individual development sites.

In 2018, RVDC retained Golder Associates to prepare a geotechnical investigation for Phase 1 of their land holdings. Per the ***Geotechnical Investigation – Phase 1*** dated February 2018, the recommended grade raise restriction is 2.0 m across the entire Phase 1 site.

In 2019, RVDC retained Golder Associates to prepare a geotechnical investigation for Phase 2 and 3 of their land holdings. Per the ***Geotechnical Investigation – Phase 2/3*** dated August 2019, the recommended grade raise restriction is 2.0 m in the roadway and 1.3 m at the house.

In 2019, Mattamy (Jock River) Limited retained Paterson Group to prepare a supplemental geotechnical investigation for their land holdings. Per the ***Geotechnical Investigation Report PG4683-2***, the maximum grade raise constraints have been updated for Mattamy (Jock River) Limited. Paterson noted that the south and central portions of the proposed development consist of shallow bedrock and no grade raise restriction is required. Refer to enclosed figure PG4683-2 by Paterson Group, enclosed in ***Appendix B***.

3.2 Regulatory Floodplain

The Jock River and Van Gaal Drain are adjacent to the subject lands and have established regulatory floodplains that are subject to modifications approved through the ***CDP*** process. The following sections describe the regulatory floodplain limits and the amendment process.

3.2.1 Jock River

The Rideau Valley Conservation Authority completed floodplain mapping for the Jock River in November 2004.

Figure 3 was extracted from the Jock River Flood Risk Map and illustrates a significant portion of the subject lands south of Ottawa Street within the Regulatory Flood Limit.

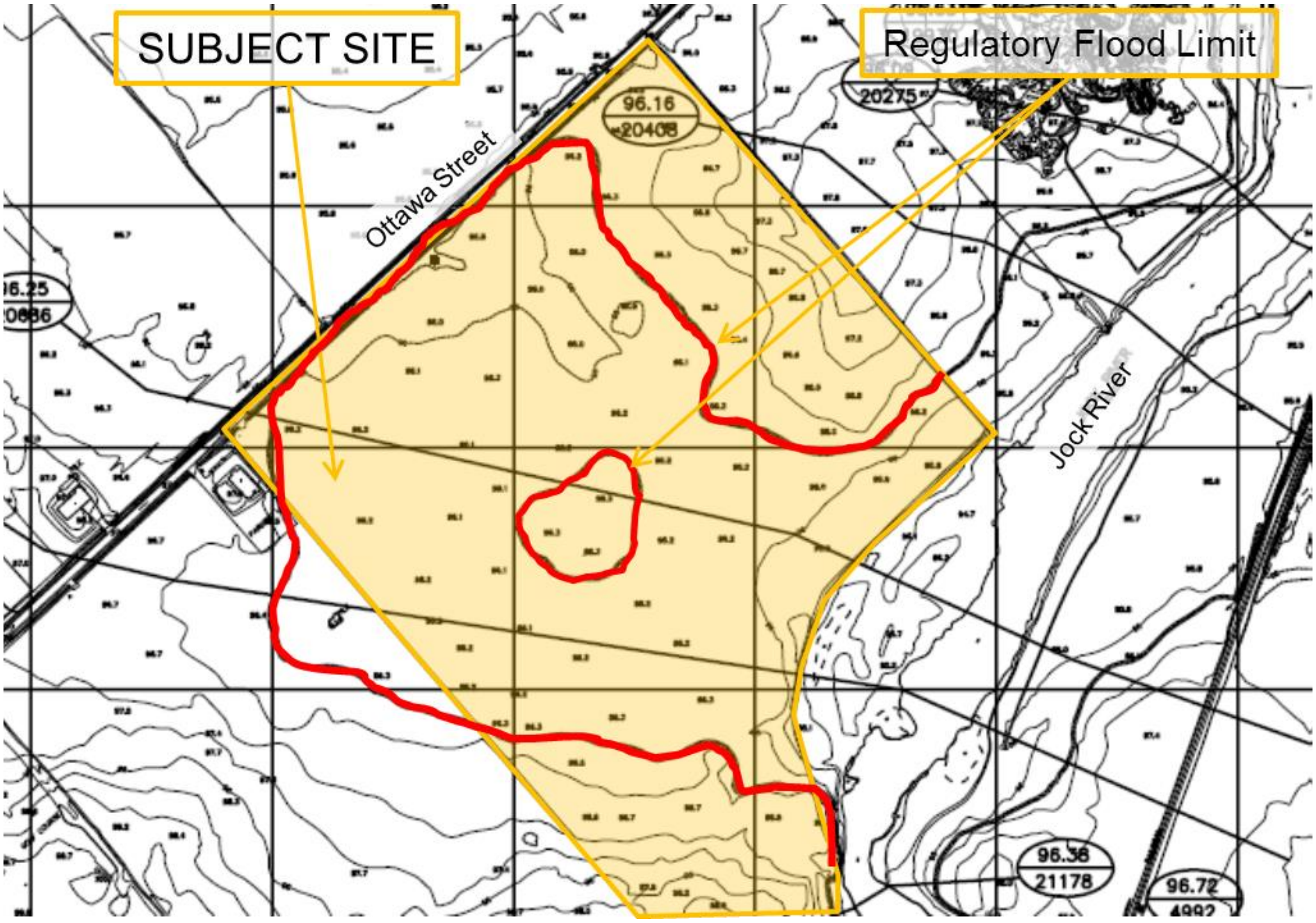

Figure 3: Regulatory Floodplain Mapping – Jock River

In December 2005, a letter of permission was issued by the RVCA to the original landowner for the construction of a berm to maintain flood risk mapping land levels as per (the 1980 Acres Floodplain) Mapping Study (96.0 m) south of Ottawa Street. On March 3, 2009, the RVCA issued a letter of permission, included in ***Appendix C***, authorizing works to be conducted based on past approvals granted on the property. The authorized works involved removal of the existing berm and relocation to the approved 2005 location. The existing flap gate and culvert from the drainage easement were removed. The berm also extends parallel along both sides of the drainage easement north up to Ottawa Street. The permission letter also included the placement of fill between the new berm and Ottawa Street to a maximum level of 96.5 m**.**

It is acknowledged that the RVCA letter of permission, dated March 3, 2009, is almost 10 years old and as such, the letter is considered expired. Mattamy, DSEL and JFSA met with the RVCA on October 31, 2018 where the RVCA confirmed that the revised proposal can move forward with the same submission as what was proposed in the March 3, 2009 permission letter.

An updated proposal was submitted to the RVCA under Ontario Regulation 174/06 and was approved June 14, 2019. The new permit to place fill between the berm and Ottawa Street to a maximum level of 96.5 m is enclosed in ***Appendix A***. The placement of fill was the only outstanding work from the 2009 permit.

3.2.2 Van Gaal Drain

The Rideau Valley Conservation Authority completed floodplain mapping for the Van Gaal Drain in November 2009.

Figure 4 was extracted from the Van Gaal and Arbuckle Drain Floodplain Mapping and illustrates a significant portion of the subject lands north of Perth Street within the Regulatory Flood Limit.

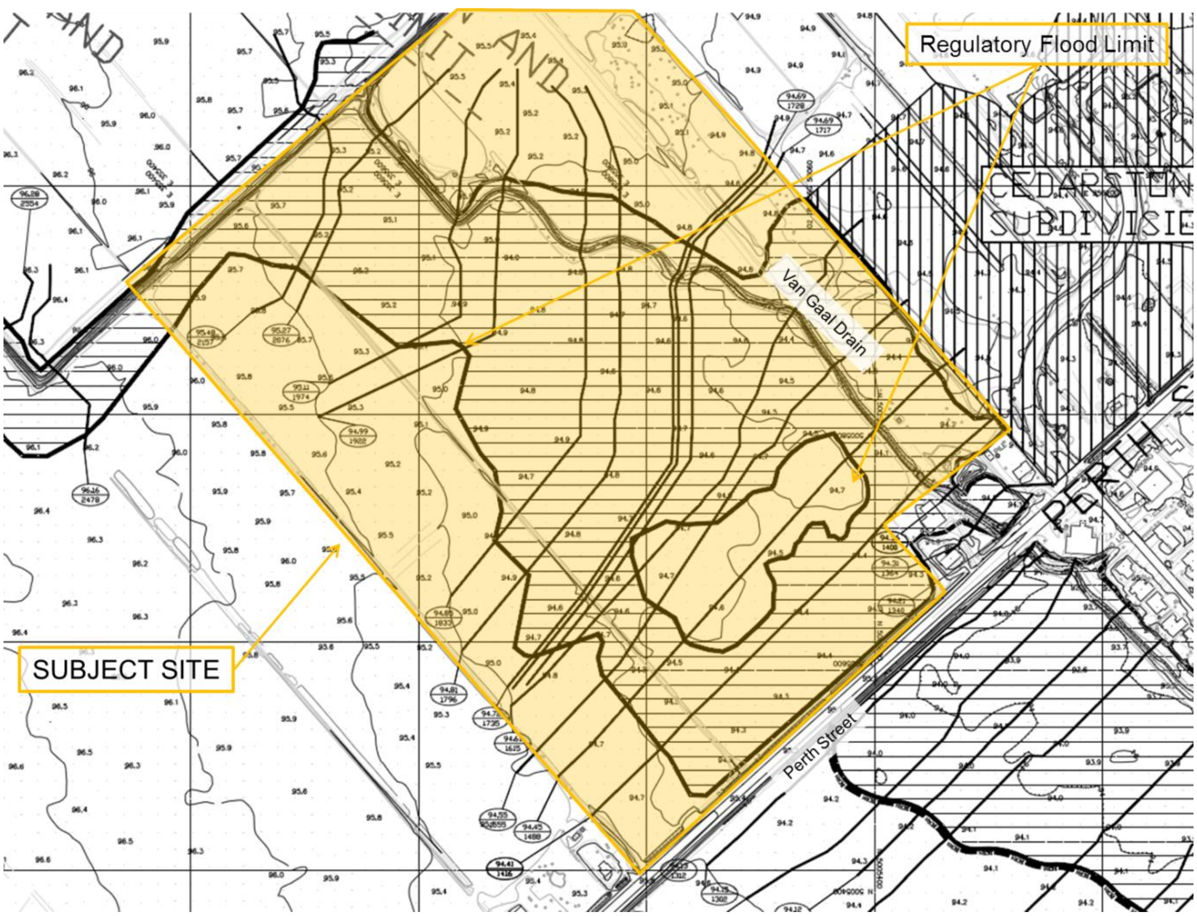

Figure 4: Regulatory Floodplain Mapping – Van Gaal Drain

The "*Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drain in the Village of Richmond (November 2009)"* was supported by RVCA staff and was brought forward for approval to the January 28, 2010 RVCA Executive Board Meeting. At this meeting, the Board approved the report and mapping as the regulatory floodplain mapping. The Board also approved the RVCA staff recommendation to allow for channel modifications to be undertaken north of Perth Street that would allow for an amendment to the regulatory floodplain limit. The approach and process are documented in the January 14, 2010 minutes of meeting which are contained in ***Appendix C*.** In summary, additional channel modifications will be completed north of Perth Street to increase the channel's conveyance capacity that meet the 1:100-year water surface profile in J.F. Sabourin & Associates Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains Report (November 2009). On approval and completion of the channel modifications, RVCA will amend its flood hazard and regulation limits mapping based on the completed works.

DSEL prepared a preliminary design for the proposed Van Gaal Drain modifications based on comments received during a pre-consultation meeting that took place on May 19, 2011 and a revised draft plan. The submission package is included in ***Appendix C***. RVCA reviewed the preliminary proposal and issued comments via email on October 16, 2012, included in ***Appendix C***. A copy of the JFSA modelling memo entitled ***Richmond Village Development / Proposed Realignment of Van Gaal Drain*** dated April 20, 2017 is included in ***Appendix C***.

3.3 Geomorphology

RVDC retained Coldwater Consulting Ltd. (Coldwater) to complete an erosion threshold analysis and provide a channel design for the realignment of the existing Van Gaal Drain. The erosion analysis study, along with modelling to assess the condition of the existing Van Gaal Drain / Arbuckle Drain, is enclosed in ***Appendix D***. The design analysis included a 'natural channel design' for the low-flow inner channel, bank erosion assessment and recommendations and planting recommendations. The proposed realignment of the existing Van Gaal Drain has gone through the Drainage Act process and the Engineer's Report ***Amendment to the Engineer's Report for the Van Gaal Municipal Drain*** prepared by Robinson Consultants dated January 2019 was approved by City Council on June 12, 2019. The Agricultural and Rural Affairs Committee report to Council is provided in ***Appendix D***.

Approximately 900 m of the existing Van Gaal Drain will be realigned to follow the boundary of the Richmond Village Development Corporation site. The goal of natural channel design for the realignment is to restore the hydraulic and ecological function of the channel through the re-creation of natural features and vegetation. A conveyance channel with a trapezoidal form will be constructed to carry flows up to the 100-year return period flow. A meandering low flow channel has been designed to fit within the 10 m wide base of the conveyance channel. Coldwater has included several cross vane weirs, constructed with small boulders and stones, to add diversity and anchor the pools. Straw fibre erosion control blankets are to be including in the main channel for soil erosion and allowing natural vegetation to become established. Shrubs and seed mix are to be applied on the outside banks of the meandering stream to help the natural succession of vegetation soil.

Further details of the channel design are discussed in ***Natural Channel Design: Van Gaal Drain*** prepared by Coldwater February 23, 2017, enclosed in ***Appendix D***.

3.4 Pre-Development Drainage Conditions

JFSA was retained to develop hydrologic and hydraulic models of the existing areas to assess the impact of the proposed urban development. The calculated flows included in ***Appendices E and I*** were prepared based upon the same methodology used for the 2009 Richmond Floodplain Mapping study, taking into consideration the timing of peak flows of the Van Gaal drain and Jock River. The calculated water surface elevations (WSELs) were determined using the 2009 Richmond Floodplain HEC-RAS spring and summer models, which do not include features including the berm that has been constructed upstream of Perth Street or any modification to Fortune Street culvert.

Table 2
Summary of Peak Flows to be conveyed through Subdivision

Tributary Area	100-year, 3-hour Chicago Storm	100-year, 12-hour SCS Type II Storm	100-year 10 Day Spring Snowmelt and Rainfall Event
	(m^3/s)	(m^3/s)	(m^3/s)
VG-2 & VG-5	2.55	3.19	1.86
VG-6	1.42	1.89	1.61
VG-7 & JR-1	1.60	2.01	1.30

Refer to ***Richmond Village (South) Limited Subdivision / Preliminary Stormwater Management Plan*** prepared by JFSA dated January 10, 2014 in ***Appendix I***, for locations of external areas to be conveyed through the proposed development.

Figure 5, included in ***Figures***, illustrates the Existing Conditions Storm Drainage. The subject property is tributary to both the Van Gaal Drain and the Jock River, ultimately all stormwater from the subject area reaches the Jock River. As depicted, 1,147 ha is tributary to the Van Gaal Drain, of which approximately 115 ha is the subject site. Approximately 32 ha of the subject development is tributary to the Jock River. Furthermore, approximately 34 ha west of the subject site and south of Ottawa Street drains through the development site to the Jock River.

3.5 Hydrogeology

RVDC retained Golder and Associates (Golder) to evaluate the proposed drainage plan with respect to the hydrogeological conditions encountered at the site. Golder has conducted and compiled field observations and sampling and have analysed the hydrogeological effects of subsurface drainage for the proposed development. ***Appendix F*** contains Golder's technical memorandum of their oneyear review of groundwater monitoring as well as their technical memorandum assessment of subsurface drainage and analysis of the 100-year flood event. ***Sections 5.2.4*** and ***6.3*** of this study discuss the results of their findings in detail.

After construction of Phase 1 of the RVDC lands, Golder has undertaken an additional groundwater monitoring program of the groundwater levels in order to verify that they are at, or lower, than the underside of footings of the units. A copy of the ***Groundwater Monitoring Results*** by Golder dated July 9, 2019 is included in ***Appendix F***. Paterson Group has been retained by Mattamy (Jock River) Limited to complete groundwater monitoring for their site. On-going monitoring and reporting will continue through coordination with the City of Ottawa, as required.

4.0 SWM SERVICING ALTERNATIVES

This section of the revised MDP has been included for historical reference; however, the proposal of SWM servicing alternatives has not been revisited. The final SWM servicing strategy was approved through the Ontario Municipal Board Decision in 2014.

In December 2008, a three-day design workshop in Richmond to develop a land use concept plan for their lands. Looney Ricks Kiss (LRK) facilitated the design workshop with input from the consultant team, City staff, residents and other stakeholders. Building upon the visioning principles established through the ***CDP*** process, a preliminary land use concept plan was developed (***Figure 6***). In order to finalize and support the development land use concept plan, the stormwater management requirements need to be established.

Figure 6: Preliminary Land Use Concept Plan

4.1.1 End of Pipe Stormwater Alternatives

There are several suitable end-of-pipe options for the treatment of stormwater runoff from urban areas including – Infiltration Basins, Wetlands, Dry Ponds, Wet Ponds, and Hydrodynamic Separation Units. ***Table 3*** presents the four options and their suitability as described in ***SWMPDM*** (MECP, March 2003).

Table 3
End of Pipe Treatment Systems Considered

Stormwater Management Practice	Description
Infiltration Basins	Infiltration basins are above-ground pond systems which are constructed in highly pervious soils. Water infiltrates into the basin and either recharges the groundwater system or is collected by an underground perforated pipe network and is discharged to a downstream outlet.
Wet Ponds	Wet ponds are the most common end-of-pie stormwater facilities in Ontario. The performance does not depend on soil characteristics, permanent pool minimizes re-suspension of captured solids and minimizes blockages at the outlet. Furthermore, the biological removal of pollutants occurs. Wet ponds are suited to drainage areas 5ha and greater
Wetlands	Wetlands are normally more land-intensive than wet ponds because of their shallower permanent pool depth. They provide similar quality benefits as wet ponds, although the biological processes are enhanced.
Dry Ponds	Dry ponds have no permanent pool of water. As such the removal of containments is purely a function of the detention time in the pond.
Hydrodynamic Separation Units	Hydrodynamic Separation Units or Oil / Grit separator are manufactured concrete units for the expressed purpose of trapping sediment and oil. The processes are patented and sizing is dependent on the manufactures specifications and tends to work well with small (less than 5.0ha) catchments. These units tend to occupy less land area.

In developing the various end of pipe stormwater management alternatives, two additional considerations were given priority. First, siting a SWMP at the lowest elevations of the site was considered over higher elevations. Second, the ponds should be situated nearest to their respective outlet locations.

Jock River Outlet Options

One of the SWMP options conceived was to locate a facility at the southernmost extent of the site to outlet directly to the Jock River within the subject lands. However, the 100-year flood elevation at this location is 96.40, which is higher than the northern portion of the development. An alternate outlet location was considered at the end of Ottawa Street where the 100-year level in the Jock River lowers dramatically, by approximately 2.0m, 1200 m downstream at Ottawa Street which could facilitate drainage of the majority of the subject lands.

Outlet routes from the subject area to Jock River at Ottawa Street were considered along Queen Charlotte, Royal York Street, Burke Street, and Ottawa Street. Based on 'as-built' information received from the City of Ottawa Information Centre, it was found that an existing sanitary sewer would be in conflict with a proposed sewer routing along Royal York and Burke Streets at Fortune Street. An outlet route to the Jock River via Martin, Hamilton and Perth is not possible as the storm sewer is unable to cross under the existing Van Gaal Drain. As such, routing along Queen Charlotte Street and Ottawa Street are the storm sewer route most feasible from the subject lands should flows be directed to the Jock River at the end of Ottawa Street.

Van Gaal/Arbuckle Outlet Options

An outlet directly to the Van Gaal/Arbuckle Drain was considered for the development area north and south of Perth Street. It will be required to demonstrate that there would be no increase in flood levels along the Van Gaal Drain as well as providing erosion impulse control in accordance with the ***Geomorphology Study***.

Preliminary Screening of End of Pipe Stormwater Management Alternatives

Infiltration basins require low ground water tables and permeable soils. The ***Geotechnical Study*** illustrated that ground water elevations are within 0.60 m to 1.2 m of the existing ground surface. Furthermore, the soils are predominately clays with low percolation rates. Therefore, infiltration basins are not suitable in this application.

According to the ***SWMPDM*** wetlands tend to raise the temperature more than wet ponds. The ***Environmental Study*** indicated that the downstream watercourse has thermal sensitive species. Therefore, and end of pipe facility that minimizes temperature increase was given priority.

Based on the site characteristics, constraints, and requirements; stormwater management solutions incorporating wet ponds, dry ponds, and oil/grit separators will be investigated in additional detail.

4.1.2 Lot Level Stormwater Management Alternatives

Table 4 summarizes investigated lot level stormwater management practices.

Table 4
Lot Level Treatment Systems Considered

Stormwater Management Practice	Description
Rain Barrel	Harvesting rainwater by capturing rooftop runoff by connecting roof leaders to 'barrels' for watering during periods of dry weather.
Cistern	Harvesting rainwater by capturing rooftop runoff and directing stormwater to an underground storage tank. Water is pumped for watering during dry periods.
Green Roof	Consist of a thin layer of vegetation and growing medium installed on top of a convention flat or sloped roof. Reduces the 'heat' island effect and reduces runoff volume.
Roof downspout disconnection	Roof downspouts are disconnected from the weeping tile and are directed to grassed areas.
Soakaway, infiltration trench or chamber	Rectangular or circular excavations lined with geotextile filter cloth and filled with clear stone designed to promote groundwater infiltration.
Bioretention / Biofilter	Consists of a filter bed consisting of a mixture of sand, soil, and organic material. Bioretention facilities are designed to capture small storm events to retain and filter stormwater runoff. Plantings promote evapotranspiration.
Permeable pavement	An alternative to traditional impervious pavement to allow stormwater to drain through into an aggregate reservoir and infiltrate into the ground water.
Enhanced grass swale	Vegetated open channels designed to convey, treat, and attenuate stormwater runoff. Check dams and vegetation in the swale promote attenuation and infiltration.
Dry Swale	A dry swale incorporates an engineered soil medium and a perforated pipe under drain.
Perforated pipe system	Underground stormwater conveyance systems usually incorporated into the right-of-way drainage system.

Residential subdivisions typically consist of urban right-of-way cross-sections and residential homes with peaked roofs.

As such the following measures were not considered:

- Cisterns – Would increase the cost of each home.
- Green Roofs – Not standard practice in residential homes.

- Biorentention / Biofilter – not part of a standard City of Ottawa cross-section. Would increase right of way maintenance.
- Permeable Pavement – not standard practice in the City of Ottawa.
- Enhanced Grass Swale – Would have to take place in rear yards. It is anticipated that home owners will remove check dams.
- Perforated pipe system – not typical sewer design practice in the City of Ottawa. Would increase maintenance costs.

The proposed subdivision will consist of the following:

- Roof Leaders to Grassed Areas.
- Dry Swales.
- An education program to promote rain barrels.

4.1.3 Screening of Options

Three stormwater management servicing alternatives, illustrated on ***Figures 7, 8, 9*** in ***Appendix G*** were developed for evaluation:

Option 1 (Figure 7)

- Four Stormwater Management Ponds (SWMPs)
- Three facility are “Wet Ponds” with MECP ‘Enhanced’ TSS removal. While Pond 3 is a dry pond for quantity control and a hydrodynamic separator to provide quality control.
- External drainage tributary to the subject lands will be conveyed through proposed storm sewers and drainage ditches. The existing channels identified as the Moore Tributary and existing outlet to the Jock River will be enclosed.
- External drainage west of the development currently being conveyed along the Perth Street roadside ditches will continue to outlet to the Van Gaal Drain. Once the road is widened to an urban cross-section the external drainage from west of Perth Street will be conveyed to the Van Gaal Drain via storm sewers.
- External drainage currently being conveyed through the Moore Tributary will be conveyed to Pond 1 via new storm sewers.
- Jock River Estates drainage will be conveyed north of Ottawa Street through the new storm sewer system to Pond 1.
- Pond 1 will be designed to receive flow from the majority of the area between Perth Street and Ottawa Street, approximately 58 ha.

- This wet pond will be designed to attenuate post-development runoff rates to predevelopment levels, while flows up to and including the 2-year event will be attenuated to 330 L/s in accordance with the ***Geomorphic Study***.
- <u>Pond 2</u> will be designed to receive runoff from approximately 8 ha north of Ottawa and the developable land south of Ottawa Street.
- Pond 2 is a wet pond and has one outlet directing post-development runoff rates to the Jock River via a proposed storm sewer along Ottawa Street. The 100-year release rate from Pond 2 will be restricted to the free-flowing capacity of the outlet sewer.
- <u>Pond 3</u> will be designed as a dry pond with a hydrodynamic separator to collect and retain runoff from approximately 3 ha north of Perth Street east of the Van Gaal Drain.
- This pond will be designed to attenuate flows to 330 L/s in accordance with the ***Geomorphic Study***.
- The proposed facility will incorporate a hydrodynamic separator to provide 80% TSS removal per ***SWMPDM***.
- <u>Pond 4</u> will be designed to collect and retain runoff from approximately 28 ha north of Perth Street east of the Van Gaal Drain and will outlet to the Van Gaal Drain.
- This pond will be designed to attenuate post-development runoff rates to predevelopment levels, while flows up to and including the 2-year event will be attenuated to 330 L/s in accordance with the ***Geomorphic Study***.

<u>Option 2 (Figure 8)</u>

- Three Stormwater Management Ponds (SWMPs)
- Ponds 1 and 2 are “Wet Ponds” with MECP ‘Enhanced’ TSS removal. Pond 3 is a dry pond for quantity control and a hydrodynamic separator to provide quality control.
- External drainage tributary to the subject lands will be conveyed through proposed storm sewers and therefore the existing tributaries identified as Moore and Jock River Estates will be enclosed. A portion of the Moore tributary along Queen Charlotte will remain open.
- External drainage west of the development currently being conveyed along the Perth Street roadside ditches will continue to outlet to the Van Gaal Drain. Once the road is widened to an urban cross-section the external drainage from west of Perth Street will be conveyed to the Van Gaal Drain via storm sewers.

- External drainage currently being conveyed through the Moore Tributary will be conveyed to Pond 1 via new storm sewers.
- Jock River Estates drainage will be conveyed north of Ottawa Street through the new storm sewer system to Pond 1.
- <u>Pond 1</u> will be designed to receive runoff from 45 ha between Ottawa and Perth Streets in addition to 28 ha north of Perth Street on the west side of the Van Gaal Drain. Pond 1 will have two outlets:
- The first channel will be designed to convey low flows up to and including the 2-year event attenuated to 330 L/s in accordance with the ***Geomorphic Study***. The channel will provide both surface and subsurface conveyance. The channel will be bordered by strategic planting to promote shaded cover, while the subsurface component will enhance cooling opportunities.
- The second channel will be designed to convey the treated stormwater runoff from the less frequent storm events generated during the 5 to 100-year return periods.
- <u>Pond 2</u> will be designed to receive runoff from 21 ha north of Ottawa and the developable land south of Ottawa Street.
- Pond 2 has one outlet directing post-development runoff rates to the Jock River via a proposed storm sewer along Ottawa Street. The 100-year release rate from pond 2 will be restricted to the free-flowing capacity of the outlet sewer.
- <u>Pond 3</u> will be designed as a dry pond for quantity control / hydrodynamic separator to collect and retain runoff from approximately 3 ha north of Perth Street east of the Van Gaal Drain.
- This pond will be designed to attenuate flows to 330 L/s in accordance with the ***Geomorphic Study***.
- The pond outlet structure will be designed to mitigate increases in water levels in the Van Gaal Drain
- The proposed facility will incorporate an oil / grit sedimentation chamber to provide 80% TSS removal per ***SWMPDM***.

<u>Option 3 (Figure 9)</u>

- Three Stormwater Management Ponds (SWMPs)
- Ponds 1 and 2 are “Wet Ponds” with MECP ‘Enhanced’ TSS removal, while Pond 3 is conceived to be a dry pond for quantity control and a hydrodynamic separator to provide quality control.
- In this stormwater management option, the Moore Tributary for its entire length will be left open and Jock River Estates drain will be enclosed within

the development area. The existing channel will need to be redesigned to ensure that the channel contains the 100-year event. JFSA prepared a hydrologic and hydraulic model to confirm the proposed cross-sections, see ***Appendix I*** for the detailed analysis.

- External drainage west of the development currently being conveyed along the Perth Street roadside ditches will continue to outlet to the Van Gaal Drain. Once the road is widened to an urban cross-section, the external drainage from west of Perth Street will be conveyed to Pond 1 via storm sewers.
- External drainage currently being conveyed through the Moore Tributary will be conveyed to the Van Gaal/Arbuckle Drain via the redesigned Moore Tributary channel.
- Jock River Estates drainage will be conveyed along Ottawa Street through a new storm sewer to the new SWM Wetland 2 facility. The envisioned sequencing of events that has been vetted through RVCA is to: (1) construct SWM Pond 2 and trunk sewer along Ottawa Street; (2) close the existing drain outlet south of Ottawa Street in coordination with the RVCA.
- The Fortune Street Culvert will be modified to lower 100-year summer water levels upstream of Fortune Street.
- Pond 1 will be designed to receive runoff from 45 ha between Ottawa and Perth Streets in addition to 28 ha north of Perth Street on the west side of the Van Gaal Drain. Pond 1 will have two outlets:
- The first outlet will be designed to convey low flows up to and including the 2-year event attenuated to 330 L/s in accordance with the ***Geomorphic Study***. The pond will be designed to enhance cooling opportunities where possible.
- The second outlet will be designed to convey the treated stormwater runoff from the less frequent storm events generated during the 5 to 100-year return periods.
- Pond 1 is situated in the 100-year regulatory floodplain, outside the 100-year erosion limit and 100-year summer flood elevation of the Van Gaal/Arbuckle Drain.
- Pond 2 will be designed to receive runoff from 21 ha north of Ottawa and the developable land south of Ottawa Street.
- Pond 2 has one outlet directing post-development runoff rates to the Jock River via a proposed storm sewer along Ottawa Street. The 100-year release rate from Pond 2 will be restricted to the free-flowing capacity of the outlet sewer.

- Pond 3 will be designed to collect and retain runoff from approximately 3 ha north of Perth Street east of the Van Gaal Drain.
- This pond will be designed to attenuate flows to 330 L/s in accordance with the ***Geomorphic Study***.
- The proposed facility will incorporate an oil / grit sedimentation chamber to provide 80% TSS removal per the ***SWMPDM***.

4.2 Selection of Preferred SWMP

4.2.1 Evaluation Process

The three stormwater management options presented in ***Section 4.1*** were brought forward for evaluation through a pair-wise comparison matrix. The evaluation matrix was developed as part of the Village of Richmond Master Servicing Study (***Servicing Study***). These evaluation criteria were presented and reviewed by the Technical Advisory Committee and the public.

The evaluation criteria consist of criterion in four major categories: Natural Environment, Caring and Healthy Communities, Constructability and Functionality, and Cost. Each of these major categories has been assigned a weighting which is summarized in ***Table 5***.

Table 5
Summary of Decision Matrix Categories

Parameter	Indicators	Weighting
Natural Environment		**21%**
N1 Impact on significant natural features	Loss, displacement, disruption fragmentation of natural areas (wetlands, woodlands, terrestrial ecology, ANSI's and associated corridors).	3%
N2 Impact on ecological processes	Fragmentation of natural areas, interruption of natural linkages.	3%
N3 Impact on aquatic systems	Number of stream crossings, impact on significant fish habitat	7%
N6 Effects on green space and open space	Interference with linear green way systems.	7%
Caring and Healthy Communities		**25%**
C3 Impact on level of service	Maintains or improves level of service to the existing and future village residents.	13%
C4 Disruption to community	Compatibility with existing community character.	6%
C9 Consistency with infrastructure planning policies	Compatibility with infrastructure servicing corridors and flexibility for enhancements to land use.	6%
Constructability and Functionality		**29%**
CO2 Schedule / Staging Opportunities	Ability to phase infrastructure to facilitate development phasing	6%
CO3 Construction Risk	Conforms to geotechnical, geomorphology, hydrological	6%
CO4 Impact on existing infrastructure	Relocation of existing services (i.e. sanitary sewers, wells) and other utilities	6%
CO5 Disruption during construction	Location of new infrastructure in built up areas and nuisance effects	6%
CO6 Operation and maintenance	Proven track record, ease of operating and maintenance	6%
Cost		**25%**
E9 Total 25-year life cycle cost	Cost effective life cycle costs	6%
E11 Total Capital Cost	Cost effective capital costs.	19%

Each alternative is ranked based on the criteria presented previously. The ranking values assigned to the alternatives based on the various criteria are given over a relative range from 1 to 5. The description of these rankings is presented in **Table 6**:

Table 6
Decision Matrix Categories Ranking System

Ranking	Description
5 - Positive or No Impact	The alternative meets all applicable requirements, provides tangible benefits
4 – Minor Impact	The alternative has some minor negative impacts or dis-benefits that may easily be mitigated or compensated for
3- Moderate Impact	The alternative has noticeable negative impacts, however, the severity of the impacts may be reduced or compensated for
2 – Noticeable Negative Impact	The alternative has significant negative impacts which may be mitigated, although these may be costly, time consuming or result in other negative impacts
1 - Negative or Significant Impact	The alternative does not meet applicable requirements, results in significant dis-benefits and/or negative impacts cannot be mitigated

Under this ranking system, each individual criterion is ranked <u>relatively</u> for each alternative. For example, for Criteria N1 (Impact on Natural Features), the 1 to 5 ranking for an individual alternative is determined based on the relative impact on the environment compared to all the other alternatives being evaluated.

4.2.2 Discussion of Preferred Option

The results of the evaluation of the three stormwater management options are contained in ***Table 7*.** Kilgour & Associates were retained to complete the evaluation of the three options for the Natural Environment criteria.

Table 7
Stormwater Management Evaluation

Parameter	Weighting	Option 1			Option 2			Option 3		
		Description	Score	Weighting	Description	Score	Weighting	Description	Score	Weighting
Natural Environment	**21%**									
N1 – Impact on Significant Natural Features	3%	There is no footprint of the SWM facilities on significant natural features (NESS Area 422, Significant Woodlands, Jock River corridor).	5	0.15	There is no footprint of the SWM facilities on significant natural features (NESS Area 422, Significant Woodlands, Jock River corridor).	5	0.15	There is no footprint of the SWM facilities on significant natural features (NESS Area 422, Significant Woodlands, Jock River corridor).	5	0.15
N2 – Impact on Ecological Processes	3%	There are no terrestrial corridors impacted by this option. New outlets being introduced into watercourses.	4	0.12	There are no terrestrial corridors impacted by this option. New outlets being introduced into watercourses.	4	0.12	There are no terrestrial corridors impacted by this option. New outlets being introduced into watercourses. Riparian corridors being enhanced.	5	0.15
N3 – Impact on Aquatic Systems	7%	Loss of some 3660 m^2 of indirect fish habitat; loss of some 2510 m^2 of direct fish habitat	2	0.14	Loss of some 3285 m^2 of indirect fish habitat; loss of some 177 m^2 of direct fish habitat	2	0.14	Conversion of existing indirect fish habitat to direct fish habitat, for a total gain of direct fish habitat of some 3386 m^2. Creation of new potential fish spawning habitats in outlet channel.	5	0.35
N6 – Effects on Greenspace and Open Space	7%	Less greenspace as hedgerows removed and entire length of Moore Tributary enclosed.	2	0.14	Less greenspace as portion of Moore Tributary (VG-R2-2) enclosed and hedgerows removed. VG-R3-1 remains open retaining existing vegetation.	3	0.21	Entire length of Moore Tributary open and hedgerow reestablished along VG-R3-2. Enhancement of tributary and SWM Pond integrated with Martin Street Pedestrian Extension	4	0.28

Caring and Healthy Communities	**25%**									
C3 – Impact on Level of Service	13%	New facilities. All options meet SWM criteria and flood protection for downstream recipients.	4	0.52	New facilities. All options meet SWM criteria and flood protection for downstream recipients.	4	0.14	New facilities. All options meet SWM criteria and flood protection for downstream recipients.	4	0.52
C4 – Disruption to Community	6%	Village currently does not have wet pond SWM facilities. Ponds situated in development lands.	3	0.18	Village currently does not have wet pond SWM facilities. Ponds situated in development lands.	3	0.21	Village currently does not have wet pond SWM facilities. Ponds situated in development lands.	3	0.18
C9 – Consistency with Infrastructure Planning Policies	6%	Pond technology and design consistent with the City and Ministry Guidelines. Grading north of Perth Street exceeds Geotechnical recommendations.	2	0.12	Pond technology and design consistent with the City and Ministry Guidelines.	4	0.24	Pond technology and design consistent with the City and Ministry Guidelines. Location of ponds in floodplain not common but permitted under the Provincial Policy Statement based on certain criteria being met	3	0.18

Constructability and Functionality	**29%**									
CO2 – Schedule /Staging Opportunities	6%	Four ponds equally distributed to allow for ease in project phasing	4	0.24	One large centrally located facility does not provide the ease of construction phasing	3	0.18	One large centrally located facility does not provide the ease of construction phasing	3	0.18
CO3 – Construction Risk	6%	Exceeds geotechnical recommendations.	1	0.06	Exceeds geotechnical recommendations.	1	0.06	Conforms to geotechnical recommendations	5	0.30
CO4 – Impact on Existing Utilities	6%	Storm sewer outfall along Queen Charlotte and Ottawa street	2	0.12	Storm sewer outfall along Ottawa Street	3	0.18	Storm sewer outfall along Ottawa Street	3	0.18
CO5 – Disruption during Construction	6%	4 Ponds – additional pond construction over other options	2	0.12	3 Ponds with Pond 1 setback farther from existing residents	3	0.18	3 Ponds with Pond 1 situated closer to existing residents	2	0.12
CO6 – Operation and Maintenance	6%	Use of proven technology – additional pond to maintain	3	0.18	Use of proven technology	4	0.24	Use of proven technology	4	0.24
Economy	**25%**									
E9 – Total 25-year Life Cycle Costs	8%	Highest O&M costs.	2	0.12	Lower O&M than option 3	4	0.24	Lower O&M than option 1	3	0.18
E11 – Total Capital Costs	13%	Highest total capital cost	1	0.19	Lower capital cost than 1.	3	0.57	Lower capital cost than 2.	5	0.95
Total				**2.4**			**3.2**			**4.0**
Ranking				**3**			**2**			**1**

Based on the above analysis recommended alternative was found to be Option 3, where it scored ***4.0***.

For Natural Environment Criteria, all three options received the same rating for N1 – Impact on Significant Natural Features as all ponds have been situated outside of significant woodlands and the Jock River Corridor. For the remaining criterion, the Fish Habitat Risk Assessment was relied on to assess each option. This assessment identified re-grading of the Mattamy land holdings, and the subsequent construction and operation of the SWM ponds will cause some moderate changes under Options 1 and 2, and a net gain in direct fish habitat in Option 3. Fish habitats that would be altered are generally indirect intermittent habitats or are man-made. SWM Option 3 is anticipated to provide a significant and net benefit to direct fish habitat, in association with the following aspects of the proposed design. Sections 6 and 7 of the Moore Branch will be re-graded to enhance the conveyance function of the feature. That will result in a change in the status of Sections 7 and 8, which are currently classified as indirect intermittent fish habitat, to direct intermittent fish habitat. Fish will continue to be able to access Section 7 for spawning, while the improved grading is anticipated to allow larvae/fry to migrate out of the system as water levels recede over the course of the spring/summer. A French drain will be incorporated in the SWM pond design to provide cool base flow to the lower Moore Branch, and maintain the cool-water function of that feature. The outlet channel for SWM Pond 1 will be designed to provide spring fish spawning habitat. Additional riparian plantings along the Moore Branch will enhance its ability to cool surface waters and to provide a naturalized corridor. Riparian plantings along the main stem of the Arbuckle Drain will provide additional shade and course woody material to that feature. Option 3, with a large SWM pond in the 100-year floodplain of the Arbuckle Drain, would provide net benefits to fish habitat with up to an additional 3,386 m^2 of fish habitat created as a result of the undertaking. As such, Option 3 ranked highest for criterion N2, N3, N6 *(Kilgour and Associates).*

For Caring and Healthy Communities criteria, the three options have similar ranking for the three criteria except for C9 – Consistency with Infrastructure Planning Policies. All options will meet the SWM criteria established for the receiving watercourses. C4 – Disruption to Community is defined as compatibility with existing Village character. The Village does not have stormwater management so this is new infrastructure being introduced, however, all ponds are contained on future development lands. Option 2 ranked highest for C9 as it is most consistent with applicable policies.

For Constructability and Functionality, Option 1 ranks the highest for CO2 – Schedule/Staging opportunities as the additional pond provides greater staging flexibility. CO3 – Construction Risk was based meeting JWL grade raise limits. Option 3 ranked highest as it conforms to the grade raise limits with Option 1 and 2 exceeding geotechnical recommendations. CO4 – Impact on Existing Utilities was defined as any new storm sewers required within existing right-of-ways. Option 1 ranked the lowest as it proposes a storm sewer along Queen Charlotte Street. Option 2 ranked highest for CO5 –

Disruption during Construction as it has 3 ponds with Pond 1 situated farther away from existing residents. All options were equal for CO6 – Operations and Maintenance as the technology is consistent among the options and has a proven track record.

Economy represents 25% of the score. Based on a relative comparison of costs, Option 2 ranks highest for E9, Total 25-year Life Cycle Costs as it had the lowest life cycle costs. For E11, Total Capital Costs, Option 3 had the lowest costs and therefore ranked first.

Figure 10, including in ***Figures***, illustrates the post development drainage tributary to the Van Gaal Drain and the Jock River. As described previously the subject property is tributary to both the Van Gaal Drain and the Jock River, ultimately all stormwater from the subject area reaches the Jock River. The proposed stormwater management scheme will reduce the total area tributary to the Van Gaal Drain by approximately 67 ha. The external areas VG-7, JR-1 will be tributary to Pond 2, which outlets to the Jock River. Areas tributary to the Jock River will remain so in the post development scenario.

5.0 EVALUATION STORM CONVEYANCE SYSTEMS

This section of the revised MDP has been included for historical reference; however, the evaluation of storm conveyance systems has not been revisited. The final storm conveyance strategy was approved through the Ontario Municipal Board Decision in 2014.

Modern storm conveyance systems were considered in light of ***Sewer Design Guidelines,*** the Technical Memorandum Technical Bulletin ISD-2012-1, as well as the proposed subdivision plan and streetscaping plan presented in the ***CDP***.

The City of Ottawa provided feedback on the evaluation matrix utilized to assess the preferred stormwater management scheme presented in the ***March 2010 SWM Report***. ***Table 8*** summarizes the evaluation criterion employed to select the preferred conveyance and servicing system.

Table 8
Summary of Decision Matrix Categories

Parameter	Indicators	Weighting
Caring and Healthy Communities		**30%**
C3 Impact on level of service	Maintains or improves level of service to the existing and future village residents.	15%
C9 Consistency with infrastructure planning policies	Compatibility with infrastructure servicing corridors and flexibility for enhancements to land use.	15%
Constructability and Functionality		**30%**
CO2 Schedule / Staging Opportunities	Ability to phase infrastructure to facilitate development phasing	6%
CO3 Construction Risk	Conforms to geotechnical, geomorphology, hydrological, etc.	9%
CO5 Disruption during construction	Location of new infrastructure in built up areas and nuisance effects	6%
CO6 Operation and maintenance	Proven track record, ease of operating and maintenance	9%
Cost		**40%**
E9 Annual Cost	Estimated annual maintenance cost	15%
E11 Total Capital Cost	Estimated capital costs.	25%

Each alternative is ranked based on the criteria presented in ***Table 9***. Under this ranking system, each individual criterion was ranked relatively for each alternative. For example, the 1 to 5 ranking for an individual alternative is determined based on the relative impact compared to all the other alternatives being evaluated. In regards to cost, the least costly will be automatically assigned a 5, while the most will be 1, with the remaining option prorated between 1 and 5 according to their estimated costs.

Capital cost for each scenario considered cut / fill requirements, trunk routing, and local storm services. While life cycle cost was considered to be the anticipated maintenance and operation of the sewer collection system, excluding the stormwater management facilities. The estimated costs are based on past data and are presented for comparison of alternatives only and are not for budgetary purposes.

Table 9
Decision Matrix Categories Ranking System

Ranking	Description
5 - Positive or No Impact	The alternative meets all applicable requirements, provides tangible benefits
4 – Minor Impact	The alternative has some minor negative impacts or dis-benefits that may easily be mitigated or compensated for
3- Moderate Impact	The alternative has noticeable negative impacts, however, the severity of the impacts may be reduced or compensated for
2 – Noticeable Negative Impact	The alternative has significant negative impacts which may be mitigated, although these may be costly, time consuming or result in other negative impacts
1 - Negative or Significant Impact	The alternative does not meet applicable requirements, results in significant dis-benefits and/or negative impacts cannot be mitigated

5.1 Summary of Alternatives Assessed

The conveyance systems reviewed contain minor and major conveyance components. Minor components were those with a 5-year carrying capacity, while the major system designed to convey runoff in excess of the minor capacity. The following summarizes the conveyance systems and storm service arrangements evaluated for use in the subject area.

- Foundation service to street storm sewer – Gravity connection
- Foundation service to dedicated foundation collector – Gravity connection
- No Foundation Service – Slab on grade units
- Foundation service to street storm sewer – Sump pump

5.2 Description of Alternatives

5.2.1 Foundation service to street storm sewer

A foundation service that outlets to a street storm sewer with a gravity connection is typically applied throughout the City of Ottawa in greenfield developments. In this servicing arrangement homes are established with underside of footings set 0.30 m above the modeled 100-year hydraulic grade line in the sewer. ***Figure 11*** in ***Appendix G*** illustrates the servicing arrangement. ***Figure 11*** illustrates the estimated sewer size and associated HGL determined for the recommended solution at MH ID 402.

The majority of the existing Village of Richmond is reliant on sump pumps for foundation drainage. A gravity serviced home in the Village of Richmond would raise the level of service in the area as the home owner would not be reliant on maintenance of privately-owned sump pumps.

Construction phasing and staging is contingent upon the completion of the receiving stormwater management facility.

As illustrated this servicing arrangement results in an approximate grade raise of 1.6m above existing ground, and therefore will result in areas exceeding grade raise restriction. In order to mitigate the settlement, surcharging is commonly employed. Any surcharging requirements necessary to construct homes would have potential negative impact on construction phasing. Most notably the time spent on waiting for settlement objectives to be reached as well as the transportation of surcharge material.

It was estimated that the site required a total net fill of ***1,906,500 m^3***. See ***Figure 12*** in ***Appendix G*** for an overview of estimated cut / fill.

The estimated capital cost for the construction of storm sewers and earthworks was ***$74,987,000***, while the 25-year life cycle costs were estimated to be ***$99,000***. See ***Appendix G*** for detailed cost breakdown.

5.2.2 Foundation service to dedicated foundation collector

Foundation services connected to a dedicated foundation collector sewer are not typically employed in Greenfield subdivision developments in the City of Ottawa. However, these systems are used in site plan developments where the parking lot drainage is separated from foundation drainage. The advantage being that the foundation drainage is hydraulically separated the system collecting street and parking lot drainage. ***Figure 13*** illustrates the estimated sewer size and associated HGL determined for the recommended solution at MH ID 402.

Several foundation drain routing options were investigated. Due to the topography of the area, a gravity outlet is not available to the site that would be cost effective from either a fill or sewer routing perspective. Therefore, it was conceived that this servicing arrangement would utilize a lift station to convey foundation drainage collected into the Van Gaal Drain. This would enable the site grading to take place at a much lower elevation. As depicted in ***Figure 13*** in ***Appendix G***, the site would be approximately ***1.1 m*** lower than ***Option 4.2.1***.

As described in ***Section 5.2.1***, the majority of the Village of Richmond is reliant on sump pumps for foundation drainage. This alternative would increase the level of service to the home owner as the home owner would not be reliant on maintenance of privately-owned sump pumps. In this scenario, the liability would be on the municipality to ensure continuous operation of the pump station during periods where foundation drainage was collected.

Construction phasing and staging is contingent upon the completion of the receiving stormwater management facility and foundation drainage lift station.

This servicing arrangement respects the grade raise restriction throughout the development area. It was estimated that the site required a total net fill of ***619,858 m³***. See ***Figure 14*** in ***Appendix G*** for an overview of estimated cut / fill.

The estimated capital cost for the construction of storm sewers and earthworks was ***$30,219,000***, while the 25-year life cycle costs were estimated to be ***$288,000***. See ***Appendix G*** for detailed cost breakdown.

5.2.3 No Foundation Service – Slab on grade units

Slab on grade units, i.e. no basements or limited crawl spaces only, do not require foundation drainage. Foundation walls have equal amount of hydrostatic pressure on both sides and there would be no living space in the subsurface that would require a storm service. Slab on grade units have never been constructed for an entire community within the City of Ottawa.

As depicted in ***Figure 15*** in ***Appendix G*** the street storm sewer would be placed a minimum elevation below the finished grade.

This servicing arrangement respects the grade raise restriction throughout the development area.

It was estimated that the site required a total net fill of ***967,439 m³***. See ***Figure 16*** in ***Appendix G*** for an overview of estimated cut / fill.

The estimated capital cost for the construction of storm sewers and earthworks was ***$29,529,000***, while the 25-year life cycle costs were estimated to be ***$99,000***. See ***Appendix G*** for detailed cost breakdown.

5.2.4 Foundation service to street storm sewer – Sump pump

Foundations equipped with sump pumps that outlet to storm sewers are not typically employed in Greenfield subdivision developments in the City of Ottawa. In this servicing arrangement homes are situated with underside of footings 0.15m above the invert of the receiving sewer. The sump pump will be equipped with a swan neck that is 0.30m above the modeled 100-year hydraulic grade line. ***Figures 17 and 18***, included in ***Appendix G*** illustrate the servicing arrangement. ***Figure 17*** illustrates the estimated sewer size and associated HGL determined for the recommended solution at MH ID 402

As described in ***Section 5.2.1***, the majority of the Village of Richmond is reliant on sump pumps for foundation drainage. This alternative remains consistent with the existing level of service within the Village of Richmond.

Construction phasing and staging is contingent upon the completion of the receiving stormwater management facility.

As depicted in ***Figure 17***, the street storm sewer would be placed a minimum elevation below the finished grade. This servicing arrangement respects the grade raise restriction throughout the development area.

Golder Associates were retained to assess the hydrogeological effects of subsurface drainage for the subject lands to determine the suitability of employing sump pump as a means to provide foundation drainage. Their technical memorandum is included in ***Appendix F***. Their analysis concluded that the majority of the development would have USFs established above the long-term (steady-state) groundwater elevations. During a 100-year storm event and spring freshet it is anticipated that standard, commercially available sump pumps will function as intended. An extra level of protection with backup sump pumps with reserve power is also proposed alongside of the typical sump pump arrangement. With a predicted inflow rate of up to 2.0 m^3/day as summarized in the memorandum this would equate to up to 21 days of backup pumping (see DSEL memorandum also found in ***Appendix F***).

It was estimated that the site required a total net fill of ***671,257 m^3***. See ***Figure 19*** in ***Appendix G*** for an overview of estimated cut / fill.

The estimated capital cost for the construction of storm sewers and earthworks was ***$26,586,000*** while the 25-year life cycle costs were estimated to be ***$99,000***. See ***Appendix G*** for detailed cost breakdown.

5.3 Comparison of Alternatives

Table 10
Comparison of Alternatives

Parameter	Option 4.2.1. Gravity System	Option 4.2.2. Foundation Collector	Option 4.2.3. Slab on Grade Units	Option 4.2.4 Sump Pumps
Caring and Healthy Communities				
C3 Impact on level of service	Improves level of service when compared to Village of Richmond at large	Improved level of service to individual home owner	Reduced level of service. No basements provided.	Consistent with Village of Richmond level of service.
C9 Consistency with infrastructure planning policies	Consistent with City of Ottawa Greenfield development. Potential negative impact on land use due to fill requirements.	A departure from typical greenfield development.	Limits land uses by not providing foundation drainage services.	A departure from typical greenfield development outside of the Village of Richmond. However, common with Village limits.
Constructability and Functionality				
CO2 Schedule / Staging Opportunities	Phasing potentially inhibited by fill requirements, obtaining fill and potential surcharging requirements in areas exceed grade raise parameters.	Increased capital cost on the outset of the project for lift station. Third pipe will increase construction time.	No impact to construction phasing.	No impact to construction phasing.
CO3 Construction Risk	Exceed geotechnical parameters.	Meets geotechnical parameters.	Meets geotechnical parameters.	Meets geotechnical parameters.
CO5 Disruption during construction	Significantly more imported material to site for filling. Increased construction traffic	Increased construction duration for third pipe and lift station construction.	No additional construction disturbance expected.	No additional construction disturbance expected.
CO6 Operation and maintenance	Sewer arrangement a proven track record, with normal operating and maintenance expected. Anticipate increased road work maintain for potential settlement issues.	Increased operation and maintenance for additional pipe and lift station. A lift station failure would impact entire development.	Sewer arrangement a proven track record, with normal operating and maintenance expected.	Sewer arrangement would require normal operating and maintenance. Sump pump maintenance would be required by home owner.
Cost				
E9 Est. Maintenance cost	$99,000	$288,000	$99,000	$99,000
E11 Est. Capital Cost	$74,987,000	$30,219,000	$29,529,000	$26,586,000

5.4 Ranking of Alternatives

Table 11
Ranking of Alternatives

Parameter	Weighting	Option 5.2.1		Option 5.2.2		Option 5.2.3		Option 5.2.4	
		Score	Rank	Score	Rank	Score	Rank	Score	Rank
Caring and Healthy Communities									
C3 Impact on level of service	15%	5	0.75	4	0.60	1	0.15	2	0.30
C9 Consistency with infrastructure planning policies	15%	5	0.75	3	0.45	2	0.30	3	0.45
Constructability and Functionality									
CO2 Schedule / Staging Opportunities	6%	1	0.06	2	0.12	5	0.30	5	0.30
CO3 Construction Risk	9%	1	0.09	5	0.45	5	0.45	5	0.45
CO5 Disruption during construction	6%	1	0.06	2	0.12	5	0.30	5	0.30
CO6 Operation and maintenance	9%	4	0.36	1	0.09	5	0.45	2	0.18
Cost									
E9 Est. Maintenance cost	15%	5	0.75	1	0.15	5	0.75	5	0.75
E11 Est. Capital Cost	25%	1	0.25	4.6	0.51	4.7	0.98	5	1.25
Total	**100%**		**3.07**		**3.14**		**3.87**		**3.98**

5.5 Conveyance System Conclusion

Each alternative was described in detail under ***Section 5.2.*** and was compared side by side in tabular format in ***Section 5.3***. ***Section 5.4*** presented the weighting and ranking that was applied to each based on the discussion presented in the previous subsections. Option 5.2.4 emerged with the highest ranking.

Option 5.2.1, was ranked lowest. The capital cost for developing this option is cost prohibitive. Not only that a substantial amount of fill is required, a majority of the subdivision will have footings above the existing ground. Therefore, structural fill will be required to support the footings. Furthermore, due to exceeding grade raise recommendations, the significant amount of fill required and associated concerns, this option was not selected.

Option 5.2.2 scored poorly in sections C06, E9 and E11. Operating and maintaining a third pipe as well as a lift station set this alternative back.

Option 5.2.3, scored strongly in construction and functionality as well as capital cost. However, it scored slight lower in the C3 and C9 categories than the preferred solution.

Sections 6.0 - Stormwater Conveyance and ***7.0 - Stormwater Management Facilities***, provide master servicing level detailed information designed on the basis of Option 5.2.4. – Foundation Service to street storm sewer with homes equipped with sump pumps.

6.0 STORMWATER CONVEYANCE

As presented in ***Section 5.0***, the recommended stormwater servicing solution consists of a major system, a minor system, and homes with basements will be equipped with sump pump to provide foundation drainage. The City of Ottawa released Technical Bulletin ISTB-2019-02 on July 8, 2019 regarding the use of sump pumps. The sump pump configuration is presented on ***Figure 18***, included in ***Figures***.

As design has advanced, it is currently proposed that sump pumps are not utilized for the lands south of Ottawa Street. This design is reflected on the Master Grading Plan, which is depicted on ***Drawing 2***, which allows for the basement to be serviced by gravity.

The November 2013 MDP conceptualized the stormwater management system based on the City of Ottawa standard criteria at the time (i.e. 5-year level of service for sewers and 30 cm of ponding, etc.). With the release of new standards in September 2016, the stormwater design has been updated to reflect the new standards. See ***Section 6.2*** for additional discussion.

Further to the updates to the ***Sewer Design Guidelines***, a revision to the drainage split between Pond 1 and Pond 2. The area x runoff coefficient was maintained to each pond to ensure there was no impact to the design of each facility and their associated approvals. Refer to Section 6.0 of the ***Executive Summary*** for the figures showing the revision to the drainage split. The updated modelling reflects these changes as detailed in the ***Addendum to Preliminary Stormwater Management Plan (JFSA Modelling Memo)*** by JFSA dated October 9, 2019, which is included in ***Appendix I***.

The following sub-sections provide additional analysis of the recommended stormwater servicing solution.

6.1 Grade Control Plan - Major System

The proposed master grading plan is depicted on ***Drawing 2***. ***Drawing 2*** illustrates centerline of road grades, which were established on three criteria:

- Minimum depth to pipe invert = 2.1 m
- Minimum depth to pipe obvert = 1.5 m
- Minimum slope of saw tooth road pattern = 0.15% from high point to high point.

Where major system flow is shown to cross Perth Street and Ottawa street, the minor system was designed to convey flow under these streets. Additional information regarding conveyance through the minor system is contained in ***Section 6.2***.

6.2 Minor System

Drawing 3 illustrates the proposed minor system. The storm sewer system will be designed in accordance with the amendment to the storm sewer and stormwater management elements of the Ottawa Design Guidelines – Sewer (Technical Bulletin PIEDTB-2016-01, September 6, 2016). The primary changes to the minor system, with the publishing of this Technical Bulletin, are as follows:

The minimum sewer size for local streets has been revised from the 5-year event to the 2-year event without ponding. Collector streets remain at the 5-year capture and arterial roads at the 10-year capture. The maximum HGL remains at 0.30 m below the underside of footing.

The minor storm sewer system will be sized as follows:

- 2-year event for local streets;
- 5-year event for collector streets; and
- 10-year events for arterial roads

Refer to ***Figure 23***, included in ***Figures***, which depicts the road classification for the different minor system levels of service as described above. ***Table 12*** summarizes the minimum parameters utilized to size the stormwater conveyance system.

Table 12
Storm Sewer Design Criteria

Design Parameter	Value
Minor System Design Return Period	2-Year (Local Streets), 5-Year (Collector Streets), 10-Year (Arterial Streets) – PIEDTB-2016-01
Minor System Capture for Parkland	5-Year
Minor System Capture for Institutional Lands	5-Year
Major System Design Return Period	100-Year
Intensity Duration Frequency Curve (IDF) 2-year storm event: A = 723.951, B = 6.199, C = 0.810 5-year storm event: A = 998.071, B = 6.053, C = 0.814 10-year storm event: A = 1174.184, B = 6.014, C = 0.816	$i = \frac{A}{(t_c + B)^C}$
Minimum Time of Concentration	10 minutes
Rational Method	$Q = CiA$
Runoff coefficient for paved and roof areas	0.90
Runoff coefficient for landscaped areas	0.20
Storm sewers are to be sized employing the Manning's Equation	$Q = \frac{1}{n} AR^{2/3} S^{1/2}$
Minimum Sewer Size	250 mm diameter
Minimum Manning's 'n'	0.013
Service Lateral Size	100mm dia. PVC SDR 28 with a minimum slope of 1.0%. Homes to be equipped with sump pump flow.
Minimum Depth of Cover	2.0 m from crown of sewer to grade (insulation when not possible)
Minimum Full Flowing Velocity	0.8 m/s
Maximum Full Flowing Velocity	3.0 m/s
Additional Considerations	Storm sewer maintenance holes serving sewers 900 mm diameter and less shall be constructed with 300 mm deep sumps. Maintenance holes for storm sewers greater than 900 mm must be benched.
Extracted from Sections 5 and 6 of the City of Ottawa Sewer Design Guidelines, October 2012, Technical Bulletin PIEDTB-2016-01	

A Rational Method storm sewer design sheet is enclosed in ***Appendix H***. The pipe sizes were confirmed through hydraulic modelling as described in ***Section 6.3***.

The subject lands sloped generally from west to east under pre-development conditions. As described in ***Section 3.4***, there are significant areas west of the subject land that drain through the development property under pre-development conditions. As illustrated on ***Drawing 3***, the external areas are summarized below:

- 63.1 ha Perth Street road side ditch north;
- 34.4 ha Perth Street road side ditch south;
- 94.2 ha approximately midpoint between Perth and Ottawa Streets;
- 39.2 ha Ottawa Street road side ditch north and;
- 32.6 ha Ottawa Street road side ditch south.

The above external areas will be serviced by the two SWM ponds as they were included in the design of Pond 1 and Pond 2.

Due to anticipated urbanization of Perth Street and Ottawa Street as well as the site at large, these external areas will be collected and conveyed within storm sewers. These areas will be directed through the stormwater management facilities.

6.2.1 Deviations from Design Guidelines

The design of the sewer outfall from SWM Facility #1 (see ***Section 7.1*** of this report for Facility #1 details) results in a circumstance where it has to cross underneath the existing Moore tributary as noted in the ***Ultimate Pond 1 Design Brief***. Due to site constraints (i.e. grading and both conveyances outletting to the same tributary) there is minimum cover between the ditch invert and the obvert of the sewer outfall (0.10 m). In the detailed design of SWM Facility #1, twin 525 mm storm pipes were proposed and installed, crossing under the Moore tributary to mitigate the depth of cover. As a result, some of the storm sewers in the RVDC lands use spring line to spring line connections, deviating from obvert to obvert connections per *Section 6.2.10* of the ***Sewer Design Guidelines***. Justification for spring line to spring line connections is provided in ***Deviations from Guidelines and Standards Report (Springline Connections) Fox Run Subdivision Richmond – Phase 2 (South)*** prepared by DSEL, dated May 31, 2019 for the RVDC lands. If necessary, justification for spring line connections will be provided in the detailed design of the other land holdings within the Western Development Lands.

6.3 Sump Pump Service

The majority of the Village of Richmond is reliant on sump pumps for foundation drainage as discussed in ***Section 5.2.4***. The use of sump pumps for the subject lands remains consistent with the existing level of service within the Village of Richmond.

As noted in ***Section 6.0***, it is proposed that the areas south of Ottawa Street will have foundation drainage serviced by gravity. All other areas are proposed to have foundation drainage serviced by sump pumps.

In 2019, the City published Technical Bulletin ITSB-2019-02 (July 8, 2019), which outlines the criteria for sump pumps, the requirements for hydrogeological assessments areas with sump pumps, and revised information on HGL for storm sewers with sump pumps. In detailed design, the proposed sump pump design will conform to Technical Bulletin ITSB-2019-02 (July 8, 2019). The sump pump detail can be found on ***Figure 18***, included in ***Figures***, and the sump pump components and requirements are outlined in the following table.

Table 13
Sump Pump Design Criteria

Component	Requirements
Sump Pump (General)	Shall be: ○ In accordance with City of Ottawa Technical Bulletin ISTB-2019-02 (July 8, 2019); ○ A submersible pump; ○ Automatically controlled and set to maintain the water level at the same elevation as the foundation drain; capable of discharging a minimum flow of 0.9 L/s at 3.6 m head.
Sump Pump (Primary)	Shall be: ○ CSA Approved; ○ Connected to an electrical circuit that supplies no other outlets, switches or equipment; ○ Equipped with a self-resetting thermal overload protection switch; ○ Rated for continuous duty.
Sump Pump (Backup)	Shall be: ○ CSA Approved; ○ Connected to an electrical circuit that supplies no other outlets, switches or equipment except: A) Charging equipment for backup power and B) Alarm system for primary pump and power failure; ○ Equipped with a self-resetting thermal overload protection switch; ○ Rated for continuous duty; ○ Equipped with an audible failure alarm to notify homeowner that the primary pump has failed or the power supply has been interrupted; ○ Capable of discharging a minimum capacity of 0.90 L/s at 3.6 m head; ○ Powered by a deep-cycle lead-acid battery with a minimum ampere-hour (AH) rating of 100 AH.
Sump Pit	Shall: ○ Have walls and bottoms constructed of concrete polyethylene, polypropylene, or fiberglass; ○ Be provided with a sealed cover; ○ Have a cover which must be secured in a manner acceptable to the authority having jurisdiction; ○ Be vented to the outdoors.
Discharge Pipe System from Sump Pump	Shall: ○ Be in accordance with *Appendix 9 – Standard Sump Pump Configuration in Greenfield Subdivisions with Clay Soils on Full Municipal Services*; ○ Consist of materials and be installed in conformance with the Ontario Building Code; ○ Have a minimum internal diameter of 38 mm (1-1/2") from the sump pump to the 100 mm (4") storm building drain; ○ Have a union, a check valve and a shut-off valve installed in that sequence in the direction of discharge outside of the sump pit;

	○ Have a goose neck with a height of no more than 250 mm below the top of the foundation wall and discharge into the vertical leg of the storm building drain; ○ Have a minimum dimension of 600 mm from the vertical leg of the storm discharge pipe to the horizontal offset upstream of the backwater valve; ○ Include a CSA approved backwater valve for the stormwater discharge; ○ Include an emergency discharge pipe to the outside ground surface; ○ Be vented to the outdoors; Be graded or otherwise protected to prevent the freezing of water in the system.
Connections	○ Only the perimeter foundation drainage system will be connected to the sump pit. Eaves trough, surface exterior drainage, swimming pool backwash, floor drains and any other water sources shall not be connected to the sump pit; ○ All new residences with installed sump pump systems must include: ○ Eaves troughs discharging to the surface with appropriate drainage away from the house at the time of the original sale; ○ Drainage layer as per the Ontario Building Code; ○ Clay backfill placed against the drainage layer with the clay extending a minimum 1.5 m out from the drainage layer for all sides of the foundation; ○ Impervious backfill capping at the ground surface surrounding the perimeter of the residence area and slope away from the building after settling of backfill; except in areas where window wells are required by Ontario Building Code; The sump pump shall be directly connected to a storm building drain from the building to the property line.

6.4 Hydraulic Grade Line

JFSA was retained to prepare hydrological and hydraulic models to assess the performance of the sewer system. Results of their analysis are presented on ***JFSA Modelling Memo***, which is included in ***Appendix I***.

As detailed in the ***JFSA Modelling Memo***, the performance of the minor and major drainage systems for the drainage areas to Pond 1 and Pond 2 have been evaluated using the SWMHYMO and XPSWMM programs. It is noted that sump pump flows were included in the XPSWMM model at a rate of 0.23 L/s/ha, for those lands proposed to be equipped with sump pumps for foundation drainage (all lands north of Ottawa Street). Refer to the ***JFSA Modelling Memo*** in ***Appendix I*** for full details of the Pond 1 and Pond 2 minor system analysis. The 0.23 L/s/s/ha of flow was based on average development density of approximately 27.8 lots/ha, where 50% of sump pumps are on at any given time and a flow contribution of 1.44 m^3/day/lot as estimated by Golder Associates Limited.

Profiles of the trunk sewers are illustrated on ***Drawings 4, 5 and 6***. The profiles illustrate the existing ground, minimum depth of cover to finished grade, and hydraulic grade line elevations.

6.5 Moore Tributary

As shown on ***Drawings 1, 2 and 3***, there is an existing Moore Tributary along the western property line that then traverses the Mattamy (Jock River) Limited Lands to the Arbuckle Drain. The Realignment of the Moore Tributary is shown on ***Figure 22.*** There are proposed to be two road crossings, which will be addressed by way of box culverts in the Moore Tributary. There will be a minimum of 0.30 m clearance (top of pipe to bottom of pipe) between the box culverts and the associated storm sewer crossings, in line with typical pipe crossing criteria.

The minimum slope on the Moore Tributary is 0.10% and this slope is constrained by existing grades upstream and downstream, as well as maintaining the clearance as noted above at the culvert crossings.

7.0 STORMWATER MANAGEMENT FACILITIES

JFSA was retained to prepare hydrological and hydraulic models to assess the performance of the proposed stormwater management facilities. While Pond 1 has progressed to detailed design and construction (for an interim condition to service Phase 1 of the Fox Run Subdivision), Pond 2 is at the conceptual design stage. The current overall analysis for Pond 1 and Pond 2 is detailed in the ***JFSA Modelling Memo*** by JFSA dated October 9, 2019.

The following summarizes each stormwater management facility as well as the operational parameters of each.

7.1 Stormwater Management Facility #1

Pond 1 is located south of Perth Street and will treat part of the proposed development and then discharge to the Arbuckle Drain. Details of the interim Pond 1 design that has been constructed is discussed in the ***Interim Stormwater Management Pond 1 Western Development Lands – Richmond*** prepared by JFSA and DSEL dated March 2018. In September 2019, JFSA and DSEL prepared ***Design Brief for Stormwater Management Pond 1 Western Development Lands – Richmond (Ultimate Pond 1 Design Brief)*** for the ultimate Pond 1 design. The overall Western Development Lands have a total drainage area of 156.24 ha, 89.54 ha of which will be serviced by Pond 1. Additionally, 1.55 ha of external Perth Street and 99.36 ha of undeveloped lands southwest of the proposed development are also tributary to Pond 1, for a total drainage area of 190.45 ha to Pond 1.

Pond 1 is proposed as a wet pond with an erosion, quality, and quantity release components. Pond 1 outlets to the existing Arbuckle Drain. Water quality control is provided by the permanent pool sized for enhanced level of protection per MECP guidelines (80% TSS Removal). Erosion control is provided by controlling the 2-year release rate to 330 L/s, in accordance with the erosion threshold identified in the March 2009 ***Natural Environmental & Impact Assessment Study for Mattamy Richmond Lands*** by Parish Geomorphic. Furthermore, the October 26, 2012 Van Gaal Drain Erosion Assessment memo by JTB Environmental Systems Inc. indicated that the 2-year to 100-year outflows from Pond 1 should discharge to the Van Gaal / Arbuckle Drain at a velocity of 0.225 m/s or less. This is achieved by a velocity reduction measures at the Pond 1 extended detention outlet pipe to the watercourse. Water quantity control is provided to ensure that there is sufficient pond storage to meet the 5- to 100-year target release rates based on pre-development flows.

Low flows are directed to a storm sewer and outlet approximately 40 m downstream of the Fortune Street culvert. Runoff generated during events in excess of a 25-year storm would be released to the Arbuckle Drain through the overflow weir in addition to the low flow outlet. The outlet structure will consist of two orifices to attenuate flow to the Quality and Erosion control targets. ***Table 14*** summarizes the outlet control design parameters from the ***Ultimate Pond 1 Design Brief***.

Table 14
Summary of SWMP 1 Outlet Structure Design

Baseflow Control	Quality Control	Erosion Control	Quantity Control
Vertical Orifice	Vertical Orifice	Vertical Orifice	Rectangular Weir
100 mm dia.	300 mm dia.	300 mm dia.	67 m Wide
INV = 92.10	INV = 92.35	INV = 92.65	INV = 93.68

Table 15a and ***15b*** summarizes the pond's operational characteristics.

Table 15a
Summary of SWMP 1 Storage Characteristics (Free Outfall Conditions)

Pond Component	Total Inflow (m^3/s)	Pond Level (m)	Pond Outflow(2) (m^3/s)	Volume Used(2) (m^3)
Permanent Pool	N/A	92.350	N/A	45,330
Quality Control	N/A	92.607	0.080	7,618
2yr/24hr SCS	7.263	93.235	0.317	27,917
5yr/24hr SCS	11.494	93.668	0.418	43,496
10yr/24hr SCS	14.960	93.726	1.584	45,800
25hr/24hr SCS	18.304	93.757	2.715	47,046
50yr/24hr SCS	21.635	93.771	3.429	47,643
100yr/24hr SCS	23.506	93.785	4.084	48,196

Table 15b
Summary of SWMP 1 Storage Characteristics (Restrictive Downstream Conditions)

Pond Component	Total Inflow (m^3/s)	Pond Level (m)	Pond Outflow(2) (m^3/s)	Volume Used(2) (m^3)
Permanent Pool	N/A	92.350	N/A	45,330
Quality Control	N/A	92.607	0.080	7,618
2yr/24hr SCS	7.263	93.558	0.000	39,285
5yr/24hr SCS	11.494	93.717	0.920	45,450
10yr/24hr SCS	14.960	93.744	1.833	46,536
25hr/24hr SCS	18.304	93.767	2.880	47,483
50yr/24hr SCS	21.635	93.780	3.484	47,990
100yr/24hr SCS	23.506	93.793	4.171	48,563

7.1.1 Base Flow Augmentation

In coordination with the RVCA, a base flow augmentation outlet to the tributary (Arbuckle Drain) of Jock River has been provided. The depth of the permanent pool within Pond 1 is set at 2.0 m at an elevation of 92.35 m, whereas ***SWMPDM*** suggest a mean depth between 1.0 and 3.0 m. Therefore, up to 1.0 m of contemplated permanent pool is available to provide base flow augmentation. Controlled flows from the base flow augmentation orifice will be conveyed by the 300 mm pipe with a slope of 0.13% and a capacity of 35 L/s. Base flow outflow to the 300 mm pipe is 32 L/s, which is less than the 35 L/s capacity, and will discharge to the Arbuckle Drain. Refer to ***Figure 21***, included in ***Figures***, for depiction of SWM Pond 1. A backwater valve is also provided in accordance with the ***Section 7.1.2*** of this report for the facility operation discussion.

7.1.2 Facility #1 Operation

In the pond design it is anticipated that spring floodwaters will back into Pond 1 for events more frequent than the 25-year spring event via the 300 mm diameter quality control orifice (92.35 m invert) and 300 mm diameter erosion control orifice (92.65 m invert). However, as explained below, until the quantity control weir is overtopped, this effectively only raises the permanent pool (i.e. dead storage) elevation and does not negatively impact the quality control performance of the pond. The base flow augmentation outlet, proposed below the permanent pool elevation of 92.35 m, will be equipped with a backwater valve to ensure that the Arbuckle Drain will not back into Pond 1 through this outlet.

The Pond 1 quality control and erosion control orifices outlet to the Jock River tributary downstream of the quantity control weir, via a constructed 900 mm diameter pipe discharging to the drain between Fortune Street and Maitland Street. A short section of outlet pipe crossing under the Moore tributary has been replaced by two 525 mm storm pipes. As such, while the 25-year spring water level at the quantity control weir is 93.69 m (HEC-RAS cross-section 961), the water level at the quality/erosion control outlet is 93.43 m (HEC-RAS cross-section 521). Note that the 2-year spring water levels at these locations are 93.28 m and 92.65 m, respectively.

The active storage volume required for quality control in Pond 1 is 7,618 m^3 based on 40 m^3/ha for a 190.452 ha drainage area (89.54 ha subdivision drainage area, 1.555 ha external drainage area from Perth Street and 99.36 ha natural lands south of the subdivision). Please note the 40 m^3/ha is per the ***SWMPDM***. The 25-year spring flood level at the quality / erosion control outlet effectively raises the permanent pool (i.e. dead storage) elevation of Pond 1 from 92.35 m to 93.43 m, leaving 11,046 m^3 of active storage volume between the effective permanent pool and the invert of the quantity control weir (93.68 m).

Therefore, for spring events up to the 25-year return period, more than sufficient active quality control volume is provided in Pond 1 below the quantity control weir to treat runoff from the 91.82 ha subdivision drainage area. As previously noted, for events exceeding the 25-year return period, flood levels will not overtop the quantity control weir until almost 5 days into the 10-day event; well after the "first flush" containing much of the winter's accumulation of road salt and grit has passed through the pond.

Similarly, the "first flush" of the 2- to 25-year spring events, taken as the first 25 mm of rainfall / snowmelt, will pass between 30 to 100 hours before the peak on the Van Gaal Drain.

It is noted that the 80% TSS removal required by the MECP is not a target to be met for every storm, but a long-term statistical average. Therefore, some storm events, and in particular large rainfall events, will not have 80% TSS removal; this is balanced by the TSS removal for smaller, more frequent storm events.

7.2 Stormwater Management Facility #2

Pond 2 is located north of Ottawa Street and is proposed to be a wet pond discharging to the Jock River and requires quality control only. The total drainage area to Pond 2 is 110.46 ha, which includes 38.66 ha of subdivision drainage and 71.8 ha of undeveloped land west of the subject site as shown on ***Drawing 3. Figure 21*** illustrates the proposed pond layout and cross-section.

Quality control will be provided for Pond 2 in accordance with MECP enhanced protection requirements (80% TSS removal). It is understood that quantity control is not required for discharging to the Jock River. However, Pond 2 will be limited to 100-year release rate of 2.235 m^3/s based on the capacity of the 1500 mm diameter outlet (0.10% slope) pipe to the Jock River. JFSA has evaluated the Pond 2 outflows and they do not exceed the outlet pipe capacity of 2.235 m^3/s and the 100-year pond elevations are well below the top of berm elevation. Refer to ***Addendum to Preliminary Stormwater Management Plan*** memo prepared by JFSA on October 9, 2019 in ***Appendix I*** for further details.

The sewer profile of the outlet is shown on ***Drawing 6*** in ***Drawings*** (labelled Pond Outlet Pipe)***.***

The outlet structure will consist of a vertical orifice and rectangular weir to attenuate flow to the quality and quantity control targets. ***Table 16*** summarizes the outlet control design parameters.

Table 16
Summary of SWMP 2 Outlet Structure Design

Quality Control	Quantity Control
Vertical Orifice	Rectangular Weir
280 mm dia.	1.60 m Wide
INV = 93.20	INV = 93.70

Table 17 summarizes the pond's operational characteristics.

Table 17
Summary of SWMP 2 Storage Characteristics

Pond Component	Pre-development Outflow (m^3/s)	Pond Level (m)	Pond Outflow[(2)] (m^3/s)	Volume Used[(2)] (m^3)
Permanent Pool	N/A	93.20	N/A	16,669
Quality Control	N/A	93.70	0.101	6,446
2yr/24hr SCS	0.705	93.97	0.530	10,6633
5yr/24hr SCS	1.094	94.12	0.906	13,336
10yr/24hr SCS	1.364	94.22	1.173	15,138
25hr/24hr SCS	1.708	94.33	1.499	17,255
50yr/24hr SCS	1.976	94.43	1.795	19,152
100yr/24hr SCS	2.267	94.52	2.094	21,037

7.3 Stormwater Management Conclusions

JFSA was retained to prepare hydrological and hydraulic models to assess the performance of the proposed stormwater management facilities. While Pond 1 has progressed to detailed design and construction, Pond 2 is at the conceptual design stage.

Parts of the drainage systems tributary to Pond 1 have progressed to detailed design stage and construction is underway. Other areas, including the full drainage system tributary to Pond 2, are at the conceptual design stage and a preliminary analysis has been completed to confirm that the design is in accordance with current standard City of Ottawa modeling techniques. The elements of design that have been updated with the release of technical bulletins since the last version of this report have been fully incorporated.

In addition to updates based on the technical bulletins, additional revisions have been made. The drainage split between Pond 1 and Pond 2 has been updated but the overall areas x runoff coefficient have remained consistent to ensure there are no revisions to the existing pond designs and corresponding approvals.

Previously the entire Western Development Lands were planned to be designed with sump pumps providing foundation drainage. The updated design allows for the units south of Ottawa Street to have foundation drainage by gravity.

8.0 WATER BUDGET

To investigate the effect of proposed developments on existing infiltration rates the pre and post development hydrologic models prepared for this study were converted to continuous simulations. This included the conversion of CALIB NASHYD and CALIB STANDHYD commands to CONTINUOUS NASHYD and CONTINUOUS STANDHYD. The input and output files are included on a CD at the back of this report. These new hydrograph commands add time dependent parameters used in updating various hydrologic data during continuous simulations including initial abstraction recovery time, interval event time, etc. These new hydrographs commands are used with a COMPUTE API (Antecedent Precipitation Index) command which also updates various hydrological parameters during continuous simulations. Simulations were completed using AES (Atmospheric Environment Services Canada) rain gauge data from 1967 through to 2003 (excluding missing 2001 rainfall data).

Table 18 summarizes the estimated average annual infiltration volume for the proposed development under existing conditions and post-development conditions. The complete results of the Continuous simulation from 1967 to 2003 are located in ***Appendix J*** along with a technical memorandum prepared by JFSA.

Table 18
Pre-development Infiltration

Description	Area (ha) [1]	Estimated Annual Infiltrated Volume (m^3/yr)		
		Average	Minimum	Maximum
Total Rainfall	126.81	747,066	407,821	1,187,449
Runoff (no Infiltration)	126.81	415,191	233,521	713,598
Runoff (With Infiltration)	126.81	201,113	99,838	403,700
Infiltration	126.81	**214,079**	109,247	328,818

(1) Note: For a 126.81ha drainage area as per the October 2013 Preliminary Stormwater Management Plan memo by JFSA (found in ***Appendix I***).

Table 19 summarizes the average percent decrease in infiltration as a result of development. As demonstrated, directing roof leaders to grassed areas improves post-development infiltration substantially.

Table 19
Post-development Infiltration

Description	Area (ha)	Estimated Annual Infiltrated Volume (m^3/yr)		
		Average	Minimum	Maximum
Total Rainfall	126.81	747,066	407,821	1,187,449
Runoff (no Infiltration)	126.81	425,089	241,345	724,288
Runoff (With Infiltration)	126.81	336,083	189,264	595,639
Infiltration	126.81	**89,007**	47,693	143,321

(1) Note: For a 126.81ha drainage area as per the October 2013 Preliminary Stormwater Management Plan memo by JFSA (found in ***Appendix I***).

Based on the existing and proposed continuous simulations, the average annual infiltration over the drainage are is approximately 58.4% less under proposed conditions (89,007 m^3) than under existing conditions (214,079 m^3).

In addition to the above, there are areas of the development land (i.e. southwest portion) where there are silty sands which may be conducive to the incorporation of infiltration measures. It is proposed that a modified City Standard S29 (Perforated Pipe installation) be utilized which will include an additional depth of clear stone below the pipe invert. This added measure will be limited to rear yards and park spaces where receiving sewers will not be designed to accept flow from streets.

9.0 CONCLUSION AND RECOMMENDATIONS

Mattamy (Jock River) Limited has retained David Schaeffer Engineering Ltd. (DSEL) to update a stormwater management report in support of their application for draft plan of subdivision. This study constitutes a resubmission of previously submitted work and addresses the City of Ottawa comment that the Master Drainage Plan (MDP) be updated to reflect the updates to the ***Sewer Design Guidelines***.

Adjacent to the Mattamy (Jock River) Limited lands, the RVDC Lands comprise part of the overall Master Drainage Plan. The RVDC Lands were draft approved in 2015, with Phase 1 currently under construction and Phase 2 in detailed design stage. This report provides sufficient detail with respect to the stormwater management system including minor and major system conveyance and stormwater facilities to support the Mattamy (Jock River) Ltd.'s draft plan of subdivision application.

DSEL recommends the following:

- Works required to amend floodplain limits will need to be implemented prior to the development proceeding in the respective areas;
- A storm sewer system consisting of a minor and major systems with homes serviced via sump pumps is recommended;
- Two stormwater management facilities will service the development lands; of this one is currently constructed (to be expanded to ultimate) and one is conceptually designed;
- A site grading scheme for the Mattamy (Jock River) Ltd lands was developed to ensure major system conveyance and respect the grade raise restrictions;
- The detailed design for the Richmond Village Phase 1 and Fox Run Phase 2 (north and south) as well as the external areas are designed in accordance with updated City of Ottawa design criteria; and
- The preliminary design for the Mattamy (Jock River) Ltd lands has been completed in accordance with updated City of Ottawa design criteria

Prepared by,
David Schaeffer Engineering Ltd.

J. Ailey

LICENSED PROFESSIONAL ENGINEER
2019/10/15
J. AILEY
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J. Ailey
PROVINCE OF ONTARIO

Per: Jennifer Ailey, P.Eng.

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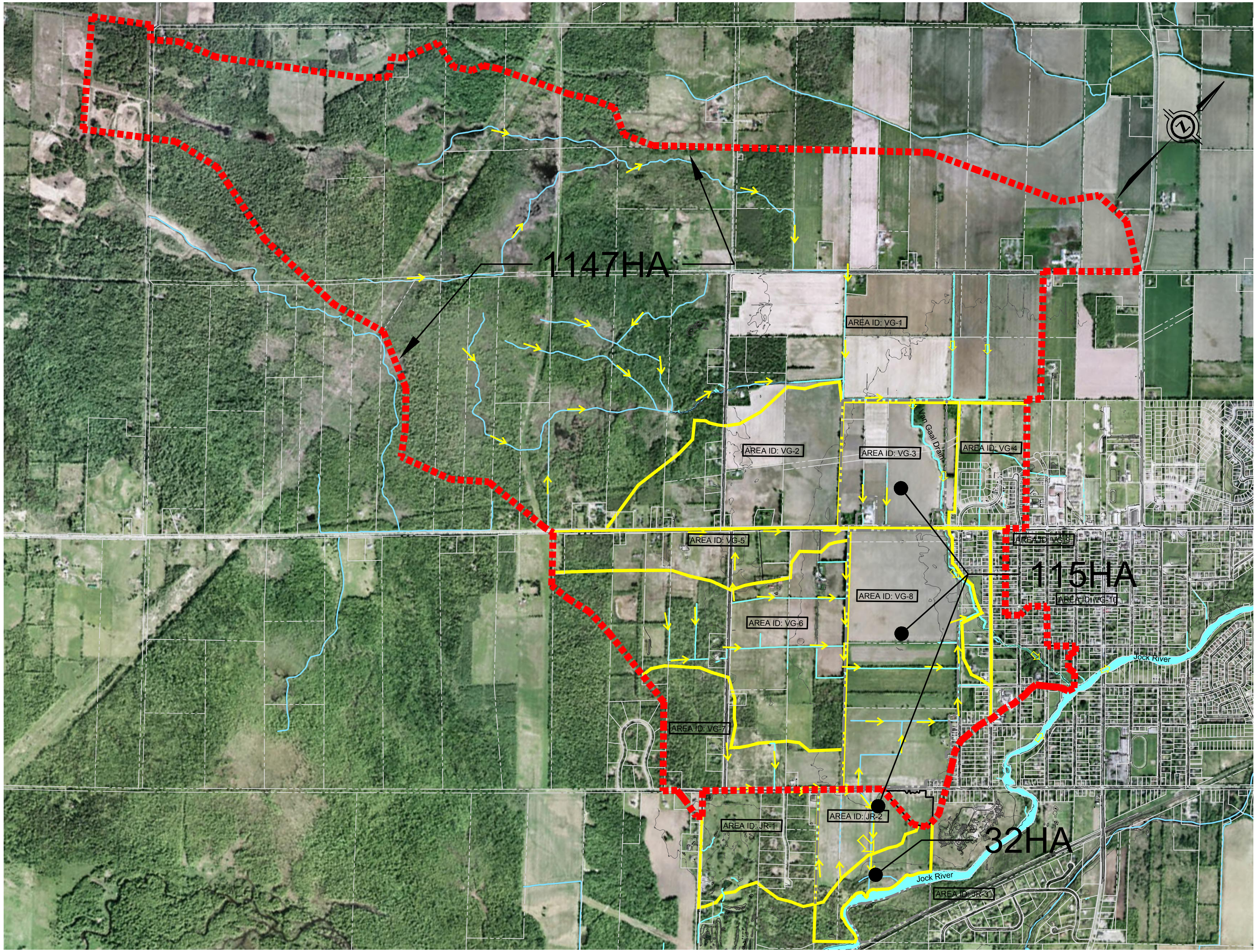
Figures



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VILLAGE OF RICHMOND

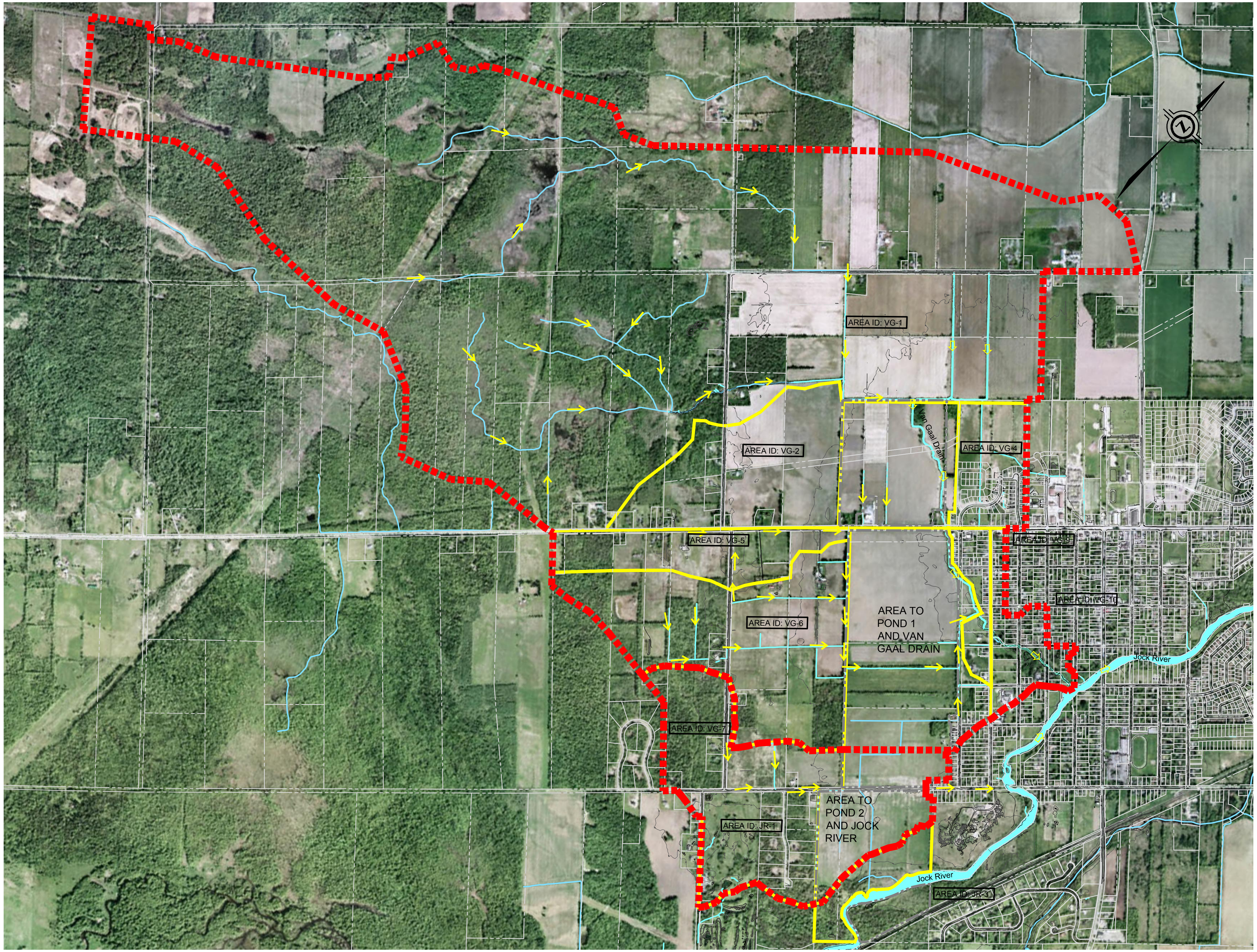
EXISTING CONDITIONS STORM DRAINAGE PLAN

CITY OF OTTAWA

LEGEND

- Van Gaal Drainage Boundary (per Robinson Consultants dwg 00063-A1, Oct 2002)
- Sub Area (per JFSA/RVCA 2010 Flood Plain Mapping)
- Subject Area
- Channel Flow Direction
- AREA ID: VG-8 — Drainage Area ID

PROJECT No.:	07-303
DATE:	2012-11-09
DRAWN BY:	ADF
SCALE	NTS
FIGURE:	5



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VILLAGE OF RICHMOND

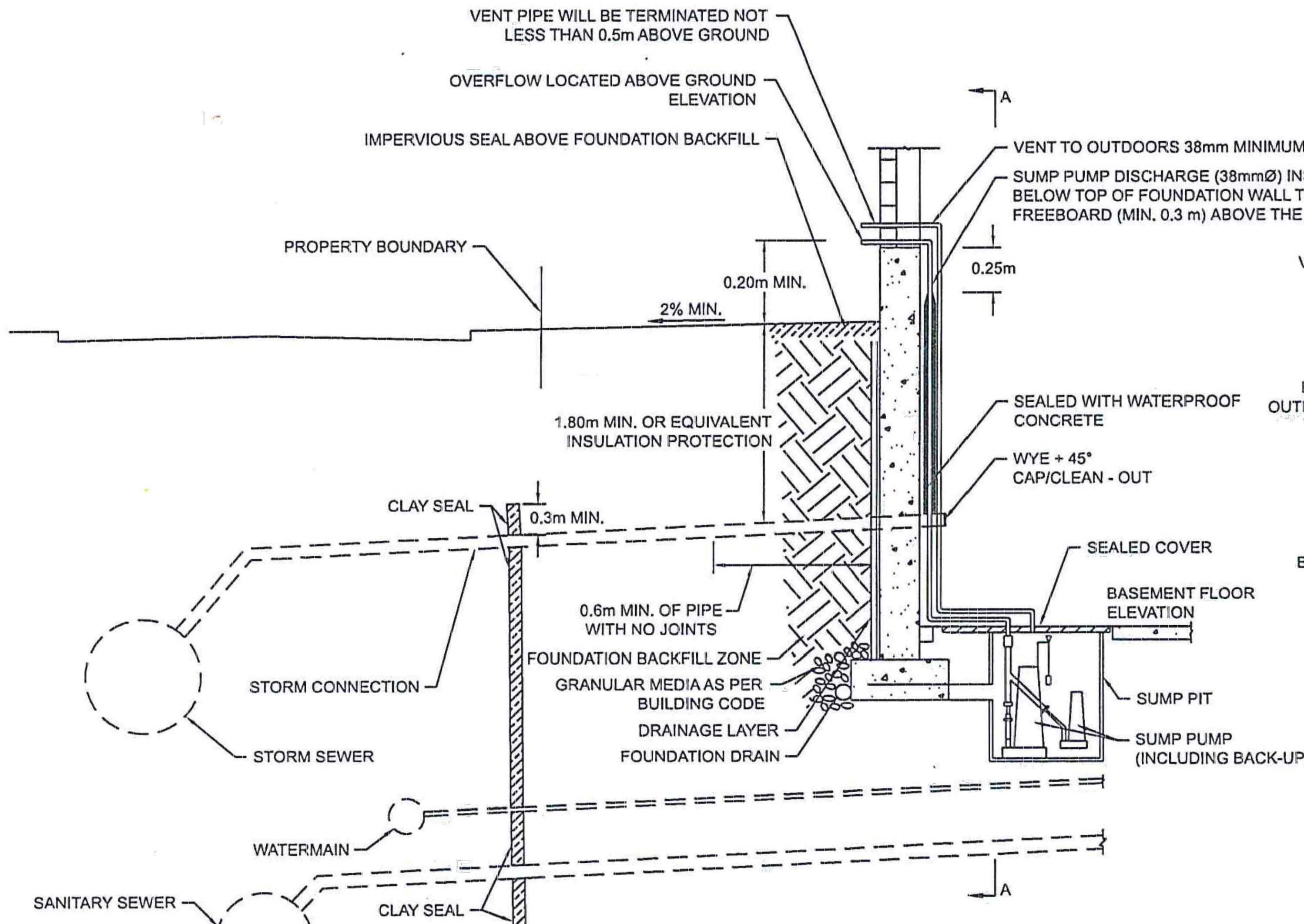
POST-DEVELOPMENT CONDITIONS STORM DRAINAGE PLAN

CITY OF OTTAWA

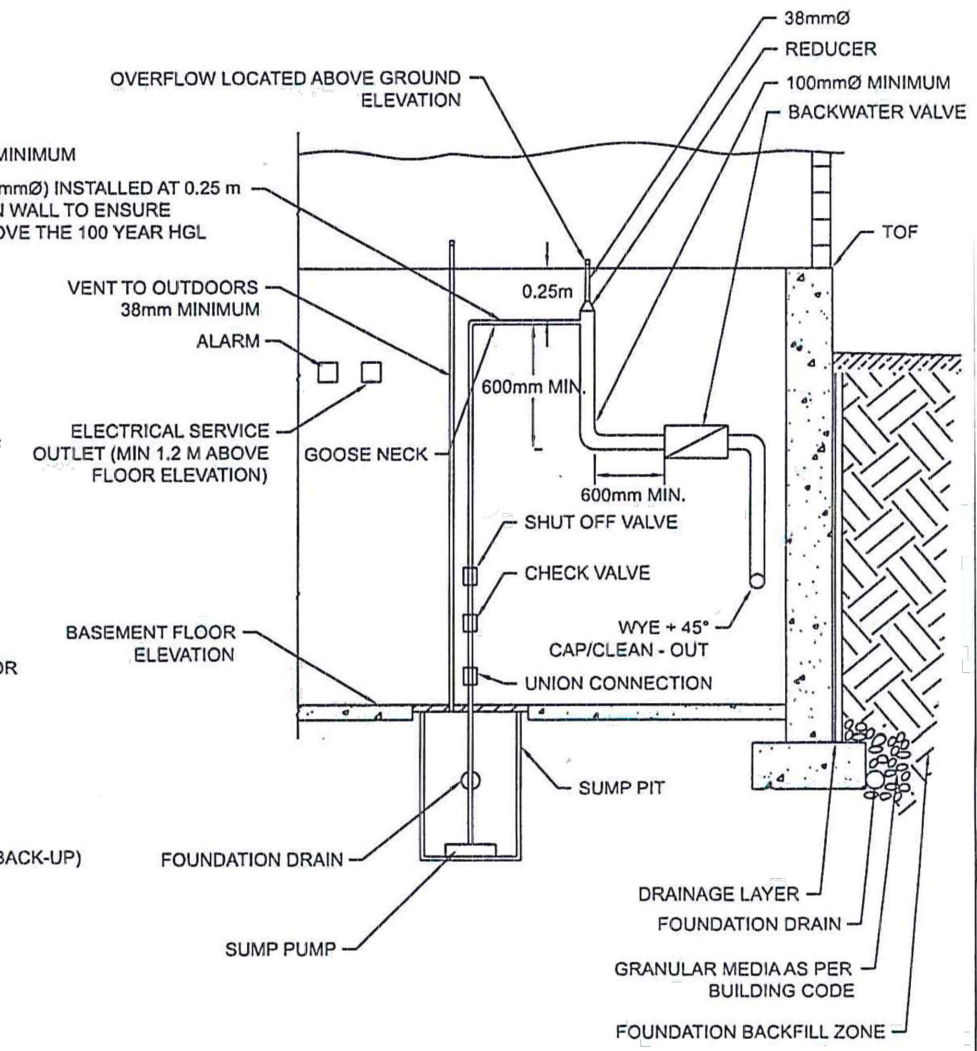
LEGEND

- Van Gaal Drainage Boundary (per Robinson Consultants dwg 00063-A1, Oct 2002)
- Sub Area (per JFSA/RVCA 2010 Flood Plain Mapping)
- Subject Area
- Channel Flow Direction
- AREA ID: VG-8 — Drainage Area ID

PROJECT No.:	07-303
DATE:	2012-11-09
DRAWN BY:	ADF
SCALE	NTS
FIGURE:	10



SUMP PUMP
N.T.S.



SECTION A-A
N.T.S.

NOTES:

1. WORKS TO BE COMPLETED IN ACCORDANCE WITH CITY OF OTTAWA STANDARDS, POLICIES AND GUIDELINES.
2. PRIMARY DISCHARGE TO STORM SEWER WITH OVERFLOW TO GRADE, AS INDICATED.
3. SERVICE TRENCH WILL HAVE CLAY SEAL TO PREVENT GROUNDWATER FLOW THROUGH SERVICE TRENCH TO FOUNDATION.
4. INSULATION DETAIL MUST BE PROVIDED BY PROFESSIONAL ENGINEER.
5. BACKWATER VALVE TO BE CSA APPROVED AND COMPLETE WITH ADEQUATE SUPPORT.
6. REFER TO GUIDELINES FOR SUMP PIT LOCATION.
7. IMPERVIOUS SEAL TO EXTEND BEYOND THE LINE OF EXCAVATION, SLOPED AWAY FROM BUILDING A MINIMUM OF 2% AFTER SETTLING OF BACKFILL. SEAL CAN BE CLAY, OR A MEMBRANE OR LOW-PERMEABILITY INSULATION BOARD PLACED JUST BELOW GROUND.
8. FILL PLACED IN SERVICE TRENCH MUST BE COMPACTED TO AT LEAST 98% OF ITS STANDARD PROCTOR MAXIMUM DRY DENSITY AS PER CITY STANDARD S6 AND S7 UNLESS OTHERWISE SPECIFIED IN APPROVED GEOTECHNICAL REPORT.
9. FOUNDATION BACKFILL ZONE WILL CONSIST OF CLAY WITH A MINIMUM HORIZONTAL WIDTH OF 1.5m EXCEPT AROUND SERVICE LATERALS WHERE BACKFILL IS PLACED AS PER NOTE 8.
10. DRAINAGE LAYER REQUIRED AS PER BUILDING CODE.
11. EVERY SERVICE TRENCH REQUIRES CLAY SEAL AS PER CITY STANDARD S8. CLAY SEAL TO EXTEND A MINIMUM 0.3m ABOVE THE OBVERT OF THE STORM SERVICE PIPE.
12. SEWER LATERALS THAT PASS THROUGH PORCH FOUNDATION MUST HAVE NO JOINTS FOR A LENGTH OF 0.6m MEASURED FROM THE EXTERIOR PORCH WALL.
13. RODENT GUARD/SCREEN TO BE PROVIDED AT THE END OF THE OVERFLOW (EMERGENCY DISCHARGE) PIPE AND AT THE END OF THE VENT PIPE.

Ottawa	STANDARD SUMP PUMP CONFIGURATION GREENFIELD SUBDIVISIONS WITH CLAY SOILS AND FULL MUNICIPAL SERVICES	DATE:	JUNE 2018
		REV. DATE:	JULY 2019
		DWG. No.:	P 01

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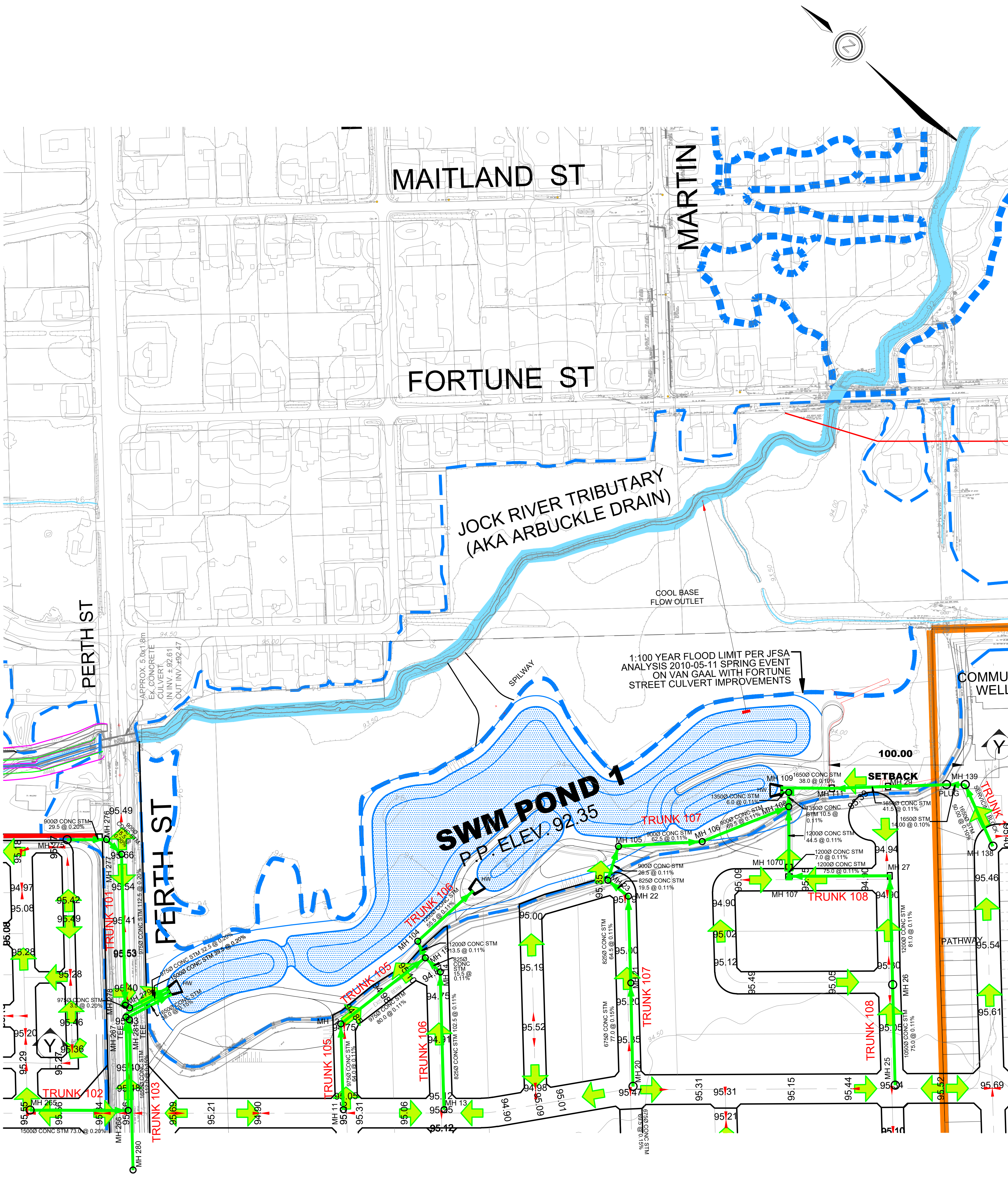
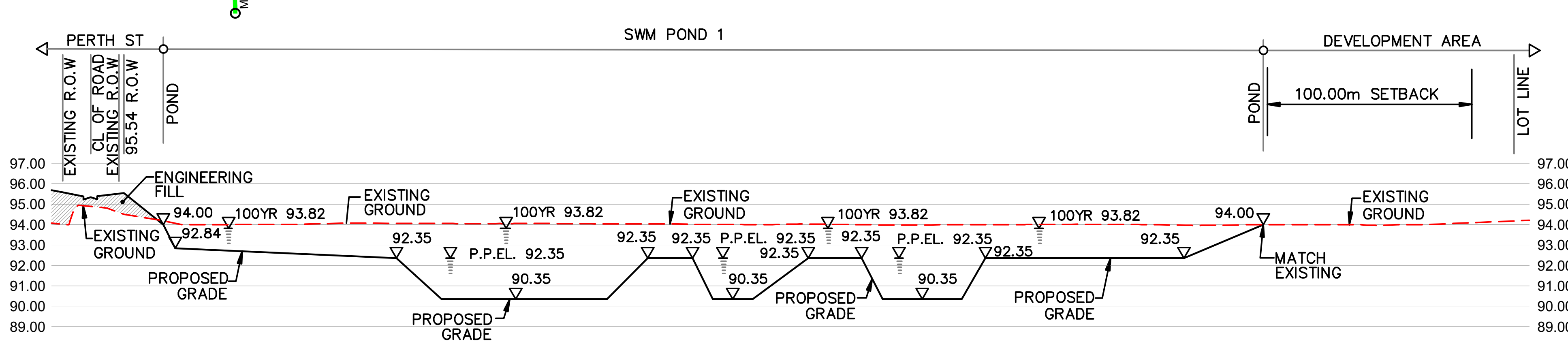
WESTERN DEVELOPMENT LANDS

SUMP PUMP DETAIL

CITY OF OTTAWA

PROJECT No.:	17-977
DATE:	October 2019
SCALE:	N.T.S.
FIGURE:	18





SWM POND 1
SECTION Y-Y
SCALE HOR. 1:3000
VER. 1:300

LEGEND

- STUDY LIMIT
- 1:100 YEAR REGULATORY FLOOD LINE PER JFSA NOVEMBER 2009 (BACKWATER FROM JOCK RIVER)
- EMERGENCY OVERFLOW DIRECTION
- EXISTING DITCH
- EXISTING ELEVATION CONTOUR
- OVERLAND FLOW DIRECTION

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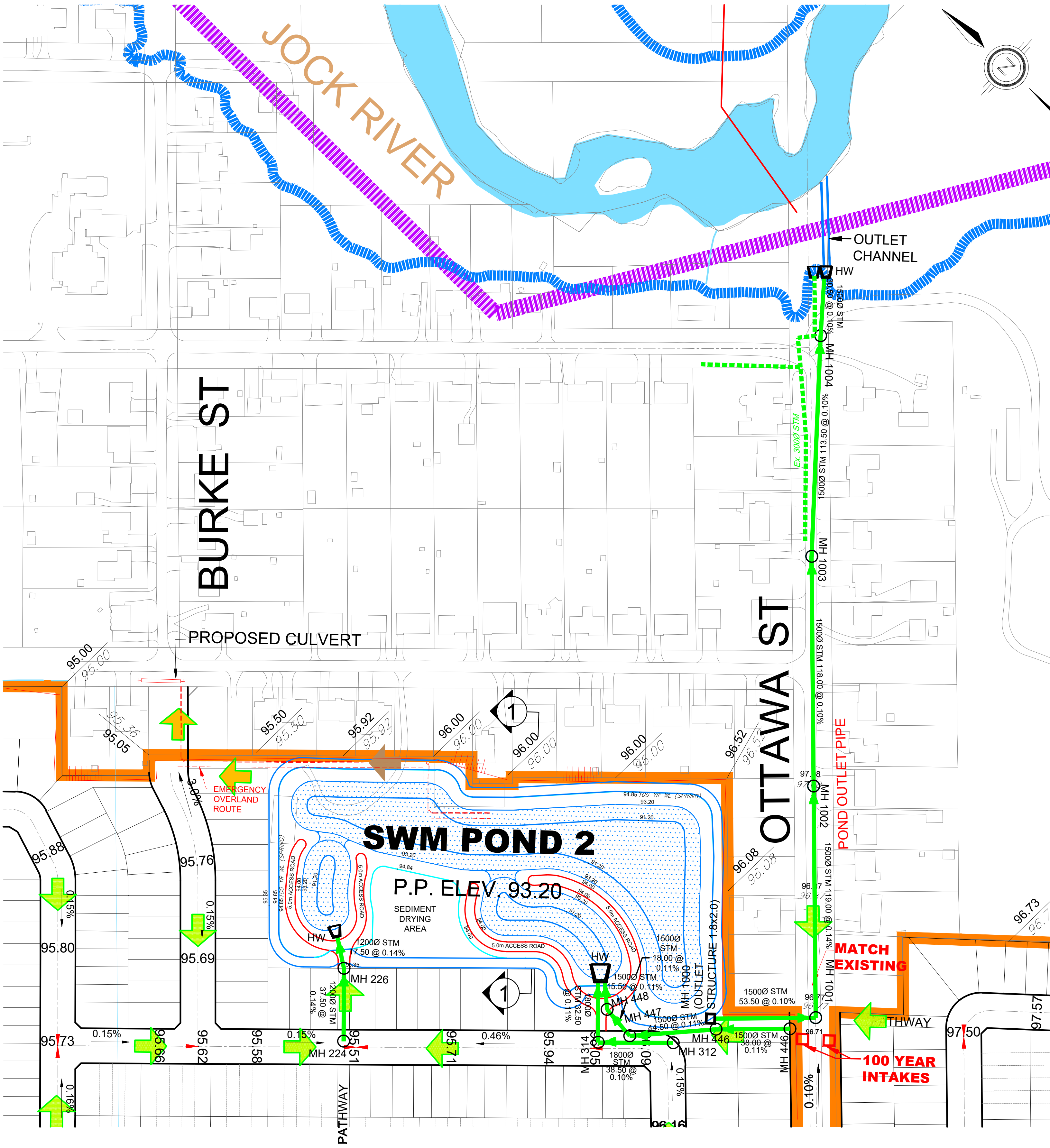
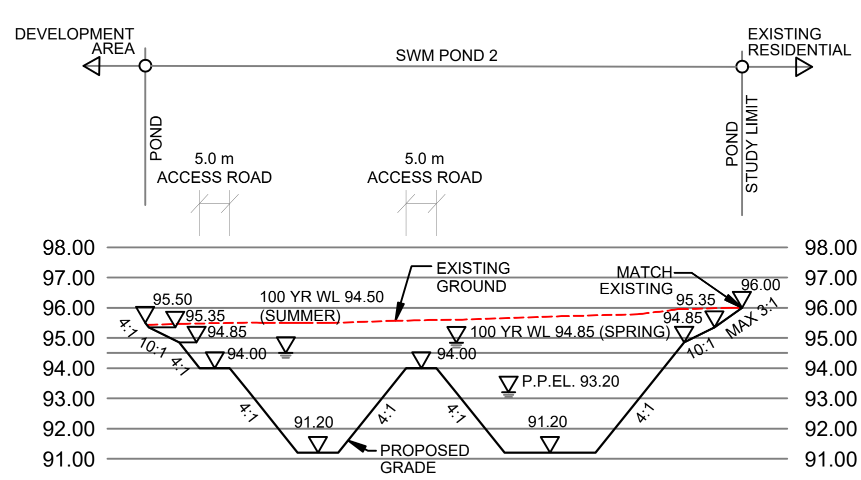
WESTERN DEVELOPMENT LANDS

SWM POND 1

CITY OF OTTAWA

PROJECT No.:	17-977
DATE:	October 2019
SCALE:	1:3000
FIGURE:	20





SWM POND
SECTION 1-1
SCALE HOR. 1:1250
VER. 1:250

LEGEND

- STUDY LIMIT
- MEANDER BELT
- 1:100 YEAR REGULATORY FLOOD LINE PER JFSA NOVEMBER 2009 (BACKWATER FROM JOCK RIVER)
- OVERLAND FLOW DIRECTION
- EMERGENCY OVERFLOW DIRECTION
- EXISTING DITCH
- 95.00 EXISTING ELEVATION CONTOUR

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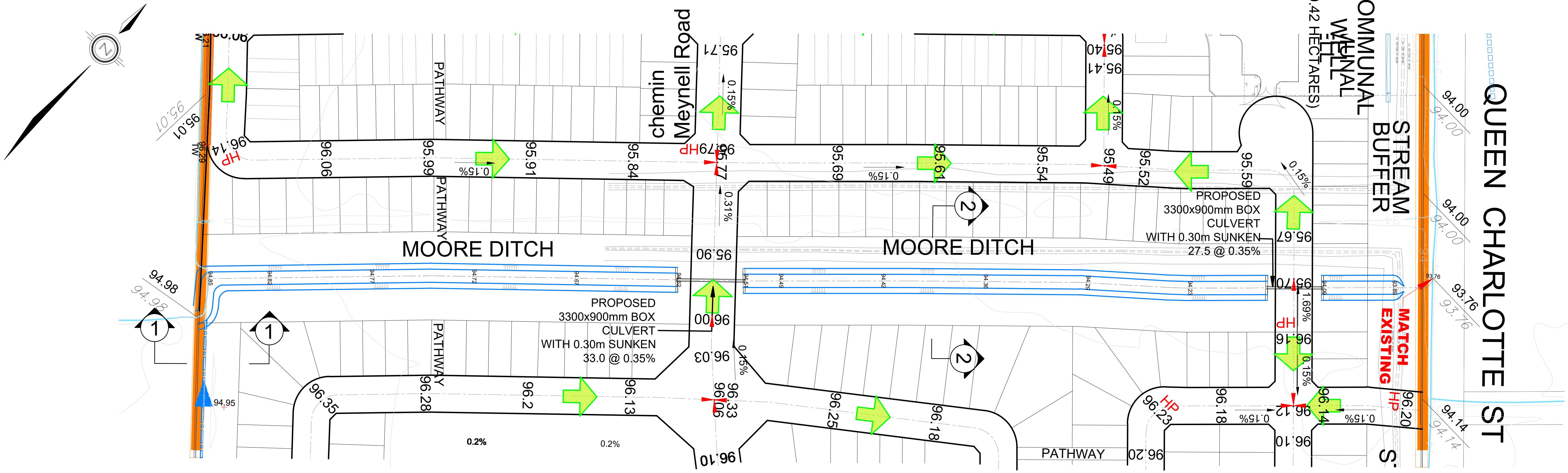
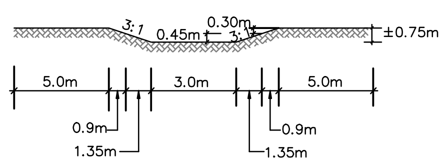
WESTERN DEVELOPMENT LANDS

SWM POND PLAN

CITY OF OTTAWA

PROJECT No.:	17-977
DATE:	October 2019
SCALE:	1:2500
FIGURE:	21





TYPICAL CHANNEL CROSS SECTION 1-1
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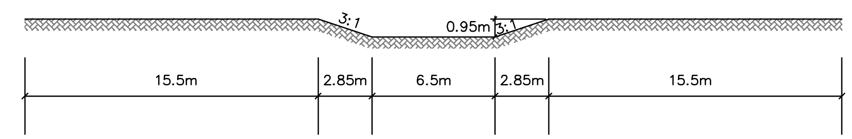
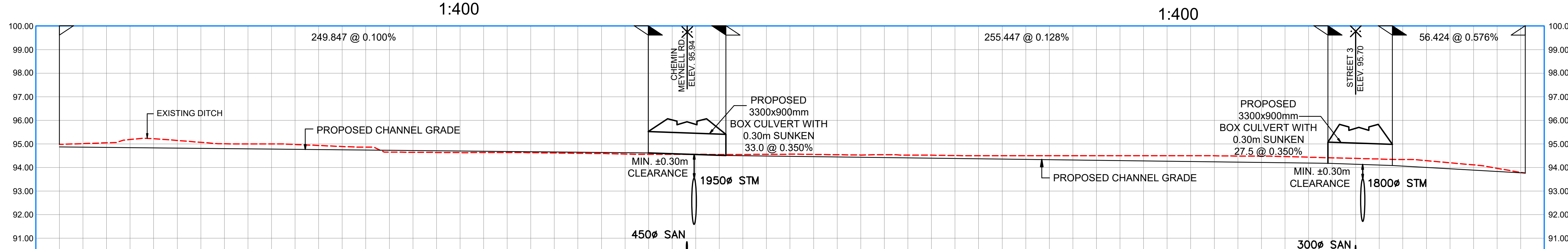


TYPICAL CHANNEL CROSS SECTION 2-2
1:400



CENTERLINE CHAINAGE	PROPOSED DITCH ELEVATION
0+000.000	94.873
0+020.000	94.853
0+040.000	94.833
0+060.000	94.813
0+080.000	94.793
0+100.000	94.773
0+120.000	94.753
0+140.000	94.733
0+160.000	94.713
0+180.000	94.693
0+200.000	94.673
0+220.000	94.653
0+240.000	94.633
0+249.847	94.623
0+260.000	94.588
0+280.000	94.518
0+282.780	94.508
0+300.000	94.486
0+320.000	94.460
0+340.000	94.435
0+360.000	94.409
0+380.000	94.383
0+400.000	94.357
0+420.000	94.332
0+440.000	94.306
0+460.000	94.280
0+480.000	94.255
0+500.000	94.229
0+520.000	94.203
0+538.227	94.180
0+540.000	94.174
0+560.000	94.104
0+565.552	94.085
0+580.000	94.002
0+600.000	93.887
0+620.000	93.771
0+621.976	93.760

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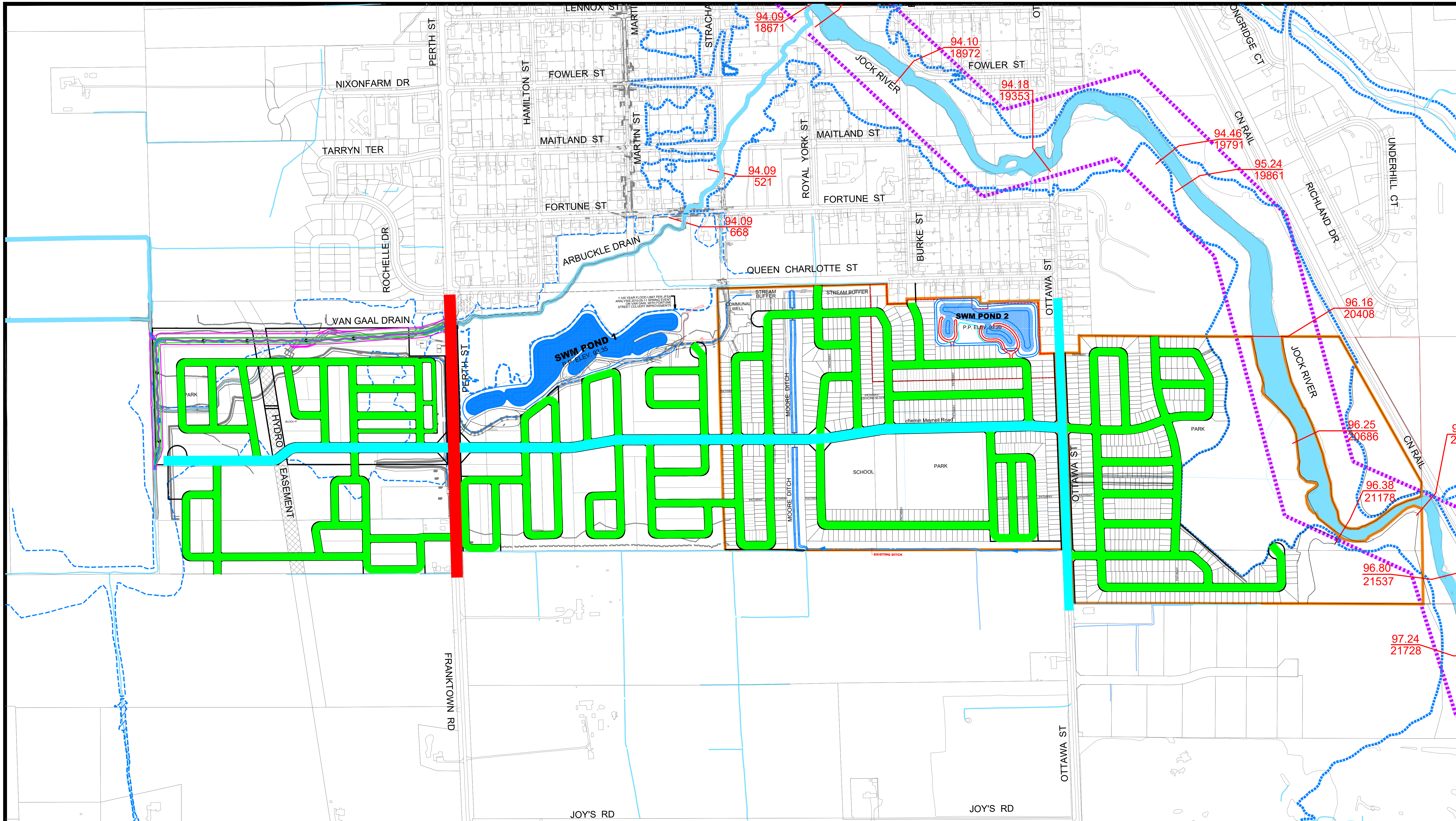
WESTERN DEVELOPMENT LANDS
MOORE TRIBUTARY - PLAN PROFILE
CITY OF OTTAWA

LEGEND
- STUDY LIMIT
- REGULATORY FLOOD LINE
- OVERLAND FLOW DIRECTION
- EXISTING DITCH
- 95.00 EXISTING ELEVATION CONTOUR

PROJECT No.:	17-977
DATE:	October 2019
SCALE:	1:2000
FIGURE:	22



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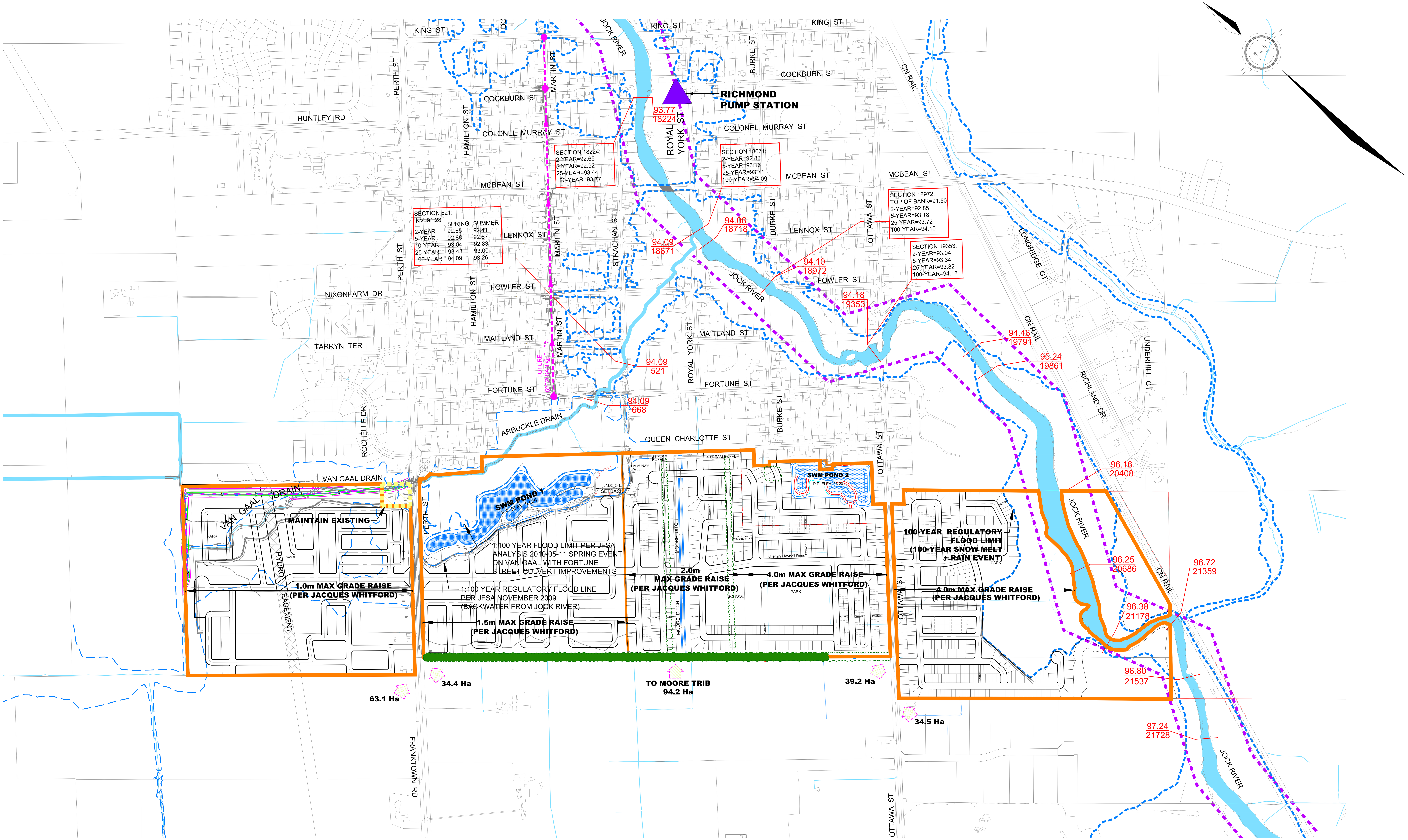
WESTERN DEVELOPMENT LANDS
ROAD CLASSIFICATION WITH MINOR SYSTEM LEVELS OF SERVICE
CITY OF OTTAWA

LEGEND
- LOCAL ROAD- 2YR MINOR SYSTEM LEVEL OF SERVICEDESIGN MINOR
- COLLECTOR ROAD - 5YRMINOR SYSTEM LEVEL OF SERVICEDESIGN MINOR
- ARTERIAL ROAD - 10YR MINOR SYSTEM LEVEL OF SERVICEDESIGN MINOR

PROJECT No.:	17-977
DATE:	October 2019
SCALE:	1:8000
FIGURE:	23

Drawings



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WESTERN DEVELOPMENT LANDS
CONSTRAINTS PLAN
CITY OF OTTAWA

LEGEND

	STUDY LIMIT	96.80 / 21537	FLOOD LINE ELEVATION / FLOOD LINE SECTION
	REGULATORY FLOOD LINE		EXISTING ELEVATION CONTOUR
	MEANDER BELT		PROTECT EXISTING HEDGE
	EXISTING DITCH		EXTERNAL OVERLAND FLOW DIRECTION
	1:100 YEAR REGULATORY FLOOD LINE PER JFSA NOVEMBER 2009 (BACKWATER FROM JOCK RIVER)		

PROJECT No.:	17-977
DATE:	October 2019
SCALE:	1:5000
DRAWING:	1

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WESTERN DEVELOPMENT LANDS
GRADING PLAN
CITY OF OTTAWA

LEGEND

- STUDY LIMIT
- EXISTING DITCH
- EXISTING ELEVATION CONTOUR
- MAJOR OVERLAND FLOW
- EXTERNAL DRAINAGE
- 1:100 YEAR REGULATORY FLOOD LINE PER JFSA NOVEMBER 2009 (BACKWATER FROM JOCK RIVER)
- EMERGENCY OVERLAND FLOW
- STORM MAJOR TRIBUTARY AREA
- 30.8Ha POND 1 — DRAINAGE AREA

CUT-FILL DEPTH ALONG CENTER LINE:

CUT DEPTH (m)	FILL DEPTH (m)
0 - 1	0 - 1
1 - 2	1 - 2
2 - 3	2 - 3

PROJECT No.:	17-977
DATE:	October 2019
SCALE:	1:3000
DRAWING:	2

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WESTERN DEVELOPMENT LANDS

STORM SERVICING PLAN

CITY OF OTTAWA

LEGEND

- STUDY LIMIT
- EXISTING DITCH
- STORM TRIBUTARY AREA
- STORM TRUNK
- LOCAL STORM SEWER
- EXISTING STORM TRUNK
- STORM TRUNK BY OTHERS
- 1:100 YEAR REGULATORY FLOOD LINE PER JFSA NOVEMBER 2009 (BACKWATER FROM JOCK RIVER)
- 8.26Ha 0.62 — DRAINAGE AREA IMPERVIOUSNESS
- EXTERNAL DRAINAGE
- 100 YEAR INTAKE AREA

PROJECT No.:	17-977
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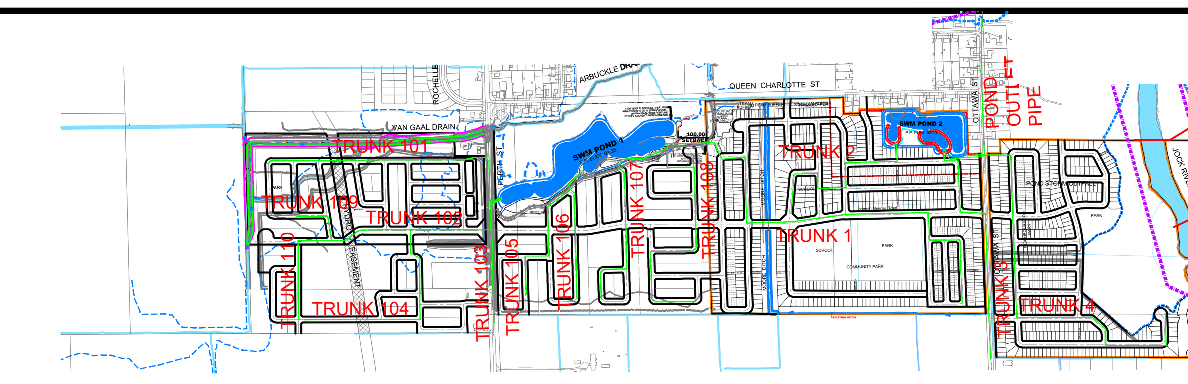
DRAWING:	3



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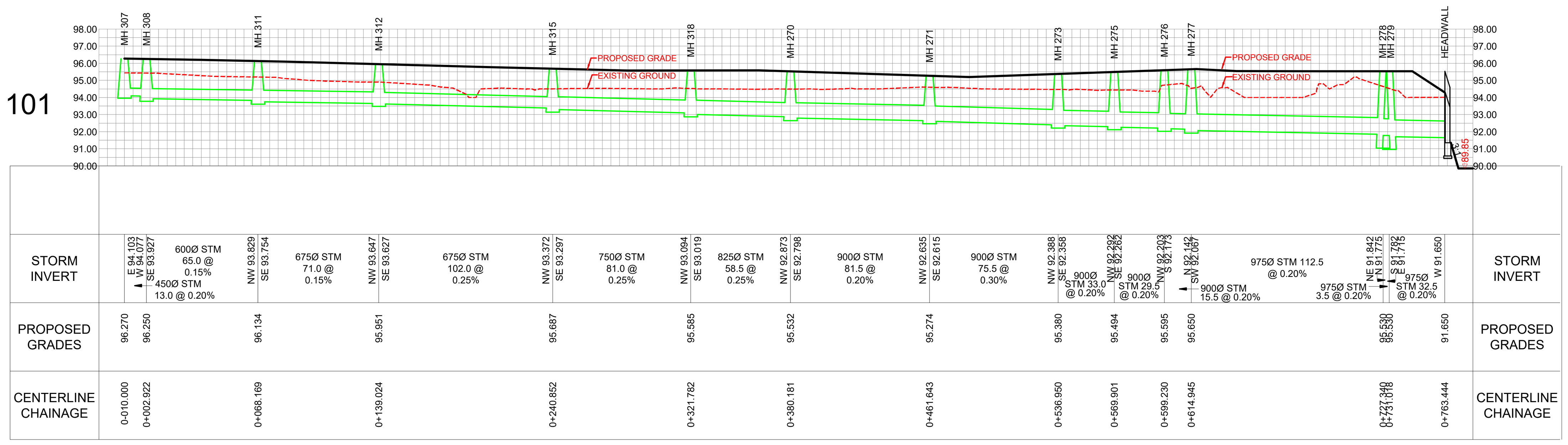

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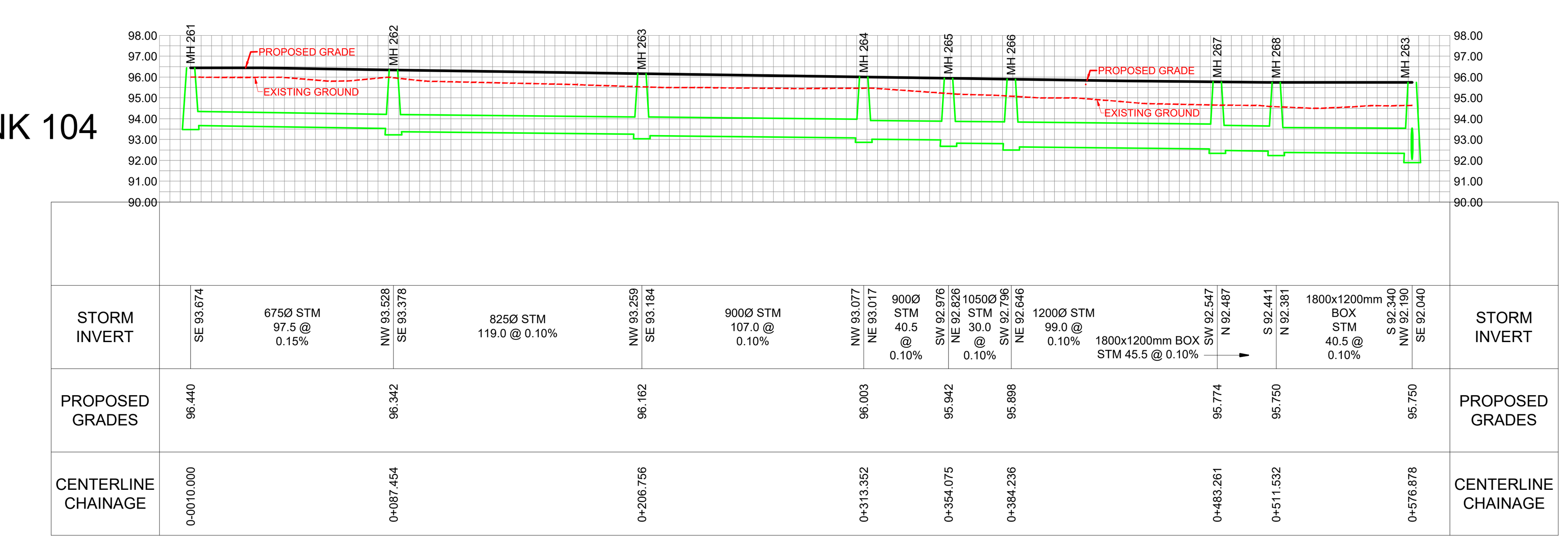

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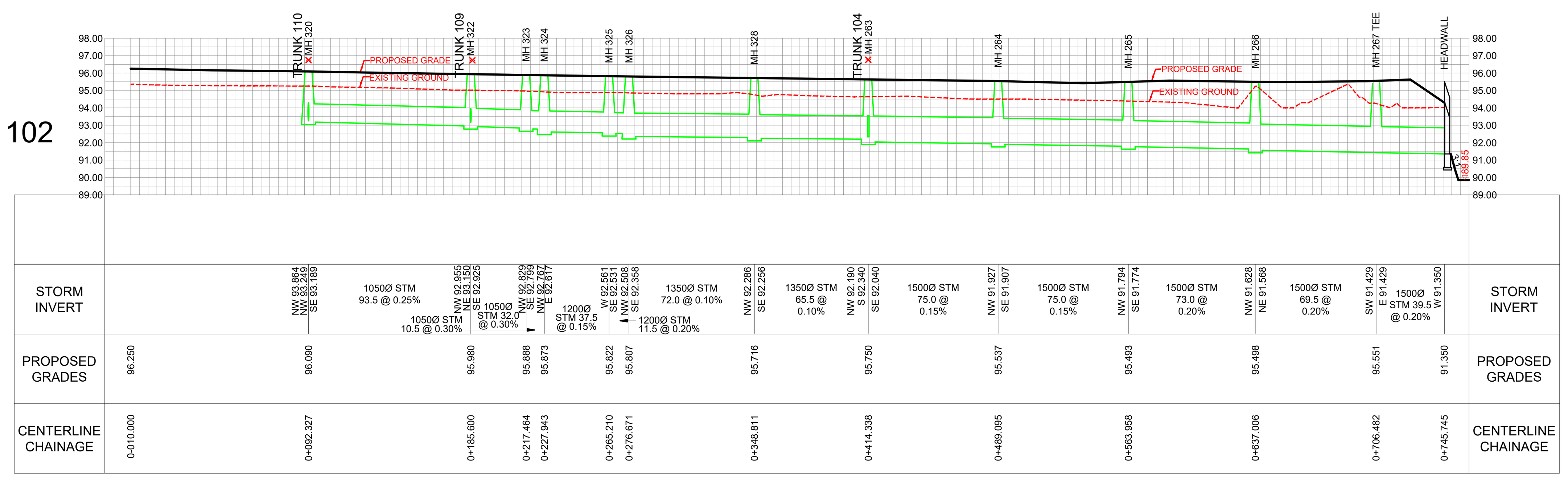

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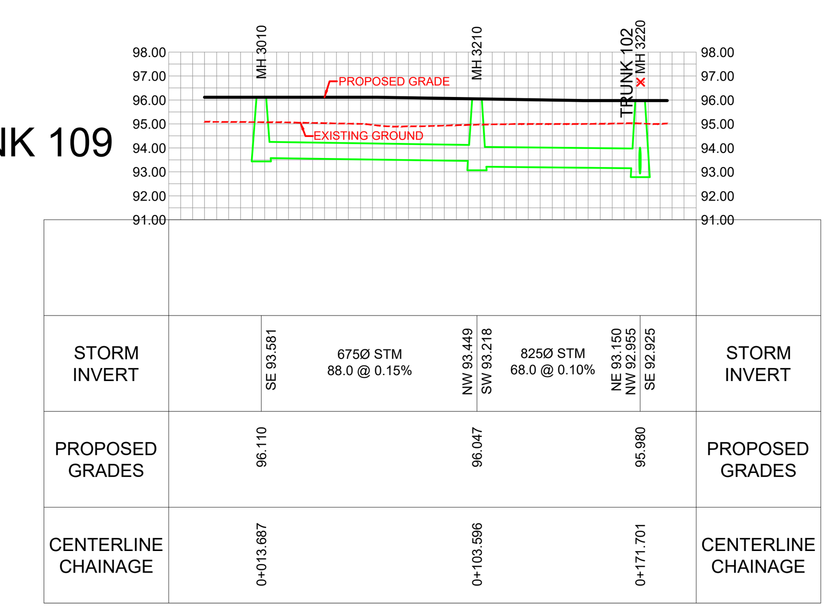

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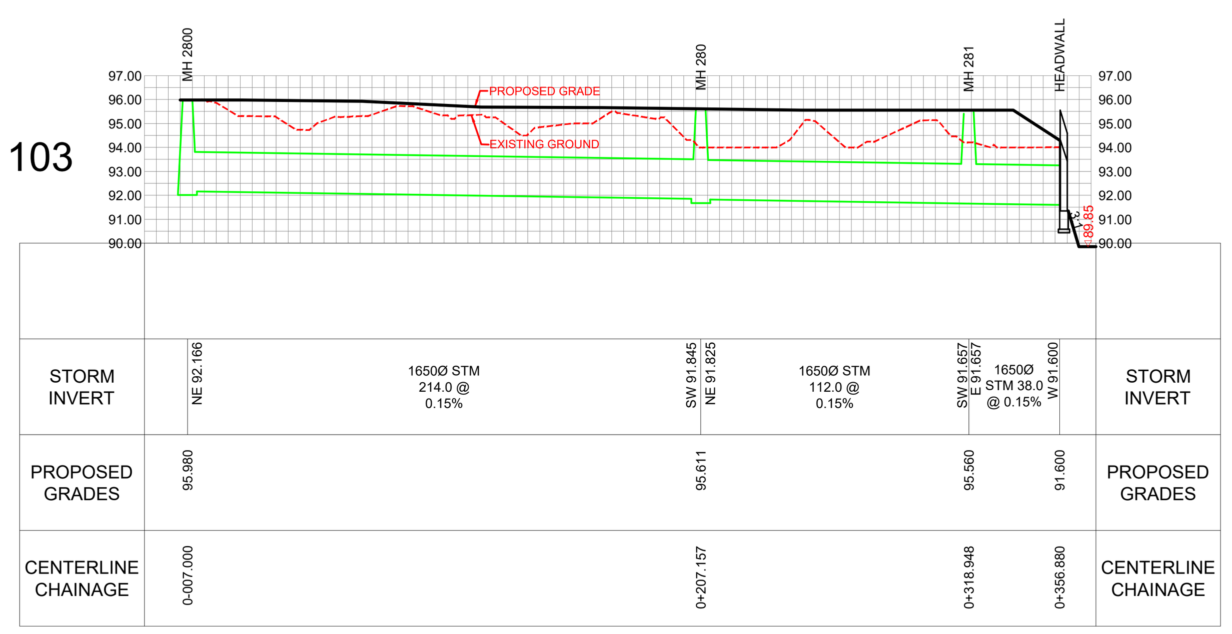

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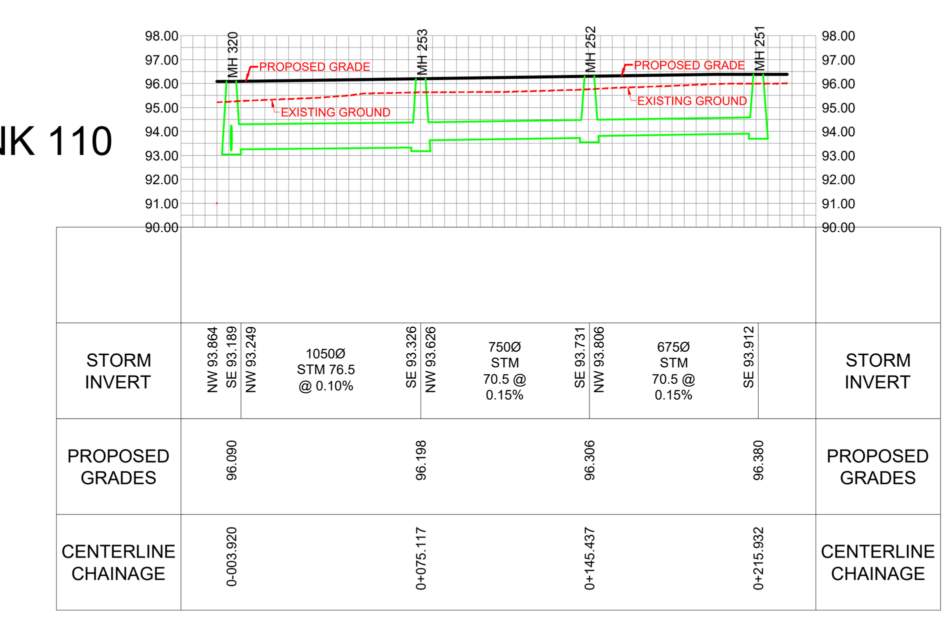

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PROJECT No.:	17-977
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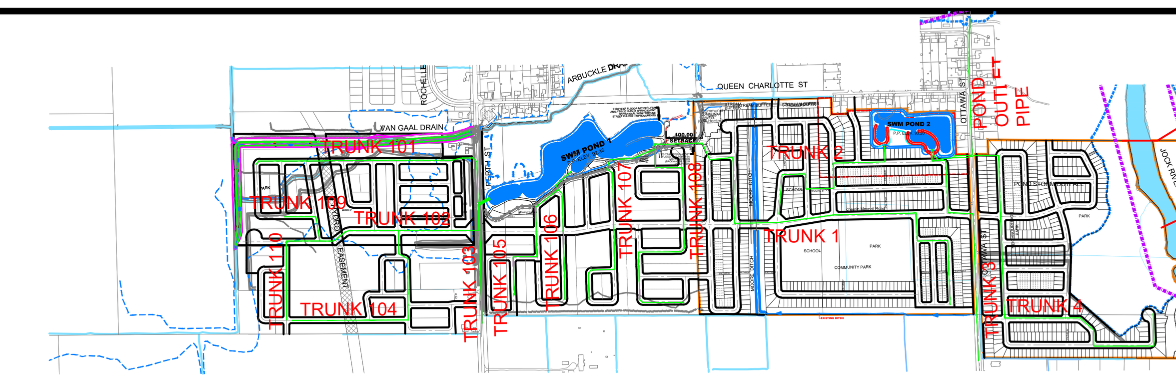
DRAWING:	4



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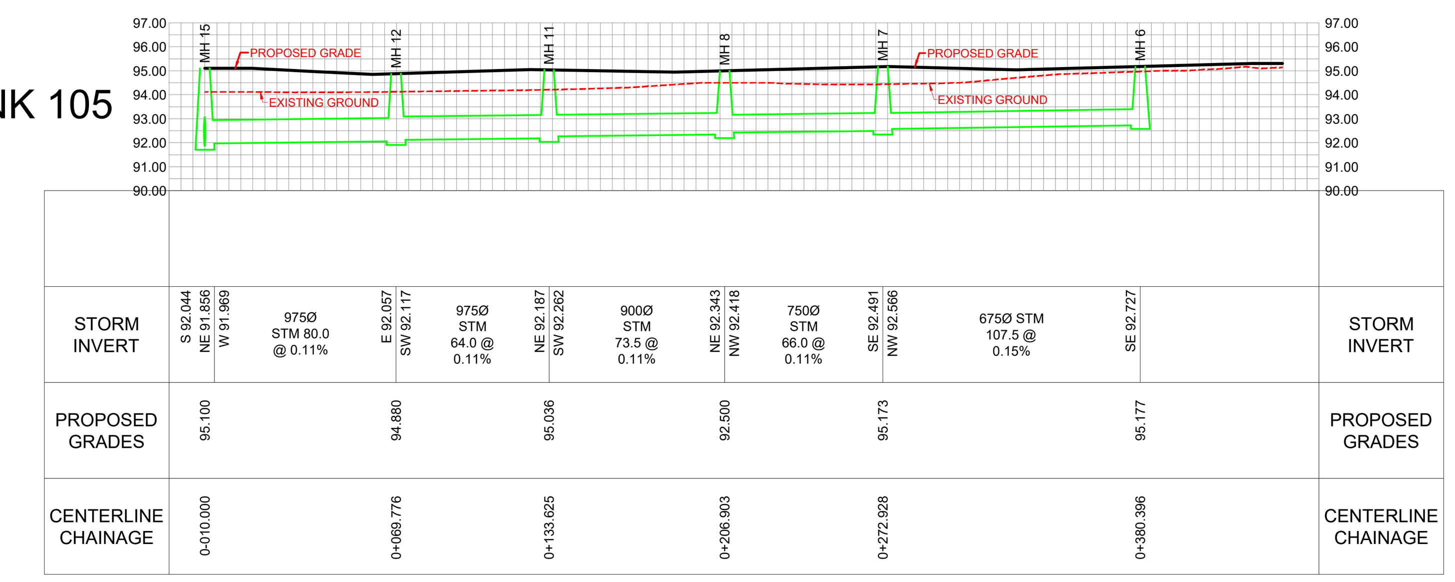

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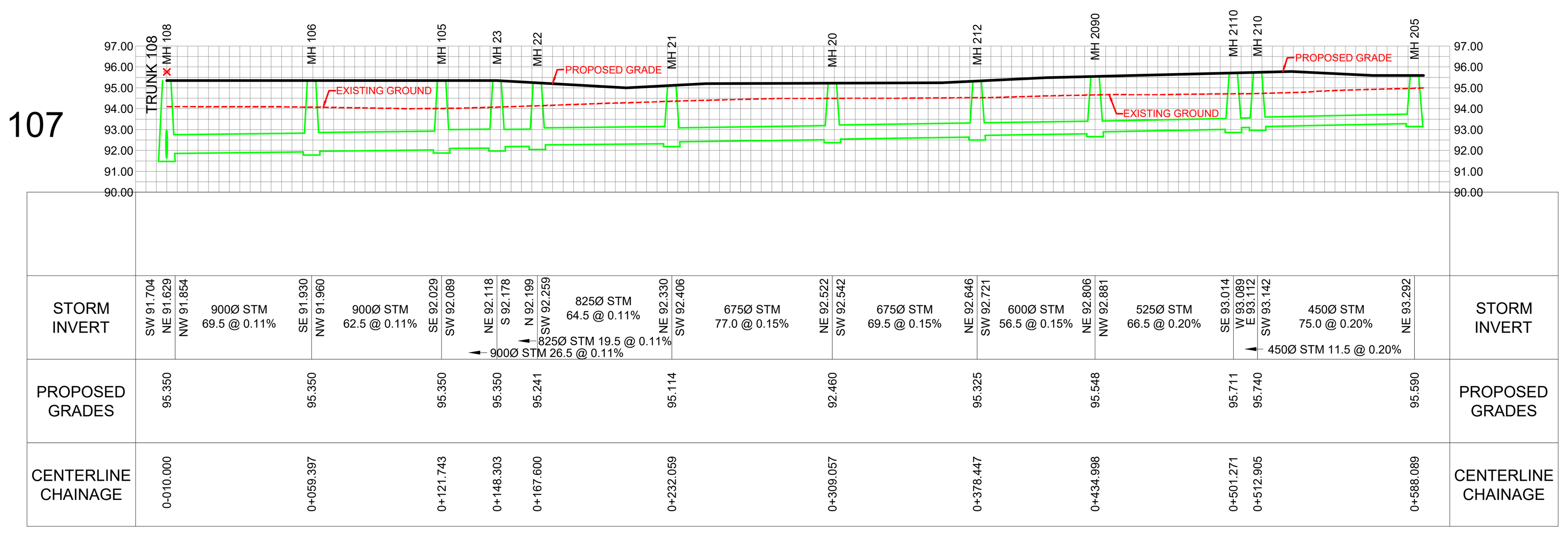

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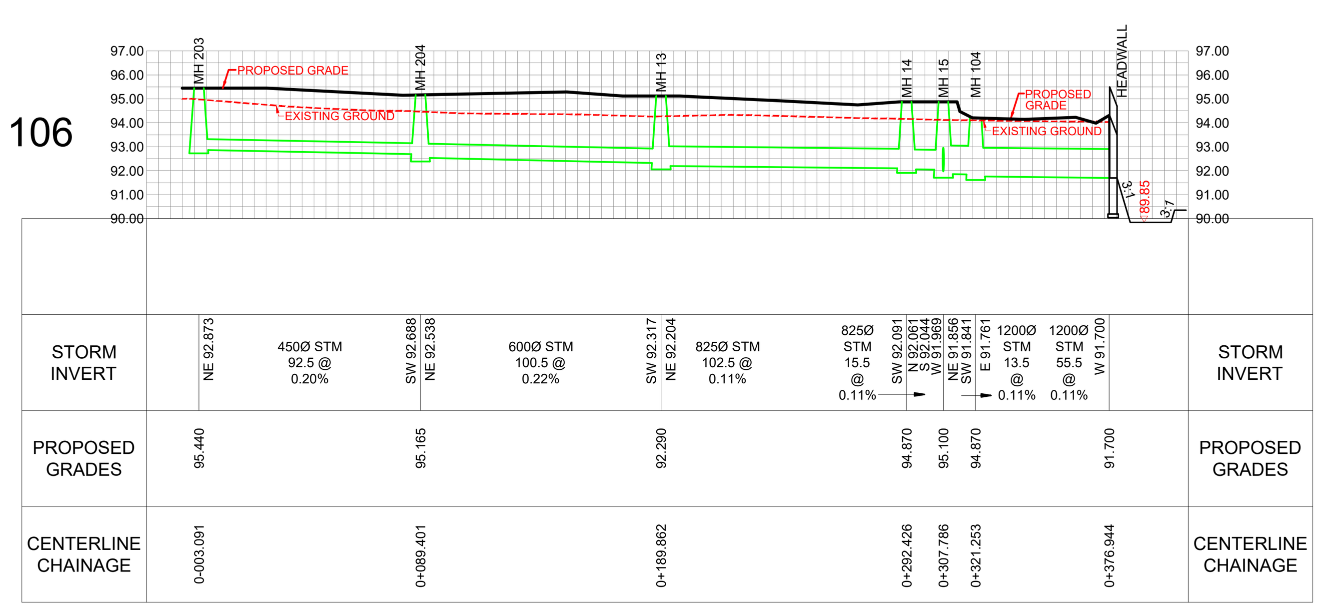

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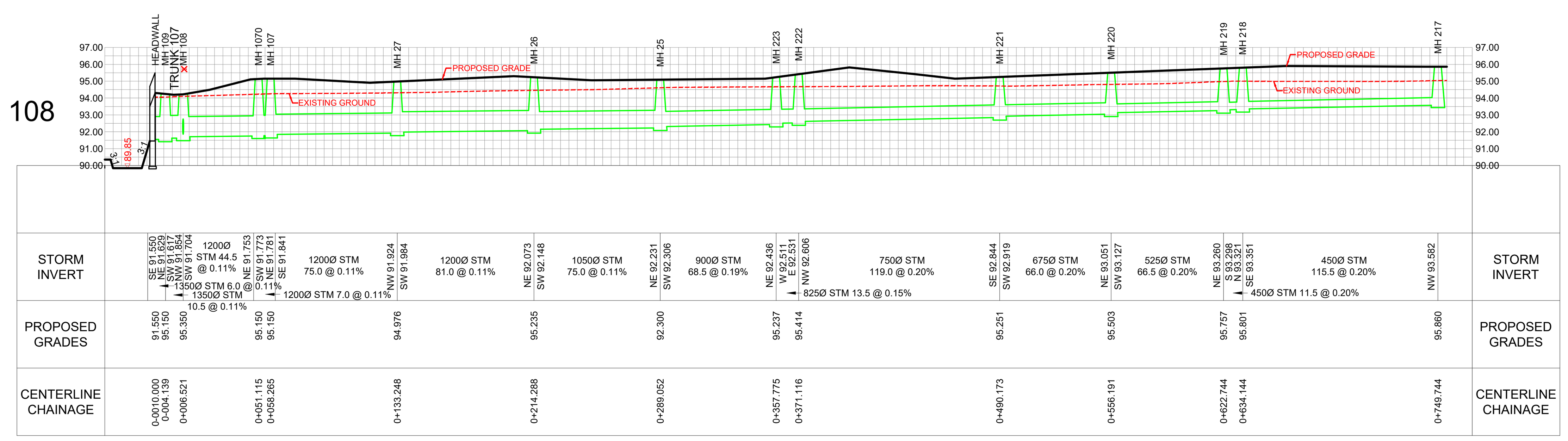

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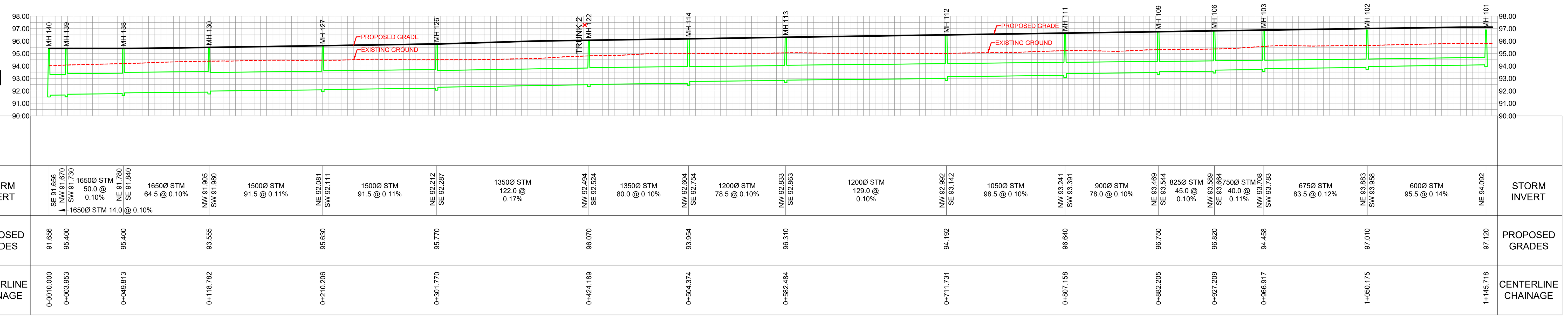
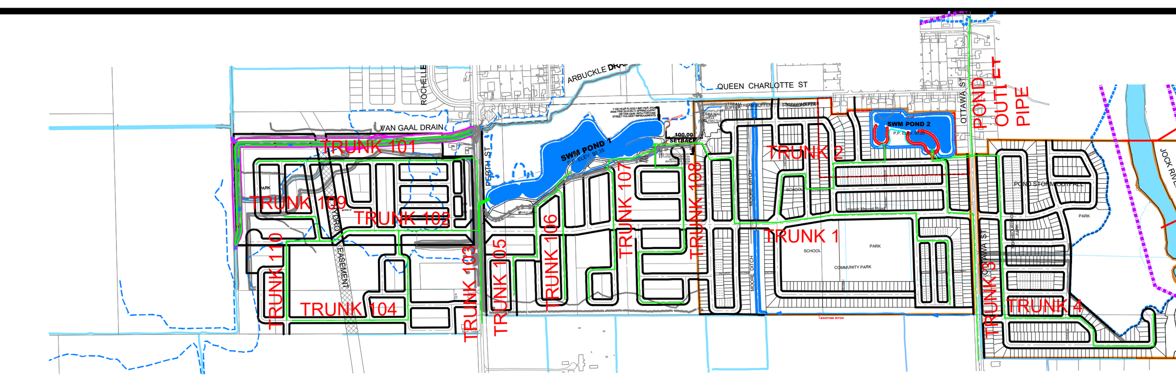
TRUNK 1





PROFILES KEYPLAN SCALE: 1:8000

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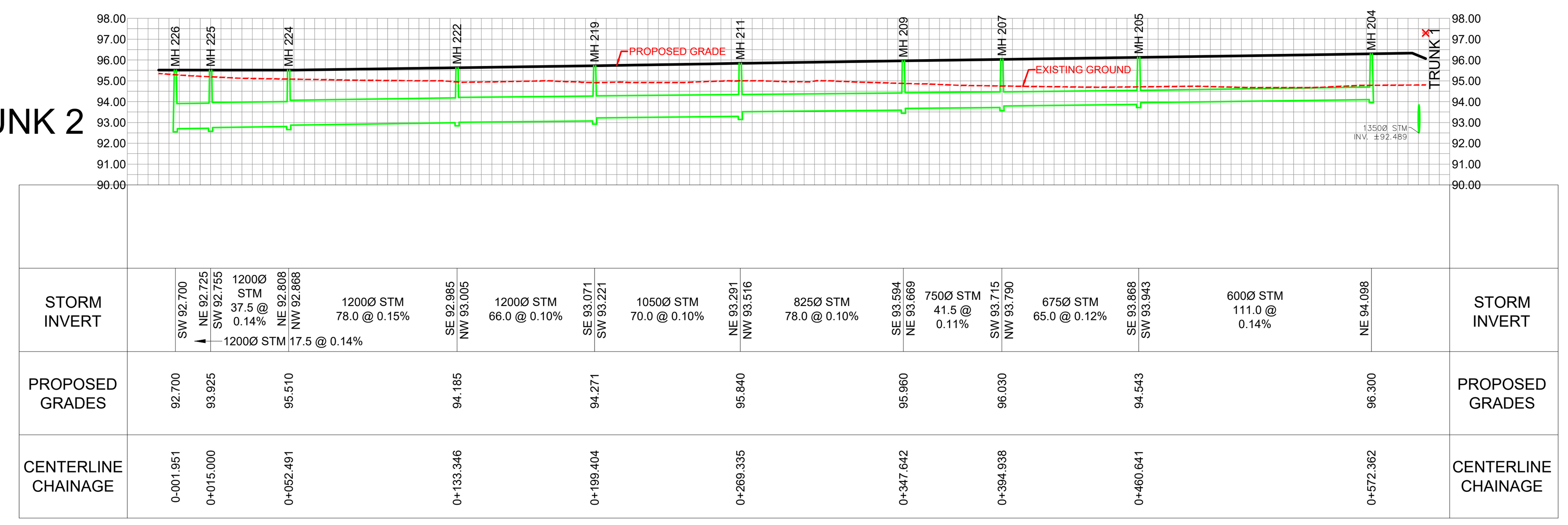

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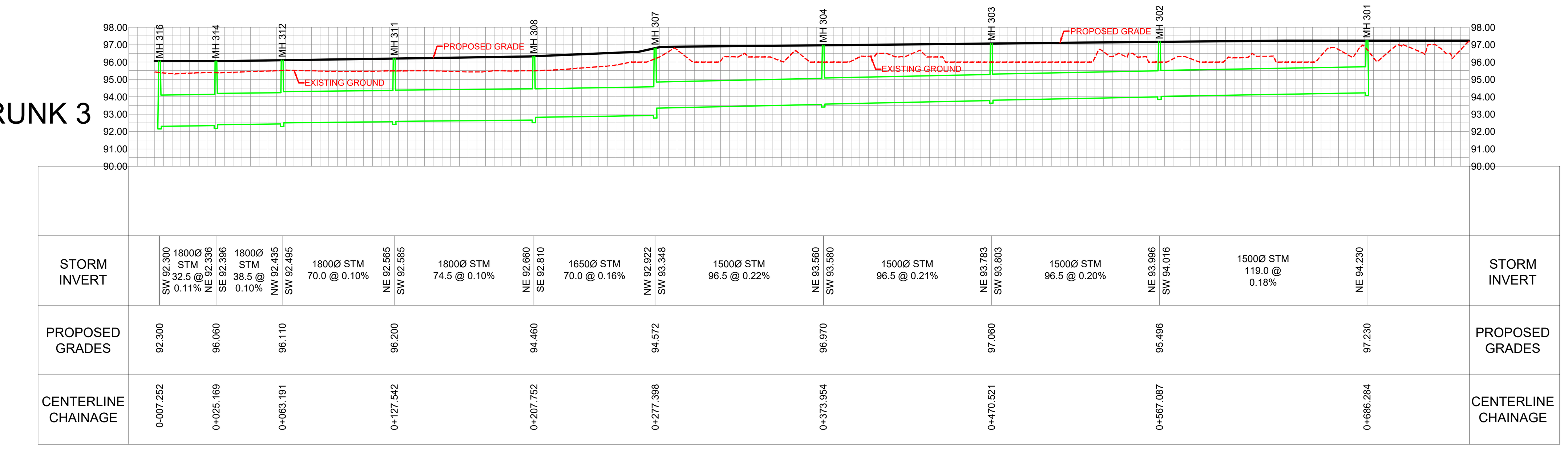

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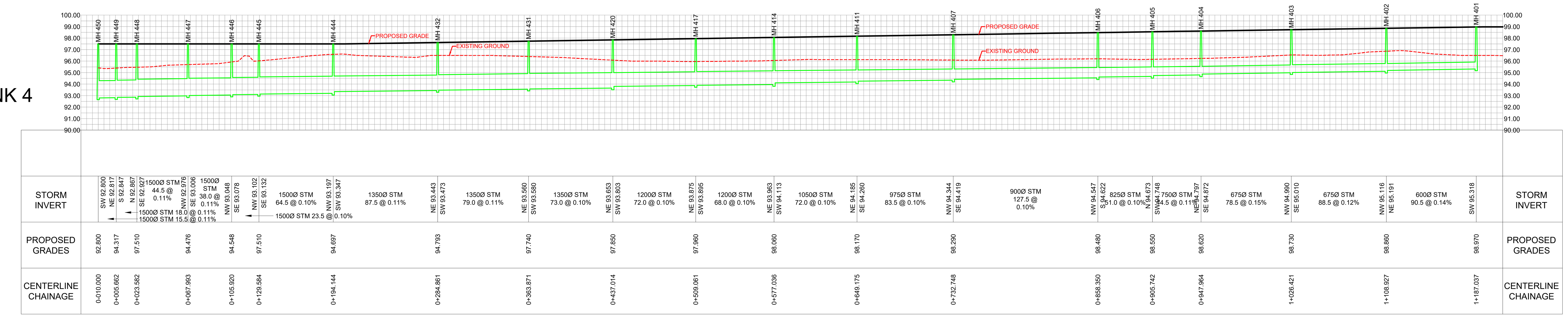
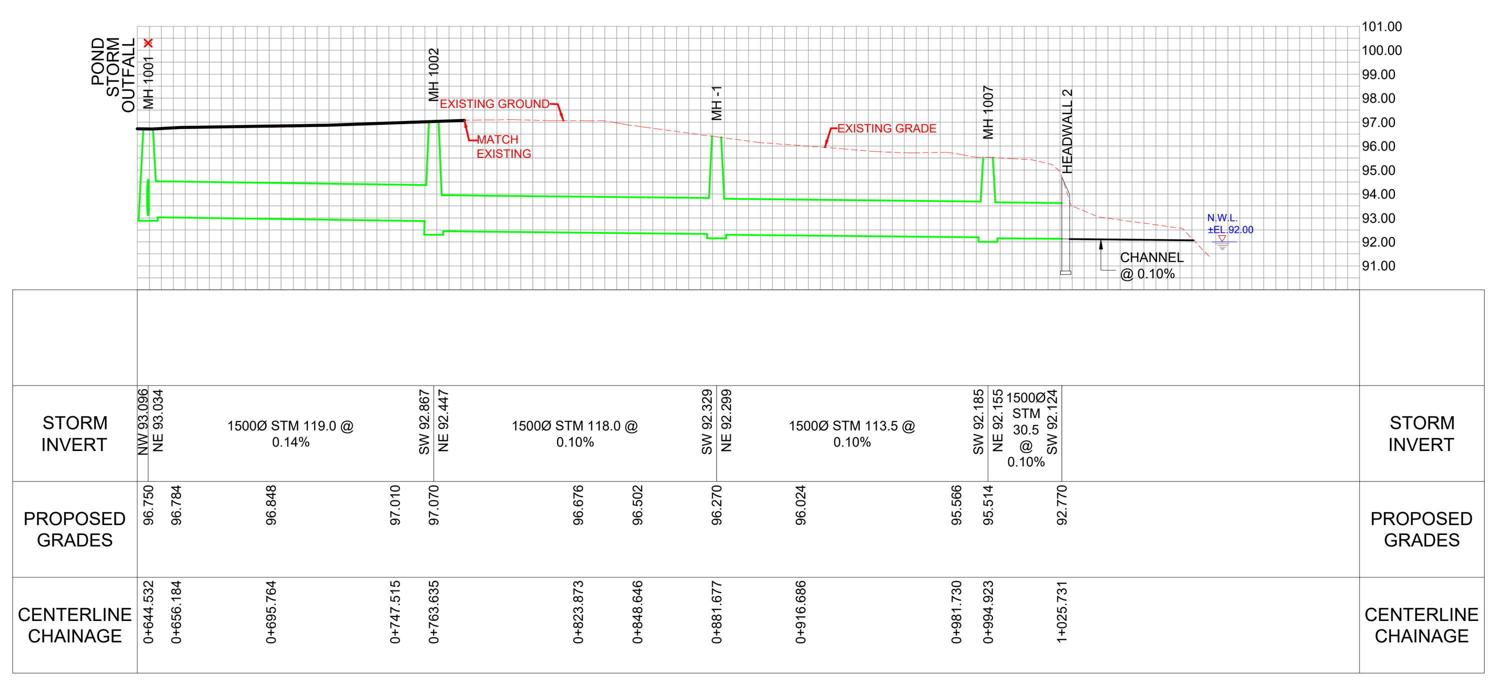
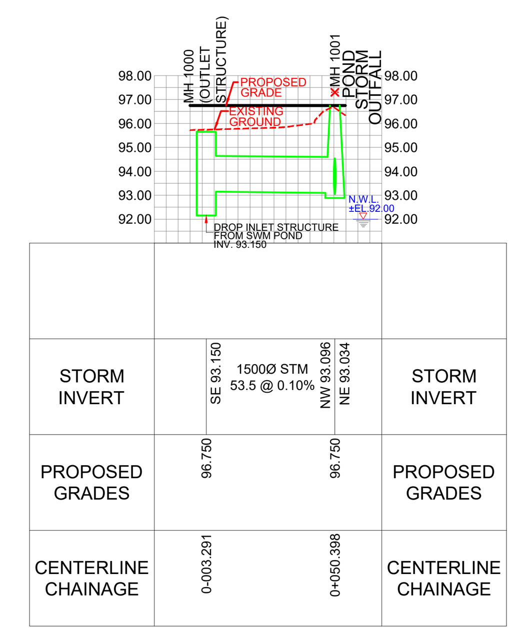


POND OUTLET PIPE



POND OUTLET PIPE



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APPENDIX A

City of Ottawa / Agency Comments and Consultation Summary (from March 2010 Report) and Existing Approvals

Attachment 1

Item		Comment	Action / Response	Reference	City Response	
City Comments Dated December 14, 2012 - Richmond Village - SWM and Drainage RE: Western Development Lands					**11-Jul-13**	
From: Darlene Conway To: Cheryl McWilliams						
	A. Major system drainage analysis					
NEW		We have noticed that the 100-Year, 24hr SCS rainfall volume used for the drainage area to the Van Gaal Drain and the Jock River is smaller than the 106.7 mm volume that should be used according to the City Ottawa Sewer Design Guidelines. Please clarify.				The 100-year, 24-hour SCS type II storm used to model the Van Gaal Drain and Jock River is based on Ottawa CDA rainfall data (88.6 mm volume) rather than City of Ottawa Sewer Design Guidelines (106.7 mm volume). This design storm was used in order to be consistent with the November 2004 *Jock River Flood Risk Mapping (within the City of Ottawa) Hydraulics Report* , and the November 2009 *Floodplain Mapping Report for the Van Gaal and Arbuckle Drains in the Village of Richmond* .
1	1	The major system drainage analysis has been reviewed based upon the revised draft plan. As previously commented, it appears that subsequent to the STANDHYD command, each catchment is routed within its down drainage area (rather than routing commencing in the adjacent downstream catchment), using a ROUTE CHANNEL command. For example, the total flow from catchment 705b is routed from MH 701 to MH 705 (see Figure 1). This is typical of how the overland flows have been routed which appears to provide more attenuation than may actually occur. We do not agree that this is consistent with standard modeling practice. While this may be the case for DDSWMM (where catchments are typically quite small), this is not the case for how this development has been modeled with SWMHYMO (larger, longer catchments). Channel routing should not be applied to the flow generated within its own catchment at this level of analysis.	In accordance with City comments, the SWMHYMO model will be revised to commence routing for each catchment in the next downstream segment, rather than within the catchment itself. Please note that the model has been updated accordingly for the subsequent Mattamy draft plan application submitted to the City, April 2013.	Appendix I	Comment addressed.	
2	2	Section 6.1 of the DSEL report states: "Where major system flow is shown to cross Perth Street and Ottawa street, the minor system was designed to convey flow under these streets." From the SWMHYMO output files, it appears that the major flow is not fully captured (e.g., carry over is 112 l/s for Trunk 2 at MH 213 and 680 l/s for Trunk 11 at MH 1109). Please revise the modeling and sewer sizing as required and confirm how the major flow is captured before it crosses Perth Street and Ottawa Street (i.e., provide an indication of the CBs required. Please note excessive numbers of catchbasins should be avoided).	100% of the 100-year flows at Perth Street (538 L/s) and Ottawa Street (680 L/s) are captured to the minor system at SWMHYMO segments 1500aX and 1600aX, including the flows identified in Village comments for Trunks 2 and 11. Four double catchbasins (two on each side of the street) should be sufficient to capture these 100-year flows on Perth Street and Ottawa Street even with 50% blockage of the inlet grates.	Appendix I	Comment addressed.	
3	3	It appears that the carry over flow from Trunk 1 is not accounted for downstream of MH 107. In other words, the overland flow from MH 107 to MH 109 is missing (see Figure 2). Please revise the modeling and storm sewer sizing as required.	100% of the 100-year overland flow from MH 107 is captured to the minor system at SWMHYMO segment 1500aX, in order to prevent overland flow from crossing Perth Street.	Appendix I	Comment addressed.	
4	4	To inform the future draft plan, minimum widths for the easements located downstream of MH 710 and MH1108 must be confirmed based upon the respective proposed sewers and overland flows to be conveyed (provide conceptual calculations for each location).	The easement width is depicted as 6.0m per City Design guidelines. The 100-year flow to the 6.0 m wide easement from MH 1108 is approximately 1.04 cms, and the 100-year flow to the 6.0 m wide easement from MH 710 is approximately 1.16 cms. A trapezoidal channel with 4.0 bottom width, 6.0 m top width, 0.5% longitudinal slope and 3H:1V side slopes would be sufficient to convey these flows at depths of less than 30 cm. Therefore, the indicated easement width is sufficient to convey the 100-year flow and contain the proposed storm sewer.		Please provide typical details, calculations and confirm that sufficient freeboard is provided.	Note: Updated modelling area breakdown and flow routes have resulted in flow rates that differ than those discussed previously. A 4.0 m wide overland flow route in the easement from MH 710 to SWM Facility 1, with a curb cut width of 4.0 m, will convey the 100-year overland flow safely to the SWM facility without flooding any of the properties within the subdivision. Note that the 100-year flow depth of 12.8 cm is contained within the 6.0 m wide easement assuming 3H:1V side slopes for 1 m on either side of the 4.0 m bottom width (33.3 cm maximum depth). A 4.0 m wide overland flow route in the easement from MH 1108 to SWM Facility 2, with a curb cut width of 4.0 m, will convey the 100-year overland flow safely to the SWM facility without flooding any of the properties within the subdivision. Note that the 100-year flow depth of 24.6 cm is contained within the 6.0 m wide easement assuming 3H:1V side slopes for 1 m on either side of the 4.0 m bottom width (33.3 cm maximum depth).
5	5	As previously commented, it must be confirmed how the major system flows from south of Pond 1 will be conveyed into Pond 1 without filling in the floodplain (see figure 3). Again, provide conceptual design/grading, easement width, cross-section, etc.	Conceptual grading is illustrated on Drawing 2. Upstream road grade is 95.78m, 100-year floodplain elevation is 94.11 at this location. No filling is being proposed with floodplain.	Drawing 2	Comment not addressed: The level of detail shown on Drawing 2 of the latest Functional Servicing Report (DSEL, April 2013) does not demonstrate that the major system flow can be conveyed to Pond 1 without filling in the flood plain. Please provide sufficient detail to demonstrate this.	No filling of the floodplain (100-year Spring = 94.11 m) will take place in order to convey overland flows to Pond 1; the subdivision areas to be developed south of Pond 1 are outside of the floodplain under existing conditions, as the limits of the pond block are defined by the floodplain. The roads south of Pond 1 are graded between 94.76 m and 95.05 m under proposed conditions. It should be noted that overland flows from 30.79 ha of the subdivision will discharge directly to the Van Gaal Drain upstream of Perth Street, and overland flows from 21.75 ha of the subdivision (and 94.2 ha of natural lands to the south) will discharge directly to the Moore Drain Tributary. Furthermore, 100% of the 100-year flows draining to Perth Street from 3.71 ha of the subdivision (and 97.5 ha of natural lands to the south) will be captured to the minor system. As such, only 35.57 ha of the subdivision will drain overland to Pond 1.

6	6	Section 6.1 of the DSEL report states: "The hydraulic analysis assumed that the external areas would be captured in the minor system". Please confirm the conceptual design of the inlets required to convey this external flow.	The following 100-year flows are to be captured to the minor system from external areas (refer to Attachment 1 of the November 9, 2012 memo for area characteristics): 2392 L/s from VG-2; 992 L/s from VG-3; 867 L/s from VG-5; 908 L/s from VG-7 and 1259 L/s from JR-1. A 1200 mm x 600 mm ditch inlet catchbasin (DICB) has a capacity of approximately 741 L/s under a 30 cm head, and a 600 mm x 600 mm DICB has a 370 L/s capacity under 30 cm of head. The lead pipes of these ditch inlet catchbasins will be sized, based on head over the lead pipe to be determined at the detailed design stage, such that they do not restrict these inflows. One or two ditch inlet catchbasins on each area, as appropriate, should therefore be sufficient to capture the 100-year flows to the minor system for all but VG-2. The 2392 L/s 100-year flow on VG-2 may be captured by four 1200 mm x 600 mm DICBs, or by other means deemed appropriate at the detailed design stage.	Appendix I	Comment addressed.	
7	7	As per the Technical Bulletin (January 2012), the maximum flow depth on streets under either static or dynamic conditions shall not exceed 30 cm. From the modeling results provided, Table 1 summarizes the locations where the dynamic depth exceeds 15 cm. Please confirm that the assumptions used to account for the static ponding (stage-storage relationship) account for the reduced static ponding depths that would be available in these locations.	The model assumes that 30 cu.m./ha of surface storage, on average, will be provided on the streets. Exact surface storage volumes for each street segment will be calculated and modelled at the detailed design stage. Any reduced surface storage in segments with increased flow depths can be compensated for in other segments with the opportunity for greater than average surface storage, as necessary.	Appendix I	As previously requested, please confirm that the assumptions used to account for the static ponding (stage-storage relationship) account for the reduced static ponding depths that would be available in these locations.	Yes, assumptions used to account for the static ponding account for the reduced static ponding depths that would be available in locations with significant flow depth.
8	8	Where are details of the future cross-section of the Moore Drain provided? Confirmation should be provided that the cross-section has sufficient capacity to convey the 100 year peak flow through the subdivision.	Figure 22 illustrates the conceptual design of the Moore channel. The Moore Channel was included in the overall proposed conditions Van Gaal Drain / Jock River model. The model shows some encroachment outside of the block due to the culverts for the road crossing. While the channel is adequate the culverts will need to be reviewed. Note that the proposed conditions model also included: - proposed conditions flows as simulated in SWMHYMO - the realignment of Van Gaal Drain upstream of Perth Street - the replacement of the Forture Street culvert	Appendix I and Figure 22.	There is insufficient clearance between the storm sewer and the proposed Moore tributary channel grade at Street 3. In addition, the design of the culvert must be revised to avoid any encroachments of the 100-year water level outside of the block. Please also plot the 100-year water level on the drawing to clearly demonstrate it is contained and ensure that sufficient freeboard is provided to the adjacent lots. What roughness has been assumed for the channel? To aovid the need for excessive maintenance, a manicured condition should not be assumed.	The 900 mm diameter circular culverts proposed at the three proposed crossings of the Moore Drain Tributary have been revised to 1800 mm by 900 mm rectangular culverts; under these conditions, there are no encroachments of the 100-year flood level outside of the channel block. The Moore Drain Tributary was modelled under summer conditions using Manning's roughness coefficients of 0.035 and 0.08 in the low flow channel (3 m top width) and on the banks, respectively. Under spring conditions, the Manning's roughness coefficient will remain as 0.035 in the low flow channel, but is reduced to 0.05 on the banks to reflect the lack of standing vegetation during that time of year. These values are appropriate for channels that are not subject to regular maintenance.
	B. Erosion Concerns					
9	1	To complete the review of the report (Van Gaal Drain Erosion Assessment, JTBES, October 26, 2012) and follow-up memo (Richmond Village Development: Exiting Erosion Remediation Costs, JTBES, November 22, 2012) a location plan identifying the location of the erosion sites identified is required. Please provide such a figure (i.e., locating all erosion sites and clearly identifying those proposed for remediation). Also, some description/summary of the high and medium priority class sites should be provided in the body of the report and/or in a summary table format, i.e., what is the particular infrastructure and/or property threatened? private or public, etc.?	JTBES prepared "Van Gaal Drain Restoration Memo" - January 25, 2013 and has included figures indicating a location plan.	JTBES - Van Gaal Drain Restoration Memo, January 25, 2013.	Refer to separate memo from Darlene Conway, P. Eng., dated July 11, 2013, for comments on the JTBES memo of January 25, 2013.	Please refer to October 31, 2013 *Richmond Village (South) Limited Subdivision / Continuous Erosion Analysis* memo by JFSA found in Appendix D. Coldwater Consulting Ltd report can be found in Appendix D.
10	2	While the report uses the term "Van Gaal Drain," it is important to note that the reaches in question are not part of the Van Gaal, but part of the Arbuckle Award Drain which does not have municipal drain status. As much, if not all, of the reaches in question are on private property, access to the erosion sites for remediation purposes will require a Drainage Act process in order to secure access to private property. This will presumably have to be coordinated with the proposed realignment of the Van Gaal Drain upstream of Perth St. In the alternative, drainage easements across all private properties affected will have to be negotiated if the advantage of using the Drainage Act is not taken. Please confirm how the required remediation work is to proceed.	Richmond Village Ltd will pursue coordinating the finalization of the engineer's report to create the Arbuckle Drain.		Confirmation from the proponent(s) of their commitment to implement the recommended works via a Drainage Act process and to the satisfaction of the City is required.	Caivan
11	3	Given that the subsequent JTBES memo of November 22, 2012 recommends rehabilitation of the erosion sites identified in the October 2012 JTBES report, detailed comments will be not be provided on the October 2012 report. However, based upon the information provided to date, the City questions the report's conclusion that the development will not exacerbate existing erosion rates in the drain. Nevertheless, subject to confirmation of the proposed remediation work (provide further details as noted above) and the proponent's commitment to undertake the required works to the satisfaction of the City and in keeping with the required Drainage Act process (or negotiation of required easements), this conclusion would appear to be moot.	No comment.		Confirmation from the proponent(s) of their commitment to implement the recommended works via a Drainage Act process and to the satisfaction of the City is required.	Caivan

12	4	The recommendation for the application of the suggested erosion threshold to the design of SWM pond 1 requires clarification. Specifically, on p.15, the report notes: Assessment of the conditions of the creek show that the banks are comprised of consolidated clay materials, ranging from coarse to fine clay. When these materials are exposed to flowing water, velocities of between 0.225 metres per second (coarse clay) and 0.400 metres per second (fine clay) are required to entrain (erode) these materials (ref. Hjulstrom, 1935). The report then recommends the following re: discharge from the SWM pond: Stormwater discharge from new facilities to the Drain be controlled to a maximum velocity of 0.225 metres per second for all flows up to and including the 2-year event, and to as many return events as is possible above the 2-year event. If the 0.225 m/s criterion is based on the erodability of the drain's banks, then the impact of the attenuated pond discharge should presumably be assessed based upon the total flow in the receiver, i.e., the pond discharge plus the upstream flow and how this does or does not meet the specified critical velocity and associated discharge (in the receiver)?	JTBES indicates that flows from the pond be controlled to a maximum velocity of 0.225m/s. This low target will not exacerbate the existing erosion occurring within the drain. Having said that, Richmond Village Ltd are pursuing the finalization of the Arbuckle Drain. JTBES indicates that the drainage works will provide an erosion threshold release target of at least 330L/s.	JTBES - letter Re: Richmond Village Development: Van Gaal Drain Erosion Thresholds, March 6, 2013.	**Comment not addressed:** Related to this comment, the purpose of the March 6, 2013 letter is not clear and it appears the intent of this comment may not have been understood. Further discussion with City staff is recommended to facilitate the resolution of this and other related comments.	Please refer to October 31, 2013 *Richmond Village (South) Limited Subdivision / Continuous Erosion Analysis* memo by JFSA. Coldwater Consulting Ltd report can be found in Appendix D.
14	5	There also appears to be a lack of coordination between the design of SWM pond 1 and the recommendations from the October 2012 JTBES report. i) From the JFSA memo of November 9, 2012 (Appendix I of DSEL November 2012 report): Erosion control for SWM Pond 1 will be provided by controlling the 2-year release rate from each pond to 330 L/s or less, where 330 L/s is the erosion threshold for the Van Gaal Drain identified by Parish Geomorphic in the Natural Environment & Impact Assessment Study for the Mattamy Richmond Lands (March 2009). Furthermore, the October 26, 2012 Van Gaal Drain Erosion Assessment memo by JTB Environmental Systems Inc. indicates that the 2-year outflows from Pond 1 should discharge to the Van Gaal Drain at a velocity of 0.225 m/s or less. This may be achieved by a plunge pool or other velocity reduction measures at the Pond 1 extended detention outlet pipe to the Van Gaal Drain. Is there any relationship between the Parish release rate and the JTBES critical velocity? Also, as noted above, the relevance of a plunge pool to limit discharge velocities from the pond is not apparent?	Addressed by JTBES. We may continue to use 330L/s.	JTBES - letter Re: Richmond Village Development: Van Gaal Drain Erosion Thresholds, March 6, 2013.	**Comment not addressed:** Related to this comment, the purpose of the March 6, 2013 letter is not clear and it appears that the intent of this comment may not have been understood. As previously requested, the provision of a continuous pre- and post simulation exercise is required, coordinated and integrated with the fluvial geomorphological work. Further discussion with City staff is recommended to facilitate the resolution of this and other related comments.	Please refer to October 31, 2013 *Richmond Village (South) Limited Subdivision / Continuous Erosion Analysis* memo by JFSA. Coldwater Consulting Ltd report can be found in Appendix D.
15	6	In summary, an understanding should be provided of the overall response in the receiver and a comparison made between existing and post-development conditions. As previously requested, a continuous simulation should be undertaken to assess the impacts of increased runoff volume, peak flow attenuation and the increased duration of flows. To demonstrate that the recommended targets are achieved, assessments of velocities at critical cross-sections in the drain for representative events should be provided for existing and post development conditions with the proposed stormwater management solution and instream works in place.	In accordance with City comments, a continuous model will be prepared to compare pre- and post-development peak flows and flow duration over a given threshold. Furthermore, velocities at critical cross-sections in the drain will be compared under pre- and post-development conditions for an appropriate design storm.	To be provided.	**Comment not addressed:** Please provide the information requested for review.	Please refer to October 31, 2013 *Richmond Village (South) Limited Subdivision / Continuous Erosion Analysis* memo by JFSA found in Appendix D. Coldwater Consulting Ltd report can be found in Appendix D.
	C. Class EA					
16	1	The most recent response to this issue, provided in the Roberts memo of November 9, 2012, does not address the issue of piecemealing as originally raised in July 2010 (see Attachment 1). If the position is that this approach does not represent piecemealing as defined in the MEA Class EA then this should be documented by the proponent. As there appears to be a difference of professional opinion on this matter and given that piecemealing is in contravention of the EA Act, this should also be confirmed with the Ministry of the Environment.	Having reviewed the correspondence related to piecemealing, it has become evident that there is a misunderstanding on the operation of the sump pumps. The sump pumps are not connected to the sanitary sewer system. As attached to the referenced correspondence, the MOE had provided feedback on this matter.	Delcan / Soloway Wright / RVCA / MOE	**Comment not addressed:** There is no misunderstanding. The issue of piecemealing has not been addressed: please refer to the correspondence noted in the previous comment. As per the e-mail from Cheryl McWilliams to Sarah Millar Martin (February 13, 2013), it is the City's position that an addendum to the Master Servicing Class EA is required.	Caivan?
	D. Pond design/modelling					
17	1	Please expand the summary tables that compare pre- and post-development peak flows and water levels to include the full range of frequency events.	In accordance with City comments, pre- and post-development peak flows and water levels on the drain under spring and summer conditions will be compared for the 2-, 5-, 10-, 25- and 100-year return periods.	To be provided.	**Comment not addressed:** Please provide the information requested for review and approval.	Please refer to Attachment 7 of the October 31, 2013 *Richmond Village (South) Limited Subdivision / Preliminary Stormwater Management Plan* memo by JFSA found in Appendix I.

18	2	Per previous comments: As currently proposed, the bottom of Pond 2 is some 3 to 4 meters below existing grade and into bedrock. The bottom of Pond 1, some 3 meters below existing grade as currently proposed, may be at or marginally below bedrock. Some of the sewers (storm and sanitary) may also intercept the bedrock, in particular below Ottawa St. There has been no discussion provided as to the potential impacts on pond operation, existing wells, contribution to base flows, etc. Some discussion should be provided regarding these potential concerns and recommendations provided to mitigate any potential impacts provided as required.	The results of the subsurface investigations indicate that the hydraulic conductivity of the shallow bedrock in the area of Pond 1 and Pond 2 is moderate (1x10-5 m/s and 5x10-6 m/s at MW10-3 and MW10-6 respectively), similar to the hydraulic conductivity of the overlying silty sand and silty clay deposits. However, the design of the ponds should consider the possibility that vertical fractures in the shallow bedrock might permit increased groundwater flow through the bottom of the ponds, which could hamper their construction. Therefore, shallower pond designs should be considered if construction in the bedrock is not required, and a plan to control the inflow of water from the shallow bedrock during construction of the ponds should also be developed, if necessary. The normal operating levels in Ponds 1 and 2 will be approximately 1.5 and 1.2 metres below the typical groundwater levels as measured in groundwater monitors MW10-3 and MW10-6 respectively. Therefore, groundwater levels in in the areas immediately adjacent to the ponds (including in the upper bedrock) will be reduced by a maximum of approximately 1.2 to 1.5 metres. The effect of the ponds on groundwater levels will diminish at greater distance from the pond. Considering that local water wells are typically cased a minimum of 6 metres below ground surface and are on the order of 30 meters deep, such small and localized reductions in the groundwater levels is not expected to negatively impact the water supply of local water wells. DSEL has reviewed pond 2 in further detail. Pond 2 is revised to a dry pond employing hydro-dynamic separators to meet quality control objectives. The bottom of Pond 2 is situated above the rock elevation per test pit data.	To be provided.	It is not possible to review or comment on this response in the absence of supporting documentation and design information. Please provide the supporting information for review, sealed as required by the professional making the recommendation(s). Please also note that the City is inquiring about the risk to wells from pond leakage through fractures. Notwithstanding the hydraulic conductivity derived from a continuum (macroscopic) approach, porosity will vary erratically at volumes lower than the representative elementary volume. Individual fractures become significant at the finer level, particularly for contaminant transport. Also, please note that the City was not inquiring about the construction methodology of the pond, but rather about the long-term effect of groundwater on its operation, existing wells, contribution to base flows, etc.	As discussed with City staff a wetland facility is proposed for Pond #2. Incorporation of this type of facility has allowed for a bottom elevation that is above the anticipated rock surface and therefore minimizes disturbance. Golder Associates has provided a memo for the justification of avoiding rock excavation (see Appendix F and discussion in Section 7.2)
19	3	From the Nov.9, 2012 JFSA memo (Appendix I) - where is the future 16.5ha commercial site that is referenced located?	The 16.5ha property are the lands north of Perth street, immediately west of the Richmond Village (North) Ltd., parcel, inside the Western development expansion area, and includes the existing retail parcel on Perth Street. This is to be revised to represent the land uses contemplated in the CDP.	Appendix I	Please clearly delineate all external areas on the drainage plan for existing and future conditions.	Base plans have been updated to reflect the areas. Note that the 16.5ha area is no longer being considered as a commercial site and is being modelled as residential in line with the CDP.
		Pond 1				
20	4	Per previous comments: The justification for locating the pond in the floodplain is based upon locating it above the summer event given that the higher regulatory flood level results from a backwater effect from the Jock River. However, the 100-year spring event on the drain (93.83m at 910), though lower than the backwater condition from the Jock, is still higher than the summer event (93.60 at 910, Fortune St. culvert upgraded). While the timing of peak flows may apply to the much larger Jock River and the spring event backwater condition, it is not apparent this is an appropriate assumption when comparing spring and summer events on the much smaller drain. Further, the rationale of locating the pond only above the summer condition floodplain could set a precedent such that ponds are proposed in future within the regulatory (spring) floodplain where there is no comparable backwater effect. From a technical perspective, the pond should be located above the 100-year spring event on the drain.	JFSA completed additional hydraulic modeling of the development and pond's impact on water levels within the receiving water courses. The analysis has demonstrated technical feasibility. Noting that this is a unique feature of these lands in particular.	Appendix I	This rationale is inconsistent with the rationale being used to justify locating the pond within the regulatory (spring) event on the Jock River and sets a bad precedent, however, resolution of this matter is deferred to RVCA.	See discussion of the SWM Pond #1 operation in Section 7.1.2
21	5	Per previous comments, a 0.30m freeboard is required above the design high water level. This is a standard design criterion that must be incorporated into all pond designs – in this case, without filling in the floodplain. Therefore, the pond design must be revised accordingly to explicitly achieve this criterion.	As per the MOE SWMPD manual, a 0.3 m freeboard should be provided between the design high water level in the pond and surrounding grades. This qualification does not apply to that side of the pond adjacent to the Van Gaal Drain, which will be inundated by floodwaters during significant spring flood events. However, a 0.3 m freeboard should be provided on the sides of the pond adjacent to the proposed development (roads, residential lots, etc.).	MOE Design Guidelines - Section 4.2 Sitting of Facilities.	**<u>Comment not addressed</u>:** It appears that the purpose of providing freeboard for engineered works may not be fully appreciated. In this case, a key purpose of the pond is to provide flood control storage: providing the minimum standard freeboard around the pond ensures that a reasonable safety factor is provided that recognizes inherent modeling limitations, allows for construction tolerances, minor future settlement, etc., to ensure that the design flood control storage will be available for the life of the pond. It is not relevant whether the pond fronts on lots or onto the floodplain. Please revise the design accordingly such that the minimum standard freeboard of 0.3m is provided above the pond's design (100 year) water level for the entire pond.	JFSA / DSEL / City to meet and debate this point.
22	6	The draft plan indicates 2 sediment management areas are provided for Pond 1 (total area approximately. 2100 m2). The City requires that these areas be sized approximately equal to the size of the forebay(s) at the permanent pool elevation (total area approximately 6000 m2). Adjust the draft plan to provide for sufficient area for sediment storage purposes outside of the regulatory floodplain. These areas should also be clearly demarcated on the appropriate figures in the DSEL report.	The sediment pond drying area was sized employing the MOE Design guidelines for estimating sediment build-up in the forebays and a clean-out frequency of 20-years. This volume would be spread over the drying area at an average depth of 0.60m.	Calculation to be included in future submission	**<u>Comment not addressed</u>**: Please provide the calculations/documentation and identify the required sediment drying area on the drawings for review and approval.	As discussed at Sept 12/13 meeting, drying area is shown. Sediment loading calculations can be found in Appendix I and a summary is provided in Section 7.3.
23	7	Please indicate the location of the Pond 1 spillway on Drawing 3 and Figure 20. Also note that the scale on Drawing 3 should be 1:4000.	Duly noted		**<u>Comment not addressed:</u>** The pond 1 spillway is still not shown on Drawing 3.	See updated Drawing 3 and Figure 20.
24	8	Per previous comments, the outlet invert elevation for Pond 1 (92.35m) is lower than the 2 year flood elevation. This is not consistent with the criterion specified in the MOE SWM Planning and Design Manual.	The MOE recommendations reads that the SWMP <u>should</u> be higher than the 2-year floodline and the overflow <u>must</u> be above the 25 year floodline.	MOE Design Guidelines - Section 4.2 Sitting of Facilities.	**<u>Comment not addressed.</u>**	Agreed to at Sept 12/13 meeting that the pond can have its outlet lower than the 2-year event. Pond design remains as is.
		Pond 2				

25	9	As currently proposed, the quantity control weir elevation for Pond 2 (93.35m) is below the 25-year floodline (93.82 m). This is inconsistent with the design criteria in the MOE SWM Planning and Design Manual	The design criteria speak to the overflow elevation above the 25-year, not the outlet. Pond 2 emergency overflow is at 96.00m spilling toward Burke Street. Note that 100-year elevation is Pond 2 is 94.31m.	Figure 21.	Based on the proposed design of pond 2, the water quantity weir elevation is below the 25 year floodline. As shown in Table 5B, the elevation of 96.0 m corresponds to the top of berm: how has the design accounted for a controlled spill out of the pond? (based on the proposed grading, the pond will spill toward the existing lots located on Ottawa Street).	The water quantity weir will function as a partially-submerged weir once the water level in the SWM facility exceeds that of the Jock River at the proposed outlet. The performance of the facility under these conditions was verified in XPSWMM based on the 100-year spring flood level of 94.18 m on the Jock River (conservatively assuming initial conditions where it has backed up into the SWM facility such that it also has a water level of 94.18 m). Under these conditions, the maximum water level in the facility was simulated as 94.84 m - well below the top of berm at 96.0 m.
26	10	The block for Pond 2 has not accounted for the required sediment drying storage area – please revise/expand the block accordingly.	Please note that sediment drying area indicated on Figure 21.	Figure 21.	**Comment not addressed**: As for Pond 1, please provide the calculations/documentation supporting the sizing of the sediment drying area.	As discussed at Sept 12/13 meeting, drying area is shown. Sediment loading calculations can be found in Appendix I and a summary is provided in Section 7.3.
27	11	It is not clear where the emergency overflow from Pond 2 would be directed (should blockage or partial blockage of the outlet structure occur). Please confirm there is an appropriate emergency outlet/flow path to the river that will not impact existing and future homes and indicate this on the appropriate figures.	Pond 2 emergency overflow is at 96.00m spilling toward Burke Street. Note that 100-year elevation is Pond 2 is 94.31m, therefore there is 1.7m of available emergency storage.	Figure 21.	For 100 year conditions, the flow from the outlet of pond 2 is about 2.14 cms, which exceeds the capacity of the downstream trunk sewer: confirm that any surcharge does not exceed the road elevation and/or increase the pipe size accordingly.	As discussed at Sept 12/13 meeting, emergency outlet to demonstrate conveyance to the Jock River tributary (aka Arbuckle Drain). Due to road grading constraints, an outlet along rear yards is shown with a positive outlet to Queen Charlotte Street. The SWM facility outlet pipe has been updated to reflect a 1500 mm diameter pipe, with a capacity of 2.235 m^3/s.
		Figure 4, derived from the City's LiDAR data, indicates fill areas even without the required minimum freeboard provided.			**Comment not addressed**: As previously commented, please revise the design to ensure minimum freeboard is provided and filling in the regulatory floodplain is not required to provide the necessary quantity control storage.	As discussed at Sept 12/13 meeting, City defers to the RVCA.
	E. Storm sewer servicing					
28	1	Per standard design practice, sewer obverts should be matched at the crossing of the Moore Drain and minimum clearance provided between the Moore Drain crossing and the storm sewer.	Requesting deviation from Sewer Design Guidelines (6.2.10). In regards to standard engineering practices - invert to invert connections do not have a noticeable effect on hydraulics (See Haestad Methods Stormwater Conveyance Modeling and Design - Page 421/422.) Also note that invert to invert connections have been made numerous other circumstances when either depth of cover or volume of imported material is a problem.	Haestad Methods - Stormwater Conveyance Modeling and Design - Page 421/422	Matching obverts is a basic design requirement. Please revise the design accordingly. However, if a deviation is pursued further, rationale per the Sewer Design Guideline's exception criterion is to be provided for vetting by the Infrastructure Services and Environmental Services Departments.	Agreed to at Sept 12/13 meeting that deviation is acceptable. A section on deviations from Design Guidelines is provided in Section 6.2.1 regarding potenial use of multiple barrels with invert to invert connections.
29	2	As previously commented, the use of a 300mm deep x 1800mm wide box culvert is not acceptable. It is apparent that this is being proposed to provide clearance from the existing servicing on Fortune St. – but it is not acceptable. Revise the design to an appropriate storm sewer cross-section and provide the minimum clearance required between existing storm and sanitary services. Provide the confirmed invert on the existing sanitary sewer at the crossing (drawings indicate this is still to be confirmed). In the alternative, relocate the outlet further upstream and revise the pond design accordingly. Note: this is not a detailed design issue as it brings into question whether the proposed outlet location is feasible. There is also minimal cover where the outfall sewer crosses the Moore Drain (approx. 0.30m based upon a drain invert of approx. 93.38m from LiDAR data).	Two options exist to resolve the conflict at Fortune Street. One, provide a multiple barrel outlet versus a custom box culvert. Two, lower the existing sanitary service on Fortune Street and connect to new sanitary sewer on Martin Street. Moore Drain crossing to be reviewed with Drainage Engineer.		**Comment not addressed**: Please provide the details of an acceptable design solution so that it may be reviewed: it appears that a lowering of the existing sanitary sewer on Fortune St. may be unavoidable and address the lack of cover outfall under Moore Drain.	Solutions discussed at Sept 12/13 meeting. Minimal separation below the Moore ditch is still shown (with a 750mm pipe). A section on deviations from the Design Guidelines is provided in Section 6.2.1 for potential invert to invert connections using multiple pipes to provide clearance from the Moore ditch. In addition, the sanitary sewer conflict has been rectified with the new sanitary servicing solution shown in Drawing 7.
30	3	The extensive use of box culverts (close to 1400m in total) is inconsistent with Sewer Design Guideline. Operations staff have confirmed that in lieu of box culverts, multiple round conduits that provide equivalent flow capacity are required.	Duly noted, multiple barrels will be investigated at detailed design.		Comment addressed.	
31	4	Per previous comments, the report notes (p.21) that the Jock River Estates drainage (MAT-E) is proposed to be conveyed north of Ottawa Street through a new culvert to the redesigned Moore Tributary channel and then to the Van Gaal/Arbuckle drain. It is not clear how this is to be achieved with a culvert. Please clarify. The report and drawings also note that this drainage will be picked up and conveyed to Pond 2. Whatever the case, consistency is required between drawings and documentation – please revise as required.	Page 21 outlines a high level review of servicing strategies. It is proposed to collect and convey the Jock River Estates drainage through Pond 2.		Please clearly document in the report and on the drawings how this drainage is to be dealt with.	To be included with the RVCA submission for the Mattamy draft plan. Flows will be conveyed through Pond 2. Discussion on the proposed sequencing of closure of the existing ditch is included in updated text in Section 4.1.3 "Option 3".
32	5	Minimum cleansing velocities (0.80 m/s at the 5 year design flow) have not been met for all storm sewers: 600 mm diameter: 244 m (4 pipe sections); 675 mm Diameter: 264 m (6 pipe sections). Please revise the design accordingly.	City of Ottawa Guidelines Section 6.1.2.1 "Storm sewers must be designed to provide a minimum velocity o 0.80m/s when flowing full."		**Comment not addressed**: Please revise design accordingly to ensure that mimimum velocities are achieved. .	At the macro design level there are still some pipe segments that are shown marginally below the 0.8m/s cleansing velocity. These select pipe segments will be refined to meet the 0.8m/s at the detailed design stage.
33	6	Per previous comments: Given that the pond outlet crosses under (not into) the Moore Drain to connect to the Van Gaal, it is not apparent how cool "baseflow" can continue to be directed to the top of section 2 of the Moore. Is this still a requirement? If yes, how is it to be addressed?	Addressed with RVCA. Pond 1 to involve a bottom drain outlet to provide cool base flow to the Van Gaal.		Please provide the proposed concept on the drawing for review.	Coordinated with RVCA, see Section 7.1.1 for descriptions/discussion. Outlet shown on Drawing 3 and Figure 20.
34	7	Regarding the Pond 2 outfall along Ottawa St. – it appears there may be potential for conflicts between existing sanitary services connections toward the end of Ottawa St.	The proposed pond 2 outlet is contemplated to be on the south side of Ottawa Street, therefore the existing homes on the south side of the street would be in potential conflict. However, this is limited to one home where the existing sanitary sewer is only slightly above the proposed storm, indicating that there is no conflict, only the possibility that the service may be close.	Drawing 6	Given confirmation that a conflict(s) may exist, clearly identify this on the drawing and indicate it will be further confirmed/addressed during detailed design.	The potential conflict is noted on Drawing 6 for "Pond Storm Outfall 2" and that it is to be reviewed at the detailed design stage.
	F. Sanitary HGL					
35	1	Comments will be provided pending resolution of the foundation drainage servicing.			Foundation drainage servicing not yet resolved.	
City Comments Dated December 14, 2012 - Review of Updated Assessment of Subsurface Drainage and Analysis of 100 Year Flood Event						
From: Darlene Conway To: Cheryl McWilliams						
	Detailed Comments:					

36	1	The Golder memo of October 3, 2012 documents assumptions, conclusions and limitations but does not appear to provide specific recommendations with respect to engineering design. What are the recommendations related to the design of a foundation drainage system that can be offered from this modeling exercise? It would be of assistance for the author(s) of the memo to compare the utility of this modeling exercise to other technical work used to support the engineering design of this proposed development, for example, the recommendations proceeding from the Golder geotechnical memo of June 27, 2011 or the hydrotechnical modeling completed by JFSA (Appendix I in the DSEL November 2012 report).	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013	Defer to detailed comments provided by others (Dillon, Michel Kearney).	
37	2	From the Golder October 2012 memo (emphasis added): In order to establish an initial groundwater condition, the model recharge was adjusted until the simulated groundwater elevation was directly beneath the foundation drains (which occurred at a recharge rate of 90 mm/yr). Using this initial condition, the 100 year storm was simulated transiently over a 24 hour period, during which time groundwater elevations in the storm sewer trench and service stub were increased from 92.98 masl to 94.11masl. Water levels were assumed to increase instantaneously at the onset of the storm. To simulate the additional impact of the 100 year storm occurring concurrently with the spring freshet, the recharge was increased to 2000 mm/year during the same 24 hour period. This value of recharge resulted in an average head throughout the model domain that approximated the 100 year storm water level. The magnitude and duration of the spring freshet used for the modelling were assumed values; however, the selected parameters are considered to be conservative. The 100 year spring event used to simulate the regulatory (100 year) flood level on the Jock River is a 10day snowmelt +rainfall event having a volume of approximately 270mm. The 100 year 24 hour storm has a volume of approximately 107mm. Pond operating levels under this condition are also higher than in the receivers. Further clarification regarding the contention that the parameters used to model the spring 100year condition are conservative would be helpful.	The 100 year storm event simulation increased the water table to the elevation of the foundation drains, increased the water elevation in the pond and in the service trenches to the designed operating level (94.11 masl) and added additional infiltration (2000 mm/yr recharge) due to rainfall. Higher rates of recharge have been included in the revised model, to be described in a separate memorandum	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013	**<u>Comment not addressed:</u>** The analysis does not consider the impact of the extended duration of the event that generates the regulatory flood level (94.11m) on the Jock River which is a *10-day* rain on snow event - not a 24 hour event. Further, under the regulatory (spring, 10-day) event, the levels in the ponds are higher than 94.11m (the flood level in the river/drain). To further clarify: the regulatory event that generates the 100 year flood level of 94.11m is an extended event, resulting in days, not hours, of elevated flood levels that would presumably require sump pumps to operate for days in succession.	
38	3	The attached tables summarize pond operating levels and Jock River flood levels for various conditions and frequencies. Separate from the issue of lowering the existing water table, the numbers in this table indicate that, based upon the USF elevations proposed, sump pumps could be expected to operate very frequently and at length, considering the fractured bedrock conditions in the southern portion of the site. Every USF is located below the 2 year flood elevation (section 20686) on the Jock River. Has the worst case scenario been considered in this exercise? What is to prevent the need for continuous operation of sump pumps given the 2 year flood level in the Jock River and the fractured bedrock conditions?	DSEL / Golder reviewed site grading in the area adjacent to the River. If USF's are situated in rock their elevations have been increased to be above the 100-year water level in the Jock River.		Please provide an updated grading plan for review that confirms the response provided.	
39	4	From the Golder October 2012 memo: A service stub was specified using a constant head boundary from the storm sewer to towards the house. The stub was terminated at a distance of 3 m from the house. A 2 m width was assumed for the stub trench. The constant head boundary was assigned at the same elevation as the storm sewer trench; The modeling also assumed that the granular material within the service trenches will not directly connect to foundation drains. Inspection during construction, to ensure implementation of this design, is recommended. Given the above modeling assumptions, is the memo recommending that sufficient protection would be provided during the 100 year event (and per the tables above events as frequent as the 5 year) by a width of some 2m of non-granular backfill material (assuming 1m of granular backfill adjacent to the foundation wall) that is further dependent on stringent inspection during the backfilling process?	Yes, the technical memorandum is recommending that sufficient protection would be provided.		Based upon typical construction practices and the extent of site supervision available, it is not apparent that this is an acceptable approach on which to base the protection of basements from flooding due to backwatering of the service trenches.	
40	5	Can examples from other municipalities be provided where all basements have been built well below the existing water table elevation on the basis of a groundwater modeling exercise with similar assumptions, along with a list of contacts such that the City may follow up on the performance of any such examples?	Please note that not all basements are situated below the existing high groundwater table. Where basements are lower than the recorded high groundwater table, it should be noted that the proposed USF's are higher than the adjacent existing properties on Fortune and Queen Charlotte where it is expected that pre-development conditions were similar.		**<u>Comment not addressed</u>**: No examples from other municipalities where all (or a significant number of) basements have been built well below the existing water table elevation on the basis of a groundwater modeling exercise with similar assumptions have been provided. To clarify, this request was referring to relatively recent developments from municipalities with relatively current/comparable design guidelines. If such examples cannot be pointed to, please indicate this.	
City Comments Dated December 14, 2012 - Sump Pump Strategy and Numerical Modeling						
From: Michel Kearney To: Darlene Conway						
	Fundamental Considerations					
41	1	These comments are to be read in conjunction with the peer review performed by Dillon Consulting, dated November 29, 2012. There has been an effort to avoid, as much as possible, the duplication of comments, but where deemed appropriate a comment made by Dillon may be reiterated, either for emphasis or for contextualization.	No comment.			

42	2	The use of sump pumps, as proposed, is a deviation from the Ottawa Sewer Design Guidelines. DSEL(285)3 refers to §§ 3.2.2, 5.7.3 and 5.9 of the Guidelines; however, §3.2.2 refers to infill developments and requires that sump pumps drain to the surface, §5.7.3 refers to sewers with limited capacity constraints and recommends discharge of the sump pump to the ground surface (this section mentions slab on grade as a means to eliminate the need for a sump pump), and § 5.9 refers to ditch pipes with storm sewer systems, and even though it does not refer to where the sump pump should discharge, in view of the shallowness of the ditch pipes and considering the other references in the Guidelines regarding sump pump discharge, it is understood that discharge is to be directed to the surface in this instance as well.	Is the City suggesting that the Sump pumps could be approved if they were directed to the surface? In our previous discussions regarding sump pump, the City had expressed concerns regarding this arrangement due to the possibility of future home owners creating illegal connections. Please advise.		**Comment misinterpreted:** The comment from the City was addressing the assertion by DSEL that the use of sump pumps in this development falls within the City of Ottawa Design Guidelines. DSEL quoted §§3.2.2, 5.7.3 and 5.9; however, as pointed out by the City, these sections of the Guidelines all refer to circumstances other than those found in the Richmond Western Development Lands (i.e., is the discharge of sump pumps into storm sewers). The possibility of sump pumps discharging to the surface of the ground (as an option for the subject lands) is not something that was being discussed in the comment.	
43	3	DSEL continues to use a matrix evaluation procedure, even though it has been pointed out that the use of a weighted matrix is not appropriate at the subdivision level (see DSEL(14)). The use of a matrix may be justified for the first three options only, i.e. not the sump pump option (see DSEL 308, 309), as sump pumps can only be considered once it has been determined that other options are not viable.	Noted, it was determined by the client that the first three options are not financially viable. As described in Section 5.0 of the report, Option 1 exceeds grade raise recommendation throughout the subdivision.		**Comment not addressed:** There are other components to viability besides financial considerations. We reiterate that a matrix evaluation procedure is not appropriate at the subdivision level.	
44	4	In view of the lower level of service provided by sump pumps, compared to the other three options, it has not been justified why future residents should be subjected to the lower level of service provided by sump pumps. The level of service must be addressed on its own merit and not based on a decision matrix.	Please note that Section 5.0 of the SWM report describes each option in its own light. The matrix provides a comparison table for the options and was not the sole vehicle for arriving at the sump pump conclusion.		**Comment not addressed:** As stated by the City, the matrix presented by DSEL is inappropriate as a comparison tool, even if the matrix was not the sole vehicle for arriving at the sump pump conclusion.	
45	5	Although most of Richmond is currently on sump pumps, the vast majority of properties are historical and have sump pumps that discharge to the surface. There is a smaller and more recent subset of Richmond properties where sump pumps discharge into a storm sewer, but these developments are not as dense as the proposed Western Development Lands, and our review indicates, to the best of our knowledge, that the foundations were kept above the pre-development water table condition.	No comment.		No further comment required	
46	6	The City has never considered approving the Western Development Lands on the basis of footing elevations that are lower than the existing water table4. In fact, it has been stated numerous times that footing elevations have to be above the water table (DSEL 15, 270, 271, 273, 274, 276, 290, 294, 314, 316). Although it is recognized that the proposal before the City is for the lowering of the existing water table, based on a predictive assessment of the effect of the storm sewer network and service stubs, this proposed solution is unprecedented at the City. Rather, it has been the practice of the City to only approve developments on sump pumps where it can be demonstrated that the foundation is above the pre-development high water table5. That being the case, it would have been prudent to liaise with the City prior to commencing a modelling exercise that looks at lowering the water table.	The City's reference to the determination of the high water table elevation by the Ottawa Septic office demonstrates that the high water table is typically determined after draft approval, and after other servicing (roads and storm drains) have been constructed. It also demonstrates that the City is typically satisfied with an estimation of the water table elevation, based on one-time observations. The City suggests that, "it would have been prudent to liaise with the City prior to commencing a modelling exercise that looks at modelling the water table." However, Golder participated in a meeting with the City, on February 17, 2010, and in a memorandum by the City dated April 29, 2010, the City states, "It was agreed at the meeting [of February 17th] that more fieldwork would be required in order to obtain better quality information on water table elevations and soil hydraulic conductivities. In conjunction with the fieldwork, Golder would perform a numerical modeling exercise in order to investigate some theoretical scenarios, which could later be fine-tuned with the new field information." It is our recollection that it was the City, not Golder, that suggested the use of groundwater modelling in order to assess the sump pump issue.		**Comment not addressed:** The City's reference to the Ottawa Septic System Office (OSSO) was in the context of an individual lot in the rural area, not in the case of a subdivision, where the City requires that the water table be determined as part of the design of the subdivision. Also the estimate of the water table by the OSSO is not a "one-time observation," but is rather based on the experience of the inspector in that particular area. The model referenced by Golder is not the same model as the one currently proposed. It was a much simpler model, and it was to be used to estimate a parameter under review at the time, which was dubbed by Golder "time to flood." The model was not suggested by the City and it had a fundamental flaw that rendered it unusable for the purpose intended by Golder at the time. When Golder recognized that the sump pit would be a direct conduit for groundwater accumulating around the foundation, the option of using the granulars under the floor slabs as storage was abandoned. This preliminary and abandoned model is not relevant to the current discussion, where Golder is proposing to use a model to predict the lowering of the water table for the purpose of setting the foundations at a lower elevation (than the existing monitored water table).	
47	7	The relationship between basement elevations and the water table is of crucial importance for future homeowners within the subdivision, and it is evident that a high comfort level needs to be provided against the possibility of basement flooding. There is considerable doubt whether such a comfort level can be achieved through a predictive groundwater model. There is ample literature discussing the role of models in decision-making. It is widely recognized that groundwater numerical models have an important role to play in decision-making, as analytical solutions are available for only the simplest of problems; however, great caution needs to be exercised when relying on model predictions. In a recent issue of Ground Water7, Hunt and Zheng state that "models can never be considered crystal balls predicting the future, no matter how well constructed". They go on to say that this does not mean that models do not have utility today, but that it must be kept in mind that models have a "societal decision-making context", and that models are "better thought as heuristic8 science-based tools to assess what has happened, what is in the realm of possible for the future, and how uncertain the conjectures are". Golder is very familiar with these concepts, but they are nevertheless presented here for the non-specialist who is reading these comments and seeking understanding.	Golder has the necessary expertise and experience regarding the appropriate application of groundwater models. Golder has completed many projects involving groundwater modelling for many clients, including the City of Ottawa. In Golder's opinion, the models we have developed for this project reasonably approximate the real systems that they were developed to simulate, to the extent that they provide reasonable predictions of future groundwater levels. With regards to third party reliance, Golder's professional work produce was produced for the use of our client for the stated purpose only, as we have a contractual relationship with our client, only. Golder would not provide reliance to any third party in the absence of a contractual relationship. It is important to note that contracts and limitations statements address specific non-technical issues that are not related to quality of work or professional standards. The City should not confuse issues of a contractual and technical nature. We recommend that the City investigate the degree to which the City can rely on the services provided by the consultant it has retained in relation to this project (Dillon Consulting).		**Comment not addressed:** Godler's expertise is not being questioned by the City. The comment provided by the City was to highlight for the non-specialist the normal use of models, and that they have to be used with great caution when making predictions. The City does not agree with Golder that setting foundations based on a modeling exercise is appropriate. Dillon, in their July 11, 2013 review letter have also expressed a similar concern. In addition to this concern, the City is also concerned that it is excluded from the parties that can rely on the Golder report (see Dillon on this matter also).	

		Golder has properly outlined the limitations of the model, stating that "[h]ydrogeological investigations and groundwater modelling are dynamic and inexact sciences" and that "groundwater systems are complicated beyond human capability to evaluate them comprehensively in detail". Golder also seems to acknowledge the heuristic use of the model when they state that "the behaviour of a valid groundwater model reasonably approximates that of the real system". It is however a large step to go beyond system behaviour to then predict future water table elevations with sufficient confidence to set basement elevations. Recognizing these limitations, Golder states that third parties9 can only rely on the model at their own risk. Dillon has pointed out that "[g]iven the significant limitations listed in the report, it is unclear if the assessment approach used is an adequate method to predict the impacts caused by the development." The City shares this concern. There is a need to couch the model within the "societal decision-making context", which in this case we understand to consist, at least partly, in protecting future homeowners who would have to deal with potential flooding problems should the model predictions be incorrect. It must therefore be recognized that the utility of a modelling exercise is limited when trying to establish basement elevations.				
	Specific Comments on the Golder Technical Memorandum (TM)					
48	8	On page 1 the TM states that its contents represent a summary of the results; however, as pointed out by Dillon, additional documentation is required for a complete review. This review is therefore preliminary.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013	**<u>Comment partially addressed:</u>** Additional information has been provided by Golder, but some information is still missing (see Dillon review letter, July 13, 2013).	
49	9	There is a width of 2 m assumed for the service trench (page 2); however, this seems to be significantly wider than typical. Is a 2 m trench required in the model? (Also see Comment 18 below).	A 2 metre trench is not necessary. The width of the trench in the model has been revised to 1 m. The revised model is described under separate cover.		**<u>Comment partially addressed:</u>** The width of the service trench was reduced to 1 m, but no explanation was provided (as to the need for a specified trench width).	
50	10	On page 3 there is an assumption that initial groundwater drainage will occur through the granular backfill material within service trenches; however, sewer trench bedding consists of Granular "A"10, which is a fairly well-graded material with substantial amounts of fines, and hence does not appear to exhibit the drainage characteristics assigned in the model. This premise of the model therefore needs to be reviewed. The hydraulic conductivity of the granular bedding material must be taken into account, and the longitudinal flow component of the dewatering regime—i.e. along the storm sewer bedding to the outlet—needs to be quantified.	Granular A was not specified in the Golder memo. We would recommend Granular O, which is Granular A with the fines removed, and thus is free draining.			
51	11	On page 3 weathered bedrock is assigned a hydraulic conductivity of 5x10-5 m/s, which appears to be an average value based on the measured values; however, since the fractured rock areas may be the worst case areas, it is important to assess the sensitivity of the model to the higher hydraulic conductivity (see also Comment 13 below).	The hydraulic conductivity of the upper bedrock was assigned a value that was the average of the measured values. This value is considered reasonable, and, based on the results of the subsurface investigation, is representative of the average conditions across the site		**<u>Comment not addressed:</u>** It is standard practice to provide a sensitivity assessment (see also Dillon's July 11, 2013 review letter).	
52	12	On page 3 an anisotropic ratio of 10:1 is applied to all layers; however, justification should be provided for assigning this ratio to the overburden. The sensitivity of the model to isotropic conditions in the overburden needs to be investigated.	The anisotropy of the overburden in the model has been revised. The revised model is described under separate cover.		Comment addressed.	
53	13	On page 3 the worst case scenario is said to occur at the location shown on Figure 1; however, it would appear that a worst case may be at a location near the Jock River, where excavation is proposed in fractured bedrock, with fractures possibly connected to the river and where house excavations may open up more fractures. The entire area south of Ottawa Street therefore needs to be investigated separately. More field investigations may be required in order to better assess the connectivity between the fractures in the bedrock and the Jock River. All the foundations are below the 2-year flood level in the Jock River and many of these foundations are likely below even more frequent events. In houses constructed into the bedrock the sump pumps may not be able to keep up with the possible high flows from some parts of the fracture network. A work plan should be devised as to how this issue can be investigated.	DSEL / Golder reviewed site grading in the area adjacent to the River. USF's have been increased to either be situated above the 100-year water level in the Jock River or the rock elevation, which ever is lower.		**<u>Comment partially addressed:</u>** Please provide the revised Grading Plan.	
54	14	The second bullet on page 4 states that the drain boundary elevations were specified at an elevation of 0.05 m above the storm sewer invert elevation to represent the potential flowing water depth in the sewer; however, the water in the sewer is not connected to the water in the trenches. Clarification is required, especially in view that the sixth bullet on the same page seems to indicate the opposite.	As stated by the City, water in the sewer is not to be connected to water in the trench bedding. This is clarified in the memorandum prepared by Golder regarding the revised model.		Comment addressed.	

55	15	On page 5 there is a rationale for a 24-hour, 100-year storm; however, this rationale seems to miss the issue raised by the City. It appears that Golder is attempting to address the issue represented in DSEL(184). The City was raising the concern about the effect of the regulatory flood event, and also other events that might impact the basements, on houses located to the south of Ottawa Street. As stated above, there may be a hydraulic connection between the river and the fractured bedrock and the concern is that sump pumps may not keep up where basements are located below the water table and/or below the regulatory flood event (all underside of footing elevations south of Ottawa Street are located well below the regulatory flood elevation). The hydrograph for the regulatory flood will peak and recede relatively slowly. Assessing the effect of a 24-hour storm at the north portion of the subdivision does not address the City's concerns expressed in DSEL(184). See also Comment 13 (above) on this issue.	DSEL / Golder reviewed site grading in the area adjacent to the River. USF's have been increased to either be situated above the 100-year water level in the Jock River or the rock elevation, which ever is lower.		**Comment partially addressed:** Please provide the revised Grading Plan.	
56	16	Page 5 states that it will take 475 days for the water table to lower to a level where most basements are at or higher than the predicted water table. It should be specified whether it is intended to wait 475 days before the construction of the first house, after it has been confirmed in the field that the water table lowering has been achieved. Also, in view of Comment 9 (above), the lowering of the water table may not be achieved if the trenches are not free draining as is assumed in the model.	The modelling results provide general guidance regarding the timing of the lowering of the water table, under average conditions. Many factors may increase or decrease the actual time to achieve the required water table lowering. As such, field confirmation of the water table elevation during construction is recommended. Active dewatering during construction will likely be necessary (as is typical) for construction of the buried services, so it is likely that a combination of active and passive dewatering methods will achieve the water table lowering necessary to enable house construction.		**Comment misinterpreted:** The City was inquiring whether the developer will be waiting 475 days (now 400 days) to ensure that the water table has been lowered (we assume that this would be confirmed through monitoring). The City was not inquiring about the construction methodology.	
57	17	On page 7 there is a predicted peak inflow into the sump pit of 1.07 m3/house/day based on the model. It would be useful to look at actual studies to see if this value is in fact an upper range for similar conditions. For example, there is a study by the Ministry of the Environment12, where rain and pumping volumes were measured for a number of houses, and where flows exceeding 15 m3 were measured from a single house foundation drain over a period of approximately 25 hours.	Noted. Golder's analysis was specific to the study area.		**Comment not addressed:** The City is not necessarily asking Golder to provide data from studies in other areas; however, the City is suggesting that since the proposed solution is of a unique nature it would be useful to make use of data from studies where flows from foundations have been measured. The City provided a reference for one such study.	
58	18	Page 6 mentions that inspection is recommended in order to ensure that the service trench granular material is not connected to the house; however, this is not an area that is currently closely inspected. There may not be a mechanism to ensure that this gets inspected and therefore this particular inspection point should not be assumed as part of the solution. Under the proposed scheme, there is in effect only approximately 2 m of soil between the granular in the house service trench and the free draining material along the perimeter of the foundation (typically around 1 m).	Clay seals are commonly designed for City sewers and watermains, and presumably the City carries out inspections to ensure that they are installed as designed. Our recommendation in this regard is that inspections be conducted at all service stubs, to ensure that the seals are installed as per the final designs.		**Comment not addressed:** The clay seals that Golder is referring to are normally in the main sewer trench, where continuous inspection is provided by the developer's consultant and supplemented by inspection by the City. The service trenches are not inspected to this degree.	
59	19	Although the model is based on measured hydraulic conductivities, there is still a need to bracket parameters within possible ranges and run the model for several scenarios in order to determine the sensitivity of the model to variable inputs.	Golder has revised the groundwater model in response to questions and comments from the City's consultant. Description of the revised model and modelling results are presented under separate cover. In our opinion, the model is appropriately representative of the site conditions, based on site specific data, and as such, the model results present our best estimates of the groundwater conditions that will occur, in accordance with the scenarios as described. Further refinement or adjusting of model parameters is unlikely to provide better, or more accurate results.		**Comment not addressed:** It is standard practice to provide a sensitivity assessment (see also Dillon's July 11, 2013 review letter).	
60	20	The Technical Memo by Hatch Mott MacDonald refers to an attached sketch showing a check valve, an isolation valve and a union; however the supporting drawing provided to the City (Figure 18, Dec 2012, "SUMP PUMP – DETAIL") does not show any valve(s). Notwithstanding the sketch, the memo states that the "[u]se of a backwater valve ahead of the 100 mm Y, is not considered necessary as potential backflow would be inhibited by the rise of the pump discharge coupled with the sump pump check valve", and further adds that "[g]iven that the pump discharge will be from a 40 or 50 mm pipe to a 100 mm pipe, there will be free air surface at the junction of the Y connection, therefore siphoning will not be an issue"; however, this would only happen if the 100 mm storm service was free draining, which will not be the case under 100-year conditions (and more frequent events as well), since the sewer in the street and the entire length of the storm service will be surcharge, and hence under a pressurized condition—i.e. there will be no air in the service connection. That being the case, the premise of relying on a check valve to protect against siphoning must be properly vetted and a case made for review by the City.	Duley noted, however there will be air in the outlet line at the top of the 'U' where it is exhausted above. Note that this is a typical arrangement employed throughout the GTA.		**Comment not addressed:** How will air enter the pipe at the top of the "U"? If the check valve in the sump pit (assuming that there is a check valve at this location) malfunctions, then the siphoning action will begin almost immediately after the sump pump shuts off. There is no time for air to come in (presuming that some kind of air entry device is designed—see question above). Please provide the details of the GTA arrangement (ensure that the level of detail is of "shop-drawing" level).	DSEL to provide shop drawings of the proposed arrangment. Refer to Goulbourn standard for the proposed sump pump arrangement.

61	21	In view of the assumptions used, the uncertainties inherent in the modelling exercise and the limitations in the TM, the City does not have a comfort level that the water table will lower as predicted. Also, it would appear that a significant number of houses will not have any freeboard between the predicted water table and the foundation; in fact, some houses will be in the water table even after 475 days (page 5 of the TM). Notwithstanding the comments provided on the Golder model, it is anticipated that given the inherent risks with sump pumps in this particular setting, the requirements of the deviations/exceptions Section (§ 1.3) of the Ottawa Sewer Design Guidelines will not be met using this method of foundation drainage13. Consideration may have to be given to constructing homes without basements, or including a foundation drain collector system, should increased filling of the property be deemed not viable.	Please note that the sump pumps are expected to operate normally during the spring time where the ground water level is highest. The long term model predicts that the high ground water level will be lower than existing due to the presence of the development.		**<u>Comment not addressed:</u>** The City does not concur with Golder that a groundwater model can used as the basis for setting foundation elevations where the current water table is above the underside of footings.	
Third Party Review Comments Dated November 29, 2012 - Review of Oct 3, 2012 Technical Memorandum on Assessment of Drainage and Analysis of 100 year flood event.						
From: Dillon Consulting To: Darlene Conway						
62	1	Dillon is only in a position to provide limited comments at this time on the modeling work completed as the level of documentation is currently insufficient to support a full review. Additional documentation required to support a more complete review should include the following:	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013	For comments on proponent responses provided, please refer to: Village of Richmond, Western Development Lands, Review of June 5, 2013 Technical Memorandum on Assessment of Drainage and Analysis of 100 Year Storm Event, Dillon Consulting, July 11, 2013	
		• A figure showing the boundary conditions including assigned head elevations.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
		• A figure showing hydraulic conductivity zones in both plan and section.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
		• A figure showing actual water level distribution (in plan) and a comparison figure of modelled water level distribution.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
		• A figure showing the predicted (modelled) water level distribution in plan after water levels have decreased after development and comparison to foundation elevations.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
		• A figure showing the amount of drawdown (decrease in water levels) predevelopment versus post-development.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
		• Similar documentation for the 100 Year Storm Event Model.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
		• An assessment of the sensitivity in the model to assumed and variable input parameters including hydraulic conductivity assumptions and recharge rates.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		

63	2	Overall, further description should be provided to allow a better understanding of the methodology, assumptions and results of the modeling exercise. This should include supporting information on the basis and justification for the approach and assumptions applied. Given the significant limitations listed in the report, it is unclear if the assessment approach used is an adequate method to predict the impacts caused by the development. Further description and justification of the overall approach should be provided, specifically with respect to the level of reliance that should be placed upon the model predictions.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
64	3	The use of constant head boundaries to simulate the storm sewer infrastructure requires further description and justification. Constant head boundaries assume that the sewer trench is completely free-draining. The basis of this assumption should be discussed in greater detail. Also it is unclear if the elevations used as the basis of the constant heads take into account the rise in the sewer invert elevation away from the storm ponds.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
65	4	The 100 year storm event simulation methodology is unclear and would be better supported by a graphic. What is the basis for assuming a 24 hour period for the storm event effect on water levels? Likewise what is the basis for the assumption that water levels will instantaneously decrease after 24 hours?	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
66	5	Similarly, it is assumed that the constant heads simulating the foundation drains remained active during the 100 year storm event simulation. This should be confirmed and the requirements for ensuring that the storm sewer remains a viable outlet discussed.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
67	6	More explanation should be provided to support the conclusion "… would not adversely effect baseflow to adjacent water courses, …" Are the expected flow rates greater than 50,000 L/day and is a Permit to Take Water required from the MOE?	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
68	7	Other potential complicating factors should be considered and commented upon, whether implicitly as part of the modeling exercise or through discussion of their potential effects. This should include: a. the presence of upward gradients in the bedrock at some locations; b. variable hydraulic conductivity in both the overburden and bedrock, as observed in the estimates provided in the TM; c. whether underside of footing (USF) elevations at some locations may encroach upon or be in contact with the more conductive bedrock materials (either within or beyond the modeled domain).	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
69	8	As noted previously, further discussion should be provided with respect to the sensitivity of the model results to variations in model assumptions and a discussion of specific sources of uncertainty should be included with the overall conclusions of the assessment.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
70	9	Potential settlement issues associated with the water table lowering should be explicitly addressed.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		
71	10	In the limitations section, the City of Ottawa and other review agencies should be included as third parties that can rely on the Golder report.	Addressed by Golder in updated technical memorandum.	Golder Associates - Updated Assessment of Subsurface Drainage and Analysis of 100-year storm event, Proposed Village of Richmond Development, June 5, 2013		

Community Information Session

Status of the Village of Richmond Western Development Lands

You are invited to attend a public meeting regarding this application on:

Wednesday, May 08, 2019

7 to 8:30 p.m.

Richmond Memorial Community Centre
6095 Perth Street, Richmond

The purpose of the meeting is to provide the community with a status update of planning applications and development in Western Development lands in the Village of Richmond. Topics to be covered include:

New Municipal Well System and Source Water Protection
Sanitary System

- Martin Street Sewer
- Capacity for development in the Village
- Infiltration and inflow reduction projects

Master Drainage Plan
Mattamy Subdivision
Fox Run (Caivan) Subdivision– Phase 1, Phase 2 revision and extension
Official Plan Amendment – Landowner agreement for funding infrastructure
Area Parks Plan – Western Development Lands

For additional information, please contact:

Cheryl McWilliams
Planning, Infrastructure and Economic Development Department
Tel: 613-580-2424, ext. 30234
E-mail: Cheryl.mcwilliams@ottawa.ca

Ontario

Ministry of the Environment and Climate Change
Ministère de l'Environnement et de l'Action en matière de changement climatique

AMENDED ENVIRONMENTAL COMPLIANCE APPROVAL

NUMBER 1060-AY8JK4
Issue Date: May 30, 2018

Richmond Village Development Corporation
2934 Baseline Road, Suite 302
Ottawa, Ontario
K2H 1B2

Site Location: Western Development Lands
6350 Perth Street
Lot 22, Concessions 2, 3, 4
City of Ottawa, Ontario

You have applied under section 20.2 of Part II.1 of the Environmental Protection Act*, R.S.O. 1990, c. E. 19 (Environmental Protection Act) for approval of:*

an amendment to existing stormwater management works for the collection, treatment and disposal of stormwater run-off servicing 33 hectare of an approximately 92 hectare residential subdivision development, located at 6350 Perth Street, west of Queen Charlotte Street, east of Joy's Road, north of CN Rail and the Jock River and south of Garvin Road, in the City of Ottawa, providing Enhanced Level water quality control and erosion protection and attenuating post-development peak flows to pre-development levels for all storm events up to and including the 100-year storm event, consisting of the following:

Proposed Works:

- outlet relocation to the Arbuckle Municipal Drain (originally located at the intersection of Arbuckle Drain and the Strachan Street road allowance) to a point downstream of the Fortune Street Culvert;

- headwall and storm sewer size adjustment to inlets of the proposed stormwater management pond described below.

Previous Works:

- storm sewers on Meynell Road, Equitation Circle, Hackamore Crescent, Cantle Crescent, Pelhem Crescent, Reynard Crescent, and Noriker Court collecting stormwater from the site, discharging into the wet pond mentioned below;

- stormwater management facility (catchment area 33 hectares): - one (1) wet pond with a sediment forebay, located just west of an unopened road allowance for Queen Charlotte Street, having a permanent pool volume of 23,546 cubic metres, an extended detention volume of 23,817 cubic metres, and a total storage volume of approximately 34,182 cubic metres, including the permanent pool volume, at a total depth of approximately 1.78 metres, receiving inflow from the storm sewers on-site, discharging to the Arbuckle Municipal Drain and ultimately to the Jock River;

- storm box culvert with a width of 3 metres and a height of 2.4 metres, beside the existing box culvert located under Fortune Street;

including erosion/sedimentation control measures during construction and all other controls and appurtenances essential for the proper operation of the aforementioned Works;

all in accordance with the submitted application and supporting documents listed in Schedule "A" forming part of this Approval.

For the purpose of this environmental compliance approval, the following definitions apply:

1. "Approval" means this entire document and any schedules attached to it, and the application;

2. "Director" means a person appointed by the Minister pursuant to section 5 of the EPA for the purposes of Part II.1 of the EPA;

3. "District Manager" means the District Manager of the appropriate local District Office of the Ministry, where the Works are geographically located;

4. "EPA" means the *Environmental Protection Act,* R.S.O. 1990, c.E.19, as amended;

5. "Ministry" means the ministry of the government of Ontario responsible for the EPA and OWRA and includes all officials, employees or other persons acting on its behalf;

6. "Owner" means Richmond Village Development Corporation, and includes its successors and assignees;

7. "OWRA" means the Ontario Water Resources Act, R.S.O. 1990, c. O.40, as amended;

8. "Works" means the sewage works described in the Owner's application, and this Approval.

You are hereby notified that this environmental compliance approval is issued to you subject to the terms and conditions outlined below:

TERMS AND CONDITIONS

1. GENERAL CONDITIONS

1.1 The Owner shall ensure that any person authorized to carry out work on or operate any aspect of the Works is notified of this Approval and the conditions herein and shall take all reasonable measures to ensure any such person complies with the same.

1.2 Except as otherwise provided by these Conditions, the Owner shall design, build, install, operate and maintain the Works in accordance with the description given in this Approval, the application for approval of the works and the submitted supporting documents and plans and specifications as listed in this Approval.

1.3 Where there is a conflict between a provision of any submitted document referred to in this Approval and the Conditions of this Approval, the Conditions in this Approval shall take precedence, and where there is a conflict between the listed submitted documents, the document bearing the most recent date shall prevail.

1.4 Where there is a conflict between the listed submitted documents, and the application, the application shall take precedence unless it is clear that the purpose of the document was to amend the application.

1.5 The conditions of this Approval are severable. If any condition of this Approval, or the application of any condition of this Approval to any circumstance, is held invalid or unenforceable, the application of such condition to other circumstances and the remainder of this Approval shall not be affected thereby.

1.6 The issuance of, and compliance with the conditions of, this Approval does not:

(a) relieve any person of any obligation to comply with any provision of any applicable statute, regulation or other legal requirement, including, but not limited to, the obligation to obtain approval from the local conservation authority/MNRF necessary to construct or operate the sewage works; or

(b) limit in any way the authority of the Ministry to require certain steps be taken to require the Owner to furnish any further information related to compliance with this Approval.

1.7 This Approval is for the treatment and disposal of stormwater run-off from approximately 33 hectares draining to the stormwater management facility, based on an average imperviousness of 51%. Any changes within the drainage area that might increase the required storage volumes or increase the flows to or from the stormwater management facility or any structural/physical changes to the stormwater management facility including the inlets or outlets will require an amendment to this Approval.

2. EXPIRY OF APPROVAL

2.1 The approval issued by this Approval will cease to apply to those parts of the Works which have not been constructed within five (5) years of the date of this Approval.

2.2 In the event that completion and commissioning of any portion of the Works is anticipated to be delayed beyond the specified expiry period, the Owner shall submit an application of extension to the expiry period, at least twelve (12) months prior to the end of the period. The application for extension shall include the reason(s) for the delay, whether there is any design change(s) and a review of whether the standards applicable at the time of Approval of the Works are still applicable at the time of request for extension, to ensure the ongoing protection of the environment.

3. CHANGE OF OWNER

3.1 The Owner shall notify the District Manager and the Director, in writing, of any of the following changes within thirty (30) days of the change occurring:

(a) change of Owner;

(b) change of address of the Owner;

(c) change of partners where the Owner is or at any time becomes a partnership, and a copy of the most recent declaration filed under the Business Names Act, R.S.O. 1990, c.B17 shall be included in the notification to the District Manager; and

(d) change of name of the corporation where the Owner is or at any time becomes a corporation, and a copy of the most current information filed under the Corporations Information Act, R.S.O. 1990, c. C39 shall be included in the notification to the District Manager.

3.2 In the event of any change in ownership of the Works, other than a change to a successor municipality, the Owner shall notify in writing the succeeding owner of the existence of this Approval, and a copy of such notice shall be forwarded to the Water Supervisor and the Director.

3.3 The Owner shall ensure that all communications made pursuant to this condition refer to the number at the top of this Approval.

3.4 Notwithstanding any other requirements in this Approval, upon transfer of the ownership or assumption of the Works to a municipality if applicable, any reference to the District Manager shall be replaced with the Water Supervisor.

4. TEMPORARY EROSION AND SEDIMENT CONTROL

4.1 The Owner shall install and maintain temporary sediment and erosion control measures during construction and conduct inspections once every two (2) weeks and after each significant storm event (a significant storm event is defined as a minimum of 25 mm of rain in any 24 hours period). The inspections and maintenance of the temporary sediment and erosion control measures shall continue until they are no longer required and at which time they shall be removed and all disturbed areas reinstated properly.

4.2 The Owner shall maintain records of inspections and maintenance which shall be made available for inspection by the Ministry, upon request. The record shall include the name of the inspector, date of inspection, and the remedial measures, if any, undertaken to maintain the temporary sediment and erosion control measures.

5. MONITORING AND RECORDING

5.1 The Owner shall, upon commencement of operation of the Works, carry out the following monitoring program:

(a) All samples and measurements taken for the purposes of this Approval are to be taken at a time and in a location characteristic of the quality and quantity of the effluent stream over the time period being monitored.

(b) Samples shall be collected at the following sampling points, at the frequency specified, by means of the specified sample type and analyzed for each parameter listed and all results recorded, as outlined in Schedule "B".

(c) The methods and protocols for sampling, analysis and recording shall conform, in order of precedence, to the methods and protocols specified in the following:

i. the Ministry's Procedure F-10-1, “Procedures for Sampling and Analysis Requirements for Municipal and Private Sewage Treatment Works (Liquid Waste Streams Only)”, as amended from time to time by more recently published editions;

ii. the Ministry's publication "Protocol for the Sampling and Analysis of Industrial/Municipal Wastewater” (January 1999), ISBN 0-7778-1880-9, as amended from time to time by more recently published editions; and

iii. the publication “Standard Methods for the Examination of Water and Wastewater” (21st edition), as amended from time to time by more recently published editions.

6. OPERATION AND MAINTENANCE

6.1 If applicable, any proposed storm sewers or other stormwater conveyance in this Approval can be constructed but not operated until the proposed stormwater management facilities in this Approval or any other Approval that are designed to service the storm sewers or other stormwater conveyance are in operation.

6.2 The Owner shall make all necessary investigations, take all necessary steps and obtain all necessary approvals so as to ensure that the physical structure, siting and operations of the stormwater works do not constitute a safety or health hazard to the general public.

6.3 The Owner shall inspect and ensure that the design minimum liquid retention volume is maintained in the Works at all times, except when maintenance is required.

6.4 The Owner shall undertake an inspection of the condition of the stormwater management system, at least once a year, and undertake any necessary cleaning and maintenance to ensure that sediment, debris and excessive decaying vegetation are removed from the above noted stormwater management Works to prevent the excessive build-up of sediment, debris and/or decaying vegetation to avoid reduction of capacity of the stormwater management Works. The Owner shall also regularly inspect and clean out the inlet to and outlet from the works to ensure that these are not obstructed.

6.5 The Owner shall construct, operate and maintain the Works with the objective that the effluent from the Works is essentially free of floating and settleable solids and does not contain oil or any other substance in amounts sufficient to create a visible film, sheen, foam or discoloration on the receiving waters.

6.6 The Owner shall maintain a logbook to record the results of these inspections and any cleaning and maintenance operations undertaken, and shall make the logbook available for inspection by the Ministry upon request. The logbook shall include, but not necessarily be limited to, the following information:

(a) the name of the Works; and

(b) the date and results of each inspection, maintenance and cleaning, including an estimate of the quantity of any materials removed.

6.7 The Owner shall prepare an operations manual prior to the commencement of operation of the Works that includes, but is not necessarily limited to, the following information:

(a) operating and maintenance procedures for routine operation of the Works;

(b) inspection programs, including frequency of inspection, for the Works and the methods or tests employed to detect when maintenance is necessary;

(c) repair and maintenance programs, including the frequency of repair and maintenance for the Works;

(d) contingency plans and procedures for dealing with potential spills and any other abnormal situations and for notifying the Water Supervisor; and

(e) procedures for receiving, responding and recording public complaints, including recording any follow-up actions taken.

6.8 The Owner shall maintain the operations manual current and retain a copy at the Owner's administrative office for the operational life of the Works. Upon request, the Owner shall make the manual available to Ministry staff.

7. REPORTING

7.1 One (1) week prior to the start-up of the operation of the Works, the Owner shall notify the Water Supervisor (in writing) of the pending start-up date.

7.2 The Owner shall, upon request, make all reports, manuals, plans, records, data, procedures and supporting documentation available to Ministry staff.

7.3 The Owner shall prepare a performance report within ninety (90) days following the end of the period being reported upon, and submit the report(s) to the Water Supervisor when requested. The first such report shall cover the first annual period following the commencement of operation of the Works and subsequent reports shall be prepared to cover successive annual periods following thereafter. The reports shall contain, but shall not be limited to, the following information:

8. RECORD KEEPING

8.1 The Owner shall retain for a minimum of five (5) years from the date of their creation, all records and information related to or resulting from the operation and maintenance activities required by this Approval.

Schedule "A"

1. Application for Environmental Compliance Approval for Municipal and Private Sewage Works, dated March 11, 2016 and received on March 31, 2016, submitted by Richmond Village Development Corporation.
2. Stormwater Management Pond 1 Western Development Lands- Richmond, Richmond Village (South) Limited, dated August, 2015 prepared by David Schaeffer Engineering Ltd.
3. Interim Stormwater Management Pond 1 Western Development Lands- Richmond, Richmond Village (South) Limited, dated August, 2015 prepared by David Schaeffer Engineering Ltd.
4. Pipe Data Form and sewer design sheets prepared by David Schaeffer Engineering Ltd.
5. Engineering Drawings: Richmond Village Development Corporation, dated January 29, 2016 prepared by David Schaeffer Engineering Ltd.
6. Emails from Kevin Murphy, David Schaeffer Engineering Ltd. dated September 13, 2016;
7. Emails from Kevin Murphy, David Schaeffer Engineering Ltd. dated September 28, 2016;
8. Email from Kevin Murphy, David Schaeffer Engineering Ltd. dated September 29, 2016;
9. Application for Environmental Compliance Approval, dated March 12, 2018, received on April 3, 2018, submitted by Richmond Village Development Corporation;
10. Transfer of Review Letter of Recommendation, dated March 29, 2018 and signed by Damien Whittaker, P.Eng., Senior Engineer - Infrastructure Applications, Development Review, Rural Branch, Planning, Infrastructure & Economic Development Department, City of Ottawa;
11. Email from Kevin Murphy, David Schaeffer Engineering Ltd. dated April 20, 2018;
12. Email from Harry Alvey, City of Ottawa dated April 23, 2018;
13. Email from Damien Whittaker, City of Ottawa dated April 24, 2018;
14. Email from Damien Whittaker, City of Ottawa dated April 25, 2018;
15. Email from Harry Alvey, City of Ottawa dated April 27, 2018;
16. Email from Harry Alvey, City of Ottawa dated April 30, 2018;
17. Email from Kevin Murphy, David Schaeffer Engineering Ltd. dated May 2, 2018;
18. Email from Harry Alvey, City of Ottawa dated May 17, 2018; and
19. Email from Harry Alvey, City of Ottawa dated May 25, 2018.

Schedule "B"

Table 1: Effluent Monitoring
(Samples to be collected from the influent and effluent streams of the stormwater management facility)

Sample Type	Grab
Frequency	Three (3) rainfall *Wet Events* per year, with two (2) of the events occurring between May and September
Parameters	Total Suspended Solids, Phosphorus and Temperature

The reasons for the imposition of these terms and conditions are as follows:

1. Condition 1 is imposed to ensure that the Works are built and operated in the manner in which they were described for review and upon which approval was granted. This condition is also included to emphasize the precedence of Conditions in the Approval and the practice that the Approval is based on the most current document, if several conflicting documents are submitted for review. The condition also advises the Owners their responsibility to notify any person they authorized to carry out work pursuant to this Approval the existence of this Approval. Condition 1.6 is included to emphasize that the issuance of the Approval does not diminish any other statutory and regulatory obligations to which the owner is subject in the construction, maintenance and operation of the works. The condition specifically highlights the need to obtain any necessary conservation authority approvals. The condition also emphasizes the fact that this Approval doesn't limit the authority of the Ministry to require further information.

2. Condition 2 is included to ensure that, when the Works are constructed, the Works will meet the standards that apply at the time of construction to ensure the ongoing protection of the environment.

3. Condition 3 is included to ensure that the Ministry records are kept accurate and current with respect to approved works and to ensure that subsequent owners of the Works are made aware of the Approval and continue to operate the Works in compliance with it.

4. Condition 4 is included as installation, regular inspection and maintenance of the temporary sediment and erosion control measures is required to mitigate the impact on the downstream receiving watercourse during construction, until they are no longer required.

5. Condition 5 is included to enable the Owner to evaluate and demonstrate the performance of the Works, on a continual basis, so that the Works are properly operated and maintained at a level which is consistent with the design objectives specified in the Approval and that the Works do not cause any impairment to the receiving watercourse or the environment.

6. Condition 6 is included as regular inspection and necessary removal of sediment and excessive decaying vegetation from the approved stormwater management Works is required to mitigate the impact of sediment, debris and/or decaying vegetation on the treatment capacity of the Works. It is also required to ensure that adequate storage is maintained in the stormwater management facilities at all times as required by the design, and to prevent stormwater impounded in the works from becoming stagnant. Furthermore, Condition 5 is included to ensure that the stormwater management Works are operated and maintained to function as designed.

7. Condition 7 is included to provide a performance record for future references, to ensure that the Ministry is made aware of problems as they arise, and to provide a compliance record for all the terms and conditions outlined in this Approval, so that the Ministry can work with the Owner in resolving any problems in a timely manner.

8. Condition 8 is included to require that all records are retained for a sufficient time period to adequately evaluate the long-term operation and maintenance of the Works.

Upon issuance of the environmental compliance approval, I hereby revoke Approval No(s). 8358-AEEQ9G issued on October 14, 2016.

In accordance with Section 139 of the Environmental Protection Act, you may by written Notice served upon me and the Environmental Review Tribunal within 15 days after receipt of this Notice, require a hearing by the Tribunal. Section 142 of the Environmental Protection Act provides that the Notice requiring the hearing shall state:

a. The portions of the environmental compliance approval or each term or condition in the environmental compliance approval in respect of which the hearing is required, and;
b. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

Pursuant to subsection 139(3) of the Environmental Protection Act, a hearing may not be required with respect to any terms and conditions in this environmental compliance approval, if the terms and conditions are substantially the same as those contained in an approval that is amended or revoked by this environmental compliance approval.

The Notice should also include:

1. The name of the appellant;
2. The address of the appellant;
3. The environmental compliance approval number;
4. The date of the environmental compliance approval;
5. The name of the Director, and;
6. The municipality or municipalities within which the project is to be engaged in.

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary* Environmental Review Tribunal 655 Bay Street, Suite 1500 Toronto, Ontario M5G 1E5	AND	The Director appointed for the purposes of Part II.1 of the Environmental Protection Act Ministry of the Environment and Climate Change 135 St. Clair Avenue West, 1st Floor Toronto, Ontario M4V 1P5

*** Further information on the Environmental Review Tribunal's requirements for an appeal can be obtained directly from the Tribunal at: Tel: (416) 212-6349, Fax: (416) 326-5370 or www.ert.gov.on.ca**

The above noted activity is approved under s.20.3 of Part II.1 of the Environmental Protection Act.

DATED AT TORONTO this 30th day of May, 2018

C. Labarge

Christina Labarge, P.Eng.
Director

appointed for the purposes of Part II.1 of the
Environmental Protection Act

AL/

c: District Manager, MOECC Ottawa
Water Supervisor, MOECC Ottawa
Damien Whittaker, City of Ottawa (File No. D07-16-11-0014)
Clerk, City of Ottawa
Kevin Murphy, David Schaeffer Engineering Limited

Content Copy Of Original

Ministry of the Environment and Climate Change
Ministère de l'Environnement et de l'Action en matière de changement climatique

ENVIRONMENTAL COMPLIANCE APPROVAL
NUMBER 5426-A5PMR9
Issue Date: January 6, 2016

Richmond Village (South) Ltd.
3894 Prince of Wales Drive
Ottawa, Ontario
K2C 3H2

Site Location: 6350 Perth Street
Lot 22, Concession 2, 3 and 4
City of Ottawa, Ontario

You have applied under section 20.2 of Part II.1 of the Environmental Protection Act , R.S.O. 1990, c. E. 19 (Environmental Protection Act) for approval of:

sanitary sewers to be constructed in the City of Ottawa, on Block 18 (from Station 0+060.500 to Station 0+168.200), Strachan Street (from Station 0+128.500 to Station 0+304.200), Queen Charlotte Street (from Station 0+002.600 to Station 0+209.437) and Martin Street (from Station 0+016.000 to Station 0+170.600, and from Station 0+170.600 to Station 1+055.30);

all in accordance with the application from Richmond Village (South) Ltd., dated October 23, 2015, including final plans and specifications prepared by David Schaeffer Engineering Ltd.

In accordance with Section 139 of the Environmental Protection Act, you may by written Notice served upon me and the Environmental Review Tribunal within 15 days after receipt of this Notice, require a hearing by the Tribunal. Section 142 of the Environmental Protection Act provides that the Notice requiring the hearing shall state:

1. The portions of the environmental compliance approval or each term or condition in the environmental compliance approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The environmental compliance approval number;
6. The date of the environmental compliance approval;
7. The name of the Director, and;
8. The municipality or municipalities within which the project is to be engaged in.

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary* AND The Director appointed for the

purposes of Part II.1 of the Environmental Protection Act
Ministry of the Environment and Climate Change
135 St. Clair Avenue West, 1st Floor
Toronto, Ontario
M4V 1P5

Environmental Review Tribunal
655 Bay Street, Suite 1500
Toronto, Ontario
M5G 1E5

*** Further information on the Environmental Review Tribunal's requirements for an appeal can be obtained directly from the Tribunal at: Tel: (416) 212-6349, Fax: (416) 326-5370 or www.ert.gov.on.ca**

The above noted activity is approved under s.20.3 of Part II.1 of the Environmental Protection Act.

DATED AT TORONTO this 6th day of January, 2016

Gregory Zimmer, P.Eng.
Director
appointed for the purposes of Part II.1 of the *Environmental Protection Act*

YH/
c: District Manager, MOECC Ottawa District Office
M. Rick O'Connor, Clerk, City of Ottawa
Damien Whittaker, Senior Engineer, City of Ottawa (File No. D07-16-11-0014)
Linda Carkner, Program Manager, City of Ottawa
Kevin Murphy, P.Eng., David Schaeffer Engineering Ltd.

Ministry of the Environment and Climate Change
Ministère de l'Environnement et de l'Action en matière de changement climatique

ENVIRONMENTAL COMPLIANCE APPROVAL

NUMBER 9297-AV9KAL
Issue Date: January 25, 2018

Richmond Village Development Corporation
2934 Baseline Road, Unit 302
Ottawa, Ontario
K2H 1B2

Site Location: Caivan Communities - Richmond Phase 1
6350 Perth Street
City of Ottawa, Ontario

You have applied under section 20.2 of Part II.1 of the Environmental Protection Act, R.S.O. 1990, c. E. 19 (Environmental Protection Act) for approval of:

sanitary and storm sewers to be constructed in the City of Ottawa, as follows:

- sanitary sewers on Meynell Road (from Station 0+671.0 to Station 1+225.3), Cantle Crescent (from Station 0+000.0 to Station 0+267.9), Pelham Crescent (from Station 0-013.0 to Station 0+377.6), Reynard Crescent (from Station 0+000.0 to Station 0+308.6), Noriker Court (from Station 0-014.0 to Station 0+228.3), Hackamore Crescent (from Station 0+000.0 to Station 0+084.3), Equitation Circle (from Station 0+000.0 to Station 0+503.4), and Pond Inlet 3 - Storm Trunk 2 (from Station 0+080.0 to Station 0+172.6), discharging to Richmond Stormwater Management Pond 1, located in the City of Ottawa; and

- storm sewers on Meynell Road (from Station 0+687.1 to Station 1+225.7), Cantle Crescent (from Station 0+002.5 to Station 0+267.9), Pelham Crescent (from Station 0-013.5 to Station 0+380.0), Reynard Crescent (from Station 0-002.0 to Station 0+310.6), Noriker Court (from Station 0-016.0 to Station 0+238.0), Hackamore Crescent (from Station 0-002.5 to Station 0+084.3), Equitation Circle (from Station 0+002.5 to Station 0+505.8), Block 235 (from Station 0+002.5 to Station 0+070.8), Pond Inlet 2 (from Station 0+006.9 to Station 0+076.8, Pond Inlet 3 - Storm Trunk 1 (from Station 0+003.9 to Station 0+162.3), and Pond Inlet 3 - Storm Trunk 2 (from Station 0+077.7 to Station 0+206.7), discharging to Richmond Stormwater Management Pond 1, located in the City of Ottawa;

all in accordance with the submitted application and supporting documents listed in Schedule "A" forming part of this approval.

For the purpose of this environmental compliance approval, the following definitions apply:

1. "Approval" means this entire document and any schedules attached to it, and the application;

2. "Director" means a person appointed by the Minister pursuant to section 5 of the EPA for the purposes of Part II.1 of the EPA;

3. "District Manager" means the District Manager of the appropriate local District Office of the Ministry, where the Works are geographically located;

4. "EPA" means the Environmental Protection Act, R.S.O. 1990, c.E.19, as amended;

5. "Ministry" means the ministry of the government of Ontario responsible for the EPA and OWRA and includes all officials, employees or other persons acting on its behalf;

6. "Owner" means Richmond Village Development Corporation, and includes their successors and assignees;

7. "OWRA" means the Ontario Water Resources Act, R.S.O. 1990, c. O.40, as amended;

8. "Significant Threat Policy(ies)" has the same meaning as in the Clean Water Act, 2006;

9. "Source Protection Plan" means a drinking water source protection plan prepared under the Clean Water Act, 2006;

10. "Works" means the sewage works described in the Owner's application, and this Approval.

You are hereby notified that this environmental compliance approval is issued to you subject to the terms and conditions outlined below:

TERMS AND CONDITIONS

1. GENERAL CONDITIONS

1. The Owner shall ensure that any person authorized to carry out work on or operate any aspect of the Works is notified of this Approval and the conditions herein and shall take all reasonable measures to ensure any such person complies with the same.

2. Except as otherwise provided by these Conditions, the Owner shall design, build, install, operate and maintain the Works in accordance with the description given in this Approval, and the application for approval of the Works.

3. Where there is a conflict between a provision of any document in the schedule referred to in this Approval and the conditions of this Approval, the conditions in this Approval shall take precedence, and where there is a conflict between the documents in the schedule, the document bearing the most recent date shall prevail.

4. Where there is a conflict between the documents listed in Schedule "A" and the application, the application shall take precedence unless it is clear that the purpose of the document was to amend the application.

5. The conditions of this Approval are severable. If any condition of this Approval, or the application of any requirement of this Approval to any circumstance, is held invalid or unenforceable, the application of such condition to other circumstances and the remainder of this Approval shall not be affected thereby.

2. EXPIRY OF APPROVAL

1. This Approval will cease to apply to those parts of the Work which have not been constructed within five (5) years of the date of this Approval.

2. In the event that completion and commissioning of any portion of the Works is anticipated to be delayed beyond the specified expiry period, the Owner shall submit an application of extension to the expiry period, at least twelve (12) months prior to the end of the period. The application for extension shall include the reason(s) for the delay, whether there is any design change(s) and a review of whether the standards applicable at the time of Approval of the Works are still applicable at the time of request for extension, to ensure the ongoing protection of the environment.

3. CHANGE OF OWNER

1. The Owner shall notify the District Manager and the Director, in writing, of any of the following changes within thirty (30) days of the change occurring:

    a. change of Owner;

    b. change of address of the Owner;

    c. change of partners where the Owner is or at any time becomes a partnership, and a copy of the most recent declaration filed under the Business Names Act, R.S.O. 1990, c.B17 shall be included in the notification to the District Manager; or

    d. change of name of the corporation where the Owner is or at any time becomes a corporation, and a copy of the most current information filed under the Corporations Information Act, R.S.O. 1990, c. C39 shall be included in the notification to the District Manager.

2. In the event of any change in ownership of the Works, other than a change to a successor municipality, the Owner shall notify in writing the succeeding owner of the existence of this Approval, and a copy of such notice shall be forwarded to the District Manager and the Director.

3. The Owner shall ensure that all communications made pursuant to this condition refer to the number at the top of this Approval.

4. Notwithstanding any other requirements in this Approval, upon transfer of the ownership or assumption of the Works to a municipality if applicable, any reference to the District Manager shall be replaced with the Water Supervisor.

4. OPERATION AND MAINTENANCE

1. If applicable, any proposed storm sewers or other stormwater conveyance in this Approval can be constructed but not operated until the proposed stormwater management facilities in this Approval or any other Approval that are designed to service the storm sewers or other stormwater conveyance are in operation.

5. SOURCE WATER PROTECTION

1. The Owner shall ensure, if applicable, that the design, construction and operation of the Works conforms to any Significant Threat Policies in any Source Protection Plan that applies to the location of the Works.

SCHEDULE "A"

1. Application for Environmental Compliance Approval for Municipal and Private Sewage Works, dated December 19, 2017 and received on December 28, 2017, submitted by Richmond Village Development Corporation.

2. Transfer of Review Letter of Recommendation, dated December 28, 2017 and signed by Damien Whittaker, Senior Engineer, City of Ottawa.

The reasons for the imposition of these terms and conditions are as follows:

1. Condition 1 is imposed to ensure that the Works are constructed and operated in the manner in which they were described and upon which approval was granted. This condition is also included to emphasize the precedence of conditions in the Approval and the practice that the Approval is based on the most current document, if several conflicting documents are submitted for review.

2. Condition 2 is included to ensure that, when the Works are constructed, the Works will meet the standards that apply at the time of construction to ensure the ongoing protection of the environment.

3. Condition 3 is included to ensure that the Ministry records are kept accurate and current with respect to approved Works and to ensure that subsequent owners of the Works are made aware of the Approval and continue to operate the Works in compliance with it.

4. Condition 4 is included to prevent the operation of stormwater pipes and other conveyance until such time that their required associated stormwater management Works are also constructed.

5. Condition 5 is included to ensure that the Works conform to the policies of the local Source Water Protection Plan.

In accordance with Section 139 of the Environmental Protection Act, you may by written Notice served upon me and the Environmental Review Tribunal within 15 days after receipt of this Notice, require a hearing by the Tribunal. Section 142 of the Environmental Protection Act provides that the Notice requiring the hearing shall state:

a. The portions of the environmental compliance approval or each term or condition in the environmental compliance approval in respect of which the hearing is required, and;
b. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

1. The name of the appellant;
2. The address of the appellant;
3. The environmental compliance approval number;
4. The date of the environmental compliance approval;
5. The name of the Director, and;
6. The municipality or municipalities within which the project is to be engaged in.

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary*****
Environmental Review Tribunal
655 Bay Street, Suite 1500
Toronto, Ontario
M5G 1E5

AND

The Director appointed for the purposes of
Part II.1 of the Environmental Protection Act
Ministry of the Environment and
Climate Change
135 St. Clair Avenue West, 1st Floor
Toronto, Ontario
M4V 1P5

*** Further information on the Environmental Review Tribunal's requirements for an appeal can be obtained directly from the Tribunal at: Tel: (416) 212-6349, Fax: (416) 326-5370 or www.ert.gov.on.ca**

The above noted activity is approved under s.20.3 of Part II.1 of the Environmental Protection Act.

DATED AT TORONTO this 25th day of January, 2018

C. Labarge

Christina Labarge, P.Eng.
Director
appointed for the purposes of Part II.1 of the
Environmental Protection Act

RS/
c: District Manager, MOECC Ottawa
City Clerk, City of Ottawa (File No. D07-16-11-0014)
Linda Carkner, Program Mananger, Right of Way Unit (MC 26-61)
Harry R. Alvey, P.E., P.Eng., Project Manager, Rural Branch
Kevin Murphy, David Schaeffer Engineering Ltd.

Ministry of the Environment and Climate Change
Eastern Region
Technical Support Section
Water Resources
1259 Gardiners Rd, PO Box 22032
Kingston, ON
K7P 3J6
Tel: (613) 549-4000

Ministère de l'Environnement et de l'Action en matière de changement climatique
Direction régionale de l'Est
Section du Soutien Technique
Ressource en eau
1259 Chemin Gardiners, CP 22032
Kingston, ON
K7P 3J6
Tél:(613) 549-4000

August 10, 2016

Mr. Frank Cairo
Richmond Village Development Corporation
3894 Prince of Wales Drive
Ottawa, Ontario
K2C 3H2

Dear Mr. Cairo:

RE: Permit To Take Water 8563-ABNQ5G
Richmond West Development
Lots: 22 and 23, Concessions: 3 and 4
Geographic Township of Goulbourn
Ottawa
Reference Number 3202-A9SHWQ

Please find attached Permit To Take Water 8563-ABNQ5G which authorizes the withdrawal of water in accordance with the application for this Permit To Take Water, dated April 28, 2016 and signed by Frank Cairo.

Please note the attached Permit expires on July 5, 2026.

Ontario Regulation 387/04 (Water Taking and Transfer) requires all water takers to report daily water taking amounts to the Water Taking Reporting System (WTRS) electronic database (https://www.lrcsde.lrc.gov.on.ca/wtrs/). Daily water taking must be reported on a calendar year basis. If no water is taken, then a "no taking" report must be entered. Please consult the Regulation and Section 4 of this Permit for monitoring requirements.

If you have questions about reporting requirements, please call the WTRS Help Desk at 416-235-6322 (toll free: 1-877-344-2011) or by email, WTRSHelpdesk@ontario.ca. It is preferred that you submit your data directly and electronically to the WTRS. Where this is impracticable, please contact the WTRS Help Desk to arrange for written submission of your data.

Take notice that in issuing this Permit, terms and conditions pertaining to the taking of water and to the results of the taking have been imposed. The terms and conditions have been designed to allow for the development of water resources, while providing reasonable protection to existing water uses and users.

Yours truly,

Greg Faaren
Director, Section 34.1, Ontario Water Resources Act, R.S.O. 1990
Eastern Region

File Storage Number: SI OT 8563 220 (TS)

c: Caitlin Cooke, Golder Associates Ltd., ccooke@golder.com

Ottawa District Office

PERMIT TO TAKE WATER
Surface and Ground Water
NUMBER 8563-ABNQ5G

Pursuant to Section 34.1 of the Ontario Water Resources Act, R.S.O. 1990 this Permit To Take Water is hereby issued to:

Richmond Village Development Corporation
3894 Prince of Wales Drive
Ottawa, Ontario K2C 3H2
Canada

For the water taking from: SWMP Excavation
Communal Well - Pumping Station Excavation
Trunk Sanitary Sewer and Local Sewer Excavations

Located at: Lot 22 and 23, Concession 3 and 4, Geographic Township of Goulbourn
Ottawa

For the purposes of this Permit, and the terms and conditions specified below, the following definitions apply:

DEFINITIONS

(a) "Director" means any person appointed in writing as a Director pursuant to section 5 of the OWRA for the purposes of section 34.1, OWRA.

(b) "Provincial Officer" means any person designated in writing by the Minister as a Provincial Officer pursuant to section 5 of the OWRA.

(c) "Ministry" means Ontario Ministry of the Environment and Climate Change.

(d) "District Office" means the Ottawa District Office.

(e) "Permit" means this Permit to Take Water No. 8563-ABNQ5G including its Schedules, if any, issued in accordance with Section 34.1 of the OWRA.

(f) "Permit Holder" means Richmond Village Development Corporation.

(g) "OWRA " means the *Ontario Water Resources Act,* R.S.O. 1990, c. O. 40, as amended.

You are hereby notified that this Permit is issued subject to the terms and conditions outlined below:

TERMS AND CONDITIONS

1. Compliance with Permit

1.1 Except where modified by this Permit, the water taking shall be in accordance with the application for this Permit To Take Water, dated April 28, 2016 and signed by Frank Cairo, and all Schedules included in this Permit.

1.2 The Permit Holder shall ensure that any person authorized by the Permit Holder to take water under this Permit is provided with a copy of this Permit and shall take all reasonable measures to ensure that any such person complies with the conditions of this Permit.

1.3 Any person authorized by the Permit Holder to take water under this Permit shall comply with the conditions of this Permit.

1.4 This Permit is not transferable to another person.

1.5 This Permit provides the Permit Holder with permission to take water in accordance with the conditions of this Permit, up to the date of the expiry of this Permit. This Permit does not constitute a legal right, vested or otherwise, to a water allocation, and the issuance of this Permit does not guarantee that, upon its expiry, it will be renewed.

1.6 The Permit Holder shall keep this Permit available at all times at or near the site of the taking, and shall produce this Permit immediately for inspection by a Provincial Officer upon his or her request.

1.7 The Permit Holder shall report any changes of address to the Director within thirty days of any such change. The Permit Holder shall report any change of ownership of the property for which this Permit is issued within thirty days of any such change. A change in ownership in the property shall cause this Permit to be cancelled.

2. General Conditions and Interpretation

2.1 Inspections
The Permit Holder must forthwith, upon presentation of credentials, permit a Provincial Officer to carry out any and all inspections authorized by the OWRA, the *Environmental Protection Act* , R.S.O. 1990, the *Pesticides Act* , R.S.O. 1990, or the *Safe Drinking Water Act,* S. O. 2002.

2.2 Other Approvals

The issuance of, and compliance with this Permit, does not:

(a) relieve the Permit Holder or any other person from any obligation to comply with any other applicable legal requirements, including the provisions of the *Ontario Water Resources Act* , and the *Environmental Protection Act* , and any regulations made thereunder; or

(b) limit in any way any authority of the Ministry, a Director, or a Provincial Officer, including the authority to require certain steps be taken or to require the Permit Holder to furnish any further information related to this Permit.

2.3 Information

The receipt of any information by the Ministry, the failure of the Ministry to take any action or require any person to take any action in relation to the information, or the failure of a Provincial Officer to prosecute any person in relation to the information, shall not be construed as:

(a) an approval, waiver or justification by the Ministry of any act or omission of any person that contravenes this Permit or other legal requirement; or

(b) acceptance by the Ministry of the information's completeness or accuracy.

2.4 Rights of Action

The issuance of, and compliance with this Permit shall not be construed as precluding or limiting any legal claims or rights of action that any person, including the Crown in right of Ontario or any agency thereof, has or may have against the Permit Holder, its officers, employees, agents, and contractors.

2.5 Severability

The requirements of this Permit are severable. If any requirements of this Permit, or the application of any requirements of this Permit to any circumstance, is held invalid or unenforceable, the application of such requirements to other circumstances and the remainder of this Permit shall not be affected thereby.

2.6 Conflicts

Where there is a conflict between a provision of any submitted document referred to in this Permit, including its Schedules, and the conditions of this Permit, the conditions in this Permit shall take precedence.

3. Water Takings Authorized by This Permit

3.1 **Expiry**

This Permit expires on **July 5, 2026**. No water shall be taken under authority of this Permit after the expiry date.

3.2 Amounts of Taking Permitted
The Permit Holder shall only take water from the source, during the periods and at the rates and amounts of taking specified in Table A. Water takings are authorized only for the purposes specified in Table A.

Table A

	Source Name / Description:	Source: Type:	Taking Specific Purpose:	Taking Major Category:	Max. Taken per Minute (litres):	Max. Num. of Hrs Taken per Day:	Max. Taken per Day (litres):	Max. Num. of Days Taken per Year:	Zone/ Easting/ Northing:
1	SWMP Excavation	Pond Dugout	Construction	Dewatering Construction	12,000	24	6,234,000	365	18 433620 5004100
2	Communal Well - Pumping Station Excavation	Pond Dugout	Construction	Dewatering Construction	3,000	24	174,000	365	18 433925 5003850
3	Trunk Sanitary Sewer and Local Sewer Excavations	Pond Dugout	Construction	Dewatering Construction	6,000	24	6,300,000	365	18 433290 5004000
						Total Taking:	12,708,000		

4. Monitoring

4.1 The Permit Holder shall maintain a record of all water takings. This record shall include the dates and times of water takings, the rates of taking and an estimated calculation of the total amounts of water taken per day for each day that water is taken under the authorization of this Permit. A separate record shall be maintained for each source. The Permit Holder shall keep all required records up to date and available at or near the site of the taking and shall produce the records immediately for inspection by a Provincial Officer upon his or her request.

4.2 The Permit Holder shall notify all residents within 60 metres of the excavations described in Table A of the planned construction dewatering prior to commencement of dewatering operations. The residents shall be provided with contact information for the Permit Holder and shall be notified that the Permit Holder should be contacted in the event of a well water complaint.

4.3 If the Permit Holder receives a complaint regarding possible groundwater interference, the Permit Holder shall retain the services of a qualified person (Professional

Geoscientist or qualified Professional Engineer) to investigate the water well(s) where the interference is reported to be occurring within 1 day of receiving the complaint. If it is determined that the water taking authorized by this Permit is causing interference with existing groundwater user(s) then the Permit Holder shall undertake the contingency plan included as Schedule A.

5. Impacts of the Water Taking

5.1 Notification

The Permit Holder shall immediately notify the local District Office of any complaint arising from the taking of water authorized under this Permit and shall report any action which has been taken or is proposed with regard to such complaint. The Permit Holder shall immediately notify the local District Office if the taking of water is observed to have any significant impact on the surrounding waters. After hours, calls shall be directed to the Ministry's Spills Action Centre at 1-800-268-6060.

5.2 For Surface-Water Takings

The taking of water (including the taking of water into storage and the subsequent or simultaneous withdrawal from storage) shall be carried out in such a manner that streamflow is not stopped and is not reduced to a rate that will cause interference with downstream uses of water or with the natural functions of the stream.

For Groundwater Takings

If the taking of water is observed to cause any negative impact to other water supplies obtained from any adequate sources that were in use prior to initial issuance of a Permit for this water taking, the Permit Holder shall take such action necessary to make available to those affected, a supply of water equivalent in quantity and quality to their normal takings, or shall compensate such persons for their reasonable costs of so doing, or shall reduce the rate and amount of taking to prevent or alleviate the observed negative impact. Pending permanent restoration of the affected supplies, the Permit Holder shall provide, to those affected, temporary water supplies adequate to meet their normal requirements, or shall compensate such persons for their reasonable costs of doing so.

If permanent interference is caused by the water taking, the Permit Holder shall restore the water supplies of those permanently affected.

5.3 Prevention of Adverse Effects:

The Permit Holder shall ensure the taking of water under authority of this Permit does not result in an adverse effect in area waters.

5.4 Prevention of Structural Adverse Effects:

The Permit Holder shall take all measures necessary to prevent damage to buildings, bridges, structures, roads and/or railway lines that may be impacted either directly or indirectly by this taking.

5.5 Discharge Control Measures for Water that is Discharged to the Natural Environment:
Siltation control measures shall be installed at the discharge site(s) and shall be sufficient to control the volumes. Continuous care shall be taken to properly maintain the siltation control devices.

5.6 The discharge of water shall be controlled in such a way as to avoid erosion and sedimentation in the receiving stream.

5.7 The Permit Holder shall ensure that any water discharged to the natural environment does not result in scouring, erosion or physical alteration of stream channels or banks and that there is no flooding in the receiving area or water body, downstream water bodies, ditches or properties caused or worsened by this discharge.

5.8 The Permit Holder shall not discharge turbid water to any watercourse. Turbid water shall be defined as any discharge water from the excavation or diverted water with a maximum increase of 8 NTUs above the receiving stream's background levels.

5.9 Discharged Water to the Sanitary or Storm Sewer System:
The Permit Holder shall ensure that any water that is taken for dewatering purposes and discharged to the City of Ottawa sewer system is in accordance with a City of Ottawa Sewer Use Agreement.

5.10 The Permit Holder shall manage the discharge of water in accordance with Section 5.0 of the report entitled "Application for a Category 3 Permit To Take Water, Richmond West Development, On-site Water Taking, Richmond Village, Ottawa, Ontario" completed by Golder Associates Ltd. and dated May 3, 2016 included in Schedule A of this Permit.

5.11 If there are any exceedances of greater than 8 NTUs between the upstream and downstream sampling locations the Permit Holder shall notify the Ottawa District Office of the Ontario Ministry of the Environment and Climate Change. The Permit Holder shall also take water samples from the upstream and downstream locations and analyse the sample for Total Suspended Solids (TSS).

6. Director May Amend Permit

The Director may amend this Permit by letter requiring the Permit Holder to suspend or reduce the taking to an amount or threshold specified by the Director in the letter. The suspension or reduction in taking shall be effective immediately and may be revoked at any time upon notification by the Director. This condition does not affect your right to appeal the suspension or reduction in taking to the Environmental Review Tribunal under the *Ontario Water Resources Act*, Section 100 (4).

The reasons for the imposition of these terms and conditions are as follows:

1. Condition 1 is included to ensure that the conditions in this Permit are complied with and can be enforced.

2. Condition 2 is included to clarify the legal interpretation of aspects of this Permit.

3. Conditions 3 through 6 are included to protect the quality of the natural environment so as to safeguard the ecosystem and human health and foster efficient use and conservation of waters. These conditions allow for the beneficial use of waters while ensuring the fair sharing, conservation and sustainable use of the waters of Ontario. The conditions also specify the water takings that are authorized by this Permit and the scope of this Permit.

In accordance with Section 100 of the Ontario Water Resources Act, R.S.O. 1990, you may by written notice served upon me, the Environmental Review Tribunal and the Environmental Commissioner, ***Environmental Bill of Rights****, R.S.O. 1993, Chapter 28, within 15 days after receipt of this Notice, require a hearing by the Tribunal. The Environmental Commissioner will place notice of your appeal on the Environmental Registry. Section 101 of the Ontario Water Resources Act, as amended provides that the Notice requiring a hearing shall state:*

1. The portions of the Permit or each term or condition in the Permit in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

In addition to these legal requirements, the Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The Permit to Take Water number;
6. The date of the Permit to Take Water;
7. The name of the Director;
8. The municipality within which the works are located;

This notice must be served upon:

The Secretary Environmental Review Tribunal 655 Bay Street, 15th Floor Toronto ON M5G 1E5 Fax: (416) 326-5370 Email: ERTTribunalsecretary@ontario.ca	*AND*	*The Environmental Commissioner 1075 Bay Street 6th Floor, Suite 605 Toronto, Ontario M5S 2W5*	*AND*	*The Director, Section 34.1, Ministry of the Environment and Climate Change 1259 Gardiners Rd, PO Box 22032 Kingston, ON K7P 3J6*

Further information on the Environmental Review Tribunal's requirements for an appeal can be obtained directly from the Tribunal:

by Telephone at (416) 212-6349 Toll Free 1(866) 448-2248	by Fax at (416) 326-5370 Toll Free 1(844) 213-3474	by e-mail at www.ert.gov.on.ca

This instrument is subject to Section 38 of the ***Environmental Bill of Rights*** *that allows residents of Ontario to seek leave to appeal the decision on this instrument. Residents of Ontario may seek to appeal for 15 days from the date this decision is placed on the Environmental Registry. By accessing the Environmental Registry, you can determine when the leave to appeal period ends.*

Dated at Kingston this 10th day of August, 2016.

Greg Faaren
Director, Section 34.1
Ontario Water Resources Act , R.S.O. 1990

Schedule A

This Schedule "A" forms part of Permit To Take Water 8563-ABNQ5G, dated August 10, 2016.

Section 5.0 of the report entitled "Application for a Category 3 Permit To Take Water, Richmond West Development, On-site Water Taking, Richmond Village, Ottawa, Ontario" completed by Golder Associates Ltd. and dated May 3, 2016

Section 6.0 of the report entitled "Application for a Category 3 Permit To Take Water, Richmond West Development, On-site Water Taking, Richmond Village, Ottawa, Ontario" completed by Golder Associates Ltd. and dated May 3, 2016

RIDEAU VALLEY
CONSERVATION AUTHORITY

3889 Rideau Valley Drive, P.O. Box 599, Manotick, ON K4M 1A5
tel 613-692-3571 | 1-800-267-3504 | fax 613-692-0831 | www.rvca.ca

LETTER OF PERMISSION – ONT. REG. 174/06, SECTION 28 CONSERVATION AUTHORITIES ACT 1990, AS AMENDED.

Date: October 18, 2016.
File: RV5-22/16T
Contact: Hal Stimson
(613) 692-3571 Ext 1127
hal.stimson@rvca.ca

Mr. Frank Cairo
Richmond Village Development Corporation
5504 Wicklow Drive
Manotick, Ontario
K4M 1C4

Permit for Development under Section 28 of the Conservation Authorities Act for a Stormwater Management Facility at Lot 22, Concession 3, Goulbourn Township now in the City of Ottawa

Dear Mr. Cairo

The Rideau Valley Conservation Authority has reviewed your application on behalf of the Richmond Village Development Corporation and understands the proposal to be for: the construction of a new stormwater management facility within the flood plain of the Jock River and the Arbuckle Municipal Drain. Appropriate cut/fill analysis has been undertaken that meet RVCA fill policies. This infrastructure is to service the Richmond Village Residential subdivision to be located to the west of Queen Charlotte Street in Richmond in accordance with the approved Stormwater Management Report and Design Briefs. An enhanced level of treatment is expected as a result of the design and continued drainage outlet is to be provided for off-site lands in order to ensure the development does not cause flooding of other properties.

This proposal was reviewed under Ontario Regulation 174/06, the "*Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*" regulation.

PERMISSION AND CONDITIONS

By this letter the Rideau Valley Conservation Authority hereby grants you approval to undertake this project as outlined in your permit application but subject to the following conditions:

1. Approval is subject to the understanding of the project as described above and outlined in the application and submitted plans and reports including:
   - Drawing Fig-1 titled Existing Ground –vs- 2010 Floodplain dated 2015-11-17 as prepared by DSEL.
   - Drawing Fig-2 titled Proposed Pond (100yr-WL) –vs- 2010 Floodplain dated 2015-11-17 as prepared by DSEL.
   - Drawing Fig-3 titled Proposed Pond (100yr-WL) dated 2015-11-17 as prepared by DSEL.
   - Drawing Fig-4 titled Existing Ground –vs- Proposed Pond (100yr-WL) dated 2015-11-17 as prepared by DSEL.
   - Drawing SEC-1 titled Section 1 dated 2015-11-17 as prepared by DSEL.
   - Drawing SEC-2 titled Section 2 dated 2015-11-17 as prepared by DSEL.
   - Drawing SEC-3 titled Section 3 dated 2015-11-17 as prepared by DSEL.
   - Drawing SEC-4 titled Section 4 dated 2015-11-17 as prepared by DSEL.
   - Drawings dated 16-01-29 with Interim and Final SWM Pond and Outlets.
   - Report dated Feb 2016 for interim Pond Design.
   - Report dated Nov 2015 for Final Pond Design.
   - Baseflow Information provided by JFSA dated April 13, 2016.

   No conditions are subject to change/revision by the on-site contractor(s).

2. **There will be no in-water works between March 15 and July 1, of any given year to protect local aquatic species populations during their spawning and nursery time periods.**

3. It is recommended that you retain the services of an engineer to conduct on-site inspections to ensure adequacy of the work, verify stability of the final grades and confirm all imported fill is of a suitable type and has been adequately placed and compacted.

4. A final as built grading plan shall be submitted immediately upon completion of the approved works prepared by an Ontario Land Surveyor or Professional Engineer licensed to practice in Ontario indicating that grades achieved on the site conform to those indicated on the approved plan and detailing the new alignment of the 1:100 year flood line.

5. It is recommended that you ensure your contractor(s) are provided with a copy of this letter so as to ensure compliance with the conditions listed herein.

6. Any excess excavated material, as a result of the work, must be disposed of in a suitable location outside any regulatory floodplain and fill regulated area.

7. Only clean material free from particulate matter may be placed in the water. Any stockpiled materials shall be stored and stabilized away from the water.

8. All materials and equipment used for the purpose of site preparation and project completion must be operated (washed, refuelled, and serviced) and all fuel stored in a manner that prevents any deleterious substance (e.g. petroleum products, silt, debris etc.) from entering any watercourse.

9. Sediment barriers should be used on site in an appropriate method according to the Ontario Provincial Standard Specifications (OPSS) for silt barriers as a minimum. If the sediment and erosion control methods include silt fence it should be placed along the shoreline to prevent overland flow on disturbed areas from entering the watercourse. Soil type, slope of land, drainage area, weather, predicted sediment load and deposition should be considered when selecting the type of sediment/erosion control.

10. Sediment and erosion control measures shall be in place before any excavation or construction works commence. All sediment/erosion control measures are to be monitored regularly by experienced personnel and maintained as necessary to ensure good working order. In the event that the erosion and sedimentation control measures are deemed not to be performing adequately, the contractor shall undertake immediate additional measures as appropriate to the situation to the satisfaction of the Conservation Authority.

11. Work in water shall not be conducted at times when flows are elevated due to local rain events, storms or seasonal floods.

12. Develop a response plan that is to be implemented immediately in the event of flooding, a sediment release or spill of a deleterious substance. This plan is to include measures to: a) stop work, contain sediment-laden water and other deleterious substances and prevent their further migration into the watercourse and downstream receiving watercourses; b) notify the RVCA and all applicable authorities in the area c) promptly clean-up and appropriately dispose of the sediment-laden water and deleterious substances; and d) ensure clean-up measures are suitably applied so as not to result in further alteration of the bed and/or banks of the watercourse.

13. The owner is ultimately responsible for failure to comply with any and/or all of these conditions and must take all precautions to ensure no sediment runoff from the work site into any watercourse during and after the construction period. Failure to comply with the approval and/or conditions of this letter will result in the permit being revoked and may also result in legal action being initiated to resolve the matter to the Conservation Authority's satisfaction.

14. The applicant agrees that Authority staff may visit the subject property, before, during and after project completion, to ensure compliance with the conditions as set out in this letter of permission.

15. A new application must be submitted should any work as specified in this letter be ongoing or planned for or after October 18, 2018.

16. That the Authority be given twenty-four hours notice prior to the start of construction and within twenty-four hours of project completion.

17. All other approvals as might be required from the Municipality, and/or other Provincial or Federal Agencies must be obtained prior to initiation of work. This includes but is not limited to the Endangered Species Act., the Ontario Water Resources Act., Environmental Protection Act., Public Lands Act, and the Fisheries Act.

By this letter the Rideau Valley Conservation Authority assumes no responsibility or liability for any flood, erosion, or slope failure damage which may occur either to your property or the structures on it or if any activity undertaken by you adversely affects the property or interests of adjacent landowners. This letter does not relieve you of the necessity or responsibility for obtaining any other federal, provincial or municipal permits. This permit is not transferable to subsequent property owners.

Should you have any questions regarding this letter, please contact Hal Stimson at our Manotick office.

Terry K. Davidson

Terry K. Davidson, P. Eng.
Conservation Authority S. 28 Signing delegate
O. Reg. 174/06

Cc: K. Murphy, P. Eng. DSEL
D.Ryan, P. Geo., City Ottawa Drainage Manager

- Pursuant to the provisions of S. 28(12) of the Conservation Authorities Act (R.S.O.1990, as amended.) any or all of the conditions set out above may be appealed to the Executive Committee of the Conservation Authority in the event that they are not satisfactory or cannot be complied with.
- Failure to comply with the conditions of approval or the scope of the project may result in the cancelling of the permission and/or initiation of legal action under S. 28(16) of the Act.
- This letter of permission does not come into full force and effect until the attached copy of this letter is returned to the Authority offices in Manotick signed and dated which return shall be taken as indicating acceptance of the conditions of the Authority's approval and acknowledgement that the details of the proposal as described in this letter are a fair and accurate representation of the proposed undertaking.

Name: ______________________________ (print)

Signed: ______________________________ Date: ______________________________

RVCA Letter of Permission —
Ont. Reg. 174/06, S. 28 *Conservation Authorities Act*
1990, As Amended.

Rideau Valley Conservation Authority

3889 Rideau Valley Drive
PO Box 599, Manotick ON K4M 1A5
T 613-692-3571 | 1-800-267-3504
F 613-692-0831 | www.rvca.ca

Date: June 14, 2019
File: RV5-2219
Contact: Shelley Macpherson

Mattamy (Jock River) Limited
ATT: Kevin Murphy
50 Hines Road, Unit 100
Ottawa, ON
K2K 2M5

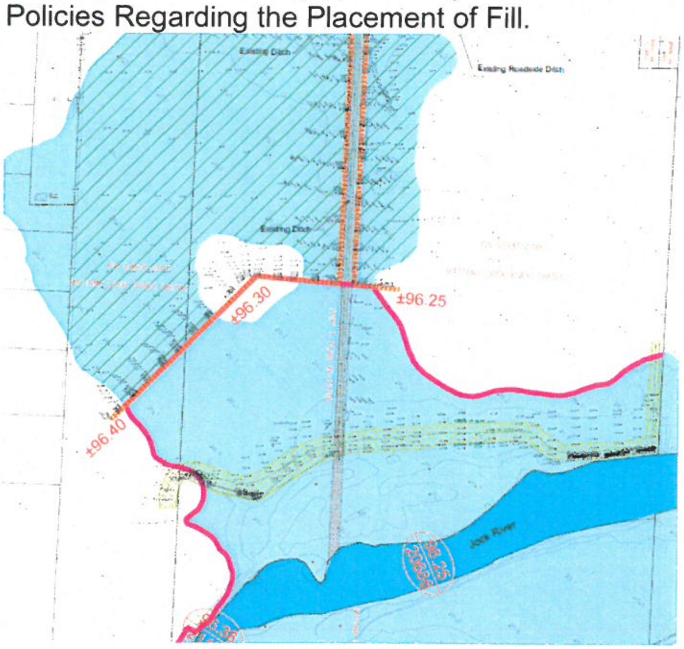
Permit for: Development Under Section 28 of the Conservation Authorities Act for the placement of fill, at 6420 Ottawa Street West, Lot 22, Concession 2, former Township of Goulbourn, now in the City of Ottawa. **Roll Number: 061427381534300000000**

Dear Mr. Murphy,

The Rideau Valley Conservation Authority has reviewed the application and understands the proposal to be for:

a) **The placement of fill between the "berm" and Ottawa Street West to a maximum level of 96.5m.**

This proposal was reviewed under Ontario Regulation 174/06, the "*Development, Interference with Wetlands, and Alteration to Watercourse and Shorelines"* regulation and the RVCA Development Policies (approved by the RVCA, Board of Directors), specifically Section 2.0 Policies Regarding the Placement of Fill.



In 2005, the RVCA issued a Letter of Permission to the previous property owner for the construction of a berm and installation of a "water control gate" to maintain flood risk mapping land levels" to the 1980 Acres Flood Plain Mapping Study (96.0 metres). On May 6, 2006 changes to the RVCA's regulatory legislation resulted in the incorporation of the revised Flood Plain Mapping Study for this reach of the Jock River. The new mapping indicated the 1:100 year flood elevation for this reach to be 96.35 metres.

In 2009, Mattamy Ltd. Also received approval for "earthworks" on the property relating to removing the original berm constructed in the Spring of 2006 and locating it at the 2005 approved location and filling from the relocated berm to Ottawa Street and the removal of the "flap gate" water control structure. The filling between the location of the relocated berm (closer to Ottawa Street) was to be to a maximum height of 96.5 metres and to taper to match grades established at the berm.

2014 airphoto

This application is to complete the filling between the berm and Ottawa Street as that portion of the project has not been completed to date.

The proposal is not expected to impact the control of flooding, pollution, erosion or conservation of land based on the findings that the work should have been completed at the time and providing conditions are followed.

PERMISSION AND CONDITIONS

By this letter the Rideau Valley Authority hereby grants you approval to undertake this project as outlined in your permit application but subject to the following conditions:

1. Approval is subject to the understanding of the project as described above and outlined in the application and submitted plans completed by David Schaeffer Engineering Ltd., dated June 6, 2019, Project #977 and there will be no filling within 2 metres of the

watercourse and sediment and erosion control measures will be in place prior to commencement of the project.

2. There will be no work completed on the south side of the existing "berm" nor will there be any work completed on the watercourse.

3. A finished grading plan will be submitted as soon as the work is complete to confirm the grading completing. A refundable deposit of $3190 is required to be submitted prior to commencement of the work. Satisfactory review of the finished grading plan and compliance with other conditions of approval will result in the return of the deposit (less 10% administrative fee).

4. The Rideau Valley Conservation Authority is to receive two-day's notice of the start of the project.

5. The applicant agrees that Authority staff may visit the subject property before, during and after project completion to ensure compliance with the conditions as set out in this letter of permission.

6. That the current municipal zoning will permit this development and no variances and/or amendments to the current zoning will be necessary in order to proceed with the development. Any Planning application will require further review and may not receive supportive comments.

7. Sediment control will be established to ensure no sediment migration from the site to either the River or the watercourse that runs through the property to the River. All grubbing and equipment storage and operation will be limited to the development envelope or North side of the berm. All areas located outside the development envelope will be left untouched. No fill including topsoil, sand, etc. will be placed outside the development envelope for any reason purpose. No equipment will be permitted to disturb area outside the development envelope.

8. A new application must be submitted should any work as specified in this letter be ongoing or planned for or after June 14, 2021.

By this letter the Rideau Valley Conservation Authority assumes no responsibility or liability for any flood, erosion, or slope failure damage which may occur either to your property or the structures on it or if any activity undertaken by you adversely affects the property or interests of adjacent landowners. This letter does not relieve you of the necessity or responsibility for obtaining any other federal, provincial or municipal permits. This permit is not transferable to subsequent property owners.

Should you have any questions regarding this letter, please contact Shelley Macpherson.

Terry K. Davidson

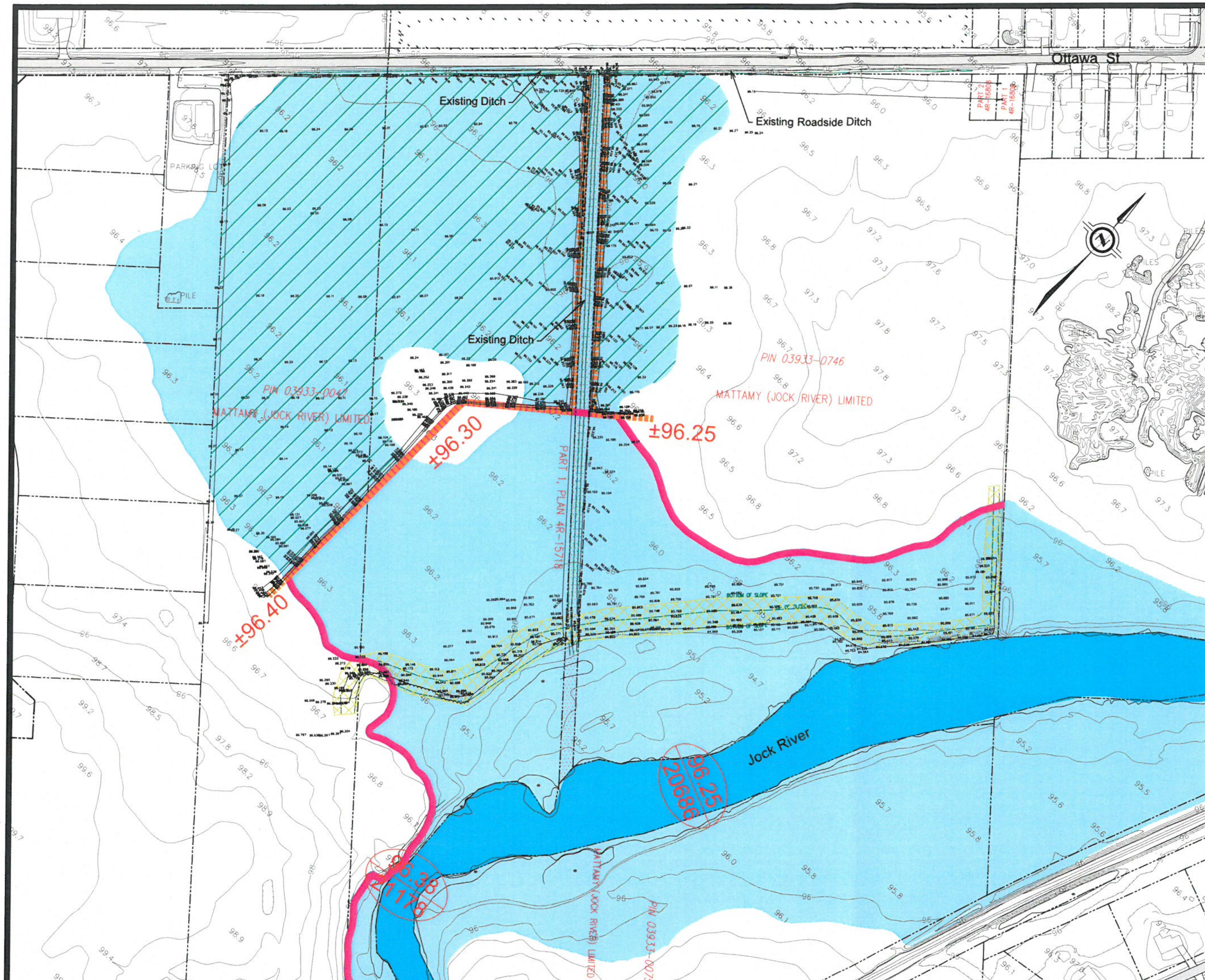
Terry K. Davidson P.Eng
Conservation Authority S. 28 Signing delegate
O. Reg. 174/06

cc: City of Ottawa
David Schaeffer Engineering Ltd.

- Pursuant to the provisions of S. 28(12) of the *Conservation Authorities Act* (R.S.O.1990, as amended.) any or all of the conditions set out above may be appealed to the Executive Committee of the Conservation Authority in the event that they are not satisfactory or cannot be complied with.
- Failure to comply with the conditions of approval or the scope of the project may result in the cancelling of the permission and/or initiation of legal action under S. 28(16) of the Act.
- Commencement of the work and/or a signed and dated copy of this letter indicates acknowledgement and acceptance of the conditions of the RVCA's approval letter concerning the application and the undertaking and scope of the project.

Name: KEVIN MURPHY (print)

Signed: ______________ Date: 14 - Jun - 2019



LEGEND

- 100-Year Floodplain per City of Ottawa GIS
- Jock River
- Existing Berm per RV5 0309 (2009-03-03)
- New 100-year floodplain limit
- Fill area requiring RCVA permit
- Removed Berm per RV5 0309 (2009-03-03)
- 96.38 / 21178 — Regulatory Flood Elevation, Cross-Section Number (Source: RVCA Flood Risk Map)
- ±96.40 — Approximate top of berm elevation (proposed)
- Centerline of existing ditch
- Drainage Easement (City of Ottawa)
- 95.849 — As-built elevation (ASL, January 24, 2019)
- 96.7 — Elevation from City of Ottawa 2K Mapping

Mattamy Homes: Date:

Rideau Valley Conservation: Date:

mattamyHOMES

DSEL
david schaeffer engineering ltd

120 Iber Road, Unit 103
Stittsville, Ontario, K2S 1E9
Tel. (613) 836-0856
Fax. (613) 836-7183
www.DSEL.ca

Mattamy (Jock River) Limited

Jock River
AS-BUILT BERM SURVEY

PROJECT No.: 977
2019-06-06
DRAWN BY: ajt
Scale = 1:1,500
Figure - 1

RIDEAU VALLEY
CONSERVATION AUTHORITY
3889 Rideau Valley Drive, P.O. Box 599, Manotick, ON K4M 1A5
tel 613-692-3571 | 1-800-267-3504 | fax 613-692-0831 | www.rvca.ca

LETTER OF PERMISSION – ONT. REG. 174/06, SECTION 28 CONSERVATION AUTHORITIES ACT 1990, AS AMENDED.

Date: September 27, 2018.
File: RV5-27/18
Previous: RV5-20/16
Contact: Hal Stimson
(613) 692-3571 Ext 1127
hal.stimson@rvca.ca

Mr. Frank Cairo
Richmond Village Development Corporation
5504 Wicklow Drive
Manotick, Ontario
K4M 1C4

Permit to alter a waterway under Section 28 of the Conservation Authorities Act for Storm Outlets at Lot 22, Concession 3, Goulbourn Township now in the City of Ottawa

Dear Mr. Cairo:

The Rideau Valley Conservation Authority has reviewed your renewed application on behalf of Richmond Village Development Corporation and understands the proposal to be for: the construction of two storm pond outlets to the Arbuckle Drain. The previous permit file RV5-2016 has expired and this new permit authorizes the completion of the unfinished portions of the project and acknowledges new and revised construction drawings. The main work yet to be completed include the storm water management facility spillway and a storm outlet with rip rap outlet protection into the Arbuckle Municipal Drain.

This proposal was reviewed under Ontario Regulation 174/06, the "*Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*" regulation.

PERMISSION AND CONDITIONS

By this letter the Rideau Valley Conservation Authority hereby grants you approval to undertake this project as outlined in your permit application but subject to the following conditions:

1. Approval is subject to the understanding of the project as described above and outlined in the application and submitted plans including:
   - Drawing Sheets No. 2B and 2C for Project No. 15-764BB titled SWM POND 1 General Plan (Interim Condition), Revision No. 11, dated 18-06-12, stamped by W.Liu, P. Eng.as prepared by DSEL.
   - Drawing Sheet No. 12 for Project No. 15-764BB titled Plan and Profile of SWM Pond 1 Outfall 2, Revision No. 10, dated 18-06- 12 stamped by W. Liu, P. Eng.as prepared by DSEL.
   - Drawing Sheet No. 14 for Project No. 15-764BB titled Erosion & Sediment Control Plan – Stage 1, Revision No. 10, dated 18-06- 12 stamped by W. Liu, P. Eng.as prepared by DSEL.
   - Drawing Sheet No. 16 for Project No. 15-764BB titled Storm Drainage Plan (Interim condition), Revision No. 10, dated 18-06- 12 stamped by W. Liu, P. Eng.as prepared by DSEL.
   - Drawing No. GEO-2 for Project No. 15078 titled SWM Pond 1 Outlet 2 Stilling Basin, Revision No. 3, dated 16-01- 27 stamped by P. Villard, P. Geo., as prepared by Geomorphix.

   No conditions are subject to change/revision by the on-site contractor(s).

2. All grades are to be restored to the current elevations and as is conditions.

3. Any excess excavated material, as a result of the work, must be disposed of in a suitable location outside any regulatory floodplain and fill regulated area. No changes to area grades are to occur as a result of the work.

4. Rip rap erosion protection to be used at the storm outlet must be placed to ensure the top elevation of the rip rap is at the same elevation as the channel bed.

5. It is recommended that you retain the services of an engineer to conduct on-site inspections to ensure adequacy of the work, verify stability and re-instatement of the final grades and confirm all imported fill is of a suitable type and has been adequately placed and compacted.

6. Only clean non-contaminated fill material will be used and all work is to occur on your property, or if on other property only with full authorization of the owner(s).

7. **There will be no in-water works between March 15 and July 15, of any given year to protect local aquatic species populations during their spawning and nursery time periods.**

8. All in-stream work should be completed in the dry by de-watering the work area and diverting and/or pumping any flows around cofferdams placed at the limits of the work area. Silt or debris that has accumulated around the temporary cofferdams should be cautiously removed prior to their withdrawal. No channel modifications or dredging is permitted or implied by this letter.

9. Work in-water shall not be conducted at times when flows are elevated due to local rain events, storms or seasonal floods. Existing stream flows must be maintained downstream of the de-watered work area without interruption, during all stages of the work. There must be no increase in water levels upstream of the de-watered work area.

10. It is recommended that you ensure your contractor(s) are provided with a copy of this letter so as to ensure compliance with the conditions listed herein.
11. Any aquatic species (fish, turtles) trapped within an enclosed work area are to be safely relocated outside of the enclosed area to the main watercourse downstream of the work zone.

12. Sediment barriers should be used on site in an appropriate method according to the Ontario Provincial Standard Specifications (OPSS) for silt barriers as a minimum. If the sediment and erosion control methods include silt fence it should be placed along the shoreline to prevent overland flow on disturbed areas from entering the watercourse. Soil type, slope of land, drainage area, weather, predicted sediment load and deposition should be considered when selecting the type of sediment/erosion control.

13. Sediment and erosion control measures shall be in place before any excavation or construction works commence. All sediment/erosion control measures are to be monitored regularly by experienced personnel and maintained as necessary to ensure good working order. In the event that the erosion and sedimentation control measures are deemed not to be performing adequately, the contractor shall undertake immediate additional measures as appropriate to the situation to the satisfaction of the Conservation Authority.

14. The waters of the creek are NOT to be considered as machine staging areas. Activities such as equipment refuelling and maintenance must be conducted away from the water to prevent entry of petroleum products, debris, or other deleterious substances into the water. Operate machinery from outside the water, or on the water in a manner that minimizes disturbance to the banks or bed of the watercourse. Equipment shall not be cleaned in the watercourse or where wash-water can enter any watercourse. Machinery is to arrive on site in a clean condition and is to be maintained free of fluid leaks

15. All disturbed soil areas must be appropriately stabilized to prevent erosion and any stockpiled materials shall be stored and stabilized away from the water.

16. Develop a response plan that is to be implemented immediately in the event of flooding, a sediment release or spill of a deleterious substance. This plan is to include measures to: a) stop work, contain sediment-laden water and other deleterious substances and prevent their further migration into the watercourse and downstream receiving watercourses; b) notify the RVCA and all applicable authorities in the area c) promptly clean-up and appropriately dispose of the sediment-laden water and deleterious substances; and d) ensure clean-up measures are suitably applied so as not to result in further alteration of the bed and/or banks of the watercourse; and e) ensure construction equipment and/or materials are located outside the 100-year floodplain in the vent of flooding.

17. Nothing in this letter of permission relieves the applicant from requirements of any other federal, provincial or municipal permits or permission including, for example, Ontario Ministry of Environment Certificate of Approvals, or stormwater or site plan approvals.

18. The owner is ultimately responsible for failure to comply with any and/or all of these conditions and must take all precautions to ensure no sediment runoff from the work site into any watercourse during and after the construction period. Failure to comply with the approval and/or conditions of this letter will result in the permit being revoked and may also result in legal action being initiated to resolve the matter to the Conservation Authority's satisfaction.
19. The applicant agrees that Authority staff may visit the subject property, before, during and after project completion, to ensure compliance with the conditions as set out in this letter of permission.

20. A new application must be submitted should any work as specified in this letter be ongoing or planned for or after September 27, 2020.

21. That the Authority be given twenty-four hours notice prior to the start of construction and within twenty-four hours of project completion.

22. All other approvals as might be required from the Municipality, and/or other Provincial or Federal Agencies must be obtained prior to initiation of work. This includes but is not limited to the Endangered Species Act., the Ontario Water Resources Act., Environmental Protection Act., Public Lands Act, and the Fisheries Act.

By this letter the Rideau Valley Conservation Authority assumes no responsibility or liability for any flood, erosion, or slope failure damage which may occur either to your property or the structures on it or if any activity undertaken by you adversely affects the property or interests of adjacent landowners. This letter does not relieve you of the necessity or responsibility for obtaining any other federal, provincial or municipal permits. This permit is not transferable to subsequent property owners.

Should you have any questions regarding this letter, please contact Hal Stimson at our Manotick office.

Terry K. Davidson

Terry K. Davidson, P. Eng.
Conservation Authority S. 28 Signing delegate
O. Reg. 174/06

Cc: M. Pichette, P. Eng. DSEL

- Pursuant to the provisions of S. 28(12) of the Conservation Authorities Act (R.S.O.1990, as amended.) any or all of the conditions set out above may be appealed to the Executive Committee of the Conservation Authority in the event that they are not satisfactory or cannot be complied with.
- Failure to comply with the conditions of approval or the scope of the project may result in the cancelling of the permission and/or initiation of legal action under S. 28(16) of the Act.
- This letter of permission does not come into full force and effect until the attached copy of this letter is returned to the Authority offices in Manotick signed and dated which return shall be taken as indicating acceptance of the conditions of the Authority's approval and acknowledgement that the details of the proposal as described in this letter are a fair and accurate representation of the proposed undertaking.

Name: ______________________________

Signed: ______________________________ Date: ______________________________

RIDEAU VALLEY
CONSERVATION AUTHORITY

A member of Conservation Ontario

3889 Rideau Valley Drive, P.O. Box 599, Manotick, ON K4M 1A5
tel 613-692-3571 | 1-800-267-3504 | fax 613-692-0831 | www.rvca.ca

LETTER OF PERMISSION - ONTARIO REGULATION 174/06, SECTION 28 CONSERVATION AUTHORITIES ACT 1990, AS AMENDED.

Date October 13, 2016
File: RV5-19/16T
Contact: Hal Stimson
(613) 692-3571 ext. 1127
hal.stimson@rvca.ca

Mr. Frank Cairo
Richmond Village Development Corporation
5504 Wicklow Drive
Manotick, Ontario
K4M 1C4

Permit to alter a waterway under Section 28 of the Conservation Authorities Act for a culvert installation at Lot 22 Concession 3, Township of Goulbourn now in the City of Ottawa

Dear Mr. Cairo

The Rideau Valley Conservation Authority has reviewed your application and understands the proposal to be for the installation of a new 3.0 by 2.4 m by 20.0 STM concrete box culvert with inlet and outlet erosion protection on the Arbuckle Municipal Drain crossing of Fortune Street in Richmond. All work is to occur within the municipal road allowance (or on other land with owner permission) with appropriate approvals of the City of Ottawa. The proposal is in support of development and the storm water and community design plans for new subdivision development in the village of Richmond.

This proposal was reviewed under Ontario Regulation 174/06, the "*Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*" regulation.

PERMISSION AND CONDITIONS

By this letter the Rideau Valley Authority hereby grants you approval to undertake this project as outlined in your permit application but subject to the following conditions:

1. Approval is subject to the understanding of the project as described above and outlined in the application and submitted drawings including:
   - Drawing Sheet No. 13 for Project No. 15-764BB titled Plan and Profile of Fortune Street (Sta. 0+000 to Sta. 0+2000), dated 16-01-29, revision No. 5, as prepared by DSEL and stamped by Z. Li, P. Eng.
   - Drawing Sheet No. 6A for Project No. 15-764BB titled SWM Pond 1 Sections (Ultimate Condition), dated 16-01-29, revision No. 5, as prepared by DSEL and stamped by Z. Li, P. Eng.

   No conditions are subject to change/revision by the on-site contractor(s).

2. **A De-watering Plan and Sediment and Erosion Control Plan must be submitted to this office by the contractor for review prior to construction activities.**

3. **There will be no in-water works between March 15 and July 1, of any given year to protect local aquatic species populations during their spawning and nursery time periods.**

4. Work in-water shall not be conducted at times when flows are elevated due to local rain events, storms or seasonal floods. Existing stream flows must be maintained downstream of the de-watered work area without interruption, during all stages of the work. There must be no increase in water levels upstream of the de-watered work area.

5. It is recommended that you ensure your contractor(s) are provided with a copy of this letter so as to ensure compliance with the conditions listed herein.

6. Any aquatic species (fish, turtles) trapped within an enclosed work area are to be safely relocated outside of the enclosed area to the main watercourse downstream of the work zone.

7. All in-stream work should be completed in the dry by de-watering the work area and diverting and/or pumping any flows around cofferdams placed at the limits of the work area (road right of way). Silt or debris that has accumulated around the temporary cofferdams should be cautiously removed prior to their withdrawal. No channel modifications or dredging is permitted or implied by this letter.

8. Sediment barriers should be used on site in an appropriate method according to the Ontario Provincial Standard Specifications (OPSS) for silt barriers as a minimum. Soil type, slope of land, drainage area, weather, predicted sediment load and deposition should be considered when selecting the type of sediment/erosion control.

9. Sediment and erosion control measures shall be in place before any excavation or construction works commence. All sediment/erosion control measures are to be monitored regularly by experienced personnel and maintained as necessary. In the event that the erosion and sedimentation control measures are deemed not to be performing adequately, the contractor shall undertake immediate additional measures as appropriate to the situation to the satisfaction of the Conservation Authority.

10. Demolition or construction debris is not to be deposited in the waters of any creek; inert concrete/asphalt debris will be considered a deleterious substance. An emergency spill kit should be kept on site in case of fluid leaks or spills from machinery.

11. The waters of the creek are NOT to be considered as machine staging areas. Activities such as equipment refuelling and maintenance must be conducted away from the water to prevent entry of petroleum products, debris, or other deleterious substances into the water. Operate machinery from outside the water, or on the water in a manner that minimizes disturbance to the banks or bed of the watercourse. Equipment shall not be cleaned in the watercourse or where wash-water can enter any watercourse. Machinery is to arrive on site in a clean condition and is to be maintained free of fluid leaks.

12. Develop a response plan that is to be implemented immediately in the event of a sediment release or spill of a deleterious substance. This plan is to include measures to: a) stop work, contain sediment-laden water and other deleterious substances and prevent their further migration into the watercourse and downstream receiving watercourses; b) notify the RVCA and all applicable authorities in the area c) promptly clean-up and appropriately dispose of the sediment-laden water and deleterious substances; and d) ensure clean-up measures are suitably applied so as not to result in further alteration of the bed and/or banks of the watercourse.

13. The RVCA is to receive 48 hours notice of the proposed commencement of the works to ensure compliance with all conditions. The applicant agrees that Authority staff may visit the subject property, before, during and after project completion, to ensure compliance with the conditions as set out in this letter of permission.

14. A new application must be submitted should any work as specified in this letter be ongoing or planned for or after October 13, 2018.

15. All other approvals as might be required from the Municipality, and/or other Provincial or Federal Agencies must be obtained prior to initiation of work. This includes but is not limited to the Drainage Act, the Endangered Species Act, the Ontario Water Resources Act, Environmental Protection Act, Public Lands Act, or the Fisheries Act.

By this letter the Rideau Valley Conservation Authority assumes no responsibility or liability for any flood, erosion, or slope failure damage which may occur either to your property or the structures on it or if any activity undertaken by you adversely affects the property or interests of adjacent landowners. This letter does not relieve you of the necessity or responsibility for obtaining any other federal, provincial or municipal permits. This permit is not transferable to subsequent property owners.

Should you have any questions regarding this letter, please contact Hal Stimson at our Manotick office.

Terry K. Davidson

____

Terry K. Davidson P.Eng
Conservation Authority S. 28 Signing delegate
O. Reg. 174/06

c.c. K. Murphy, P. Eng. DSEL
D. Ryan, P. Geo. City Drainage Manager

- Pursuant to the provisions of S. 28(12) of the Conservation Authorities Act (R.S.O.1990, as amended.) any or all of the conditions set out above may be appealed to the Executive Committee of the Conservation Authority in the event that they are not satisfactory or cannot be complied with.
- Failure to comply with the conditions of approval or the scope of the project may result in the cancelling of the permission and/or initiation of legal action under S. 28(16) of the Act.
- This letter of permission does not come into full force and effect until the attached copy of this letter is returned to the Authority offices in Manotick signed and dated which return shall be taken as indicating acceptance of the conditions of the Authority's approval and acknowledgement that the details of the proposal as described in this letter are a fair and accurate representation of the proposed undertaking.

Name: ______________________________ (print)

Signed: ______________________________ Date: ______________________________

LETTER OF PERMISSION – ONT. REG. 174/06, SECTION 28 CONSERVATION AUTHORITIES ACT 1990, AS AMENDED.

Date: July 7, 2016.
File: RV5-20/16
Contact: Hal Stimson
(613) 692-3571 ext. 1127
hal.stimson@rvca.ca

Mr. Frank Cairo
Richmond Village Development Corporation
5504 Wicklow Drive
Manotick, Ontario
K4M 1C4

Permit to alter a waterway under Section 28 of the Conservation Authorities Act for Service Crossings and Storm Outlets at Lot 22/23, Concession 3, Goulbourn Township now in the City of Ottawa

Dear Mr. Cairo

The Rideau Valley Conservation Authority has reviewed your application on behalf of Richmond Village Development Corporation and understands the proposal to be for: the installation by open cut trench of new Sanitary and Storm Sewer crossings of the Arbuckle and Moore Municipal Drains and the installation of a new storm water management facility spillway and a storm outlet with concrete headwall and rip rap outlet protection into the Arbuckle Municipal Drain.

This proposal was reviewed under Ontario Regulation 174/06, the "*Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*" regulation.

PERMISSION AND CONDITIONS

By this letter the Rideau Valley Conservation Authority hereby grants you approval to undertake this project as outlined in your permit application but subject to the following conditions:

1. Approval is subject to the understanding of the project as described above and outlined in the application and submitted plans including:
    - Drawing Sheet No. 2 titled General Plan of Services Village of Richmond Sanitary Trunk, Revision No. 3 dated 15-10-20 stamped by Z. Li, P. Eng.as prepared by DSEL.
    - Drawing Sheet No. 5 titled Plan and Profile of Strachan Street (STA. 0+120.000 to STA. 0+320.000 Village of Richmond Sanitary Trunk, Revision No. 3 dated 15-10-20 stamped by Z. Li, P. Eng.as prepared by DSEL.
    - Drawing Sheet No. 6 titled Plan and Profile of Queen Charlotte Street (STA. 0+000.000 to STA. 0+209.437 Village of Richmond Sanitary Trunk, Revision No. 3 dated 15-10-20 stamped by Z. Li, P. Eng.as prepared by DSEL.
    - Drawing Sheet No. 7 titled Plan and profile of Martin Street (STA. 0-040.000 to STA. 0+200.000 Village of Richmond Sanitary Trunk, Revision No. 4 dated 15-10-20 stamped by Z. Li, P. Eng.as prepared by DSEL.
    - Drawing Sheet No. 13 titled Siltation Control Plan Village of Richmond Sanitary Trunk, Revision No. 3 dated 15-10-20 stamped by Z. Li, P. Eng.as prepared by DSEL.

    No conditions are subject to change/revision by the on-site contractor(s).

2. **A De-watering Plan and Sediment and Erosion Control Plan must be submitted by the contractor to this office for review prior to construction activities commencing.**

3. All grades are to be restored to the current elevations and as is conditions.

4. Any excess excavated material, as a result of the work, must be disposed of in a suitable location outside any regulatory floodplain and fill regulated area. No changes to area grades are to occur as a result of the work.

5. Rip rap erosion protection to be used at the storm outlet or on the utility crossings must be placed to ensure the top elevation of the rip rap is at the same elevation as the channel bed.

6. It is recommended that you retain the services of an engineer to conduct on-site inspections to ensure adequacy of the work, verify stability and re-instatement of the final grades and confirm all imported fill is of a suitable type and has been adequately placed and compacted.

7. Only clean non-contaminated fill material will be used and all work is to occur on your property, or if on other property only with full authorization of the owner(s).

8. **There will be no in-water works between March 15 and July 15, of any given year to protect local aquatic species populations during their spawning and nursery time periods.**

9. All in-stream work should be completed in the dry by de-watering the work area and diverting and/or pumping any flows around cofferdams placed at the limits of the work area. Silt or debris that has accumulated around the temporary cofferdams should be cautiously removed prior to their withdrawal. No channel modifications or dredging is permitted or implied by this letter.

10. Work in-water shall not be conducted at times when flows are elevated due to local rain events, storms or seasonal floods. Existing stream flows must be maintained downstream of the de-watered work area without interruption, during all stages of the work. There must be no increase in water levels upstream of the de-watered work area.

11. It is recommended that you ensure your contractor(s) are provided with a copy of this letter so as to ensure compliance with the conditions listed herein.

12. Any aquatic species (fish, turtles) trapped within an enclosed work area are to be safely relocated outside of the enclosed area to the main watercourse downstream of the work zone.

13. Sediment barriers should be used on site in an appropriate method according to the Ontario Provincial Standard Specifications (OPSS) for silt barriers as a minimum. If the sediment and erosion control methods include silt fence it should be placed along the shoreline to prevent overland flow on disturbed areas from entering the watercourse. Soil type, slope of land, drainage area, weather, predicted sediment load and deposition should be considered when selecting the type of sediment/erosion control.

14. Sediment and erosion control measures shall be in place before any excavation or construction works commence. All sediment/erosion control measures are to be monitored regularly by experienced personnel and maintained as necessary to ensure good working order. In the event that the erosion and sedimentation control measures are deemed not to be performing adequately, the contractor shall undertake immediate additional measures as appropriate to the situation to the satisfaction of the Conservation Authority.

15. The waters of the creek are NOT to be considered as machine staging areas. Activities such as equipment refuelling and maintenance must be conducted away from the water to prevent entry of petroleum products, debris, or other deleterious substances into the water. Operate machinery from outside the water, or on the water in a manner that minimizes disturbance to the banks or bed of the watercourse. Equipment shall not be cleaned in the watercourse or where wash-water can enter any watercourse. Machinery is to arrive on site in a clean condition and is to be maintained free of fluid leaks

16. All disturbed soil areas must be appropriately stabilized to prevent erosion.

17. Develop a response plan that is to be implemented immediately in the event of flooding, a sediment release or spill of a deleterious substance. This plan is to include measures to: a) stop work, contain sediment-laden water and other deleterious substances and prevent their further migration into the

watercourse and downstream receiving watercourses; b) notify the RVCA and all applicable authorities in the area c) promptly clean-up and appropriately dispose of the sediment-laden water and deleterious substances; and d) ensure clean-up measures are suitably applied so as not to result in further alteration of the bed and/or banks of the watercourse; and e) ensure construction equipment and/or materials are located outside the 100-year floodplain in the vent of flooding.

18. Nothing in this letter of permission relieves the applicant from requirements of any other federal, provincial or municipal permits or permission including, for example, Ontario Ministry of Environment Certificate of Approvals, or stormwater or site plan approvals.

19. Any stockpiled materials shall be stored and stabilized away from the water.

20. The owner is ultimately responsible for failure to comply with any and/or all of these conditions and must take all precautions to ensure no sediment runoff from the work site into any watercourse during and after the construction period. Failure to comply with the approval and/or conditions of this letter will result in the permit being revoked and may also result in legal action being initiated to resolve the matter to the Conservation Authority's satisfaction.

21. The applicant agrees that Authority staff may visit the subject property, before, during and after project completion, to ensure compliance with the conditions as set out in this letter of permission.

22. A new application must be submitted should any work as specified in this letter be ongoing or planned for or after July 7, 2018.

23. That the Authority be given twenty-four hours notice prior to the start of construction and within twenty-four hours of project completion.

24. All other approvals as might be required from the Municipality, and/or other Provincial or Federal Agencies must be obtained prior to initiation of work. This includes but is not limited to the Endangered Species Act., the Ontario Water Resources Act., Environmental Protection Act., Public Lands Act, and the Fisheries Act.

By this letter the Rideau Valley Conservation Authority assumes no responsibility or liability for any flood, erosion, or slope failure damage which may occur either to your property or the structures on it or if any activity undertaken by you adversely affects the property or interests of adjacent landowners. This letter does not relieve you of the necessity or responsibility for obtaining any other federal, provincial or municipal permits. This permit is not transferable to subsequent property owners.

Should you have any questions regarding this letter, please contact Hal Stimson at our Manotick office.

Terry K. Davidson

Terry K. Davidson, P. Eng.
Conservation Authority S. 28 Signing delegate
O. Reg. 174/06

Cc: K. Murphy, P. Eng. DSEL
M. Gagné, City Ottawa Drainage Coordinator

- Pursuant to the provisions of S. 28(12) of the Conservation Authorities Act (R.S.O.1990, as amended.) any or all of the conditions set out above may be appealed to the Executive Committee of the Conservation Authority in the event that they are not satisfactory or cannot be complied with.
- Failure to comply with the conditions of approval or the scope of the project may result in the cancelling of the permission and/or initiation of legal action under S. 28(16) of the Act.
- This letter of permission does not come into full force and effect until the attached copy of this letter is returned to the Authority offices in Manotick signed and dated which return shall be taken as indicating acceptance of the conditions of the Authority's approval and acknowledgement that the details of the proposal as described in this letter are a fair and accurate representation of the proposed undertaking.

Name: ______________________________ (print)

Signed: ______________________________ Date: ______________________________

RVCA Letter of Permission —

Ont. Reg. 174/06, S. 28 *Conservation Authorities Act* 1990, As Amended.

Date: October 1, 2019
File: RV5-4619
Contact: hal.stimson@rvca.ca (613) 692-3571 Ext 1127

Rideau Valley Conservation Authority

3889 Rideau Valley Drive
PO Box 599, Manotick ON K4M 1A5
T 613-692-3571 | 1-800-267-3504
F 613-692-0831 | www.rvca.ca

Mr. Andrew Finnson
Richmond Village Development Corporation
2934 Baseline Rd - # 302
Ottawa, Ontario
K2H 1B2

Permit for: Alteration to a Watercourse under Section 28 of the Conservation Authorities Act for storm water management pond at Lot 22, Concession 3, Goulbourn Township, now the City Ottawa, known municipally as 6350 Perth Street

Dear Mr. Andrew Finnson,

The Rideau Valley Conservation Authority has reviewed your application on behalf of the Richmond Village Development Corporation and understands the proposal to be for:

> **The construction/expansion of a stormwater management facility from its existing interim size to its ultimate footprint within the floodplain of the Arbuckle Municipal Drain which is a direct tributary to the Jock River. The works will provide stormwater outlet for minor and major system flows. The work will need to be carried out cautiously due to the condition of on-site soils and to ensure current stormwater and drainage is appropriately handled given the ultimate solution is to be constructed over existing stormwater systems.**

This proposal was reviewed under Ontario Regulation 174/06, the "Development, Interference with Wetlands, and Alteration to Watercourse and Shorelines" regulation and the RVCA Development Policies (approved by the RVCA, Board of Directors), specifically Section 3 Alteration to Waterways. The proposal is not expected to impact the control of flooding, pollution, erosion or conservation of land providing conditions are followed.

PERMISSION AND CONDITIONS

By this letter the Rideau Valley Authority hereby grants you approval to undertake this project as outlined in your permit application but subject to the following conditions:

1. Approval is subject to the understanding of the project as described above and outlined in the application and submitted plans and reports including:

- Report titled Design Brief for Stormwater Management Pond 1 Western Development Lands – Richmond dated August 2015 and Revised July 2019 as prepared by DSEL & JFSA. with associated drawings

No conditions are subject to change/revision by the on-site contractor(s).

2. **A Sediment and Erosion Control Plan and a dewatering plan must be submitted to this office by the contractor for review prior to construction activities.**

3. Any changes to the proposed work must be submitted in writing to the Conservation Authority for review and approval prior to implementation.

4. Any excess excavated material, as a result of the work, must be disposed of in a suitable location outside any regulatory floodplain and fill regulated area.

5. Only clean non-contaminated fill material will be used, and all work is to occur on your property or on other property with permission of the owners.

6. **There will be no in-water works between March 15 and June 30, of any given year to protect local aquatic species populations during their spawning and nursery time periods.**

7. Work in-water shall not be conducted at times when flows are elevated due to local rain events, storms or seasonal floods.

8. All in-stream work should be completed in the dry by de-watering the work area and diverting and/or pumping any flows around cofferdams placed at the limits of the work area. Silt or debris that has accumulated around the temporary cofferdams should be cautiously removed prior to their withdrawal. No other channel modifications or dredging is permitted or implied by this letter.

9. Sediment barriers should be used on site in an appropriate method according to the Ontario Provincial Standard Specifications (OPSS) for silt barriers as a minimum. In-water work will require the use of a properly secured silt curtain. Soil type, slope of land, drainage area, weather, predicted sediment load and deposition should be considered when selecting the type of sediment/erosion control.

10. Sediment and erosion control measures shall be in place before any excavation or construction works commence. All sediment/erosion control measures are to be monitored regularly by experienced personnel and maintained as necessary to ensure good working order. In the event that the erosion and sedimentation control measures are deemed not to be performing adequately, the contractor shall undertake immediate additional measures as appropriate to the situation to the satisfaction of the Conservation Authority.

11. Activities such as equipment refueling and maintenance must be conducted away from the water to prevent entry of petroleum products, debris, or other deleterious substances into the water. Operate machinery from outside the water, or on the water in a manner that minimizes disturbance to the banks or bed of the watercourse. Equipment shall not be

cleaned in the watercourse or where wash-water can enter any watercourse. Machinery is to arrive on site in a clean condition and is to be maintained free of fluid leaks.

12. Any aquatic species (fish, turtles) trapped within an enclosed work area are to be safely relocated outside of the enclosed area to the main watercourse downstream of the work zone.

13. All disturbed soil areas must be appropriately stabilized to prevent erosion.

14. It is recommended that you retain the services of a professional engineer to conduct on-site inspections to ensure adequacy of the work, verify stability of the final grade and slopes and confirm all imported fill is of suitable type and has been adequately placed and compacted.

15. It is recommended that you ensure your contractor(s) are provided with a copy of this letter to ensure compliance with the conditions listed herein.

16. The applicant agrees that Authority staff may visit the subject property, before, during and after project completion, to ensure compliance with the conditions as set out in this letter of permission.

17. A new application must be submitted should any work as specified in this letter be ongoing or planned for or after October 1, 2021.

18. The RVCA is to receive 48 hours notice of the proposed commencement of the works to ensure compliance with all conditions. The applicant agrees that Authority staff may visit the subject property, before, during and after project completion, to ensure compliance with the conditions as set out in this letter of permission.

All other approvals as might be required from the Municipality, and/or other Provincial or Federal Agencies must be obtained prior to initiation of work. This includes but is not limited to the Drainage Act, the Endangered Species Act, the Ontario Water Resources Act, Environmental Protection Act, Public Lands Act, or the Fisheries Act.

By this letter the Rideau Valley Conservation Authority assumes no responsibility or liability for any flood, erosion, or slope failure damage which may occur either to your property or the structures on it or if any activity undertaken by you adversely affects the property or interests of adjacent landowners. This letter does not relieve you of the necessity or responsibility for obtaining any other federal, provincial or municipal permits. This permit is not transferable to subsequent property owners.

Should you have any questions regarding this letter, please contact Hal Stimson.

Terry K. Davidson

Terry K. Davidson P.Eng
Conservation Authority S. 28 Signing delegate
O. Reg. 174/06

c.c. K. Murphy, P. Eng., DSEL

- Pursuant to the provisions of S. 28(12) of the *Conservation Authorities Act* (R.S.O.1990, as amended.) any or all of the conditions set out above may be appealed to the Executive Committee of the Conservation Authority in the event that they are not satisfactory or cannot be complied with.
- Failure to comply with the conditions of approval or the scope of the project may result in the cancelling of the permission and/or initiation of legal action under S. 28(16) of the Act.
- Commencement of the work and/or a signed and dated copy of this letter indicates acknowledgement and acceptance of the conditions of the RVCA's approval letter concerning the application and the undertaking and scope of the project.

Name: ______________________________________(print)

Signed: ______________________________________ Date: ____________________

JFSA
WATER RESOURCES AND
ENVIRONMENTAL CONSULTANTS

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November 14, 2018 Project # P922(p)

Robinson Consultants Inc.
350 Palladium Drive
Ottawa, Ontario
K2V 1A8

Attention: **Andy Robinson**

Subject: **Fisheries Review of Van Gaal Drain Re-alignment and Municipal Drain Designation**

Dear Mr. Robinson,

As requested, below is a summary of the fisheries review history and status relating to proposed works on the Van Gaal Drain. Based on the below, it is unlikely that the most recent request for review will result in any changes to the design of the Van Gaal as proposed and therefore should not hold up any movement forward son the process.

<u>Record of review</u>

June 2011: Jennifer Lamoureux (RVCA), Mark Ferguson (DFO) and Bruce Kilgour (Kilgour and Assoc.) conducted a site visit to the Van Gaal and Arbuckle Drains. At the time, two separate projects were evaluated (SWM Pond and altering the Van Gaal in its current location). The attendees established the following conclusions relating to the Van Gaal:

WIDENING AND DEEPENING OF DRAIN (no realignment).

- The channel receives flows from a large wetland complex, but there have been periods of extreme low flow when the channel has been documented to be dry.
- The channel supports upwards of a dozen species of fish including pike. There is an existing pike spawning "shelf" that was previously constructed in the channel upstream of Perth Street. It is unknown if pike use that shelf, but young of year pike have been observed in the channel a few hundred metres downstream of Perth Street.
- The proposed project will widen the channel by some 7 m, from 3 m to 10 m. This will effectively reconnect the channel to its floodplain. A low-flow channel will be designed in the feature using natural channel design principals. Staging of the construction of the widened channel will consider timing windows, etc. Design of the widened channel will consider the requirements for pike spawning: elevations will require some understanding of how long water will stay in the new floodplain. Stormwater will be conveyed by pipe to the proposed SWM pond south of Perth Street, so the design must address those losses of water.
- Discussed the approach to managing risks, with the following highlights:

- Kilgour will a write fish habitat risk assessment for the proposed undertaking, following DFO's RMF. It is anticipated that the completed RMF will result in a conclusion that the project will have an overall low risk to fish and fish habitat.

NEW DRAIN REALIGNMENT PROPOSAL

August 5, 2011: Email from Jocelyn Chandler (RVCA) to Jennifer Ailey (DSEL) with comments on the revised proposal to realign the Van Gaal Drain. Indicates that an RMF must be completed regarding the development proposal and the predicted impacts to fish habitat will be required, although at this time a general statement from the biologist will suffice to achieve some degree of assurance that this will remain a Level II approval under the Federal Fisheries act.

September 7, 2012: Submission by Kilgour to DSEL reviewing the proposed realignment of the Van Gaal Drain providing a written risk assessment. Describes Van Gaal as intermittent habitat with no riparian zone providing shade. States that proposal will lengthen the channel and increase the wetted area during periods of high flow. A low flow channel will enhance the fish habitat value for longer periods of time through dry periods and the floor of the channel will be planted appropriately. The realignment of the feature should enhance ecological functions of the feature and broader area. States that the realignment presents a low risk to fisheries in the system and that provided the design includes fish habitat features, the fish species present in the drain will continue to use the drain after realignment.

Feb 4, 2013: Memo prepared by RVCA speaks to realignment Van Gaal design and fish monitoring/salvage reports. Comments provided on where more detail required and request info regarding potential fish migration barrier at perched Perth culvert during low flow conditions. No mention of requirements for DFO review.

April 10, 2013: Post effectiveness monitoring plan submitted to RVCA by Kilgour.

April 26, 2013: RVCA accepts document titled "Van Gaal Drain Realignment Proposed Effectiveness Monitoring Program"

November 2013: MDP document for Western Development Lands includes section 1.2.3 on Department of Fisheries and Oceans stating that Approval will be required from the RVCA, acting as an agent for DFO, regarding the infilling and re-alignment of the Van Gaal Drain north of Perth Street and the closure of the existing ditch(es) between Perth Street and Ottawa Street. Ultimately the impact on aquatic systems in the preferred option (Option 3) was considered to result in "conversation of indirect fish habitat to direct fish habitat, for a total gain of direct fish habitat of some 3386 m2" due to creation of new potential fish spawning habitats.

November 22, 2013: RVCA letter to Ottawa regarding upcoming approval of MDP/EA document. The RVCA considered the MDP document acceptable within review mandate, and noted that fish habitat is identified in the Van Gaal Drain. At the time the prosed alterations to the Van Gaal and Arbuckle were under review by RVCA technical staff to ensure no adverse impact to fish and fish habitat. There is no mention of DFO review required.

November 25, 2013: **Changes to DFO Fisheries Act.**

December 13, 2013: Memo from RVCA providing review comments on proposed Van Gaal Drain Channel realignment indicating that among other things, habitat features for fish and setbacks must support fish habitat.

June 23, 2014: Formal completion of EA process and accompanying November 2013 MDP via issuance of OMB decision PL130778.

November 17, 2014: DSEL submits Van Gaal natural channel design report and drawings for RVCA review. Kilgour have provided review and input into the Coldwater design to address fish passage.

March 5, 2015: Email from RVCA following review of proposed Van Gaal realignment design indicating that conditions would be required under O.Reg 174/06.

Summary

It appears that the initial plan to widen and deepen the Van Gaal and construct the SWM pond were considered by RVCA, Kilgour and DFO during their site visit. Although the plans have evolved from that period, the conclusion drawn at that time suggests that the RVCA and DFO agreed that the overall risks to fish were low therefor the prosed work would not trigger a Level 3 DFO review and would fit in the delegated Level 2 RVCA review. There is a letter prepared by Kilgour on the realignment proposal which states that the project will present a low risk to fish and will result in fishery enhancements.

With respect to how far along the decision relating to fisheries was at the time of the DFO legislative changes in November 2013, I can only reference that the MDP (and related EA) was completed and accepted by the RVCA at that time with the statement regarding "low risk" to fisheries included.

In a 2014 email on an unrelated project, Tom Hoggarth, Regional Director, Ecosystems Management DFO indicated that "If the past review indicated it was low risk and the detailed design have now come in and the project has not changed, no further DFO review is required".

At this time Kilgour has undertaken a fall 2018 site visit to update existing conditions information and are submitting a request for review to DFO. However, given the extensive review history on this file, it seems unlikely the proposed works would require revisions to the design for the purpose of satisfying fishery requirements.

I hope this information is sufficient for your purposes to continue with the Van Gaal Municipal Drainage Act process. Please let me know if you require anything further.

J Chandler

Jocelyn Chandler, RPP, MCIP
Planner/Project Manager, JFSA

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1.3 Public and Agency Consultation

Public consultation is an integral part of the preparation of Mattamy Homes Official Plan Amendment and supporting studies including the Stormwater Management and Drainage Plan exercise. A transparent process in which members of the public, community groups, residents, City of Ottawa, public agencies and other stakeholders can express their issues and concerns and obtain timely information on the study as it progresses are key components of this study. Regulatory public meetings are also a requirement of the Class Environmental Assessment Process which is being followed, in spirit, for the Stormwater Management and Drainage Plan exercise. The following consultation points are outlined under the Class EA Process for Phases 1 and 2:

Phase 1 – Problem or Opportunity

- Discretionary public consultation to review problem or opportunity

Phase 2 – Alternative Solutions

- Mandatory public and agency consultation on the identified problem or opportunity and identified and evaluated alternative solutions to the problem

The City of Ottawa initiated the Richmond Village Community Design Plan (CDP) process in March of 2008. Through the Ward Councillor, a Steering Committee made up of representatives from the Village was established to facilitate a community based approach to prepare and develop the Community Design Plan for the Village of Richmond. The Steering Committee is comprised of residents, farmers, the Richmond Village Association, business people, and individuals/companies with a development interest. The community based Steering Committee allows the Richmond Village Community Design Plan to be developed by the community, for the community. Mattamy Homes is a member of the Richmond Village Steering Committee.

A collaborative public consultation approach has been undertaken that informs both Mattamy Homes Official Plan Amendment process and the Richmond Village CDP. A number of public events have taken place either lead by the City, the Richmond Village Steering Committee or Mattamy Homes that have assisted with the preparation of the technical documents supporting Mattamy's OPA as well as the preparation of the Village CDP. These public consultation events are briefly described below with supporting documentation in ***Appendix B***.

<u>April 12th Public Open House</u>

The City of Ottawa held a public open house at the Richmond Public School from 9:00 a.m. to Noon on Saturday, April 12, 2008. The purpose of the open house was to introduce the commencement of the Richmond Village Community Design Plan process. As well, a number of information stations were displayed with City staff on hand to answer questions and share information related to: the existing village plan, heritage buildings, natural environment, groundwater and servicing. Participants were asked to identify “Places We Like Most” and “Places We Like Least” in the Village of Richmond through red (least) and green (most) dots placed on a mounted aerial photo of the Village. Participants were also asked to place yellow dots on the aerial photo to identify traffic problems and pedestrian safety “hot spots” in Richmond. This event was well attended with approximately 125 people participating in the event.

April 19th Visioning Workshop

The City of Ottawa and Richmond Village Steering Committee hosted a visioning workshop to bring together the residents and stakeholders in Richmond to see what they wanted the Village to be in 20 years. Participants were also asked to identify “greatest opportunities” and “greatest challenges” to meet the vision for the Village. The workshop was held at the Richmond Public School from 9:00 a.m. to Noon. The “Dot-mocracy” map was on display and those who had not attended the April 12th session were asked to place their red, green and yellow dots on the aerial photo of the Village. The workshop had discussion tables set up for the following topic areas: Village/Heritage Character; Future Development; Transportation and Pathways; Environment, Drainage and Floodplains; Servicing and Groundwater; Building Richmond as a sustainable community; and Recreation, Community Facilities and Open Space. Each participant could participate in 5 topic areas within the time period established for the break out sessions. City staff and Richmond Village Steering Committee facilitated the discussions at each of the topic area tables. Approximately 75 people attended and participated in the visioning workshop.

Community Visioning Principles

Based on the feedback from the April community visioning exercise, City staff and the Richmond Village Steering Committee drafted a primarily community vision for the Richmond Village which comprised of six main community principles:

- Create a Livable and Sustainable Community
- Protect and Enhance Richmond’s Historic Village Character
- Protect the Natural Environment and Incorporate Constraints in the Plan
- Expand and Maintain Transportation Infrastructure
- Create and Protect Open Space, Recreation and Community Services
- Ensure Sustainability of Servicing (Groundwater, Wastewater and Stormwater Systems)

On June 4, 2008, the Richmond Village Steering Committee hosted a Strategic Direction Workshop at the Richmond Library from 7:00 p.m. to 9:00 p.m. The public was invited to participate in a small working group session to provide input on the draft community visioning principles on: Village Character and Development; Environment, Recreation and Sustainability; Transportation and Facilities; and Servicing and Groundwater. Based on the input received, the Village of Richmond Community Vision Workbook was prepared and circulated for comment to all residents in the Village in July 2008. A total of 2461 booklet were distributed directly to residents in the Village and additional copies were available at the Richmond Library and the Valu-Mart. A total of 246 booklet responses were returned to the City. More than two-thirds of respondents agreed with the community visioning principles. The response suggests that the principles are in line with the areas that Richmond residents feel important in the planning process. The Richmond Community Visioning Principles are contained in ***Appendix B***.

September 2008 Design Workshop

The Richmond Village Steering Committee endorsed Looney Ricks Kiss (LRK), architects and community planners, to undertake a four-day design workshop in the community to define the Village Core based on the established visioning principles. The Councillor along with the Richmond Village Steering Committee invited residents to attend the four-day workshop held from September 22 to September 25 at the vacant storefront situated at 3480 McBean Street. The workshop was set up as a drop-in centre – day or night – to participate in defining and designing the village core plan.

In preparation for this workshop, LRK conducted site visit investigations to 16 villages in Eastern Ontario called benchmarking. This exercise involved measuring and documenting local built precedents and historic and contemporary examples that could be used as the base line for defining architectural character as well as urban design and landscape patterns. This process documented landscape/streetscape treatments and patterns and architectural buildings that could provide examples to draw from when preparing the Richmond Village plan.

As well, Mattamy Homes consultant team set up and manned display boards in the store on the existing conditions information related to planning, design, natural environment, stormwater management, transportation, water, groundwater and sanitary servicing. The public visiting the workshop could view the display information and asked questions to the consultant on existing information and the overall process being undertaken to support Mattamy Homes Official Plan Amendment.

This workshop was very well attended with over 250 individuals attending at least one of the four days, with many persons making repeated visits. A summary of the four day design workshop is provided below:

Monday, September 22
Focus groups were set up for the morning inviting representatives from the businesses, real estate agents, recreational groups, residents along McBean and Perth, community groups, schools, churches, and farmers. The public was invited to participate in a benchmarking tour of other Eastern Ontario villages in the afternoon to investigate comparable communities and the design examples that may be applicable to Richmond. In the evening, the Councillor sponsored a barbeque which attracted around 100

residents. Participants were asked to participate in a community design survey developed by LRK. Participants were asked through a PowerPoint presentation to vote for the image that best represents their vision for Richmond associated with: residential building design, commercial building design, parks and open space, Perth Street, McBean Street, river corridor, local streetscape. The survey was available during all four days so that all attendees could participate. A total of 120 surveys were completed.

Tuesday, September 23

On Tuesday morning, residents and stakeholders were invited to take part in a walking tour of the village core. Participants were encouraged to talk about McBean Street, Perth Street, the Jock River and the surrounding area and how these spaces can be improved.

Roundtable discussions took place in the afternoon where City staff, agencies and the public participated in several topic areas hosted by Mattamy Homes and the consultant team including: transportation, servicing, natural environment and open space, as well as the design of McBean Street. The Master Servicing Study presented the preliminary list of alternatives being considered for water and sanitary servicing for the Village.

On Tuesday evening, LRK presented the results of the visioning survey which would serve as the foundation to create the design for the Village Core. Through public input, the Village Core was defined the Perth Street and McBean t-intersection extending along McBean Street to the Jock River bridge.

Wednesday, September 24 and Thursday, September 25

The last two days of the workshop focused on the design of the Village Plan. Participants could view the progress being made on the plan and the street and building designs. The technical information was also on display for the public to review, ask questions and provide comments. On Thursday evening, LRK presented the Village Core Plan at the South March High School. Over a hundred people attended the presentation.

Mattamy's December 2008 Design Workshop

Following the September workshop, Mattamy Homes conducted a similar workshop in December to prepare a conceptual land use plan for Mattamy's lands in Richmond based on the vision developed for the Village. Looney Ricks Kiss facilitated this three-day workshop that took place at the same storefront on McBean Street from December 8-10, 2008. As well, the findings of the technical studies was available through a series of display boards related to planning, design, transportation, stormwater management, natural environment, hydrogeology, water and sanitary servicing. Mattamy Homes consultant team attended the three day event to allow the opportunity for the public to ask questions, provide input and comments on the technical findings and preliminary recommendations.

A total of 52 persons attended the event on one of the three days. This workshop was conducted to assist Mattamy Homes in preparing an Official Plan Amendment application for our future development lands in the Village of Richmond. The workshop was also advertised as a formal meeting (Phase 1) under the Municipal Engineers Association Class Environmental Assessment Process as the Master Servicing Study being prepared by Mattamy Homes is being planned as a Schedule C undertaking.

The storefront opened on Monday, December 8th at 4:00 p.m. There were two open house sessions held from 4:00 p.m. to 6:00 p.m. and again from 6:00 p.m. to 8:00 p.m. to present three different land use options for public review, input and comment. These sessions were conducted as an open house/workshop format to understand the public preferences related to the amount, distribution and type of land use for Mattamy Homes lands. On Tuesday, December 9th the doors opened at 1:00 p.m. to present to the public the consolidated land use plan based on the input heard from the public the previous evening. Mattamy's planning, design and technical studies were also presented through a series of display boards related to planning, design, transportation, stormwater management, natural environment, hydrogeology, water and sanitary servicing. Roundtable discussions took place with the public, city staff and stakeholders on various technical aspects including water and sanitary servicing. The Master Servicing study evaluation criteria were displayed and a roundtable discussion took place on the evaluation process, criteria and weighting. As well the alternatives for water and sanitary servicing were also presented and discussed.

On Tuesday evening, LRK presented the preferred concept plan for Mattamy lands based on the input received on Monday and earlier in the day. Based on the public response, LRK then finalized the concept plan. On Wednesday, December 10th, the open house started at 10:00 a.m. where the public could drop in and visit the design, planning and technical displays as well as see the land use plan that had resulted over the two day workshop. On Wednesday evening, the evolution of the concept plan for Mattamy's land was presented by LRK with design examples associated with different aspects of the plan. The plan was well received by the participants in attendance.

<u>February 12, 2009 Open House</u>

Mattamy Homes held a Public Open House on Thursday, February 12th from 5:00 p.m. to 8:00 p.m. at St. Phillips Catholic Church in the Village of Richmond. A total of 80 persons attended the public open house. The purpose of the open house was to present the land use concept plan for Mattamy's lands, the results of Phase 1 and 2 of the water and sanitary Master Servicing Class EA Study and the findings to date on the planning, natural environment, stormwater and transportation studies supporting Mattamy's Official Plan Amendment. The workshop was also advertised as a formal meeting (Phase 2) under the Municipal Engineers Association Class Environmental Assessment Process as the Master Servicing Study being prepared by Mattamy Homes is being planned as a Schedule C undertaking. The preferred solutions for water and sanitary were presented to the public along with the natural environment constraints, the preliminary stormwater management options and the recommended transportation solutions for the Village.

This meeting provided stormwater management and drainage information associated with the problem, existing conditions, and identification of alternatives satisfying Phase 1, discretionary consultation point of contact.

<u>September 12, 2009 Open House</u>

The City of Ottawa hosted a public open house on Saturday, September 12, 2009 for Mattamy's Official Plan Amendment application. The meeting was held at the Richmond Memorial Community Centre situated at 6095 Perth Street from 9:00 a.m. to Noon. The meeting was well attended with 103 signed-in attendees. The purpose of the meeting was to present the recommendations of the planning and technical studies supporting Mattamy's Official Plan Amendment application. The meeting started with a presentation on the concept plan. An "Ask the Experts" session was then available for participants to visit each of the display stations and ask questions to the consultants. Display materials were exhibited for the concept plan, transportation, stormwater management, natural environment, land use planning, water and wastewater servicing. An open "Question and Answer" period followed to allow additional questions to be asked to Mattamy, the consultant team and City staff. A list of the questions asked by attendees is contained in Appendix B.

<u>Village of Richmond Planning Project Steering Committee</u>

Ward Councillor Glenn Brooks established a Steering Committee to guide the development of the Community Design Plan for the Village of Richmond in concert with City Planning Staff. The Steering Committee was established in April of 2008 and meets once a month at the Richmond Library. These meetings are open to the public and all documentation is filed at the library. Mattamy Homes is a non-voting member of the Steering Committee. Updates on Mattamy's planning and technical studies are provided at these meetings.

<u>Technical Advisory Committee</u>

Mattamy Homes is the proponent of the Village of Richmond Water and Sanitary Master Servicing Study. The Master Servicing Study will identify preferred infrastructure projects that will ultimately be owned and operated by the City of Ottawa. As such, City input along with approval agencies and the public is required throughout the process. At the request of Mattamy Homes, a Technical Advisory Committee was established by the City of Ottawa to provide technical input and advice throughout the preparation of the MSS. As a Stormwater Management and Drainage Plan was also being prepared for Mattamy Homes lands, the TAC was broaden to include stormwater as well. Infrastructure Planning in the City's Infrastructure Services and Community Sustainability Department has been assigned the lead at the City. The Technical Advisory Committee (TAC) is comprised of City staff from various sectors of the City related to water, wastewater and stormwater in areas of policy, planning, approvals, operating and maintenance. As well representatives from the Ministry of Environment and Rideau Valley Conservation Authority participate as members of the TAC. Members of the Richmond Village Steering Committee and interested public were extended an invitation to attend the TAC meetings following the first TAC meeting.

Two meetings have taken place with the TAC through Phases 1 and 2 of the EA process. The first meeting took place on September 28, 2008 with City and agency staff that focused on the existing servicing setting in the Village of Richmond, the workplan for the MSS as well as to introduce the stormwater management and drainage plan study. The evaluation criteria were presented and distributed to the TAC for input and comments. Comments were later received by the TAC requesting that the Operation and Maintenance criterion weight be increased and equal to the capital cost weighting to make sure the maintenance of the system is sustainable in order to protect the City's infrastructure.

As per the MEA Class EA process, it is urged that the proponent contact the Regional Coordinator of the Environmental Assessment and Approvals Branch to discuss the approach being considered for the Master Plan. As well, it is recommended that First Nations and Aboriginal Peoples be recognized as a stakeholder and notified of the Class EA process being undertaken, early in the process. Mattamy Homes wrote to both of these parties in December 2008 notifying them of the Village of Richmond Master Servicing Study and stormwater management and drainage plan being undertaken by Mattamy Homes. The Regional Coordinator responded indicating no concerns with the Master Plan or stormwater management approach. The representative for the First Nations indicated an interest in the Master Servicing Study and Archeological information. This information was sent to the First Nation representative on October 5, 2009. At this time of writing this report, a reply has not been received.

A meeting was held on January 28, 2009 with the RVCA and City staff from Infrastructure Planning to discuss the Stormwater Management and Drainage Plan study as well as the floodplain mapping update being conducted for the Van Gaal Drain by the RVCA. The minutes of this meeting are contained in **Appendix B**.

The second Technical Advisory Committee Meeting was held on February 4, 2009 at City Hall. The focus of this meeting was to present the results of the evaluation of water and sanitary alternatives applying the evaluation criteria developed for the study. As well, the three preliminary stormwater management options were presented by David Schaeffer Engineering Limited. The advertisement for the February 12, 2008 open house was distributed to attendees encouraging their attendance at the meeting. The TAC minutes are contained in **Appendix B**.

<u>January 22, 2009 Agriculture and Rural Affairs Committee</u>

At the January 22, 2009 meeting of the Agriculture and Rural Affairs Committee, City staff presented a report on the status of the Richmond Village Community Design Plan and the processes associated with the future development lands. The report acknowledges the technical studies Mattamy Homes is leading and funding including the Village-wide Master Servicing Study. It states that the City will be using these studies to assist with completing the Richmond Village Community Design Plan that will be provided through Mattamy Homes Official Plan Amendment submission.

Technical Circulation Comments

Mattamy Homes Official Plan Amendment application was circulated for technical and public review and comment in June 2009. The various studies were posted on the City of Ottawa website, Mattamy Homes Richmond website as well hard copies of the reports were made available at the Richmond library. A number of comments were received on the various reports submitted as part of this application. Time has been spent on resolving the relevant issues with City staff, agencies and the public. Revised reports addressing the comments were submitted back to the City beginning in February 2010 for review and concurrence.

The comments received on the DSEL Stormwater Management and Drainage Plan report (March 2009) are contained in ***Appendix B***. This report now replaces the 2009 report originally submitted with the application. Subsequent meeting(s) maybe required with City and RVCA staff following their review of this report.

2.0 RELEVANT STUDIES, GUIDELINES AND POLICIES

2.1 Policies and Guidelines

The following provides a brief summary of the policy, standards and guidelines that are applicable to stormwater management, drainage and sewers that need to be considered when preparing this Stormwater Management and Drainage Plan.

Ottawa 20/20 Official Plan (OP) (Consolidated, 2007)
The Official Plan (OP) provides a framework for future growth in the City of Ottawa. The OP also serves as a basis for a wide range of municipal services, including water and sewage servicing requirements, as well as surface drainage.

Of particular relevance to the Richmond Village project are the determinations of water and sanitary service areas:

Drainage and Stormwater Management:
The Official Plan states that planning to be done on the basis of natural systems to protect and enhance natural processes and ecological functions (e.g. watershed planning, groundwater and surface water protection and green space policies).

Ottawa 20/20 Infrastructure Master Plan (IMP) (June 2003)
The IMP focuses on many aspects related to the planning of infrastructure systems. It is intended to direct the management and extension of public works systems related to

Ontario Municipal Board
Commission des affaires municipales de l'Ontario

Ontario

ISSUE DATE: June 23, 2014 **CASE NO(S).:** PL130778

Richmond Village (North) Ltd. and Richmond Village (South) Ltd. have appealed to the Ontario Municipal Board under subsection 34(11) of the *Planning Act*, R.S.O. 1990, c. P.13, as amended, from Council's neglect to enact a proposed amendment to Zoning By-law 2008-250 of the City of Ottawa to re-zone the subject properties known municipally as 6335-6350 Perth St. from DR1 (Developmental Reserve 1) to Village Residential Second Density, Village Residential Third Density, Open Space and Floodplain Overlay to permit a proposed plan of subdivision of 1000 units of mixed residential types and park space
OMB File No.: PL130778

Richmond Village (North) Ltd. and Richmond Village (South) Ltd. have to the Ontario Municipal Board under subsection 51(34) of the *Planning Act*, R.S.O. 1990, c. P.13, as amended, from the failure of the City of Ottawa to make a decision respecting a proposed plan of subdivision on lands composed of Lot 22, Concessions II, III, and IV, Village of Richmond, known municipally as 6335-6350 Perth St.
D07-16-11-0014
OMB File No.: PL130779

APPEARANCES:

Parties	**Counsel[+]/Representative**
City of Ottawa	T. Marc[+]
Richmond Village (North) Ltd. and Richmond Village (South) Ltd.	A.K. Cohen[+] J.L. Cohen[+]
Richmond Village Association Inc.	J. Shearer B. Webster

HEARING EVENT INFORMATION:

Hearing: Held in Ottawa, Ontario on May 26 and 27, 2014

MEMORANDUM OF ORAL DECISION DELIVERED BY R.G.M. MAKUCH ON MAY 27, 2014 AND ORDER OF THE BOARD

[1] Richmond Village (North) Ltd. and Richmond Village (South) Ltd. ("Applicants/Appellants") had applied for an amendment to the City's zoning by-law to change the zoning designation from "Development Reserve 1" (DR1) to "Village Residential Second Density", "Village Residential Third Density", "Open Space" and "Floodplain Overlay" to permit a proposed plan of subdivision of 1000 units of mixed residential types and park space across 53 hectares. They filed appeals with the Ontario Municipal Board ("Board") on the grounds that the City of Ottawa ("City") had not provided approvals within the statutory time limits set out in the *Planning Act* ("Act").

[2] Counsel for the City and the Applicants/Appellants advised the Board at the commencement of the hearing that they had reached an agreement as to a set of conditions of draft approval for the plan of subdivision after extensive discussions over the days leading up to the hearing. Representatives for Richmond Village Association Inc. were not involved in those discussions and asked the Board to stand down the hearing to give them an opportunity to discuss the proposed draft conditions with the City's engineers to get a better understanding of these draft conditions.

[3] Richmond Village Association Inc. has indicated, following its discussions with City representatives that it is now in agreement with the proposed draft conditions.

[4] The issues for determination by the Board related to storm water management, the need for environmental assessments, the need for a financial plan, sanitary servicing, water servicing, the layout of the subdivision, floodplain mapping, drainage as well as whether it was pre-mature to re-zone 6335-6350 Perth Street ("subject lands") at this time.

[5] The Board is satisfied based on the un-contradicted professional evidence of Pamela Sweet, the land use planning consultant for the Applicants/Appellants that the

proposal is consistent with the Provincial Policy Statement 2005 and 2014, is in conformity with the City's Official Plan including Official Plan Amendment 88 ("OPA 88") and as such represents appropriate land use planning.

[6] Ms. Sweet provided the Board with an overview of the planning evolution of the subject lands, which were included in the "Village" designation as far back as 1986. The approval of OPA 88 and the "Community Design Plan" in 2010 followed three years of collaborative planning/consultation which involved all stakeholders including the local community association.

[7] The Board is also satisfied that the criteria set out under s. 51(24) of the Act have been adequately considered and that the draft-plan as well as the conditions of approval fully address these criteria.

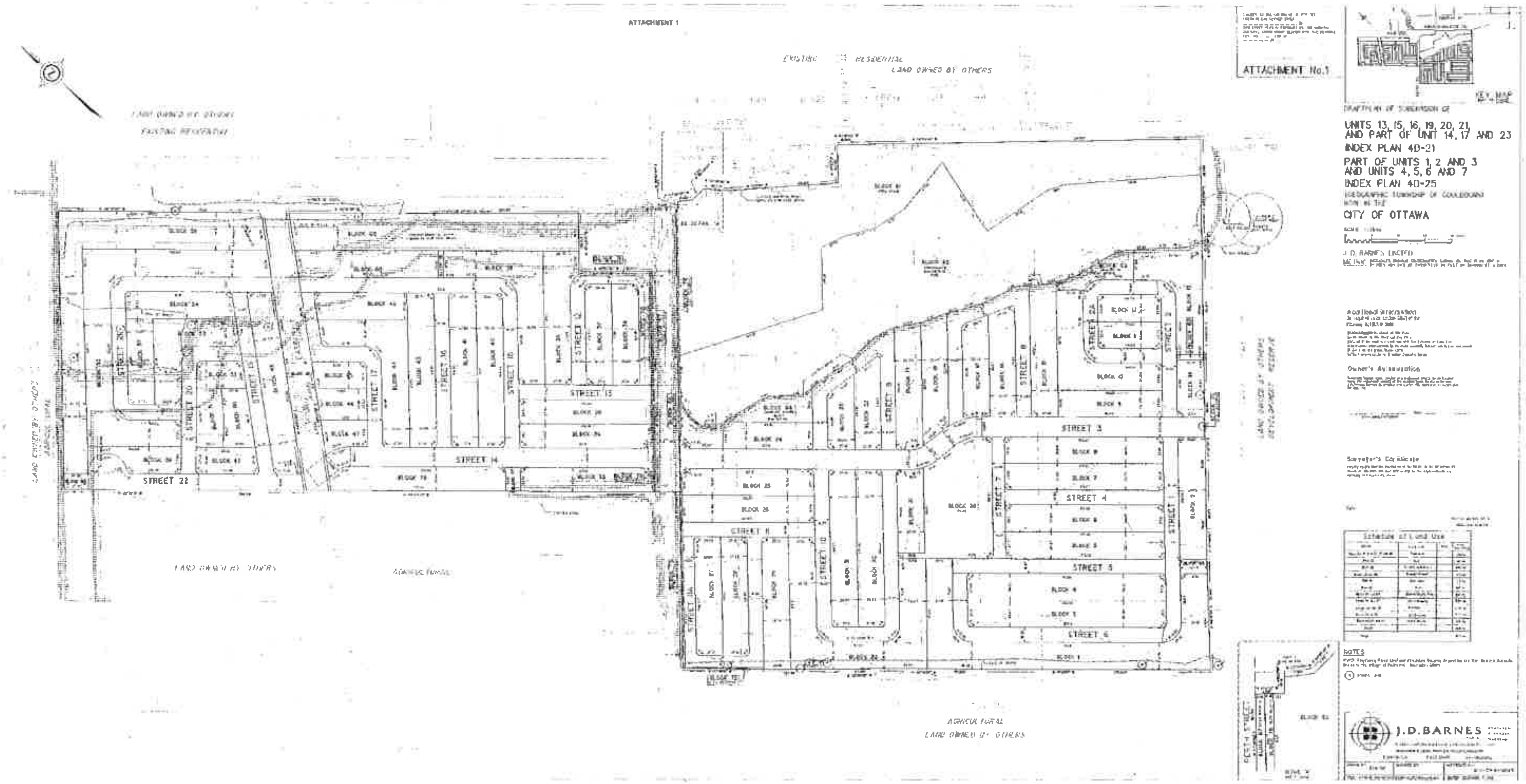
ORDER

[8] Accordingly, the appeal pursuant to s. 51(34) of the Act is allowed and Attachment 1 (Exhibit 3, Tab 18- Page 1)is hereby granted draft approval subject to the conditions set out in Attachment 2 (Exhibit 4, Tab 6). Furthermore, the appeal pursuant to s. 34(11) is also allowed and the zoning by-law attached as Attachment 3 (Exhibit 4, Tab 7) is hereby approved.

[9] The Board will retain jurisdiction with respect to the final approval of the plan of subdivision.

"R.G.M. Makuch"

R.G.M. MAKUCH
MEMBER


ATTACHMENT 1
ATTACHMENT No.1
EXISTING RESIDENTIAL
LAND OWNED BY OTHERS
LAND OWNED BY OTHERS
EXISTING RESIDENTIAL
LAND OWNED BY OTHERS
AGRICULTURAL
AGRICULTURAL
LAND OWNED BY OTHERS
LAND OWNED BY OTHERS
DEVELOPMENT RESERVE
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GEOGRAPHIC TOWNSHIP OF GOULBOURN
NOW IN THE
CITY OF OTTAWA
J.D. BARNES LIMITED
Additional Information
Owner's Authorization
Surveyor's Certificate
Schedule of Land Use
NOTES
KEY MAP
J.D.BARNES

ATTACHMENT 2

May 27, 2014
File: D07-16-11-0014

CONDITIONS
OF DRAFT APPROVAL
Richmond Village North and South
6335 & 6350 Perth Street

DRAFT APPROVED DD/MM/YYYY
REVISED DD/MM/YYYY
DRAFT APPROVAL EXTENDED FROM DD/MM/YYYY TO DD/MM/YYYY

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The City of Ottawa's conditions applying to the approval of the final plan for registration of Richmond Village North and South Subdivision (File No. D07-16-11-0014) are as follows:

This approval applies to the draft plan certified by ______________________, Ontario Land Surveyor, dated ___December 2012(Need revised plan), showing____________________ development.

1.		The Owner agrees, by entering into a Subdivision Agreement, to satisfy all terms, conditions and obligations, financial and otherwise, of the City of Ottawa, at the Owner's sole expense, all to the satisfaction of the General Manager, Planning and Growth Management.	**Clearing Agency**
		General	
2.	G1	Prior to the issuance of a Commence Work Notification, the Owner shall obtain such permits as may be required from Municipal or Provincial authorities and shall file copies thereof with the General Manager, Planning and Growth Management.	
3.	G2	Prior to commencing construction, the Owner shall enter into a subdivision agreement with the City. The subdivision agreement shall, among other matters, require that the Owner post securities in a format approved by the City Solicitor, in an amount of 100% of the estimated cost of all works, save and except non-municipal buildings. The aforementioned security for site works shall be for works on both private and public property and shall include, but not be limited to, lot grading and drainage, landscaping and driveways, roads and road works, road drainage, underground infrastructure and services (storm, sanitary, watermains), streetlights, stormwater management works. The amount secured by the City shall be determined by the General Manager, Planning and Growth Management, based on current City tender costs, which costs shall be reviewed and adjusted annually. Engineering, Inspection and Review fees will be collected based on the estimated cost of the works as noted herein and in accordance with the City's Planning Fees By-laws, as amended.	**OTTAWA Planning**
4.	G4	The Owner acknowledges and agrees that any residential blocks for street-oriented dwelling units on the final Plan shall be configured to ensure that there will generally be not more than 25 units per block.	**OTTAWA Planning**

5.	G5	The Owner acknowledges and agrees that any person who, prior to the draft plan approval, entered into a purchase and sale agreement with respect to lots or blocks created by this Subdivision, shall be permitted to withdraw from such agreement without penalty and with full refund of any deposit paid, up until the acknowledgment noted above has been executed. The Owner shall provide to the General Manager, Planning and Growth Management an acknowledgement from those purchasers who signed a purchase and sale agreement before the Plan was draft approved, that the Plan had not received draft approval by the City. The Owner agrees that the purchase and sale agreements signed prior to draft approval shall be amended to contain a clause to notify purchasers of this fact, and to include any special warning clauses, such as but not limited to Noise Warnings and easements.	**OTTAWA Legal** **OTTAWA Legal**
6.	G7	The Owner, or his agents, shall not commence or permit the commencement of any site related works until such time as a pre-construction meeting has been held with Planning and Growth Management staff and until the City issues a Commence Work Notification.	**OTTAWA Planning**
7.		The Owner acknowledges and agrees that prior to final approval of the lands associated with the HydroOne Corridor Crossings, they shall obtain ownership for the City of the road crossings for Streets 14 and 15 through the HydroOne Corridor as well as the HydroOne owned component of the realigned corridor for the Van Gaal Drain.	**OTTAWA Planning HONI/ORCI/Hydro One**
8.		The Owner acknowledges and agrees prior to the earlier of early servicing, lifting of the holding zone, final approval or commence work for the lands north of Perth Street that Owner shall obtain all approvals and complete all works necessary to remove the lands north of Perth Street from the interim flood plain subject to the approval of the Rideau Valley Conservation Authority, City's Drainage Supervisor, General Manager Planning and Growth Management.	**OTTAWA Planning CA**
9.		The Owner acknowledges and agrees that any permitted front yard projections shall not have a full foundation in order to facilitate street tree planting.	**OTTAWA Planning**
10.		The Owner shall acknowledge and agree that the agricultural tile drains encountered during construction shall be decommissioned/removed.	**OTTAWA Planning**

11. The Owner agrees that the underside of all footings shall be located at or above the elevation of the spring line of the storm sewer installed in the adjacent roadway. Owner agrees that a professional engineer or surveyor shall certify to the City that the underside of all footings have been installed at or above the level of the spring line. **OTTAWA Planning ISD**

Following the issuance of building permits, for the first phase of the first subdivision, the owner shall install monitoring wells at locations satisfactory to the City in order to verify that the sustained ground water level is at or lower than the location of the underside of footings. Reports on the levels in the monitoring wells shall be to the satisfaction of the General Manager, Planning and Growth Management.

If required based upon the monitored results, the Owner's professional engineers shall provide recommendations to the Owner and the City for any revisions to the approved Master Drainage Plan and any required reports.

12. The Owner agrees that the total number of units to be constructed within this plan shall be approximately 750 dwelling units. **OTTAWA Planning**

12.1 The Owner acknowledges that the Community Design Plan has provided guidance which responds to Village design.

Zoning

13. Z1 The Owner agrees that prior to registration of the Plan of Subdivision, the Owner shall ensure that the proposed Plan of Subdivision shall conform with a Zoning By-law approved under the requirements of the *Planning Act*, with all possibility of appeal to the Ontario Municipal Board exhausted. **OTTAWA Planning**

14. Z2 The Owner undertakes and agrees that prior to the registration of the Plan of Subdivision, the Owner shall deliver to the City a certificate executed by an Ontario Land Surveyor showing that the area and frontage of all lots and blocks within the Subdivision are in accordance with the applicable Zoning By-law. **OTTAWA Planning**

15. The Owner agrees that the minimum front yard setback for all residential zones within the subdivision shall be no less than 4.0 metres on rights of way with a 16.5 metre width or less. **OTTAWA Planning**

16. The Owner acknowledges and agrees that a holding zone will be placed on the proposed subdivision lands as follows: **OTTAWA Planning**

a) To require that prior to proceeding with registration of any phase of development the Owner shall demonstrate a program for both servicing capacity for sanitary and stormwater and water for the phase in question;
b) That the works required to remove the lands north of Perth Street from the interim flood plain are completed ; and
c) That a detailed grading and drainage plan demonstrating the underside of footings to be above the groundwater pursuant to Condition 11

17. Prior to the registration of each plan, capacity for stormwater and water must be demonstrated to the satisfaction of the General Manager, Planning and Growth Management.

A construction traffic management plan will be provided for each registration.

Individual Traffic Impact Assessments (TIA) shall be provided to discuss the transportation needs for each phase. They shall identify required road works and when modifications are warranted. Design shall be 80% complete when seeking a Road Modification Approval and approval for a construction traffic management plan for each phase.

18. The Owner acknowledges and agrees that any proposed changes to the proposed plans for subdivision registration from the draft approved plan may necessitate a zoning by-law amendment to reflect those resultant changes. This shall be at no cost to the City **OTTAWA Planning**

Roadway Modifications

19. RM1 The Owner shall pay all expenses associated with all works related to roadway modifications, and shall provide financial security in the amount of 100% of the cost of implementing the required works. **OTTAWA Planning**

20. Prior to lifting the reserves between phases the owner shall provide to the City an updated Traffic study which will identify any required roadway modifications. Should modifications be required they shall be submitted at 80% design complete as part of any application to lift reserves. Prior to registration of the reserve the RMA must have been entered into. **OTTAWA Planning**

Highways/Roads

21.	HR1	The Owner shall retain a licensed or registered professional with expertise in the field of transportation planning and/or traffic operations to prepare a Transportation Impact Assessment. The study shall comply with the City of Ottawa's Transportation Impact Assessment Guidelines. The Owner agrees to revise the Draft Plan in accordance with the recommendations of the study, if required, to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Plannin**
22.	HR2	The Owner shall provide for temporary turn-arounds for all streets terminating at the edge of any phase of development, prior to registration of the Plan, to the satisfaction of the General Manager, Planning and Growth Management. The Owner agrees that it will convey to the City at no cost any temporary easements that may be required in order to establish the temporary turn-arounds. Turning circle(s) may include a 0.3 metre reserve along the perimeter of any temporary turning circle(s), to the satisfaction of the General Manager, Planning and Growth Management. For any portion of the temporary turn-around easements that do not form part of the permanent road allowance, the easements shall be released at the expense of the Owner when the easements are no longer required by the City.	**OTTAWA Planning**
23.	HR3	The Owner shall convey to the City, at no cost to the City, an unencumbered road widening along Perth Street adjacent to the subdivision lands, in accordance with the Official Plan. The required widening shall be illustrated on the Draft M-Plan and Final Plan of Subdivision as a dimension from the existing centerline of the public highway to the required widened limit. If it is determined that a widening is not required, the Owner's Surveyor shall illustrate the distance from the existing centerline of the Public Highway to the existing road limit on the Draft M-Plan and the Final Plan of Subdivision. All of which will be to the satisfaction of the General Manager, Planning and Growth Management and the City Surveyor.	**OTTAWA Planning City Surveyo**
24.	HR4	Any dead ends and/or open spaces of road allowances created by this plan of subdivision shall be terminated in 0.3 metre reserves. This may include a 0.3 metre reserve along any temporary turning circle(s). The Owner may place 0.3 metre reserves on the following locations: • *North end of Street 22* • *West side of Street 22* • *At Block 77 and Block 69* • Block 76	**OTTAWA Planning and Legal**
25.	HR5	The Owner shall provide the following site triangles on the final plan: - *At all intersections*	**OTTAWA Planning and Legal**

26.	HR6	A 0.3 m reserve adjacent to the widened limit of Perth Street shall be indicated on the plan submitted for registration and conveyed at no cost to the City.	**OTTAWA Planning and Legal**
27.	HR8	The Owner agrees to provide a construction traffic management plan for the subdivision prior to the earlier of registration of the Agreement or early servicing. Such plan shall be to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
28.		The Owner agrees that a construction traffic management plan shall be required as a condition of each subsequent phase of the subdivision developing.	
29.	HR9	The Owner acknowledges that should the plan be registered in phases, the first phase of registration shall include: • Communal well design, construction and operation to the satisfaction of the General Manager, Planning and Growth Management • Storage and treatment capacity for the water sufficient for that phase to the satisfaction of the General Manager, Planning and Growth Management. • water system, design and, construction by the City sufficient for that phase • Stormwater management sufficient for that phase • Sanitary system upgrades sufficient for that phase	**OTTAWA Planning**
30.	HR10	All streets shall be named to the satisfaction of the Director of Building Code Services and in accordance with the Municipal Addressing By-law or the Private Roadways By-law as applicable.	**OTTAWA Planning BCS**
31.	HR11	The design of all roads and intersections shall be to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
32.	HR12	Where land has been dedicated for road widening purposes as part of the planning process, where the Owner receives no financial compensation or in-kind consideration in exchange for the widening, and where the City deems that the land is no longer required for that purpose, the lands may be conveyed back to the original Owner, or its successor in title, for $1.00. The Owner, or its successor in title, will be responsible for all costs to complete said conveyance, including an administrative fee.	**OTTAWA Planning**
33.	HR17	The Owner acknowledges that the construction of buildings may be restricted on certain lots and/or blocks until such time as Road connections are made so that snowplow turning and garbage collection can be implemented to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
34.		Prior to final approval the Owner shall ensure that the road widening along Perth Street and site triangles at the intersection of Street 3 and 14 are adequate to accommodate the future round-about.	

35. The Owner acknowledges and agrees that street 22 shall be constructed within the 18 metres right of way shown to a 22 metre standard cross section, save and except for the western boulevard which shall be finished to an acceptable interim standard and shall be the responsibility of the adjacent owner to complete as part of their development. **OTTAWA Plannin**

Public Transit

36. **PT1** The Owner shall design and construct, at its expense Streets number 3, 14, 22 and the connection through the HydroOne corridor between Streets 14 and 22, which have been identified as transit service routes, to Transportation Association of Canada standards, including right-of-way width, horizontal and vertical geometry based upon a 22 metre right-of-way. The Owner shall design and construct, at its expense transit passenger standing areas and shelter pads, to the specifications of the General Manager, Planning and Growth Management. **OTTAWA Transit Services and Planning**

37. **PT2** The Owner shall ensure that the staging of the Subdivision, including the construction of dwellings, roadways, walkways, and paved passenger standing areas, or shelter pads, shall occur in a sequence that permits the operation of an efficient, high quality transit service at all stages of development. **OTTAWA Transit Services**

38. **PT3** The Owner shall orient dwellings and vehicular accesses in the vicinity of bus stops in such a manner as to avoid traffic conflicts and visual intrusion and to submit plans to Planning and Growth Management for approval indicating the orientation of all dwellings and private accesses in the vicinity of all bus stop locations. **OTTAWA Transit Service. and Planning**

39. **PT4** The Owner shall inform all prospective purchasers, through a clause in all agreements of Purchase and Sale and indicate on all plans used for marketing purposes, those streets identified for potential transit services, the location of the bus stops, paved passenger standing areas, or shelters pads and shelters, any of which may be located in front of or adjacent to the purchaser's lot at any time. **OTTAWA Transit Services**

Geotechnical

40. **GT1** The Owner covenants and agrees that the following clause shall be incorporated into all agreements of purchase and sale for all Blocks, and registered separately against the title: **OTTAWA Planning**

"The Owner acknowledges that special soils conditions exist on this lot which will require:
(a) a geotechnical engineer licensed in the Province of Ontario to approve any proposal or design for a swimming pool installation on this lot prior to applying for a pool enclosure permit or installing the pool; and
(b) the Owner to submit a copy of the geotechnical engineer's report to the General Manager, Planning and Growth Management at the time of the application for the pool enclosure permit.

The Owner also acknowledges that said engineer will be required to certify that the construction has been completed in accordance with his/her recommendation and that a copy of the certification or report will be submitted to the General Manager, Planning and Growth Management."

41. **GT3** The Owner shall submit a geotechnical report prepared in accordance with the City's Approved Geotechnical Investigation and Slope Stability Guidelines for Development Applications by a geotechnical Engineer, licensed in the Province of Ontario, containing detailed information on applicable geotechnical matters and recommendations which matters may include, where applicable, but are not limited to: **OTTAWA Planning**

i. existing sub-surface soils, groundwater conditions;
ii. slope stability and erosion protection, in addition to any building construction requirements adjacent to unstable slopes;
iii. design and construction of underground services to the building, including differential settlement near any buildings or structures;
iv. design and construction of the shared water services and sewer services below the stacked units and confirmation that the soils will support the pipes and building, and that any settlement will not adversely effect the pipes;
v. design and construction of roadways, fire routes and parking lots;
vi. design and construction of retaining walls and/or slope protection;
vii. design and construction of engineered fill;
viii. design and construction of building foundations;
ix. site dewatering;
xii. tree planting;
xiii design and construction of swimming pools; and
xvi. any restrictions to landscaping, in particular type and size of trees and the proximity of these to structures/buildings; and
xvii. design and construction of park blocks.

42. The Owner acknowledges and agrees that as part of any submission for engineering review for early servicing or final approval an updated Geotechnical Report shall be required to be completed to the satisfaction of the General Manager, Planning and Growth Management. Such report shall include: **OTTAWA Plannin**

1) Additional subgrade soil testing in the development area with at least three samples taken north of Perth Street and two south of Perth Street and shall include:
    - Provide five soil boring locations collecting samples of soils at depths of 0.5, 1.0, 1.5, 2.0 metres.
    - Provide Atterberg Limits (per ASTM D4318) reporting Liquid Limit, Plastic Limit and Water content;
    - Shrinkage Limit (per ASTM D4943 or acceptable standard to the General Manager, Planning and Growth Management) reporting Shrinkage Ratio and Shrinkage Limit; and
    - Consolidation Testing (D2435) of soils at the natural water content of the soils, test conditions to be confirmed with City staff.
2) Recommendations based on the detailed soils tests for construction, design and maintenance of:
    - Buildings, roads, infrastructure, landscaping especially for tree planting;
    - Any required monitoring.

Sidewalks, Walkways, Fencing, and Noise Barriers

43. S2 The Owner agrees to design and construct, at no cost to the City, sidewalks in accordance with City Specifications in the following locations: **OTTAWA Planning**

- Both sides Streets 3, 14 and through the HydroOne owned lands
- South side Streets 8, 9, 10 (from Block 20 to Street 3), 16
- East side of Streets 5, 22 and Block 69
- Both Sides of Perth Street that abut this plan to connect with the existing sidewalk on the south side approximately 30 metres to the east and on the north side approximately 95 metres to the east.

44.	S3	The Owner agrees to design and construct, at no cost to the City, fully accessible walkways and related Works through the length of the public lands identified on the Plan in accordance with City Specifications in the following locations: • Blocks 49, 61, 62, 63, 64, 65, 68, • Through Block 20 connecting Street 5 sidewalk to Street 10 sidewalk • Should the Owner acquire the HydroOne owned block, a connecting walkway to Block 60 and crossing the re-aligned Van Gaal Drain, subject to the concurrence of the RVCA and being permitted through the Drainage Act process • Connection through to the open portion of Martin Street • A walkway through Blocks 59 and 60 subject to the concurrence of the RVCA and being permitted through the Drainage Act process • A connection from the walkway in Block 60 through to Street 12 subject to the concurrence of the RVCA and being permitted through the Drainage Act process unless a permanent connection is obtained through to Perth Street.	**OTTAWA Planning**
45.	S3.1	The Owner agrees to connect all new sidewalks/pathways to the existing sidewalk/pathway(s) located at Perth Street to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
46.	S4	The Owner agrees to design and construct, at no cost to the City, 1.8 metre black vinyl-coated chain link fences in accordance with the Fence By-law and all other City Specifications, at the following locations: • Block 68 • Block 20 abutting Blocks 1, 21 and 30 • Blocks abutting residential Blocks 59, 60, 62, 64.	**OTTAWA Planning**
47.	S4.1	The Owner agrees that any vinyl-coated chain link fence required to be installed under this Agreement, shall be located a minimum of 0.15 metres inside the property line of the private property.	**OTTAWA Planning**
48.	S6	The Owner agrees to design and erect, at no cost to the City, noise attenuation barriers in accordance with City Specifications at the following locations: • As required pursuant to an approved Noise Study.	**OTTAWA Planning**
49.	S6.1	The Owner agrees that any noise attenuation barrier required to be installed under this Agreement, shall be located a minimum of 0.30 metres inside the property line of the private property, and the location of the fence shall be verified by an Ontario Land Surveyor, prior to the release of securities for the noise attenuation barrier.	**OTTAWA Planning**

50.	S7	The Owner agrees to design and erect, at no cost to the City, 1.8 metre 9-gauge galvanized chain link fence in accordance with City Specifications at the following locations: • Block 62 limiting access to any control structures associated with the Stormwater Management Pond	**OTTAWA Planning**
51.	S7.1	The Owner agrees that any 9-gauge galvanized chain link fence required to be installed under this Agreement, shall be located a minimum of 0.15 metres inside the property line of the private property.	**OTTAWA Planning**
52.	S8	The Owner shall insert a clause in each agreement of purchase and sale and Deed for lands which fences have been constructed stating that: "Purchasers are advised that they must maintain all fences in good repair, including those as constructed by Richmond Village (North) and (South) along the boundary of this land, to the satisfaction of the General Manager, Planning and Growth management. The Purchaser agrees to include this clause in any future purchase and sale agreements".	**OTTAWA Planning**
53.		The Owner agrees to design and erect, at no cost to the City, a chain link fence in accordance to City Specifications around the Richmond Municipal Well parcel.	**Ottawa Planning ESD**

Landscaping/Streetscaping

54.		The Owner agrees that for all single detached and semi-detached lots, a minimum of 1 tree per interior lot and 2 trees per exterior side yard lots shall be provided on the Landscape Plan to the satisfaction of the General Manager, Planning and Growth Management. All blocks containing street townhouses or other multiple unit dwellings shall have at least half the number of street trees in relation to the total number units in the block. Said streetscape or landscape plan shall also include trees at a 6-8 metre on-centre separation distance the full extent of the road right-of-way abutting the future park block(s) and other open space areas.	**OTTAWA Planning**
55.	LS2	The Owner agrees to have a landscape plan for the draft plan of subdivision prepared by a Landscape Architect. The landscape plan shall include detailed planting location and species list, pathway width and materials, access points, fencing requirements and fencing materials and shall be approved by the General Manager, Planning and Growth Management prior to subdivision registration.	**OTTAWA Planning and Forestry Services**
56.		The Owner acknowledges that only low water consuming trees, ie. ornamental pear, Japanese lilac, crabapple cultivar, service berry cultivar, as per City of Ottawa guidelines, are acceptable as a result of sensitive marine clay soils on site. The tree species will be re-evaluated by the City following the provision of additional information and monitoring of the subdivision to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning and Forestry Services**
57.	LS3	The Owner agrees to implement the approved landscape plan to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning and Forestry Services**
58.	LS4	The Owner acknowledges having commissioned a tree conservation report prepared by an arborist, forester, landscape architect, or other qualified professional, which will be coordinated with the grading and drainage plan. The tree conservation report identified the vegetation communities and specimens that are to be preserved, to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning and Forestry Services**
59.	LS5	The Owner agrees to implement the approved tree conservation report measures, prepared in accordance with City Specifications and Standards following registration of the plan, at the cost of the Owner. The Owner shall provide the General Manager, Planning and Growth Management with an arborist's, forester's, landscape architect's, or other qualified professional's certification that the plan has been fully implemented.	**OTTAWA Planning and Forestry Services**

60.	LS6	The Owner shall implement the protection measures outlined in the tree conservation report, to ensure preservation of the trees identified for protection, to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Plannin and Forestry Services**
61.		The Owner acknowledges and agrees that it shall implement the landscaping and naturalization of the realigned Van Gaal Drain north of Perth Street pursuant to the approved Drainage Engineer's Report and the permissions of the RVCA under O.Reg 174/06.	**OTTAWA Planning RVCA**
62.		The Owner shall design the sediment storage areas on Block 63 and 64 to lie outside of the flood plain and to allow for sediment storage, required fencing, landscaping and buffering of the storage and related activities from adjacent paths and residential units.	**OTTAWA Planning**
63.		The Owner shall as part of the Landscape and Streetscape Plan and Tree Conservation Report, make reasonable efforts in accordance with the draft approved plan to preserve: the woodlot and significant trees at the north of the site; the hedge row along east side of property to south of Perth Street, and; the hedge row along west property line abutting realigned Van Gaal Drain north of Perth Street. Tree preservation details shall be demonstrated on the grading and drainage plan.	**OTTAWA Planning**

Gateway Features

64.	GF1	Community Features: The Owner acknowledges and agrees that any proposed Community Gateway Feature(s) located at Perth Street shall be designed, constructed and certified by a qualified professional and shall be in accordance with the City's Design Guidelines for Development Application Gateway Features, applicable by-laws and policies as may be amended from time to time. The Community Gateway Feature shall be subject to the approval of the General Manager, Planning and Growth Management. The Owner shall deposit security in the amount to be determined by the General Manager, Planning and Growth Management prior to registration of the Plan to meet the on-going maintenance obligations of the Feature by the Owner for a one-year period after the construction of the Feature. The amount of security shall be determined by the General Manager of Planning and Growth Management and will not be reduced or released until the expiration of the one-year period and certification by a qualified professional that the Feature is constructed in accordance with the Guidelines and approved plans and is in a good state of repair. The Owner shall file copies of the aforementioned certification with the General Manager, Planning and Growth Management. During the warranty period the Owner shall be solely responsible for the on-going upkeep and maintenance of the Community Gateway Feature to the satisfaction of the General Manager, Planning and Growth Management. The Owner shall be required to make a financial contribution to the "Maintenance Fund" as determined by the General Manager, Planning and Growth Management prior to registration of the Plan in accordance with the City's Design Guidelines for Development Application Gateway Features.	**OTTAWA Planning**
		<u>**Parks**</u>	
65.	P1	The Owner covenants and agrees that Block 20 will be conveyed to the City, at no cost, as dedicated parkland. The size and configuration of Block 20 on the Final Plan shall be to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
66.		In accordance with the *Planning Act*, the City of Ottawa Parkland Dedication By-law and the Village of Richmond Community Design Plan, the Owner shall convey Block 20 to the City for parkland purposes.	**OTTAWA Planning**

67.	P4	All Owner obligations associated with the Park Block must be completed by the time that Street 3 is constructed along the frontage of Block 20 to the satisfaction of the General Manager of Planning and Growth Management or as otherwise agreed between the Owner and the City.	**OTTAWA Planning**
68.	P5	The Owner acknowledges and agrees that no stormwater management facilities, encumbrances such as retaining walls, utility lines or easements of any kind shall be located on dedicated park blocks without the prior written approval of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
69.	P6	The Owner acknowledges and agrees that any encumbrances which are not solely for the benefit of the park such as retaining walls, utility lines or easements of any kind on lands, or portion thereof encumbering the design and function of future Park Block 20 will not form part of the required *Planning Act* parkland dedication requirements at the discretion of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
70.	P7	The Owner acknowledges and agrees, at his expense, to erect on Park Block 20, at a location(s) selected by the General Manager, Planning and Growth Management, a professionally painted sign. Sign material, size and installation and construction details shall be to the satisfaction of the General Manager, Planning and Growth Management. This sign shall clearly read, in English and in French: Future Parkland No Dumping No Removal Soil or Vegetation No Storage of Materials The Owner further agrees to maintain the sign (including graffiti removal) and that such sign shall be removed only with the approval of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
71.	P8	The Owner shall have a design approved by the City for the construction of the Park, including the timing for such construction. The construction of the Park shall be in accordance with the process for local park construction currently being developed by the City through its development charge review process.	**OTTAWA Planning**
72.	P9	The Owner shall grade areas of parkland where necessary, to the satisfaction of the General Manager, Planning and Growth Management, so as to provide a uniform surface, free of debris, necessary to establish a safe clean and maintainable surface. Park Blocks shall be graded in accordance with the approved Grading Plan for the plan of subdivision. No storage of building materials, including granular or topsoil, will be permitted on the Park Block, unless approved by the City.	**OTTAWA Planning**
73.	P10	All works shall be shown on the approved park drawings and shall be subject to the approval of the General Manager, Planning and Growth Management.	**OTTAV Planning**

74.	P13	The Owner shall install fencing of uniform appearance and quality, with a minimum height of five feet (5') (1.5m) along the common boundary of all residential lots and blocks and ravine lands, and hazard lands which abut public walkways and Park Blocks. Fences shall be installed 0.15m on the private side of the common property line, and the location of the fence shall be verified by an Ontario Land Surveyor. Fence materials will be of commercial grade and consist of 6 gauge black vinyl coated chain link material and black powder coated schedule 40 pipe rails and posts or an approved alternative.	**OTTAWA Planning**
75.		No access from private property to public property will be allowed without the prior written approval of the General Manager, Planning and Growth Management. The Owner shall place the following clause in each Agreement of Purchase and Sale and in Deeds for all Lots and Blocks: "The Transferee for himself, his heirs, executors, administers, successors and assigns acknowledges being advised that gates accessing public property are not permitted in the fences without the express written permission of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
76.	P16	The Owner shall include a clause in each Agreement of Purchase and Sale and in Deeds for all Lots and Blocks which shall provide notification to all purchasers of lands within the Subdivision that parkland within this subdivision and/or already existing in the vicinity of the subdivision may have: a) active hard surface and soft surface recreational facilities b) active lighted sports fields c) recreation and leisure facilities d) other potential public buildings/facilities.	**OTTAWA Planning**

77. Unless otherwise specified or approved on an alternate owner's engineering servicing plan, the Owner shall provide the following services and utilities to the Park Block: **OTTAWA Plannin**

a) A 300mm diameter storm sewer and CB/MH at 2m inside the park property line.

b) 50mm diameter water line at 2m inside the park property line.

c) A 120/240 volt, 200 ampere single phase hydro service at 2m inside the park property line. The Owner is responsible for making all arrangements and coordinating the connection of the new hydro service, including costs and inspections, with the respective electrical agencies.

d) 150mm diameter sanitary sewer and MH at 2m inside the park property line.

All works shall be subject to the approval of the General Manager, Planning and Growth Management.

78. At the earlier of the first registration after the City being advised that a Land Owners Agreement is in place (and for all subsequent registrations) or immediately prior to the registration of the final plan the Owner shall provide to the General Manager, Planning and Growth Management with confirmation from the Land Owners' Trustee, that the Owner is in good standing with the owners' Master Parkland Agreement for the Western Development Lands, relating to under and over dedication of parkland and requirements for payment of cash-in-lieu payments such that the payments are balanced amongst the affected Owners. **OTTAWA Planning**

Environmental Constraints

79. **EC2** The Owner shall have an Integrated Environmental Review Statement prepared, in accordance with the policies of the Official Plan, to the satisfaction of the General Manager, Planning and Growth Management. **OTTAWA Planning CA**

80. **EC3** The Owner agrees to establish a "No Touch/No Development" setback of the Van Gaal Drain watercourse as shown by Blocks 59 and 60 and as has been conceptually approved by the RVCA, which shall be 60 metres in total and subject to change, while maintaining the same principles as in Blocks 59 and 60, if required by an inability to get landowner consent for the realignment. The final approved plan of subdivision shall clearly show this setback. The 60 m corridor, if realigned, shall be subject to the approval of the RVCA and the General Manager, Planning and Growth Management. **OTTAWA Planning CA**

81.	EC4	The Owner acknowledges and agrees that the construction of the subdivision shall be in accordance with the recommendation of the approved Environmental Management Plan for the Village, the Environmental Impact Statement, where one has been required, and Tree Conservation Report.	**OTTAWA Planning CA**
82.	EC5	The Owner shall convey, at no cost to the City, the following lands (Blocks 59, 60 and the HydroOne Corridor connecting Blocks 59 and 60). Final configuration of the Blocks shall be in accordance with the Rideau Valley Conservation Authority. These lands shall not be credited towards determining parkland dedication requirements.	**OTTAWA Planning CA**
83.	EC6	The Owner shall erect protective fencing along the setback perimeter of the Van Gaal Drain prior to any site preparation works within the Subdivision to ensure no disturbance of the watercourse during construction to the satisfaction of the Conservation Authority.	**OTTAWA Planning. CA**
84.	EC7	The Owner shall prepare, to the satisfaction of the General Manager, Planning and Growth Management, a Conservation Handbook describing the natural attributes of the subdivision and the importance of good stewardship practices to ensure the long-term health and sustainability of the wetlands and woodlots. The Handbook shall be distributed to all purchasers with the Agreement of Purchase and Sale.	**OTTAWA Planning. CA**
85.	EC8	The Owner shall prepare a Homeowners' Awareness Package highlighting the advantages and responsibilities of a home or landowner living in the natural area. This package is to be included in all Agreements of Purchase and Sale.	**OTTAWA Planning CA**
86.		The Owner agrees to prepare an updated Environmental Impact Assessment, including a tree conservation report, after three years of subdivision registration in support of the next phase developing.	**OTTAWA Planning**
87.		The Owner shall be required to obtain all permissions under the Drainage Act prior to commencing any works on any municipal drain.	**OTTAWA Drainage**
88.		The Owner agrees to contact the Forester to arrange a site visit to inspect the tree protection measures prior to the commencement of any tree removal and/ or site works.	**OTTAWA Planning**
89.		Prior to registration the Owner shall provide a plan prepared by an Ontario Land Surveyor demonstrating the proposed development south of Perth Street is in compliance with the required water course setbacks as per the Official Plan and the Community Design Plan.	**OTTAWA Planning CA**

90. Prior to early servicing or final approval, whichever comes first, the Owner shall provide to the satisfaction of the RVCA, a Sediment and Erosion Control Plan, including the location of the bright orange construction fencing and sediment fences a minimum of 30 metres from the tributary of the Jock River, except where permitted work is proposed and approved by a permit under O.Reg. 174/06 within the setback. **OTTAWA Plannin CA**

91. The Owner acknowledges and agrees that an average 30 metre setback with respect to the Van Gaal Drain, as has been conceptually approved by the RVCA (wherever its location is established at any point in time) and the tributary to the Jock River south of Perth Street shall be fenced with bright orange construction fencing to identify the setback area. Protection for the watercourse setbacks shall be in place and maintained throughout the development of the subdivision lands. **OTTAWA Planning CA**

92. The Owner acknowledges and agrees to undertake any works or work programs as required by any permits issued by the RVCA under O.Reg. 174/06 for protection of the watercourses, aquatic habitat and associated vegetation. This may include planting vegetation, aquatic species removal/ relocation and monitoring programs. **OTTAWA Planning CA**

93. The Owner acknowledges and agrees that prior to registration of the phase following the completion of the construction of stormwater Pond 1, that an 'as built' elevation survey of the completed grades in the regulated floodplain area shall be submitted to the RVCA for review and acceptance in accordance with any issued permits under O.Reg. 174/06. This information shall be accompanied by documentation that the completed works have resulted in 'no net fill' placement in the floodplain to the satisfaction of the RVCA. **OTTAWA Planning CA**

94. The Owner acknowledges and agrees that approvals under Section 28 of the *Conservation Authorities Act*, Ontario Regulation 174/06, as administered by the Rideau Valley Conservation Authority are required for but not limited to the following works: **OTTAWA Planning CA**

- Construction of Pond 1;
- Construction of outlet for Pond 1 into the tributary of the Jock River;
- Construction of the base flow augmentation outlet into the tributary of the Jock River;
- Enlargement of the culvert under Fortune Street;
- Construction of any pathways, service roads, bridges within the areas regulated under O.Reg. 174/06;
- Any alterations, including erosion protection works on watercourses such as the tributary to the Jock River;
- Any works resulting in the temporary or permanent placing, dumping or removal of any materials, originating on the site or elsewhere, any construction reconstruction erection or placing of a building or structure of any kind, with the regulated areas and any works resulting in the alteration to the beds or banks of an existing river, creek, stream or watercourse.

Archaeology

95. The Owner shall adhere to the procedures of the "Contingency Plan for the Protection of Archaeological Resources in Urgent Situations" as approved by the Ministry of Citizenship, Culture and Recreation in the Archaeological Resource Potential Mapping Study of the Director, Planning and Infrastructure Approvals.

Stormwater Management

96.	SW1	The Owner shall provide to the General Manager, Planning and Growth Management any and all stormwater reports not addressed by this draft approval that may be required by the City for approval prior to the commencement of any works in any phase of the Plan of Subdivision. Such reports shall be in accordance with any watershed or subwatershed studies, conceptual stormwater reports, City or Provincial standards, specifications and guidelines. The reports shall include, but not be limited to, the provision of erosion and sedimentation control measures, implementation or phasing requirements of interim or permanent measures, and all stormwater monitoring and testing requirements. All reports shall be to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning and CA**
97.	SW2	(a) Prior to the commencement of construction of any phase of this Subdivision (roads, utilities, any off site work, etc.) the Owner shall: i. Provide an erosion and settlement control plan along with an associated stormwater management staging plan prepared by a Professional Engineer in accordance with current best management practices, ii. have said plans approved by the General Manager, Planning and Growth Management, and iii. provide certification to the General Manager, Planning and Growth Management through a Professional Engineer that the plans have been implemented. (b) Any changes made to the Plan shall be submitted to the satisfaction of the General Manager, Planning and Growth Management and the Conservation Authority. (c) The Owner shall implement an inspection and monitoring plan to maintain erosion control measures.	**OTTAWA Planning**
98.	SW3	On completion of all stormwater works, the Owner shall provide certification to the General Manager, Planning and Growth Management through a Professional Engineer that all measures have been implemented in conformity with the approved Stormwater Site Management Plan.	**OTTAWA Planning**

99.	SW4	Prior to the registration, or the making of an application for a Ministry of Environment, Environmental Compliance Approval, for any stormwater works, whichever event first occurs, the Owner shall prepare a Stormwater Site Management Plan in accordance with the approved Master Drainage Plan, Revision November 2013 and Functional Servicing Report, April 2014. The Stormwater Site Management Plan shall identify the sequence of its implementation in relation to the construction of the subdivision and shall be to the satisfaction of the General Manager, Planning and Growth Management and the Rideau Valley Conservation Authority.	**OTTAWA Planning and CA**
100.	SW5	The Owner shall maintain the stormwater management pond in accordance with the recommendations of the Stormwater Management Plan and to the satisfaction of the General Manager, Planning and Growth Management until such time as the stormwater management pond has been given Final Acceptance and assumed by the City of Ottawa.	**OTTAWA Planning**
101.	SW6	The Owner shall design and construct, as part of the stormwater management infrastructure, at no cost to the City, a monitoring facility or facilities and vehicular access to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
102.	SW7	The Owner agrees that the development of the Subdivision shall be undertaken in such a manner as to prevent any adverse effects, and to protect, enhance or restore any of the existing or natural environment, through the preparation of any storm water management reports, as required by the City. All reports are to be approved by the General Manager, Planning and Growth Management prior to the commencement of any Works.	**OTTAWA Planning**
103.	SW8	The Owner covenants and agrees that the following clause shall be incorporated into all agreements of purchase and sale for the whole or any part of a lot or block on the Plan of Subdivision, and registered separately against the title: "The Owner acknowledges that some of the rear yards within this subdivision are used for on-site storage of infrequent storm events. Pool installation and/or grading alterations on some of the lots may not be permitted and/or revisions to the approved Subdivision Stormwater Management Plan Report may be required to study the possibility of pool installation on any individual lot. The Owner must obtain approval of the General Manager, Planning and Growth Management of the City of Ottawa prior to undertaking any grading alterations."	**OTTAWA Legal**
104.		The Owner acknowledges and agrees that prior to the issuance of any building permit north of Perth Street, the Stormwater Management Pond and the Van Gaal Drain realignment shall be completed.	**OTTAWA Planning. CA**

105.	Prior to a pre-servicing agreement with the City or prior to registration, a detailed design plan for downstream erosion protection/restoration works on the receiving watercourse (tributary to the Jock River) shall be prepared to the satisfaction of the RVCA. The design shall include any appropriate works deemed necessary by the RVCA to address erosion impacts on the watercourse from the proposed stormwater management infrastructure, and shall be in conformity with the local policies under O. Reg. 174/06. Such may be achieved through the Drainage Act process or alternative means agreeable to the City and the RVCA.	**OTTAWA Planning CA**
106.	The Owner acknowledges and agrees that the use of sumps shall be designed and installed with backflow valves and back-up power supply with design and capacity in accordance with the Master Drainage Report. The details of the system, maintenance, repair and replacement shall be included within a Homeowners Handbook prepared by the Owner acceptable to the General Manager, Planning and Growth Management and supplied to each purchaser. Notice shall be placed on title and within every purchase and sale agreement of same. Such notice shall clearly indicate that the maintenance and repair of the foundation drainage systems shall be the sole responsibility of the homeowner. The notice shall also clearly indicate that failure to maintain the sump pumps and back-up systems could result in basement flooding.	**OTTAWA Planning**
107.	The Master Drainage Plan and Functional Servicing Report have been prepared and are deemed approved with the draft approval of the subdivision. In addition, refinements to the conceptual design as presented in the report "Master Drainage Plan Western Development Lands, Village of Richmond for Richmond Village (South) Limited" prepared by DSEL, project # 11-468 dated November 2013 – Rev. 3, the detailed stormwater management design plan shall: - Identify locations for perforated pipe systems in rear yards and park systems where suitable soils are identified; - Confirm that the lowering of the saturated zone (local lowering of the water table) shall not have any unintended adverse impacts on the hydrologic characteristics of any up gradient wells; - Provide mitigation solutions should the lowering of the groundwater table impact any offsite up gradient wells; - Address flow conclusions and erosions impacts with respect to the tributary to the Jock River south of Perth Street	**OTTAWA Planning CA**
108.	The Owner acknowledges and agrees that a statement shall be contained in the subdivision agreement describing any lot level BMP's relating to stormwater management and informing future owners of the function and maintenance requirements associated with these features.	**OTTAWA Planning CA**

109. Prior to final approval, the following information shall be provided to the satisfaction of the RVCA and the General Manager, Planning and Growth Management which shall include: **OTTAWA Planning CA**

- Information and documentation of final flow conclusions resulting from the construction and operation of Pond 1 on the tributary to the Jock River, storm sewer design and foundation drainage;
- An implementation plan to address any geomorphological impacts, if necessary, on the tributary to the Jock River, including when they should be undertaken in relation to servicing and construction and direction on which party (ies) shall be responsible for ensuring the downstream works and undertaken;
- Documentation on the relationship between the stormwater management servicing and infrastructure, including the enlargement of the culverts under Fortune Street, stormwater Pond 1 and any other infrastructure as they relate to management of flood risk and erosion control within the local area;
- An addendum to the Master Drainage Plan incorporating all other information and documentation relating the Master Drainage Plan but not incorporated into the November 2013 revision.

Such addendum shall be included in the Final Master Drainage Plan document.

110. The Owner acknowledges and agrees that that the final design for stormwater Pond 1 and the adjacent regulated floodplain areas shall: **OTTAWA Planning CA**

- Identify sediment storage areas outside of the mapped floodplain areas for the Van Gaal and Jock River;
- Shall maintain a 'no net fill' balance in the final grading.

111. Prior to early servicing for the lands North of Perth Street the Owner acknowledges and agrees that the Drainage Act process for the Van Gaal Drain realignment shall be completed. Should the permissions from the affected owners not be obtained then the Owner acknowledges and agrees that all drainage works required to move the drain shall be located solely on the Owner's property with respect to the abutting owner not being in agreement and that the Owner shall amend the layout of the subdivision accordingly. The Owner acknowledges that draft conditions and zoning may need to be amended to reflect the revisions and that all changes are at no cost to the City.

112. The owner agrees to hold a public meeting in Richmond, within 30 days of the later of the issuance of an ECA for the stormwater pond or the approval of the design for the communal well, at which the engineers responsible for the design of the master drainage solution and stormwater management will present them for explanation to the public. The General Manager, Planning and Growth Management shall be consulted as to the aspects of these matters that shall be presented.

Fisheries

113. The Owner acknowledges and agrees to ensure any requirements under the Federal Fisheries Act for the implementation of projects supporting the development are met.

Sanitary Services — **OTTAWA Planning CA**

114. The Owner shall submit detailed municipal servicing plans, prepared by a Civil Engineer licensed in the Province of Ontario, to the General Manager, Planning and Growth Management.

115. SS1 Where the Owner is required under this Agreement to provide and install sanitary sewers of a diameter larger and/or at a greater depth than would be required to service the area to be developed, as detailed in the approved plans of this agreement, the Owner shall convey to the City such 0.3m reserves as may be necessary to prevent the Owners and developers of adjacent lands from making connections to the sanitary sewers installed by the Owner. Insofar as it legally may, the City will require other persons connecting to the sewer to pay an equitable share of the cost thereof to the Owner, the amount of which payment shall be determined by the General Manager, Planning and Growth Management. **OTTAWA Planning**

116. SS2 Where the Owner is required under this Agreement to provide the oversize and/or over-depth storm sewers or open drains in order to make provisions for later development of upstream lands not owned by the Owner herein, as referred to in the approved plans, the City shall, insofar as it legally may, require that payment shall be made by the Owner of such upstream undeveloped land which will utilize the said storm sewers as an outlet(s), prior to the approval of a Plan of Subdivision for such land by the City, the amount of which shall be determined by the General Manager, Planning and Growth Management. **OTTAWA Planning**

117. SS3 As the Owner proposes a road allowance(s) of less than 20 meters, and if the Owner also proposed boulevards between 4.0 and 5.0 meters wide, the Owner shall meet the following requirements: **OTTAWA Planning**

a) extend water, sanitary, and storm services a minimum of 2.0 meters onto private property during installation before being capped;
b) install hydro high voltage cable through the transformer foundations to maintain adequate clearance from the gas main;
c) provide and install conduits as required by each utility;
d) provide and install transformer security walls when a 3.0 meters clearance, as required by the Electrical Code, cannot be maintained. The design and location of the security wall must be approved by the local hydro utility; and
e) install all road-crossing ducts at a depth not to exceed 1.2 meters from top of duct to final grade.

118.	SS4	The Owner acknowledges that all components of the sewage system shall be designed and constructed to ensure that there are no significant drinking water threats to the municipal drinking water source of the Richmond Municipal well and no cost to and to the satisfaction of the General Manager, Planning and Growth Management and/or Risk Management Official.	**OTTAWA Plannin**
119.		The construction of the sanitary sewer services shall be staged in accordance with a schedule that is to the satisfaction of the General Manager, Planning and Growth Management, recognizing the goal of reducing infrastructure expenditures. The number of units constructed in each stage shall be controlled through the utilization of holding provisions within the zoning by-law. The stages may include: **a)** Construction of a new length of 1,200 m of 600 mm forcemain along the Jock River from the pumping station to the lagoon. **b)** Construction of an additional 400 m of 600 mm forcemain from the lagoon to the Jock River Crossing; **c)** Upgrades to the existing pump units at the Richmond Pumping Station. Proposed stage c) will requiring further engineering analysis to be provided to the City Other options for the staging of the sanitary sewer works may be considered provided that satisfactory engineering analysis is provided to the City.	**OTTAWA Planning**
		<u>**Water Services**</u>	**OTTAWA Planning ESD**
120.		The Owner shall design and construct all necessary watermains and the details of services and meters for the lots abutting the watermains within the subject lands to the satisfaction of the General Manager, Planning and Growth Management. The Owner shall pay all related costs, including the cost of connection, inspection and sterilization by City personnel, as well as the supply and installation of water meters by the City.	
121.	W1	The details for water servicing and metering shall be to the satisfaction of the General Manager, Planning and Growth Management. The Owner shall pay all related costs, including the cost of connections and the supply and installation of water meters by City personnel.	**OTTAWA Planning**

122.	**W2**	Upon completion of the installation of all watermains, hydrants, water services and the new communal well, treatment and storage, the Owner shall provide the City with Mylar(s) of the "as-built" plan(s), certified under seal by a Professional Engineer, showing the location of the watermains, hydrants and services. Furthermore, the Owner shall provide the "as-built" information and the attribute data for the water plant installation in a form that is compatible with the City's computerized systems.	**OTTAWA Planning**
123.		The Owner shall prepare, at its cost, a hydraulic network analysis of the proposed water plant within the Plan of Subdivision. This analysis shall be submitted to the General Manager, Planning and Growth Management for review and approval as part of the water plant design submission.	**OTTAWA Planning**
124.	**W4**	The Owner agrees to construct and install all services in all the streets and offsite locations identified below and, where applicable, oversized services shall be constructed and installed in accordance with the conditions and City Specifications and approved reports: • municipal communal well water system	**OTTAWA Planning**
125.	**W5**	The Owner acknowledges and agrees not to permit any occupancy of buildings until the water plant has been installed, sterilized and placed in service to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Planning**
126.		The Owner acknowledges and agrees that no services shall be tapped into the new watermain until the disinfection has been successfully completed and the watermain has been placed in service by the City.	**OTTAWA Planning**
127.	**W7**	The Owner further acknowledges and agrees that the service post, which is the fitting located near the property line that allows access to the shutoff valve, must be visible, raised to finished grade and in working condition in order for the City to turn on the service.	**OTTAWA Planning**
128.	**W8**	The Owner acknowledges and agrees that the details of services and meters for the lots abutting the watermain shall be to the satisfaction of the General Manager, Planning and Growth Management. The Owner shall pay all related costs, including the cost of connections and the supply and installation of water meters.	**OTTAWA Planning**
129.	**W9**	The Owner acknowledges and agrees to install triple outlet fire hydrants and watermains in accordance with City specifications. The Owner further acknowledges and agrees to ensure that all hydrants shall be maintained accessible, and shall be in good operating condition at all times to the satisfaction of the General Manager, Planning and Growth Management. In the event that any hydrants are not operational, then the Owner shall clearly label these hydrants as out of service.	**OTTAWA Planning**

130.	W10	The Owner acknowledges and agrees not to apply for, nor shall the City issue, building permits for more than 50 dwelling units (or the equivalent) where the watermain for such units is unlooped. Any unit serviced by an unlooped watermain shall be required to have sufficient fire protection, to the satisfaction of the General Manager, Planning and Growth Management.	**OTTAWA Plannin**
131.	W11	The Owner prepares, entirely at its cost, a hydraulic network analysis of the proposed Communal Water System. Said report shall be submitted to the General Manager, Planning and Growth Management for review and approval as part of the design submission.	**OTTAWA Planning**
132.		The Owner acknowledges and agrees that prior to proceeding with any subsequent phase they shall demonstrate the capacity of the existing well(s), water treatment, storage and distribution system with respect to quality and quantity – including fire flow - and upgrade such systems accordingly, all to the satisfaction of the General Manager, Planning and Growth Management. This shall include the 10 State Standards, demonstrating that they still have to demonstrate the capacity of the weakest well, and they also need to meet the conditions of the MOE Minister regarding the conditional lifting of the Class EA Part II Order Request (this involves making sure that private wells in the Oxford Formation will not be unduly impacted). The Water system shall be designed to include fire flow that does not include direct pumping from the wells. The Owner acknowledges that prior to requesting any early servicing the detailed design for the proposed Municipal Communal Water System shall be approved by the City of Ottawa and the Ministry of the Environment. The Owner shall complete the design and construction of the Communal Water System to City standards and at no cost to the City. The Owner acknowledges that full building permits shall not be issued until such time as the City assumes the operation of the Communal Water System. As part of the assumption of the water system the owner shall provide the General Manager, Environmental Services Department as-built drawings, operation manuals, staff training as well as all up to date test records, Ministry of the Environment permits and licenses as may be required. This shall be at no cost to the City.	**OTTAWA Planning**

133.	Prior to supporting any building permits including conditional ones or final approval the Owner shall obtain ownership for the City of the lands containing the future Richmond Municipal well(s). It shall be appropriately sized to contain pumping, treatment, storage, setbacks or clearances from the 3 actual wells, fencing, parking and other associated works. The Owner acknowledges being required prior to draft approval to provide the City of Ottawa with an executed document from the owner (presently Mattamy) of the lands upon which the municipal wells are located to convey the ownership of the wells at the time of the registration of the Owner's first plan of subdivision, failing such conveyance Mattamy has agreed to be responsible for all costs for the expropriation of such lands. The Owner and the City acknowledge that such executed document has been received by the City. No registration of a plan and no occupancy of any dwelling can occur until the lands upon which the wells are located and are to be located have been conveyed to the City	**OTTAWA Planning ESD, Fire Services**
134.	Pursuant to the direction of the Village of Richmond Community Design Plan the Owner agrees that the design of the proposed water system shall be such that the City can expand it to accommodate any potential requirement for that system to service the existing Village if required. The balance of the design, construction and preliminary operation to final acceptance of the water system to service the Owner's lands shall be at no cost to the City. Prior to the connection by the City to the water system, the financial terms of permitting the land in the existing developed areas in the village to be serviced by the well(s) shall be as negotiated between the Owner and the City.	**OTTAWA Planning ESD**
135.	The Owner acknowledges that prior to lifting of the inhibiting order the water system shall be commissioned, and operated by the City	**OTTAWA Planning ESD**
	<u>Source Water Protection</u>	**OTTAWA Planning ESD**

136. The Owner acknowledges that much of the proposed development is located within the Wellhead Protection Area of the Richmond Municipal drinking water-well and that the Drinking Water Source Protection Plan is not in place to allow the City to ensure that any potential threat posed to the municipal drinking water is eliminated. As such, the City will not contemplate any early servicing or commence work, rezoning to allow for building to occur nor to allow for the inhibiting order to be lifted on the above-noted lots until such time as it has been demonstrated by the Owner that the lots can be developed and pose no significant threat to the municipal drinking water. This shall be to the satisfaction of the General Manager, Planning and Growth Management and Mississippi-Rideau Source Water Protection Committee and in keeping with the intent of the Ontario Clean Water Act. Further, that the Owner acknowledges and agrees to adhere to the policies of the Drinking Water Source Protection Plan on the following matters:

a) The storage and handling of heating fuel is not supported and that the subdivision will be serviced by natural gas;

b) Any stormwater management facility (i.e. pond, stormceptor) proposed to be located within the Richmond Municipal Well-head Protection Area (WHPA), shall be designed accordingly area according to the policies in the proposed Mississippi-Rideau Nation Source Water Protection Plan.

c) All sanitary and storm sewers shall be designed to ensure no significant drinking water threat.

136.1 The Owner shall take reasonable steps during construction of the sanitary sewers so as not to cause adverse effects to private wells.

137. The Owner acknowledges and agrees that parts of the subdivision and adjacent lands lie within the Wellhead Protection Area of the Richmond Municipal drinking water-well and as such covenants will be placed on title of all affected lands and in all purchase and sale agreements of affected lands to ensure that the above noted concerns are known to all land owners. **OTTAWA Planning**

137.1 Dewatering through construction or as a result of the clear stone bedding under the storm sewer will be done so as to ensure that private wells in the Oxford formation will not be unduly impacted.

138. The Owner acknowledges that the lands lie within the Wellhead Protection Area of the future Richmond Municipal Well and that prior to any on-site works shall demonstrate that the proposed construction practice to do not create a threat to the municipal drinking water source. **OTTAWA Planning**

139. The Owner acknowledges and agrees that it shall prepare a homeowner's information brochure to provide information on best practices for private homeowners within wellhead protection areas. **OTTAWA Planning**

140. The Owner acknowledges that the subdivision agreement shall contain wording acceptable to General Manager, Planning and Growth Management that the above noted conditions will be implemented. **OTTAWA Planning**

141. The Owner acknowledges and agrees that it shall provide the City with the required sentinel or monitoring wells for the subdivision in a number and location to the satisfaction of the General Manager, Planning and Growth Management, unless otherwise specified. Each required well shall be on a separate block secured by easement to and directly accessible by the City. If at all reasonably possible, access shall be provided by the road. **OTTAWA Planning**

142. The Owner acknowledges and agrees that prior to proceeding with any phase of the subdivision a construction management plan will be filed with the City demonstrating to the greatest extent feasible that all potential threats from the temporary use of any portion of the property to be used for construction purposes of the subdivision have been minimized. **OTTAWA Planning**

143. The Owner will comply with the Clean Water Act with respect to the Wellhead Protection Area Assessment. **OTTAWA Planning**

Serviced Lands

144. The Owner shall be responsible for the provisions of the following works, including oversizing and overdepth where appropriate, at its cost, in accordance with plans approved by the General Manager, Planning and Growth Management, and/or the Province; **OTTAWA Planning**

a. Watermains;
b. Sanitary Sewers;
c. Storm Sewers;
d. Roads and traffic plant(s);
e. Street Lights;
f. Sidewalks;
g. Landscaping;
h. Street name, municipal numbering, and traffic signs;
i. Stormwater management facilities; and
j. Grade Control and Drainage.

145. The Owner shall not commence construction of any Works or cause or permit the commencement of any Works until the City issues a Commence Work Notification, and only then in accordance with the conditions contained therein.

146. **SL1** The Owner shall provide services oversized and overdepth to service lands beyond the limits of the subdivision as required and to the satisfaction of the General Manager, Planning and Growth Management. **OTTAWA Planning**

147. **SL2** The Owner shall not be entitled to a building permit, early servicing, or commencement of work construction until they can demonstrate to the satisfaction of the General Manager, Planning and Growth Management that there is adequate road, sanitary, storm, and water capacity including fire flow. **OTTAWA Planning**

SL3 **HydroOttawa** OTTAWA Planning

148. The Owner shall comply with Hydro Ottawa's Conditions of Service and thus should be consulted for the servicing terms. The document, including referenced standards, guidelines and drawings, may be found at www.hydroottawa.com/development/. The Owner should consult Hydro Ottawa prior to commencing engineering designs to ensure compliance with these documents. OTTAWA Planning

149. The Owner acknowledges that servicing from new rear lanes is not permitted.

150. H1 The Owner shall pre-consult with Hydro Ottawa any proposed reduction to the City of Ottawa three-metre minimum standard setback prior to designing the electrical servicing, as it may affect the electrical servicing design, timeline for installation and cost. This includes any proposed overhang encroachment into the 3m-setback space. **Hydro Ottawa**

151. H2 The Owner may be required to enter into an Electrical Servicing Agreement with Hydro Ottawa Limited, to the satisfaction of Hydro Ottawa. **Hydro Ottawa**

152. H3 The Owner shall contact Hydro Ottawa to discuss electrical servicing for the property. By Hydro Ottawa commenting on this proposal, Hydro Ottawa has not committed to, or approved the electrical servicing of the proposed development. **Hydro Ottawa**

153. H4 The Owner may be responsible for a Capital Contribution payment(s) towards a distribution system expansion, if the proposed development requires electrical servicing greater than can be provided by the existing distribution system in the vicinity, either in capacity or in extension limit. This amount shall be in accordance with Hydro Ottawa's Contributed Capital Policy and Conditions of Service. **Hydro Ottawa**

154. H5 Hydro Ottawa's standard distribution network is overhead for any voltage system along or through open fields, business parks, rural areas, arterial, major collector and collector roads. Any additional premium costs beyond the standard shall be at the Owner's cost. In all instances, electrical distribution above 27kV is via overhead distribution. **Hydro Ottawa**

155. H6 The Owner shall be responsible for servicing the buildings within the property. Only one service entrance per property shall be permitted. **Hydro Ottawa**

156. H7 The Owner shall convey, at its cost, all required easements as determined by Hydro Ottawa. The Owner further acknowledges and agrees that the City's Inhibiting Order will not be lifted until such time as the required transfer of easements to Hydro have occurred. The Owner will be required to provide written confirmation from Hydro to the City that the required easements have been obtained to Hydro's satisfaction and that the Inhibiting Order may be lifted, subject to any other City conditions for lifting. **Hydro Ottawa**

157.	H8	Prior to commencement of any construction activities, the Owner shall inform Hydro Ottawa of any acute shock construction process or rubbelization to be used during construction, and apply Hydro Ottawa's work procedure UDS0022 "Protecting Electrical Distribution Underground Plant & Support Structures from Acute Shock Construction Processes". The Owner shall be responsible for any damage to Hydro Ottawa distribution assets.	**Hydro Ottawa**
158.	H9	The Owner shall be responsible for all costs for feasible relocations, protection or encasement of any existing Hydro Ottawa plant.	**Hydro Ottawa**
159.	H10	The Owner shall ensure that any landscaping or surface finishing does not encroach into existing or proposed Hydro Ottawa's overhead or underground assets or easement. When proposing to plant in proximity of existing power lines, the Owner shall refer to Hydro Ottawa's free publication "Tree Planting Advice". The shrub or tree location and expected growth must be considered. If any Hydro Ottawa related activity requires the trimming, cutting or removal of vegetation, or removal of other landscaping or surface finishing, the activity and the re-instatement shall be at the Owner's expense.	**Hydro Ottawa**
160.	H12	The Owner is advised that there are overhead medium voltage overhead lines along the Perth Street. The Owner shall ensure that no personnel or equipment encroaches within three meters (3.0m) of the Hydro Ottawa overhead medium voltage distribution lines, unless approved by Hydro Ottawa. The Owner shall contact Hydro Ottawa prior to commencing work when proposing to work within 3.0m of the Hydro Ottawa distribution lines as noted above. No such work shall commence without approval of Hydro Ottawa.	**Hydro Ottawa**
161.	H13	The Owner shall ensure that no permanent structures are located within the "restricted zone" defined by Hydro Ottawa's standard OLS0002, which can be found at www.hydroottawa.com/development/. The "restricted zone" surrounds overhead medium voltage pole lines, consisting of a five-meter (5m) radial distance from overhead medium voltage conductors, and a two-meters (2m) distance from a vertical line drawn from the conductors to ground level along, the length of the pole line. This standard complies with the requirements of the Ministry of Labour's *Occupational Health & Safety Act*, the Building Code and the Ontario Electrical Safety Code.	**Hydro Ottawa**
162.	H14	The Owner and its agents shall arrange for an underground electricity cable locate by contacting Ontario One Call at 1-800-400-2255, not less than seven (7) working days prior to excavating. There shall be no mechanical excavation within 1.5m of any Hydro Ottawa underground plant unless the exact position of plant is determined by hand digging methods. Direct supervision by Hydro Ottawa forces, and protection or support of the underground assets shall be at the Owner's expense.	**Hydro Ottawa**

163.	H15	Hydro Ottawa may be required to service this subdivision by means of underground wiring, thus any other underground work must be coordinated. At least 14 weeks are needed from receipt of the Owner's deposit to start the material purchase and scheduling of the work.	**Hydro Ottawa**
164.	H16	Hydro Ottawa reserves the right to raise conditions throughout the development of this proposal should revisions contain non-conformance with, for example, Hydro Ottawa's Conditions of Service or Standards. The Owner shall contact Hydro Ottawa in the request.	**Hydro Ottawa**
		<u>HydroOne</u>	**Hydro Ottawa**
165.		The Owner acknowledges that prior to final approval, copies of the lot grading and drainage plan, showing existing and final grades, must be submitted to HONI in triplicate for review and approval. Drainage must be controlled and directed away from the OILC/HONI transmission corridor.	**Hydro Ottawa**
166.		Temporary fencing must be installed along the edge of the transmission corridor prior to the start of construction at the developer's expense.	
167.		Permanent 1.5 metres fencing must be installed along the mutual property line after construction is completed at the developer's expense.	**HydroOne**
168.		The Owner acknowledges that the OILC/HONI transmission corridor is not to be used without the express written permission of the Hydro One Networks Inc. on behalf of OILC. During construction there will be not storage of materials or mounding of earth, snow of other debris on the transmission corridor. The proponent will be responsible for the restoration of any damage to the transmission corridor or HONI facilities thereon resulting from construction of the subdivision.	**HydroO**
169.		The Owner shall obtain the permission of OILC/HONI for any proposed works and road crossings of the transmission corridor. Prior to final approval the developer shall provide HONI/OILC detailed engineering. All road allowances shall be transferred directly to the City of Ottawa.	**HydroOne**
170.		All costs associated with the relocation or revisions to the facilities to accommodate the subdivision shall be the responsibility of the owner.	**HydroOne**
		<u>Fire Services</u>	**HydroOne**
171.		The Owner shall not demand of the City to issue, nor shall anyone claiming title from it or under its authority, demand of the City to issue, one or building permits to construct any building or other structure on any lots or block in the Subdivision until firebreak lots are designated to the satisfaction of the City's Fire Chief.	

172. The Owner acknowledges that adequate fire protection must be in place prior to any structural framing and be maintained accessible and operational at all times to the satisfaction of the City's Fire Chief.

173.	FS 1	The Owner agrees that as an interim measure and prior to the issuance of any full building permit, where no municipal hydrants are available the Owner shall provide an alternate means of water supply as required in the Ontario Building Code and subject to the approval of the Fire Chief.	**OTTAWA Fire Services**
174.		The Owner agrees that public street access must be provided by a road complete to first lift of asphalt prior to combustible framing. Alternatively, at times of the year when the asphalt plants are not operational, the minimum road construction shall be completed to an acceptable granular 'A' surface.	**OTTAWA Fire Services**
175.		The Owner acknowledges and agrees that, where single family home Firebreak Lots are required, no construction is to proceed past the deck stage until the adjacent units are completed with exterior classing, windows installed and roof shingles. - On lots with 12.19 metres of frontage or more, a maximum of six homes are to be constructed without a 'firebreak' of one lot; and - On lots with less than 12.19 metres of frontage, a maximum of six homes are to be construction without a 'firebreak' of two lots.	**OTTAWA Fire Services Planning**
176.		The Owner undertakes and agrees to provide and erect at its expense, such municipal street signs and unit number signs, illuminated or otherwise in such location and of such size, design and colour as submitted to and approved the Fire Chief prior to occupancy of any building, or part thereof, in the subject development, and such numbering shall be visible from the street day and night.	**OTTAWA Fire Services Planning**
		<u>Early Servicing</u>	**OTTAWA Fire Services**
177.		Upon approval of the Draft Plan of subdivision, municipal servicing relating to the Plan of Subdivision, including, works beyond the limit of the subdivision, any be permitted provided appropriate approvals have been granted, and financial security, insurance and a letter of indemnity are posted to the satisfaction of the General Manager, Planning and Growth Management.Early Servicing shall include the completion of the approved service outlets and installations and such outlets and associated works shall be completed to the satisfaction of the General Manager, Planning and Growth Management. Early Servicing shall also include the phasing of the subdivision development by submission of a preliminary 4M Plan and approval of all related engineering works associated with that phase.	**OTTAWA Fire Services**
		<u>Utilities</u>	

178.	The Owner is hereby advised that prior to commencing any work within the Draft Plan, the Owner must confirm that sufficient wire-line communication/telecommunication infrastructure is currently available to the proposed development to provide communication/ telecommunication service to the proposed development. In the event that such infrastructure is not available, the Owner is hereby advised that the Owner shall ensure, at no cost to the City, the connection to and/or extension of the existing communication/ telecommunication infrastructure. The Owner shall be required to demonstrate to the municipality that sufficient communication/telecommunication infrastructure facilities are available within the proposed development to enable, at a minimum, the effective delivery of communication /telecommunication for emergency management services (i.e. 911 Emergency Services).	**OTTAWA Planning CA**
	<u>**Canada Post**</u>	
179. U1	The Owner agrees to inform all prospective purchasers through a clause in all agreements of purchase and sale as to the locations of all potential community mailboxes.	**OTTAWA Planning**
180.	The Owner acknowledges and agrees that the locations, standards and installation of all community mailboxes shall be to the satisfaction of Canada Post.	
181.	The Owner acknowledges and agrees that all community mailboxes shall be shown on the Streetscape/Landscape plans as well as the Composite Utility Plans.	**Canada Post**
182.	<u>**Noise Attenuation**</u>	**Canada Post**
183.	The Owner shall have a Noise Study undertaken related to noise assessment and land use planning with respect to noises generated by moving and stationary sources. The study shall be to the satisfaction and approval of the General Manager, Planning and Growth Management and shall comply with: (i) the City of Ottawa's Environmental Noise Control Guidelines; and (ii) the City of Ottawa's Standards for Noise Barriers and Noise Control Guidelines; and (iii) address, and be in accordance with, the current version of the Association of Professional Engineers of Ontario Guidelines for Professional Engineers providing Acoustical Engineering Services in Land Use Planning.	**Canada Post OTTAWA Planning**
184.	The Owner shall have a Noise Study undertaken related to noise assessment and land use planning with respect to noises generated by moving and stationary sources and in accordance with the City's Environmental Noise Control Guidelines. The study shall provide all specific details on the methods and measures required to attenuate any noise that exceeds the allowable noise limits in locations as determined by the recommendations of the Noise Assessment Study.	

185.	N1	Where structural mitigation measures are required as a result of the Noise Assessment Study, the Owner shall provide, prior to final building inspection, certification to the General Manager, Planning and Growth Management, through a Professional Engineer, that the noise control measures have been implemented in accordance with the approved study. .	**OTTAWA Planning**
186.	N2	The Owner agrees that all purchase and sale agreements, and the Deed(s) for the whole or any part of the lot/block on the Plan of Subdivision shall contain the following clause in the next condition that shall be incorporated in all Transfers/Deeds from the Owner so that the clauses shall be covenants running with the lands in the Subdivision.	**OTTAWA Planning**
	N3	<u>**Notice to Purchasers**</u>	**OTTAWA Planning**
187.	N5	The Owner acknowledges and agrees that all purchase and sale agreement shall include the following types of notices to purchasers: - Proximity to an active park - Proximity to a storm pond, water course or natural area - Potential transit routes - Handbooks relating to Source Water Protection - Handbooks relating to Basement Sump Pump systems purpose, operation and maintenance - Information on the approved Streetscape/Landscape Plan - Information on the approved Grading and Composite Utility Plans - Information on Tree Planting in Sensitive Marine Clay Soils - Noise Attenuation for lots in proximity to Perth Street. - Other matters as may be determined prior to final approval.	**OTTAWA Planning and Legal**
		<u>**Land Transfers**</u>	
188.		The Owner shall convey, at no cost to the City, all lands required for public purposes, including but not limited to, reserves, road widenings, daylighting triangles, walkway blocks, open space blocks, lands required for parks (or cash-in-lieu thereof) and for storm water measures, to the satisfaction of the General Manager, Planning and Growth Management. In particular, the Owner shall convey, at no cost to the City, the following lands: i) Pathway, Walkway or Servicing Blocks – 61, 68, 78 ii) Open Space Blocks – 61 iii) Watercourses (buffer strips/riparian corridors) – 59, 60 (Subject to RVCA concurrence and Drainage Act compliance) iv) Park Blocks – 20 v) Storm Water Management Blocks – Block 62, 63, 64 vi) Road Widening Blocks – 66, 67 vii) 0.3 m Reserve Blocks – West Side and end of Street 22, Blocks 70, 72 71, 74, 73, 75, 76. viii) Municipal Well Block	**OTTAWA Planning**

The Owner shall convey, at no cost to the City, any easements that may be required for the provision of water and wastewater systems, in addition to underground or overland stormwater drainage systems to the satisfaction of the General Manager, Planning and Growth Management.

LT 1 **Development Charges** **OTTAWA Planning and Legal**

189. LT 2 The Owner acknowledges that some of the works of the Subdivision are eligible for development charges revenues pursuant to the City's applicable Development Charges By-law and background study, as well as budget approval by City Council where required. Such contributions are to be determined and agreed to by the City, prior to the commencement of the associated Works or as agreed to by the City. The Owner agrees to enter into any agreements that may be required pursuant to the applicable Development Charges By-law. **OTTAWA Planning and Legal**

190. The Owner shall inform the purchaser after registration of each lot or block of the development charges that have been paid or which are still applicable to the lot or block. The applicable development charges shall be as stated as of the time of the conveyance of the relevant lot or block and the statement shall be provided at the time of the conveyance. The statement of the Owner of the applicable development charges shall also contain the statement that the development charges are subject to changes in accordance with the *Development Charges Act, 1997* and the *Education Development Charges Act.*

191. D C1 The Owner acknowledges and agrees to enter into any front-ending agreements with the City of Ottawa for transportation, water, and waste water that are anticipated to be required in advance of the time as approved by Council. The City shall repay the Owner for the cost of works as noted herein in accordance with the approved Front-Ending Policy of the City's Development Charge By-law, and subject to budget approval of the required expenditure by City Council in the year in which it is approved. **OTTAWA Planning and Legal**

192. D C2 The Owner acknowledges that for building permits issued after January 15, 2010, payment of non-residential development charges, excluding development charges for institutional developments, may be calculated in two installments at the option of the Owner, such option to be exercised by the Owner at the time of the application for the building permit. The non-discounted portion of the development charge shall be paid at the time of issuance of the building permit and the discounted portion of the development charge shall be payable a maximum of two years from the date of issuance of the initial building permit subject to the following conditions: **OTTAWA Planning and Legal**

(a) a written acknowledgement from the Owner of the obligation to pay the discounted portion of the development charges;

(b) no reduction in the Letter of Credit below the amount of the outstanding discounted development charges; and

(c) indexing of the development charges in accordance with the provisions of the Development Charges By-law.

The Owner further acknowledges that Council may terminate the eligibility for this two stage payment at any time without notice, including for the lands subject to this agreement and including for a building permit for which an application has been filed but not yet issued.

For the purposes of this provision, "discounted portion" means the costs of eligible services, except fire, police and engineered services, that are subject to 90% cost recovery of growth-related net capital costs for purposes of funding from development charges. The 10% discounted portion, for applicable services, must be financed from non-development charge revenue sources.

"Non-discounted portion" means the costs of eligible services, fire, police and engineered services, that are subject to 100% cost recovery of growth-related net capital costs for purposes of funding from development charges.

193. D C4 **Financial Plan** **OTTAWA Planning and Legal**

The Owner agrees that all infrastructure required for this subdivision shall be at no cost to the City. This is subject to recoveries from Development Charges by the owner under the approved Background Study and to the acknowledged right of the Owner to appeal to the Ontario Municipal Board pursuant to the *Development Charges Act*, the allocation for benefit to existing development for the forcemain to be constructed.

194. **Survey Requirements**

The Owner shall provide the final plan intended for registration in a digital format that is compatible with the City's computerized system.

195.		**The Plan of Subdivision shall be referenced to the Horizontal Control Network in accordance with the City requirements and guidelines for referencing legal surveys.**	
196.	Surv 1	**Closing Conditions**	**OTTAWA Planning**
197.	Surv 2	The City Subdivision Agreement shall state that the conditions run with the land and are binding on the Owner's, heirs, successors and assigns.	**OTTAWA Surveys**
198.		At any time prior to final approval of this plan for registration, the City may, in accordance with Section 51 (44) of the *Planning Act*, amend, delete or add to the conditions and this may include the need for amended or new studies.	
199.	C1	Prior to registration of the Plan of Subdivision, the City is to be satisfied that conditions one through 198 have been fulfilled.	**OTTAWA Legal**
200.	C2 Bill 163 and 20	The Owner covenants and agrees that should damage be caused to any of the Works in this Subdivision by any action or lack of any action whatsoever on its part, the General Manager, Planning and Growth Management may serve notice to the Owner to have the damage repaired and if such notification is without effect for a period of two full days after such notice, the General Manager, Planning and Growth Management may cause the damage to be repaired and shall recover the costs of the repair plus the Management Fees under Section 427, of the *Municipal Act, 2001*, like manner as municipal taxes.	**OTTAWA Legal**
201.	C4	If the Plan(s) of Subdivision, including all phases within the draft approved plan of subdivision, has not been registered by five years from the date of draft approval, the draft approval shall lapse pursuant to Section 51 (32) of the *Planning Act*. Extensions may only be granted under the provisions of Section 51 (33) of said *Planning Act* prior to the lapsing date.	**OTTAWA Planning**
202.		The Owner shall pay any outstanding taxes owing to the City of Ottawa prior to registration.	

ATTACHMENT 3

BY-LAW NO. 2014 - XX

A by-law of the City of Ottawa to amend By-law No. 2008-250 of the City of Ottawa to change the zoning of the lands known municipally as 6335 and 6350 Perth Street

The Council of the City of Ottawa, pursuant to Section 34 of the *Planning Act*, R.S.O.1990, enacts as follows:

1. The Zoning Map of By-law No. 2008-250, entitled the "City of Ottawa Zoning By-law" is amended by rezoning the lands shown on Attachment 1 to this by-law as follows:

(a) Area A from DR1 to V1O[778r]-h,
(b) Area B from DR1 to V2E[779r]-h,
(c) Area C from DR1 to V3B[780r]-h,
(d) Area D from DR1 to O1[781r]-h.

2. Section 240 – Rural Exceptions of the said By-law No. 2008-250 is amended by adding the following exception:

I Exception Number	II Applicable Zone	Exception Provisions		
		III Additional Land Uses Permitted	IV Land Uses Prohibited	V Provisions
778	V1O[778r]-h		- all uses until holding symbol removed	- minimum front yard setback: 4.0 m - minimum rear yard setback: 6.0 m - minimum corner side yard setback: 4.0 m - total interior side yard setback 1.8m with one minimum yard no less than 0.6 m - maximum lot coverage: 60% - despite Section 57(1), the distance used to determine a corner sight triangle is 2.75 metres - despite Section 107(3)(ii) the area of the driveway cannot exceed 65 per cent of the area of the yard in which it is located

				A holding symbol can only be removed when servicing capacity is demonstrated to the satisfaction of the City A holding symbol on lands north of Perth Street can only be removed when: i. servicing capacity is demonstrated to the satisfaction of the City, and ii. at such time as the 'interim floodplain' as shown on Schedule A in the Richmond Secondary Plan is deemed to be appropriately removed by the Conservation Authority and the City
779	V2E[779r]-h	- townhouse dwelling	- all uses until holding symbol removed	- minimum front yard setback: 4.0 m - minimum rear yard setback: 6.0 m - minimum corner side yard setback: 4.0 m - despite Section 57(1), the distance used to determine a corner sight triangle is 2.75 metres - despite Section 107(3)(ii) the area of the driveway cannot exceed 65 per cent of the area of the yard in which it is located Provisions specific to detached dwellings: i. minimum lot width: 9.0 m ii. minimum lot depth: 27.0 m iii. minimum lot area: 243 m2 iv. total interior side yard setback 1.8m with one minimum yard no less than 0.6m v. maximum lot coverage: 60% Provisions specific to townhouse dwellings: i. minimum lot width: 6.0 m

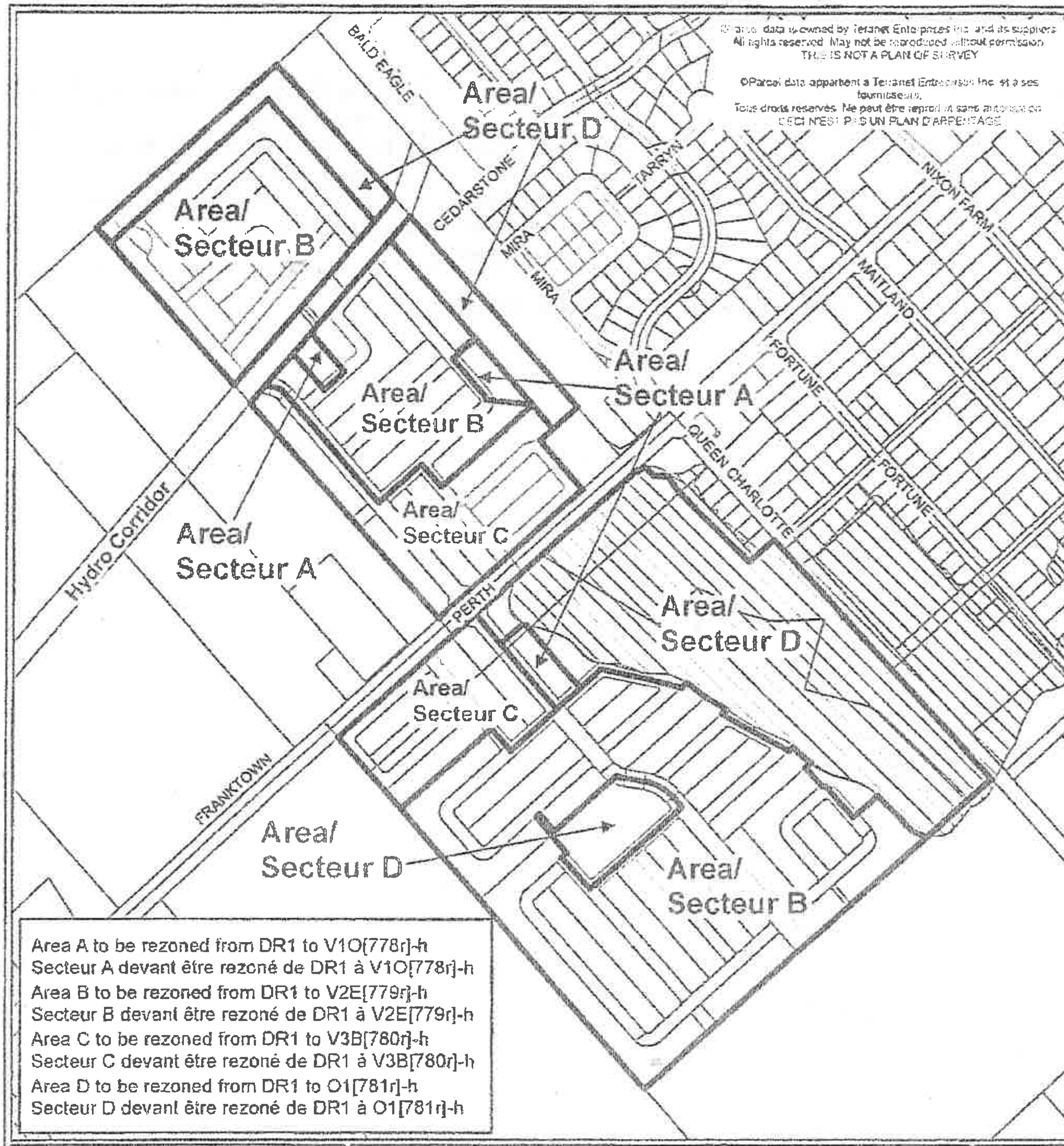
				ii. minimum lot depth: 25.0 m iii. minimum lot area: 150 m2 iv. minimum interior side yard setback: 1.5 m v. maximum lot coverage: 65% A holding symbol can only be removed when servicing capacity is demonstrated to the satisfaction of the City A holding symbol on lands north of Perth Street can only be removed when: i. servicing capacity is demonstrated to the satisfaction of the City, and ii. at such time as the 'interim floodplain' as shown on Schedule A in the Richmond Secondary Plan is deemed to be appropriately removed by the Conservation Authority and the City
780	V3B[780r]-h		- all uses until holding symbol removed	- minimum front yard setback: 4.0 m - minimum rear yard setback: 6.0 m - minimum corner side yard setback: 4.0 m - despite Section 57(1), the distance used to determine a corner sight triangle is 2.75 metres - despite Section 107(3)(ii) the area of the driveway cannot exceed 65 per cent of the area of the yard in which it is located Provisions specific to detached dwellings: i. minimum lot width: 9.0 m ii. minimum lot depth: 25.0 m iii. minimum lot area: 225 m2 iv. total interior side yard setback 1.8m with one

				minimum yard no less than 0.6m v. maximum lot coverage: 60% vi. despite Table 236, column VIII the minimum landscaped area is 25% Provisions specific to townhouse dwellings: i. minimum lot width: 6.0 m ii. minimum lot depth: 25.0 m iii. minimum lot area: 150 m2 iv. minimum interior side yard setback: 1.5 m v. maximum lot coverage: 65% vi. despite Table 236, column VIII the minimum landscaped area is 14% Provisions specific to townhouse dwellings that are attached back to back: i. minimum lot depth: 13.5 m ii. minimum lot area: 80 m2 iii. maximum lot coverage: 79% iv. despite Table 236, column VIII the minimum landscaped area is 3.0 m^2 per unit A holding symbol can only be removed when servicing capacity is demonstrated to the satisfaction of the City A holding symbol on lands north of Perth Street can only be removed when: ii. servicing capacity is demonstrated to the satisfaction of the City, and ii. at such time as the 'interim floodplain' as shown on Schedule A in the Richmond Secondary Plan is deemed to be appropriately removed by

				the Conservation Authority and the City
781	O1[781r]-h		- all uses until holding symbol removed	A holding symbol can only be removed when servicing capacity is demonstrated to the satisfaction of the City

ENACTED AND PASSED this day of , 2014.

CITY CLERK MAYOR



Ottawa

Produced by Planning and Infrastructure Portfolio
Produit par le Portefeuille urbanisme et infrastructure

D02-02-11-0066	14-1093-X

F\CO\2014\ZONING\PERTH_6335_6350

2014 / 05 / 22

REVISION DATE DE RÉVISION

Location Map / Plan de révision
Zoning Key Plan / Schema de zonage
6335, 6350 rue Perth Street

Areas to be rezoned as per Legend
Secteurs devant être rezonés conformément à la légende

Flood Plain (Section 58)
Plaine inondable (Article 58)

044370061 Denotes Teranet Polaris Parcel Identification Number

Échelle
N.T.S
Mètres

Scale
N.T.S
Metres

APPENDIX B

Geotechnical

Jacques Whitford

Environmental
Engineering
Scientific
Management
Consultants

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2781 Lancaster Road
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Canada K1B 1A7

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PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT

Proposed Residential Subdivision
Perth and Ottawa Streets
Richmond Area
Ottawa, Ontario

Mattamy Homes Ltd.

PROJECT NO. 1026929

REPORT NO. 1026929

REPORT TO

Mattamy Homes – Ottawa Division
123 Huntmar Drive
Ottawa, ON, K2S 1B9

ON

Preliminary Geotechnical Investigation
Proposed Residential Subdivision, Perth and Ottawa Streets, Richmond Area
Ottawa, Ontario

June 22, 2007

Jacques Whitford Limited
2781 Lancaster Road, Suite 200
Ottawa, Ontario
K1B 1A7

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Fax: 613-738-0721

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Jacques Whitford

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1.0 INTRODUCTION

This report presents the results of the Geotechnical Investigation carried out for the proposed residential subdivision to be located to the west of the Village of Richmond in Ottawa, Ontario. The work was carried out in general accordance with our Proposal Number 1026824, dated June 7, 2007. Authorization to carry out the work was received on June 8, 2007, from Mr. Matthew Kingston of Mattamy Homes – Ottawa Division.

This report has been prepared specifically and solely for the project described herein. It presents the factual results of the Geotechnical Investigation and provides preliminary geotechnical recommendations for the design and construction of the residential subdivision.

2.0 PROJECT DESCRIPTION

The project site location is shown on the Key Plan, Drawing No. 1 in Appendix A. The property boundaries are indicated on Drawing No. 2 in Appendix A, and is based on Drawing Reference No. 07-10-724-00 prepared by J.D. Barnes Surveying Limted and dated April 21, 2007.

Although the layout and configuration of the proposed development has not yet been completed, it is anticipated that it will include numerous single family homes and townhouses on a new street network and that the development will be connected to municipal sewer services. Water supply, it is anticipated, will be through individual private wells.

3.0 SITE DESCRIPTION AND BACKGROUND

Geological maps, of the area indicate that the soil conditions vary significantly across the site. Southeast of Ottawa Street, maps indicate that a layer of glacial till is present overlying bedrock at shallow depth. Northwest of Ottawa Street the soil map profile includes sand (beach and reworked glaciofluvial origin) over silts and clays (marine origin) over glacial till. The thickness of the silt and clay layer increase along with depth to bedrock from southeast to northwest with total overburden thickness estimated to be as much as 10 m at the northwest limit of the site.

The subject site is approximately 300 acres in area and includes nine parcels of land. The site is roughly rectangular, 600 m wide and 2500 m long, with the long axis oriented northwest to southeast. The eight parcels include PINS 0062 and 0061 to the north of Perth Street, 0285, 0286, 0287 and 0714 between Perth and Ottawa Street and the Jock River and PIN 0075 on the southeast side of the Jock River.

The site is primarily used as an agricultural field. The Jock River crosses the southern end of the site. The layout of the site is shown on Drawing No. 2 in Appendix A.

The slopes adjacent to the Jock River are indicated in Ontario Geological Society Paper MP68 to have a Factor of Safety of 2.0 to 2.5 which indicates that only routine inspection will be necessary to determine the need and extent of a geotechnical investigation.

4.0 SCOPE OF WORK

Due to time constraints the scope of work for the project is divided into two phases; the Due Diligence Phase (Preliminary Phase) and Detailed Design Phase. The work completed for this report was conducted as part of the Due Diligence Phase. The scope of for each phase is summarized below:

Due Diligence Phase (Preliminary Phase)

- Field investigation
- Laboratory testing
- Prepare an initial due diligence report which will includes a test hole location plan, draft test hole logs and discussion of the geotechnical constraints to residential development of the site.

Detailed Design Phase

- Design discussions with the project team.
- Prepare a detailed geotechnical design report for the project. The report will include test hole location plan, test hole logs and recommendations for the detailed design of the development. The report will reflect the discussions from the other members of the design team including the proposed grading and layout of the subdivision.

The present report is the due diligence report. Further discussion and analysis will be carried out prior to presenting a final report for the proposed development.

Jacques Whitford is also conducting a Phase I Environmental Site Assessment (ESA) for the site. The results of the Phase I ESA are reported separately.

5.0 METHOD OF INVESTIGATION

5.1 Geotechnical Field Investigation

Prior to carrying out the investigation, Jacques Whitford staked out the proposed borehole locations and made arrangements to identify and clear the locations of underground utilities. The drain tile system that is present on the site could not be accurately located in the field. The drain tile system was encountered and may have been damaged at test pit locations TP07-10, TP07-22 and TP07-23.

Between June 14 and 20, 2007, test holes numbered BH 07-1 to TP 07-72 were advanced at the approximate locations shown on Drawing No. 2 in Appendix A. Several parcel's of the originally planned project site were eliminated from the scope of work, therefore test holes at locations BH 07-4, CPT 07-8, TP 07-12 and BH 07-16 were dropped after initiation of the project.

The test holes consisted of boreholes, Seismic Piezocone Penetration Tests, test pits and hand auger holes.

Boreholes

The boreholes were advanced using a track mounted CME power drill and hollow stem augers. Soil samples were collected at close intervals using a split spoon sampler while conducting standard penetration testing (SPT). Several relatively undisturbed samples of cohesive materials were acquired by pushing thin-walled samplers (Shelby tubes). The undrained shear strength of cohesive soils was measured in the boreholes by carrying out vane shear and pocket penetration tests. The boreholes were backfilled with auger cuttings.

Seismic Piezocone Penetration Test (SCPTu)

The Seismic Piezocone (SCPTu) tests consisted of pushing an instrumented rod with a cone-shaped tip into the ground at a controlled rate (20 mm/s) using the hydraulics of the CME power auger drill. The device contains electronic sensors that measure tip resistance, sleeve friction and pore water pressure at very short intervals in order to provide a near continuous profile. These measurements can be used to assess a wide variety of engineering properties of the subsurface soils. The equipment standards and test procedures are outlined in ASTM D5779-95. Seismic cone tests were also conducted at 1.0 m intervals to estimate the shear wave velocity of the soil.

When performing a seismic evaluation, the cone contains a built in geophone to measure compression and shear wave velocities in addition to the standard piezocone parameters. The seismic soundings were performed approximately at 1 m intervals.

During the seismic soundings, shear waves are generated by striking the seismic beam using a sledgehammer. The seismic beam is placed under the rear stabilizers of the drill rig and secured to the ground surface by using the weight of the drill. Seismic triggers are attached to this seismic beam, which initiate the recording of the seismic wave trace.

Geophones in the body of the piezocone recognize the arriving waves generated at the ground surface. Any waves received by the geophones on the cone penetrometer are sent back up to the control unit to be displayed on an oscilloscope. On site software then plots the wave amplitude versus time to calculate wave velocities.

For this assignment the piezocone testing also included several pore water pressure dissipation tests.

Test Pits

The test pits were excavated with rubber tired backhoes. Samples of all soil types were acquired from test pit walls. The test pits were backfilled with the excavated materials.

Hand Auger Holes

Access restrictions in the south east corner of the site prevented the use of mechanized equipment. Soil conditions were evaluated based on hand auger holes.

The subsurface stratigraphy encountered in each test hole was recorded in the field by our personnel. All samples recovered were stored in moisture-proof bags and were returned to our laboratory for detailed classification and testing.

Monitoring wells and standpipes were installed in several locations to allow for the measurement of groundwater levels. Groundwater levels were measured on June 20, 2007.

5.2 Survey

Prior to the fieldwork, the borehole locations were established in the field by Jacques Whitford personnel. The ground surface elevations at the test hole locations were surveyed relative to a temporary benchmark with an assigned elevation of 100.00 m Local. The temporary benchmark was established on the top of the concrete base of a light pole located on the north side of Perth Street. The location of the temporary benchmark is shown on Drawing 2 in Appendix A.

5.3 Laboratory Testing

All samples returned to the laboratory were subjected to detailed visual examination and additional classification by a geotechnical engineer. Selected samples were tested for moisture content, organic content, particle size gradation and Atterberg Limits. Results of this testing are shown on the Borehole Records and in Appendix D. Consolidation testing on two relatively undisturbed samples and some classification testing is currently underway. The results will be forwarded when they become available.

Samples will be stored for a period of one (1) month after issuance of this report unless we are otherwise directed by the client.

6.0 RESULTS OF INVESTIGATION

6.1 Site Description

The site is primarily used as an agricultural field. Some trees and brush were noted at localized areas throughout the site. Denser trees and brush are present in the vicinity of Jock River. A fill pile was observed near the south side of Ottawa Street. The approximate location of the fill pile, trees and brush are indicated on Drawing No. 2 in Appendix A.

A large drainage ditch is located near the northeast corner of the site. Steel corrugated pipe culvert provides access over the drainage ditch. A second drainage ditch which outlets to the Jock River runs through the southern parcel of land. The approximate locations of the ditches are indicated on Drawing No. 2 in Appendix A.

The slopes adjacent to the Jock River are heavily covered in trees and brush. The slopes heights were visually estimated to be less than 3 m in height and are sloped at angles shallower than 2H:1V.

6.2 Subsurface Information

In general, the subsurface profile changes significantly across the site.

Drawings 3 and 4 in Appendix A present plan summaries of the Estimated Thickness of the Clay Deposit and the Estimated Depth to Bedrock Respectively. Drawing No. 5 in Appendix A presents two stratigraphic plots across the site.

PIN 04437-0062, 0061, PIN 03933-0285, 0286

Within these parcels of land, the soils consist of a thick deposit of clay overlying a till deposit overlying inferred bedrock. Bedrock is anticipated at depths in excess of 6 m below ground surface to the north of Perth Street and becoming shallower to the south of Perth Street. The estimated thickness of the clay deposit and the depth to inferred bedrock are shown on Drawings No. 3 and 4, respectively.

PIN 03933-0287

Within this parcel of land the soils consist of a thin deposit of clay overlying a sandy silt deposit over a till deposit over inferred bedrock. Bedrock is anticipated at depths between 3 m to 4 m below ground surface. The estimated thickness of the clay deposit and the depth to inferred bedrock are shown on Drawings No. 3 and 4, respectively.

PIN 03933-0714 and PIN 03933-0746, 0047, 0075

Within these parcel's of land the soils consist of a deposit sandy silt over a till deposit over inferred bedrock. Bedrock is anticipated at depths greater than 4 m to less than 1 m below ground surface. The depth to inferred bedrock is shown on Drawing No. 4.

The subsurface conditions observed in the test holes are presented in detail on the Test Hole Records provided in Appendix B. An explanation of the symbols and terms used to describe the Borehole Records is also provided. The result of the Seismic Piezocone Tests is provided in Appendix C.

A summary of the observed subsurface conditions is presented below.

6.2.1 Surficial Materials

Topsoil was encountered in the majority of the test pits and boreholes and was observed to range from 0 mm to 300 mm in thickness. Two organic content tests were conducted on grab sample from test pits the results will be provided when testing is complete.

6.3 Clay (CL)

Borehole and Test Pit Results

Beneath the surficial materials a clay deposit was encountered across the majority of the northern half of the site. The upper 2 m to 3 m of clay was greyish brown and had a stiff to firm consistency. This upper clay layer is commonly referred to as a "crust". Several pocket penetration tests and in-situ shear tests were conducted on the clay crust; the result indicated shear strength between 48 kPa to greater than 160 kPa. The moisture content of the crust samples tested ranged from 23% to 53%.

Beneath the crust, the clay was grey and firm as indicated by the measured in-situ shear strength which varied from 20 kPa to 53 kPa. The moisture content of the clay samples tested ranged from 38% to 65%. Soil gradation test results are presented in Appendix D.

The clay can be classified as a lean clay (CL) in accordance with the Unified Soil Classification System (USCS).

The results of consolidation testing are not yet available and will be forwarded upon completion of the tests.

Seismic Piezocone Penetration Test (SCPTu)

The SPCTu tests classify the deposit as clays and organics. The results are presented in Appendix C.

Pore pressure dissipation tests were conducted within the SCPTu. The results of the pressure dissipation tests will be presented at the detailed design stage. The results of the SCPTu tests are presented in Appendix C.

6.4 Sandy Silt (ML)

Borehole and Test Pit Results

Beneath the surficial materials or clay a deposit of sandy silt with variable quantities of gravel was encountered. The deposit was generally encountered to the south of Perth Street. The color of the deposit was brown changing to grey with depth. The deposit was generally loose to compact as indicated by the SPT 'N" values which ranged from 1 to 37.

The moisture content of the samples tested ranged from 13 % to 37%. Soil gradation test results are presented in Appendix D. This material can be classified as sandy silt (ML) in accordance with the Unified Soil Classification System (USCS).

Seismic Piezocone Penetration Test

The SCPTu test classifies the deposit as sands and silt mix. The test results are presented in Appendix C.

6.5 Silty Sand (SM)

Borehole and Test Pit Results

A deposit of silty sand with variable quantities of sand and silt was encountered. The deposit was generally encountered near the Jock River. The color of the deposit was brown changing to grey with depth. The deposit was generally compact based on visual observation during the excavation of the test pits.

Soil gradation test results are presented in Appendix D. This material can be classified as sandy silt (SM) in accordance with the Unified Soil Classification System (USCS).

Seismic Piezocone Penetration Test

The SCPTu test was not conducted in this deposit.

6.6 Glacial Till

Borehole and Test Pit Results

Beneath the sandy silt and silty sand deposits a glacial till was observed. The till consists of a variable mixture of silt, sand and gravel with frequent cobbles and boulders. The deposit was generally compact to dense based on visual observation during the excavation of the test pits.

The moisture content of the samples tested ranged from 8 % to 20%. Wash sieve analysis are presented in Appendix D. This material can be classified as sandy silt (ML) in accordance with the Unified Soil Classification System (USCS).

Seismic Piezocone Penetration Test

The SCPTu was not conducted in this deposit.

6.6.1 Inferred Bedrock

Inferred bedrock was encountered at multiple test locations. The inferred bedrock was based on auger refusal, refusal of the back hoe bucket and refusal of the SCPTu. Table 6.1 summarizes the depth to inferred bedrock and Drawing No. 4 in Appendix A visually presents the bedrock depths inferred across the site.

Table 6.1: Summary of Depth to Bedrock

Test Hole Location	Depth to Inferred Bedrock Measured from Ground Surface (m)
MW 07-18	5.9
BH 07-21	5.3
TP 07-23	4.2
TP 07-24	4.3
MW 07-25	4.8
TP 07-26	4.4
BH 07-27	3.6
BH 07-28	3.9
TP 07-29	3.8
MW 07-30	3.9
TP 07-31	3.8
TP 07-32	3.5
TP 07-33	4.0
TP 07-34	3.6
MW 07-37	3.4
TP 07-36	2.9
TP 07-39	2.9
TP 07-40	1.9
TP 07-41	2.2
TP 07-42	3.3
TP 07-44	2.3
TP 07-45	2.9
TP 07-46	4.0
TP 07-48	3.6
TP 07-49	2.0
TP 07-50	3.8
TP 07-57	0.2
TP 07-58	0.9
TP 07-59	0.5
TP 07-60	1.9
TP 07-61	0.6
TP 07-62	0.7
TP 07-63	0.4
TP 07-64	3.5
TP 07-65	2.9
TP 07-67	1.6
TP 07-71	0.6
TP 07-75	3.5

6.7 Groundwater

Standpipes were installed five of the test pits. Monitoring wells were installed at eight of the boreholes. The groundwater levels were measured on June 20, 2007. Table 6.2 summarizes the groundwater levels measured on June 20, 2007. Fluctuations in the groundwater level due to seasonal variations or in response to a particular precipitation event should be anticipated.

Table 6.2: Summary of Measured Groundwater Levels

Test Hole Location	Groundwater Level Measured Below Ground Surface on June 20, 2007 (m)
MW 07-1	1.25
MW 07-7	1.44
MW 07-13	1.09
MW 07-18	0.72
MW 07-25	1.02
MW 07-30	1.21
MW 07-37	0.78
MW 07-40	1.68
TP 07-45	1.64
TP 07-47	0.60
TP 07-55	No reading
TP 07-66	1.05
TP 07-75	1.33

7.0 DISCUSSION AND RECOMMENDATIONS

7.1 Preliminary Geotechnical Assessment

Based on the soil conditions encountered in the test holes and our understanding of the project the following geotechnical constraints should be considered:

- A compressible deposit of clay was encountered within the northern section of the site. The approximate limits of the clay deposit are shown on Drawing No. 3 in Appendix A. Due to the compressible nature of the clay, grade raises over sections of the site should be restricted to minimize total settlements. Table 7.1 summarizes the preliminary grade raise restrictions for the site.

Table 7.1: Preliminary Grade Raise Restrictions

Site Area	Maximum Grade Raise above Existing Site Grades (m)
0062, 0061; north of Perth Street	1.0
PIN 0285, 0286; parcel to the south of Perth Street	1.5
PIN 0287; parcel north of Ottawa St.	2.0
PIN 0714, 0746, 0047, 0075; parcel north and south of Ottawa St.	4.0

- Shallow bedrock was encountered within the southern half of the site. It is anticipated that bedrock excavation for underground services and building foundations will be required in the area south of Ottawa Street. Estimated depths to inferred bedrock are presented on Drawing No. 4 in Appendix A.
- The soil conditions encountered are suitable for the use of conventional spread and strip footings for the support of structures. Table 7.2 provides Geotechnical Bearing Resistance Values for Preliminary Design purposes. The values have been calculated assuming no modifications to existing grades, a footing depth of 2.4 m below finished grade with an embedment of 0.5 m and a footing width of 0.8 m.

Table 7.2: Geotechnical Resistance for Shallow Foundations

Site Area	Founding Material	ULS (kPa)	SLS (kPa)
PIN 0062, 0061	Firm Clay	125	100
PIN 0285, 0286	Firm Clay	125	100
PIN 0287	Dense sandy silt	300	150
PIN 0714, 0746, 0047, 0075	Dense sandy silt, glacial till	300	150
PIN 0714, 0746, 0047, 0075	Bedrock	500	NA

The Ultimate Limit State (ULS) bearing resistance includes a resistance factor of 0.5. The Serviceability Limit State (SLS) bearing resistance corresponds to total settlement of 25 mm. Differential settlements between footings are expected to be less than 19 mm.

Note that settlement estimates are highly dependent on grade changes. The geotechnical resistance values will need to be reviewed in conjunction with the proposed grading plan.

- The groundwater table was observed to be relatively high. Grade reductions may lead to drainage concerns.

- Several test pits were terminated between 3 m to 4 m below ground surface within the sandy silt deposit due to side wall collapse and groundwater seepage. Excavations below the groundwater level may require shoring protection or special dewatering treatments.
- Several ditch's may require backfilling and the water courses may need diverting.
- In accordance with Table 4.1.8.4.A. of the 2006 Ontario Building Code, the project site is considered to be classified under several site classifications for seismic site response. Table 7.3 summarizes the appropriate site classification for the various parcels of land.

Table 7.3: Site Classification for Seismic Site Response

Parcel of Land	Ground Profile Name	Site Class
PIN 0062, 0061,0285, 0286	Soft Soil	E
PIN 0287, 0714	Stiff Soil	D
PIN 0746, 0047, 0075	Very Dense Soil and Soft Rock	C

- Table 7.4 summarizes the possible re-uses of site generated materials.

Table 7.4: Suitable Re-uses for Site Generated Materials

Soil Deposit	Exterior Foundation Wall Backfill	Subgrade Fill	Landscaping Fill
Clay Crust		X	X
Clay			X
Sandy Silt, Silt,			X
Glacial Till, Silty Sand	X	X	X
Crushed Bedrock	X	X	X

8.0 CLOSURE

This report has been prepared for the sole benefit of Mattamy Homes Ltd and its agents, and may not be used by any third party without the express written consent of Jacques Whitford Limited and Mattamy Homes Ltd. Any use which a third party makes of this report is the responsibility of such third party.

The recommendations made in this report are in accordance with our present understanding of your project. We request that we be permitted to review our recommendations when your drawings and specifications are complete.

This report is based on the site conditions encountered by Jacques Whitford at the time of the work, and at the specific testing and/or sampling locations, and can only be extrapolated to a limited extent around these locations. The extent depends on the variability of soil and groundwater conditions as influenced by geological processes, construction activities and site use. Should any conditions at the site be encountered which differ from those at the test locations, we require that we be notified immediately in order to permit reassessment of our findings.

We trust the above meets your present requirements. Should you require any further information please do not hesitate to contact us.

Yours very truly,

JACQUES WHITFORD LIMITED

Christopher McGrath, P.Eng.
Project Manager

Fred J. Griffiths, Ph.D., P.Eng.
Principal and Group Leader
Geotechnical and Materials Engineering

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Jacques
Whitford

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Canada, K1B 1A7
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Fax: (613) 738-0721

Engineering, Scientific, Planning and Management Consultants

LETTER OF TRANSMITTAL

DATE: June 22, 2007

PROJECT NO.: 1026929

TO: Mattamy Homes – Ottawa Division
123 Huntmar Drive
Ottawa, ON K2S 1B9

RE: Preliminary Geotechnical Investigation

ATTN: Matthew Kingston

WE ARE SENDING YOU:

- ☐ Attached
- ☐ Under separate cover via:
- ☒ Draft Report
- ☐ Copy of Letter
- ☐ Plans
- ☐ Samples
- ☐ Specifications
- ☐ Final Report
- ☐ Prints
- ☐ Change Order
- ☐ Other:

COPIES	DATE	NO.	DESCRIPTION
3	June 22, 2007	1026929	Preliminary Geotechnical Investigation Report
			Proposed Residential Subdivision
			Perth and Ottawa Streets
			Richmond Area – Ottawa, Ontario

THESE ITEMS ARE TRANSMITTED:

- ☐ For Approval
- ☐ Approved as Submitted
- ☐ For Review and Comment
- ☐ As Requested
- ☐ For Your Use
- ☐ Approved as Noted
- ☐ Other

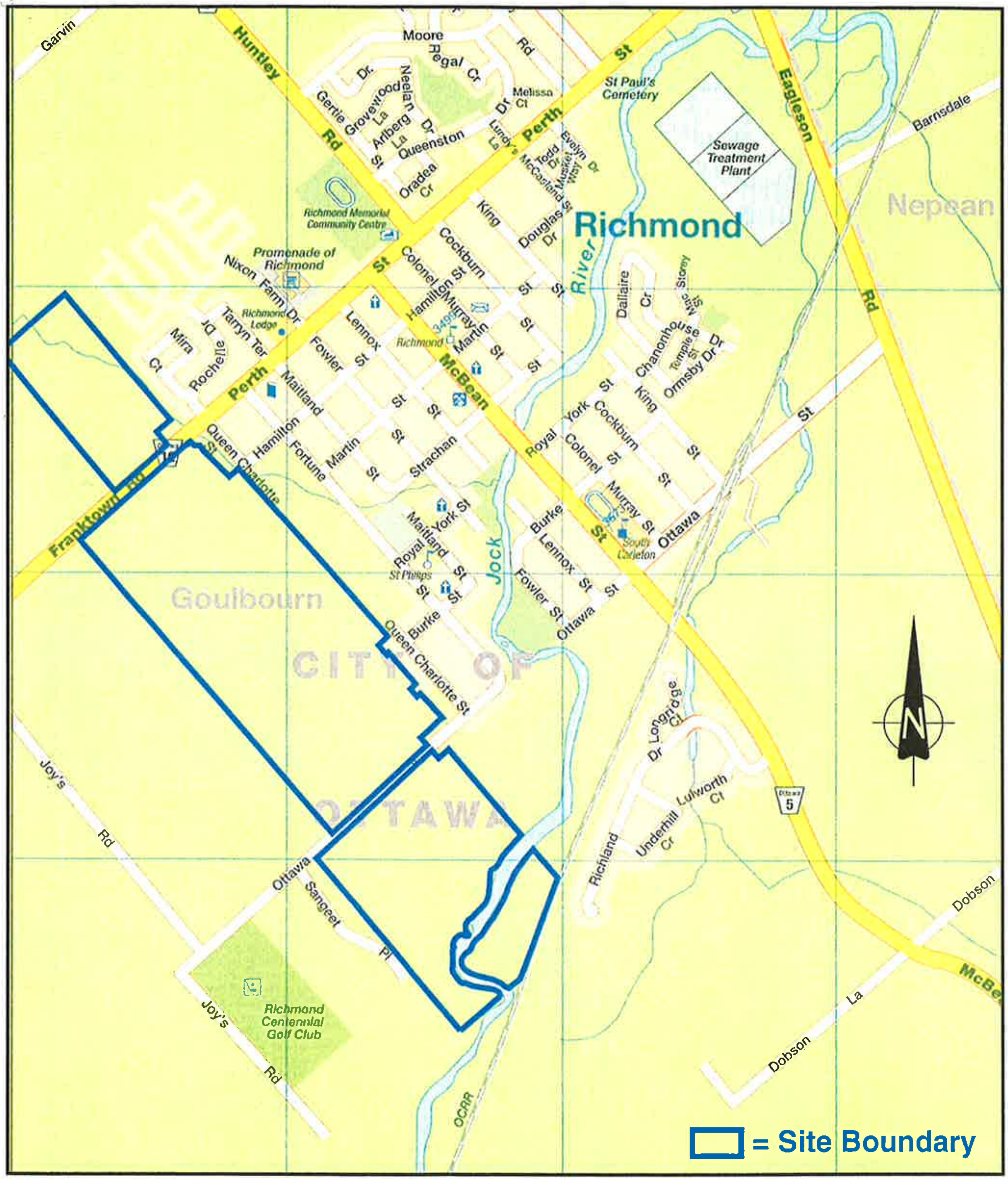
REMARKS:

SIGNED: Christine Fisher

COPY TO:

APPENDIX A

Drawing No. 1 - Key Plan
Drawing No. 2 - Test Hole Location Plan
Drawing No. 3 - Estimated Thickness of Clay Deposit
Drawing No. 4 - Inferred Depth to Bedrock
Drawing No. 5 – Stratigraphic Plot
Drawing No. 6 – Stratigraphic Plot



REFERENCE: MAPART

NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A JACQUES WHITFORD LIMITED REPORT AND MUST NOT BE USED FOR OTHER PURPOSES.

KEY PLAN

GEOTECHNICAL INVESTIGATION FOR RESIDENTIAL SUBDIVISION

PERTH & OTTAWA STREETS, OTTAWA, ON.

Client: MATTAMY HOMES

Job No.:	1026929
Scale:	1 : 20 000
Date:	07/06/21
Dwn. By:	GBB
App'd By:	
Dwg. No.:	1

Jacques Whitford

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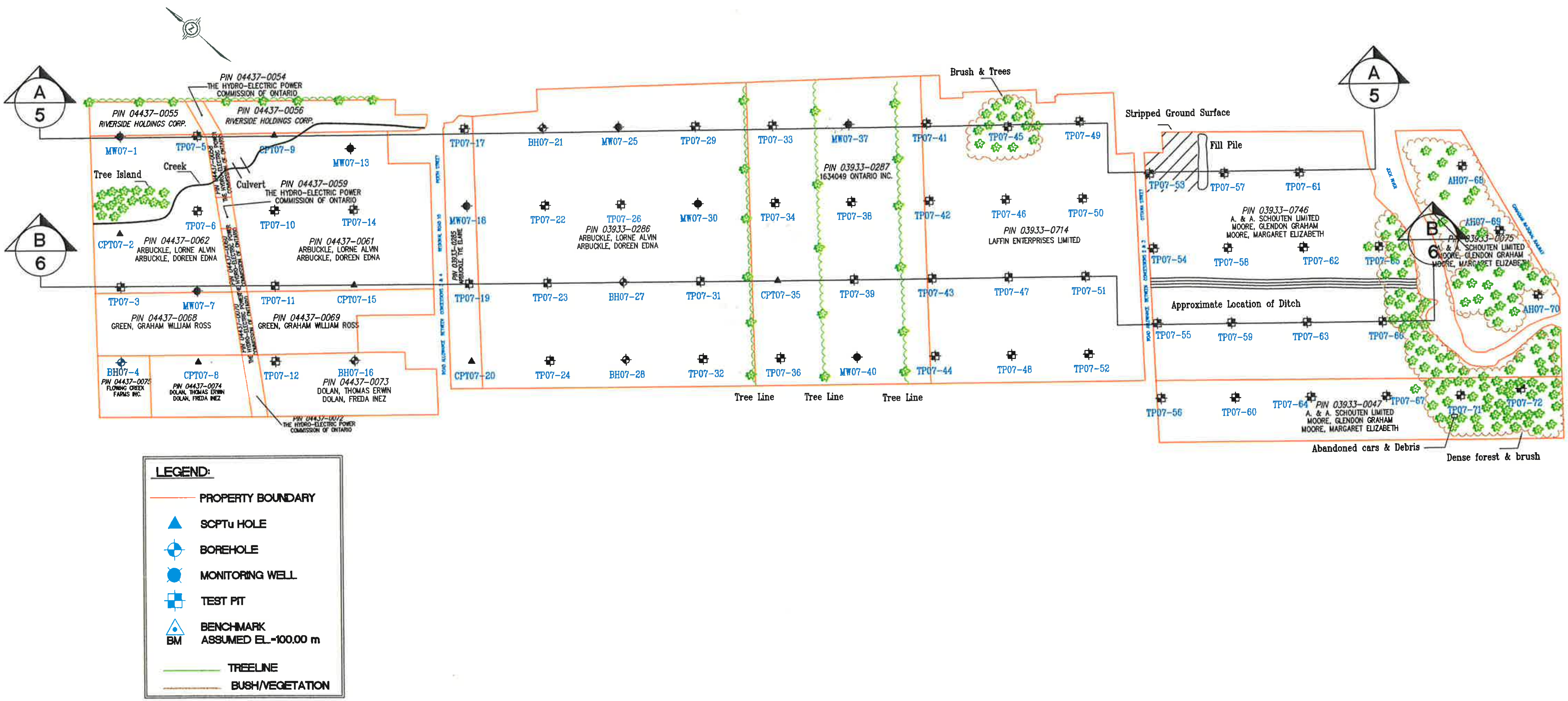

NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A JACQUES WHITFORD LIMITED REPORT AND MUST NOT BE USED FOR OTHER PURPOSES.

Reference:	Job No.: 1026929	Client: MATTAMY HOMES	GEOTECHNICAL INVESTIGATION FOR RESIDENTIAL SUBDIVISION	TEST HOLE LOCATION	Dwg. No.: 2	Jacques Whitford
Baseline Provided by J.D. Barnes Ltd. Dwg. No. 07-10-724-00 Date: April 21, 2007	Scale: 1 : 8000	Site Address				
	Date: 07/06/22	VILLAGE OF RICHMOND OTTAWA, ONTARIO				
	Dwn. By: EAG					
	App'd By:					

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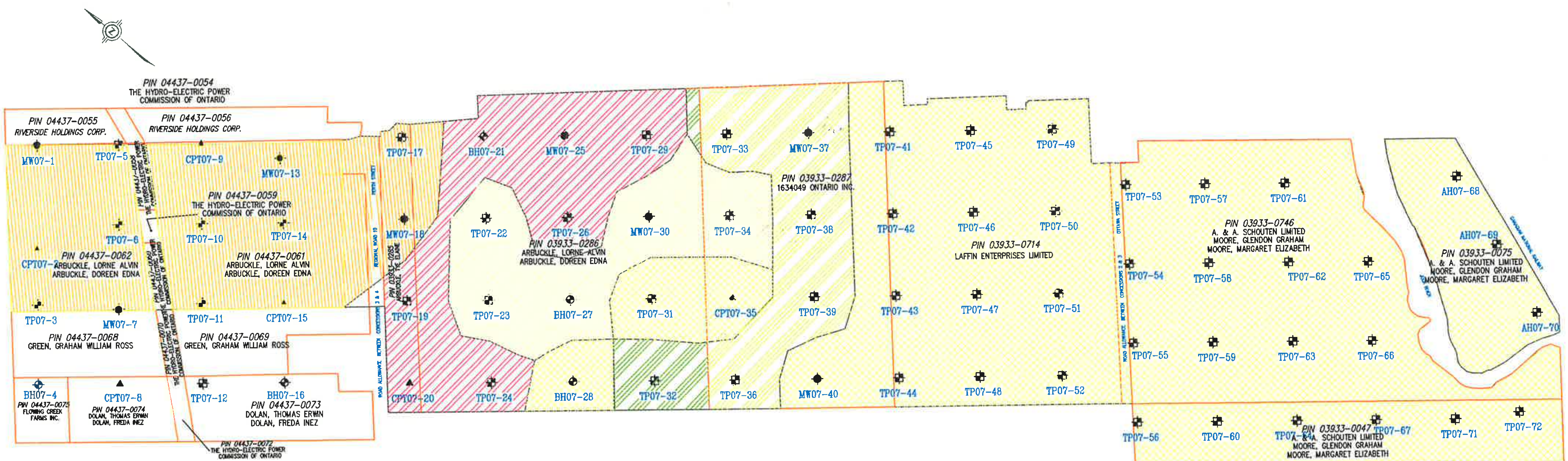

LEGEND:

ESTIMATED THICKNESS OF CLAY DEPOSIT

> 4 m in thickness	
3 m to 4 m	
2 m to 3 m	
1 m to 2 m	
No clay	

PROPERTY BOUNDARY
SCPTu HOLE
BOREHOLE
MONITORING WELL
TEST PIT
BENCHMARK (TOP OF FIRE HYDRANT) ASSUMED EL.=100.00 m

Notes :
-The thicknesses are inferred from the test hole results.
-Conditions between test holes could very from those encountered at the test hole.

NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A JACQUES WHITFORD LIMITED REPORT AND MUST NOT BE USED FOR OTHER PURPOSES.

Reference: Baseline provided by J.D. Barnes Ltd. Dwg No. 07-10-724-00 Date: April 21, 2007	**Job No.:**	1026929
	Scale:	1 : 8000
	Date:	07/06/22
	Dwn. By:	EAG
	App'd By:	

Client: MATTAMY HOMES

Site Address VILLAGE OF RICHMOND OTTAWA, ONTARIO

GEOTECHNICAL INVESTIGATION FOR RESIDENTIAL SUBDIVISION

ESTIMATED THICKNESS OF CLAY DEPOSIT

Dwg. No.: 3

Jacques Whitford

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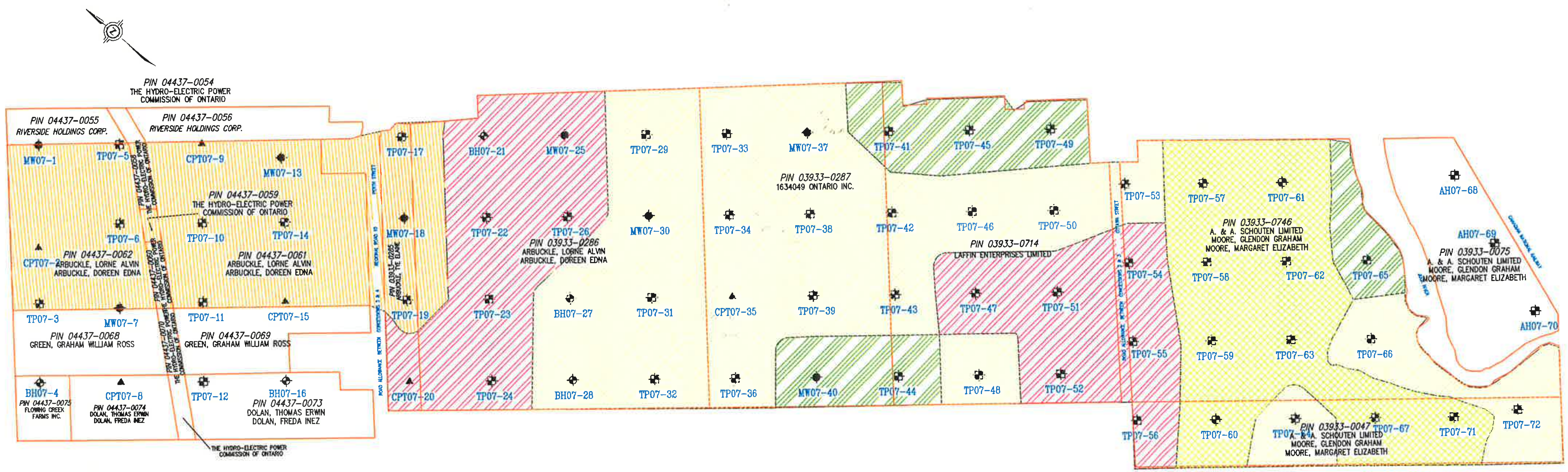

LEGEND:

ESTIMATED DEPTH TO BEDROCK

- > 6 m Below ground surface
- 4 to 6 m Below ground surface
- 3 to 4 m Below ground surface
- 2 to 3 m Below ground surface
- < 2 m Below ground surface

- PROPERTY BOUNDARY
- SCPTu HOLE
- BOREHOLE
- MONITORING WELL
- TEST PIT
- BENCHMARK (TOP OF FIRE HYDRANT) ASSUMED EL.=100.00 m

Notes :

– The estimated depth to bedrock is based on refusal on inferred bedrock at the test hole locations. Conditions between test holes could vary from those encountered at the test hole.

NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A JACQUES WHITFORD LIMITED REPORT AND MUST NOT BE USED FOR OTHER PURPOSES.

Reference:	Baseline provided by J.D. Barnes Ltd. Dwg. No. 07-10-724-00 April 21, 2007
Job No.:	1026929
Scale:	1 : 8000
Date:	07/06/22
Dwn. By:	EAG
App'd By:	
Client:	MATTAMY HOMES
Site Address	RICHMOND OTTAWA, ONTARIO
	GEOTECHNICAL INVESTIGATION FOR RESIDENTIAL SUBDIVISION
	ESTIMATED DEPTH TO BEDROCK
Dwg. No.:	4

Jacques Whitford

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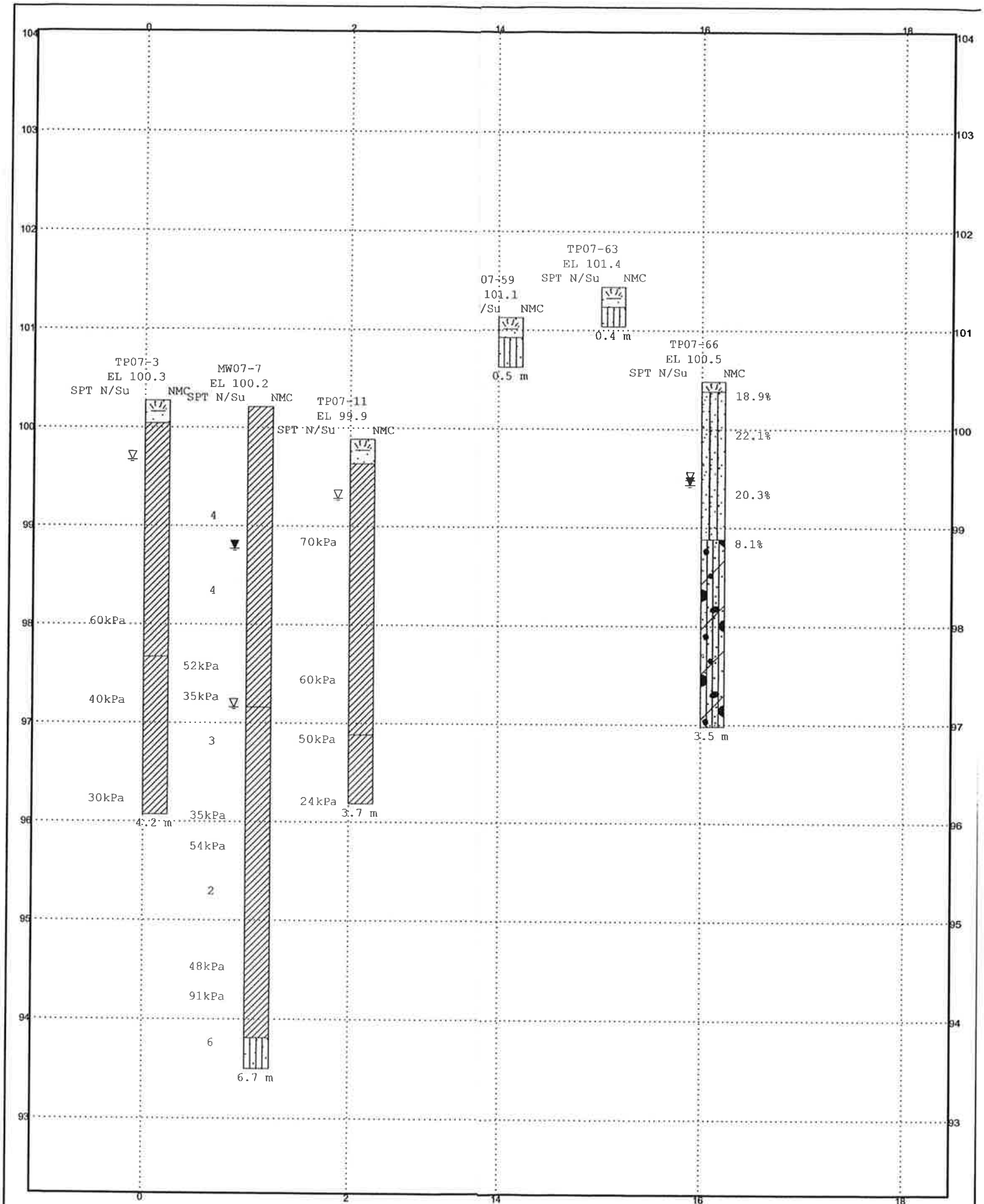


SOIL & ROCK KEY

BOULDERS, COBBLES & GRAVELS
SAND & GRAVEL
SAND
SILTY SAND
SILT
CLAY
SILTY CLAY
TILL
FILL
ORGANICS
SHALE BEDROCK
LIMESTONE BEDROCK
SANDSTONE BEDROCK

Title: **Summary of Test Hole Data**

Mattamy Homes, Village of Richmond
Cross Section B

Drawn: BDG	Approved: FG	Date: 07/06/22	Figure No. 6
			Job No. 1026929

APPENDIX B

Symbols and Terms Used on the Borehole Records
Borehole and Test Pit Records

Jacques Whitford

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

Desiccated	- having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
Fissured	- having cracks, and hence a blocky structure
Varved	- composed of regular alternating layers of silt and clay
Stratified	- composed of alternating successions of different soil types, e.g. silt and sand
Layer	- > 75 mm in thickness
Seam	- 2 mm to 75 mm in thickness
Parting	- < 2 mm in thickness

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488). The classification excludes particles larger than 76 mm (3 inches). The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present:

Trace, or occasional	Less than 10%
Some	10-20%
Frequent	> 20%

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test N-Value (also known as N-Index). A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
Very Loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very Dense	>50

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests.

Consistency	Undrained Shear Strength	
	kips/sq.ft.	kPa
Very Soft	<0.25	<12.5
Soft	0.25 - 0.5	12.5 - 25
Firm	0.5 - 1.0	25 - 50
Stiff	1.0 - 2.0	50 – 100
Very Stiff	2.0 - 4.0	100 - 200
Hard	>4.0	>200

ROCK DESCRIPTION

Terminology describing rock quality:

RQD	Rock Mass Quality
0-25	*Very Poor*
25-50	*Poor*
50-75	*Fair*
75-90	*Good*
90-100	*Excellent*

Rock quality classification is based on a modified core recovery percentage (RQD) in which all pieces of sound core over 100 mm long are counted as recovery. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. RQD was originally intended to be done on NW core; however, it can be used on different core sizes if the bulk of the fractures caused by drilling stresses are easily distinguishable from *in situ* fractures. The terminology describing rock mass quality based on RQD is subjective and is underlain by the presumption that sound strong rock is of higher engineering value than fractured weak rock.

Terminology describing rock mass:

Spacing (mm)	Joint Classification	Bedding, Laminations, Bands
> 6000	*Extremely Wide*	-
2000-6000	*Very Wide*	*Very Thick*
600-2000	*Wide*	*Thick*
200-600	*Moderate*	*Medium*
60-200	*Close*	*Thin*
20-60	*Very Close*	*Very Thin*
<20	*Extremely Close*	*Laminated*
<6	-	*Thinly Laminated*

Terminology describing rock strength:

Strength Classification	Unconfined Compressive Strength (MPa)
Extremely Weak	< 1
Very Weak	1 – 5
Weak	5 – 25
Medium Strong	25 – 50
Strong	50 – 100
Very Strong	100 – 250
Extremely Strong	> 250

Terminology describing rock weathering:

Term	Description
Fresh	No visible signs of rock weathering. Slight discolouration along major discontinuities
Slightly Weathered	Discolouration indicates weathering of rock on discontinuity surfaces. All the rock material may be discoloured.
Moderately Weathered	Less than half the rock is decomposed and/or disintegrated into soil.
Highly Weathered	More than half the rock is decomposed and/or disintegrated into soil.
Completely Weathered	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.

Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Igneous Bedrock	Meta-morphic Bedrock	Sedi-mentary Bedrock

SAMPLE TYPE

SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby tube or thin wall tube
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond coring bits.

WATER LEVEL MEASUREMENT

▼ measured in standpipe, piezometer, or well

▽ inferred

RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

N-VALUE / RQD

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (64 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (305 mm) into the soil. For split spoon samples where insufficient penetration was achieved and N-values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N value corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log. RQD is based on a modified core recovery percentage in which all pieces of sound core over 100 mm long are counted as recovery.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to A size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (305 mm) into the soil. The DCPT is used as a probe to assess soil variability. Soil type may be inferred from adjacent boreholes and test pits.

OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
γ	Unit weight
G_s	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
Q_u	Unconfined compression
I_p	Point Load Index (I_p on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer

Jacques Whitford

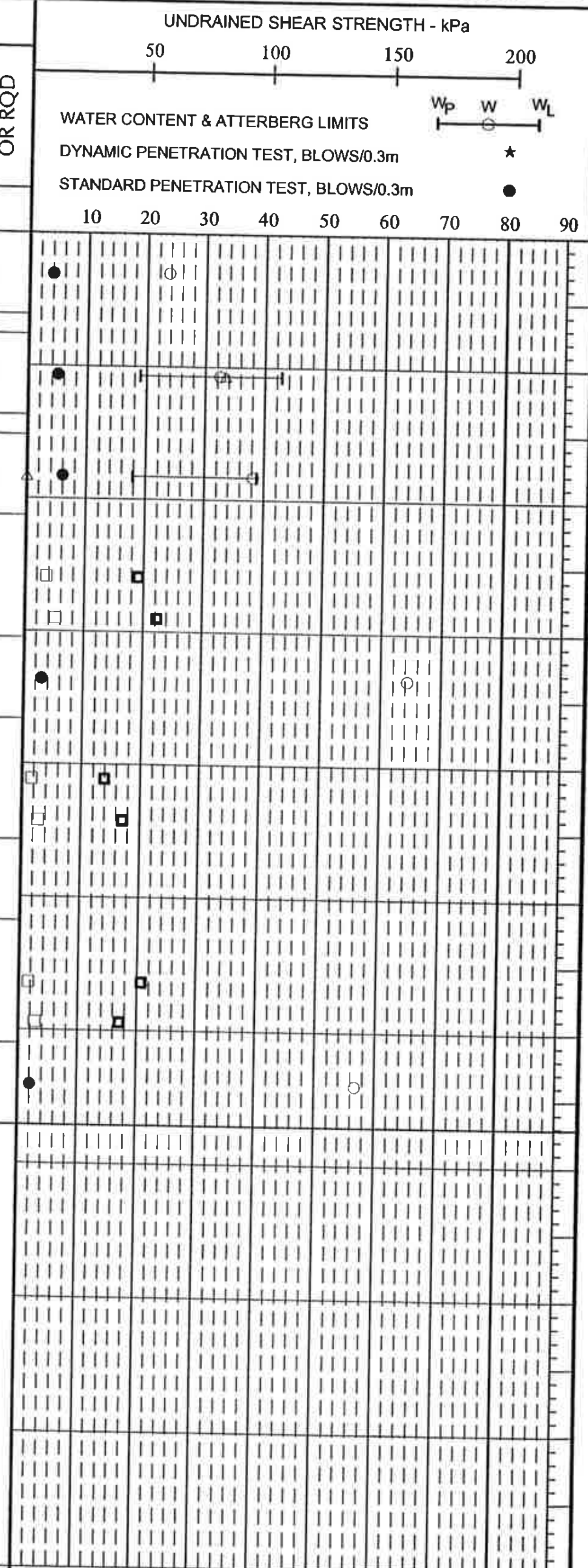
MONITORING WELL RECORD

MW07-1

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 18, 2007 WATER LEVEL June 20, 2007

BOREHOLE No. MW07-1
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	100.32							
	100.2	150 mm TOPSOIL						
		Firm to stiff, greyish brown lean CLAY (CL)			SS	1	300	4
1				▼	SS	2	610	5
2				▽	SS	3	610	6
3	97.3	Firm to stiff, grey lean CLAY						
					SS	4	610	3
4								
5					ST	5	610	
6								
	93.8				SS	6	610	2
	93.6	Very loose, grey SANDY SILT (ML)						
7		End of Borehole						
		Monitoring Well Installed						
8								
9								
10								



▽ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

▪ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ________
Date ________

Jacques Whitford

TEST PIT RECORD

TP07-3

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

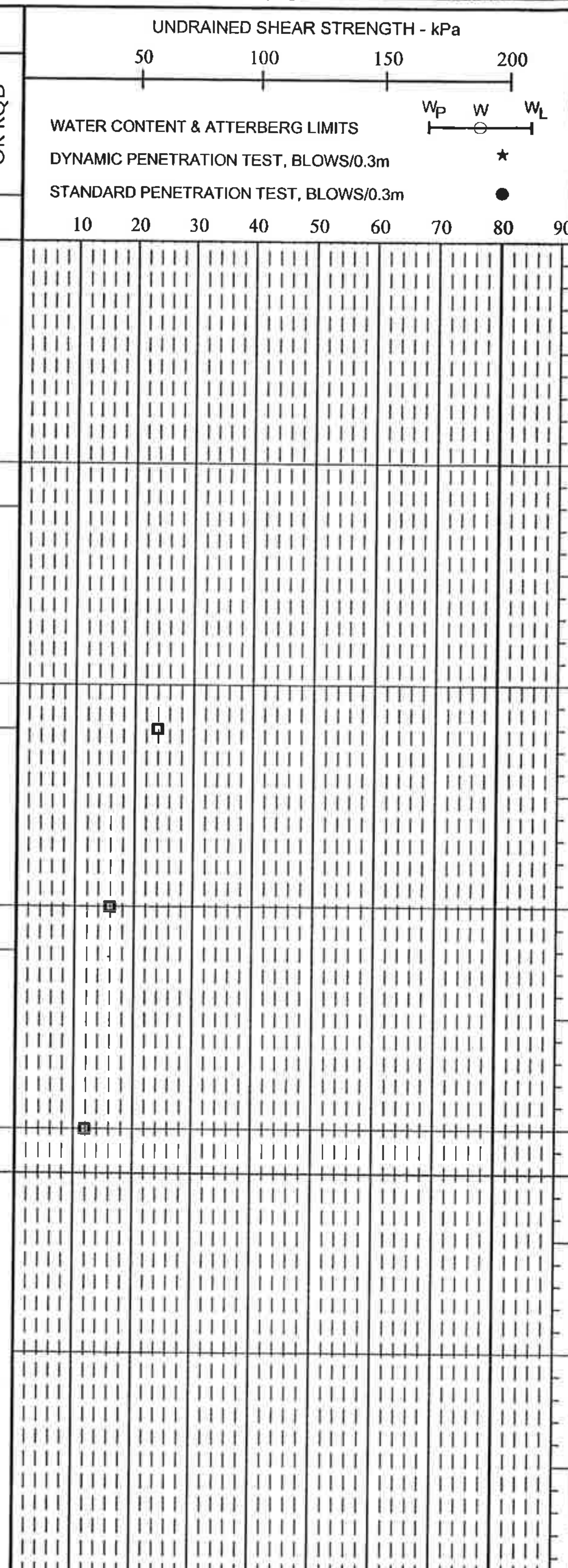
DATES: BORING June 16, 2007 WATER LEVEL

BOREHOLE No. TP07-3

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	100.27							
	100.0	230 mm TOPSOIL						
		Stiff, greyish brown lean CLAY (CL)		∇				
1					BS	1		
2					BS	2		
	97.7	Firm, grey lean CLAY (CL)						
3					BS	3		
4					BS	4		
	96.1	End of Borehole						
5								
6								



∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

Field Vane Test, kPa

Remoulded Vane Test, kPa

Pocket Penetrometer Test, kPa

App'd

Date

Jacques Whitford

BOREHOLE RECORD

BH07-4

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING ______ WATER LEVEL ______

BOREHOLE No. BH07-4

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0		Borehole was not drilled						
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Jacques Whitford

TEST PIT RECORD

TP07-5

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 16, 2007 WATER LEVEL

BOREHOLE No. TP07-5

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	100.11	250 mm TOPSOIL			BS	1		
	99.9	Stiff, greyish brown lean CLAY (CL)	▨	∇				
1					BS	2		
					BS	3		
2	98.1	Firm, grey lean CLAY (CL)	▨					
					BS	4		
3					BS	5		
4	95.9				BS	6		
		End of Borehole						
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Jacques Whitford

TEST PIT RECORD

TP07-6

CLIENT: Mattamy Homes
LOCATION: Proposed Subdivision, Richmond, ON
DATES: BORING June 16, 2007 WATER LEVEL
BOREHOLE No. TP07-6
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.85							
	99.6	250 mm TOPSOIL						
		Compact to dense, brown and grey SANDY SILT (ML)		▽	BS	1		
1					BS	2		
2	97.9	Firm, grey lean CLAY (CL)			BS	3		
3					BS	4		
4	95.6				BS	5		
		End of Borehole						
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ________
Date ________

Jacques Whitford

TEST PIT RECORD

TP07-11

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 16, 2007 WATER LEVEL

BOREHOLE No. TP07-11

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.89	250 mm TOPSOIL				
	99.6	Stiff, brown and grey lean CLAY (CL)	BS	1		
1			BS	2		
2			BS	3		
3	96.9	Firm, grey lean CLAY (CL)	BS	4		
	96.2	End of Borehole	BS	5		
4						
5						
6						

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m *

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Jacques Whitford

TEST PIT RECORD

TP07-12

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING WATER LEVEL

BOREHOLE No. TP07-12

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE OR RQD	UNDRAINED SHEAR STRENGTH - kPa (50, 100, 150, 200); WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L); DYNAMIC PENETRATION TEST, BLOWS/0.3m ★; STANDARD PENETRATION TEST, BLOWS/0.3m ● (10 20 30 40 50 60 70 80 90)
0		Test pit was not excavated							
1									
2									
3									
4									
5									
6									

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Jacques Whitford

BOREHOLE RECORD

BH07-21

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. BH07-21
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	WATER LEVEL	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	98.99						
	98.7	Loose brown sandy silt, some gravel, occasional cobbles: FILL		SS	1	100	13
1		Firm to stiff, greyish brown lean CLAY (CL)		SS	2	280	9
2				SS	3	610	5
				ST	4	620	
3	95.2		∇				
4		Compact, grey SANDY SILT (ML)		SS	5	150	
5	93.7			SS	6	360	12
		End of Borehole Auger Refusal on Inferred Bedrock					

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

Jacques Whitford

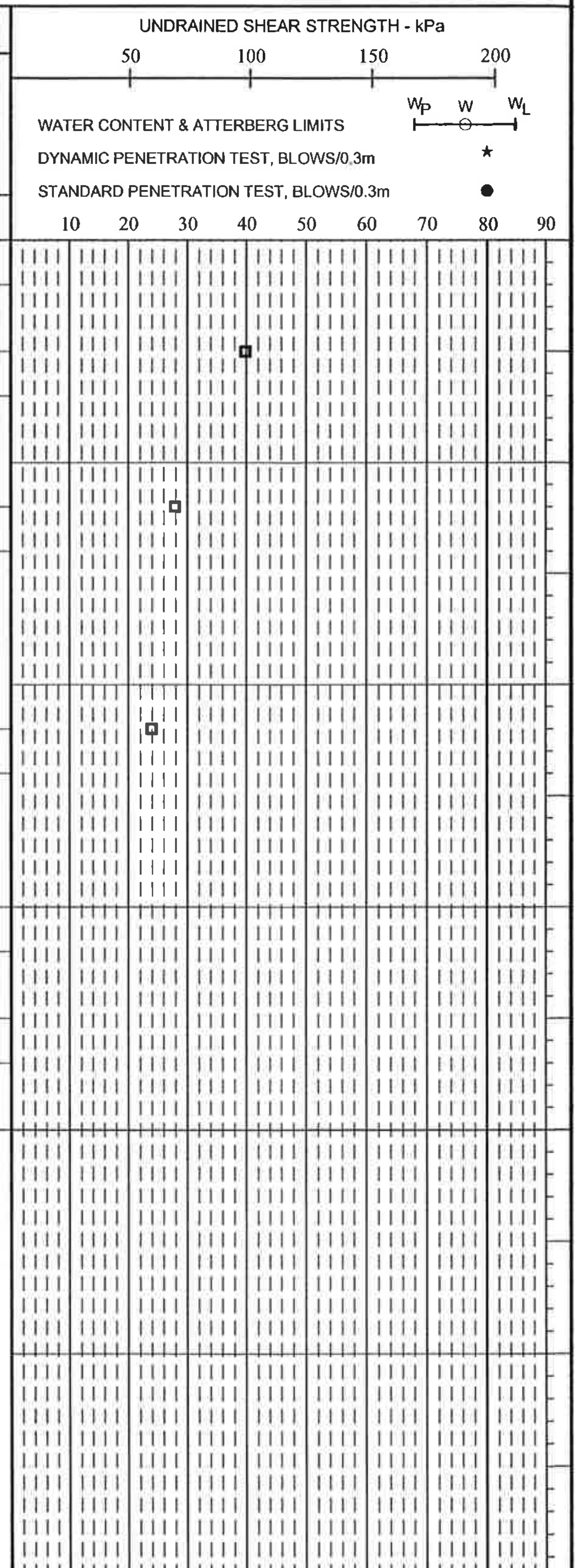
TEST PIT RECORD

TP07-22

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-22
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.23							
	99.0	200 mm TOPSOIL			BS	1		
		Stiff, greyish brown lean CLAY (CL)			BS	2		
1					BS	3		
2	97.0			∇				
		Dense, grey SANDY SILT (ML)			BS	4		
3					BS	5		
					BS	6		
4	95.2	End of Borehole						
5								
6								



∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd
Date

Jacques Whitford

TEST PIT RECORD

TP07-23

CLIENT: Mattamy Homes
LOCATION: Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-23
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	99.36							
	99.2	200 mm TOPSOIL						
		Very stiff, greyish brown lean CLAY (CL)		∇	BS	1		
1					BS	2		
2					BS	3		
	96.9	Compact to dense, grey and brown SANDY SILT (ML)			BS	4		
3					BS	5		
					BS	6		
4	95.4	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	7		
	95.1	End of Borehole Refusal on Inferred Bedrock						
5								
6								

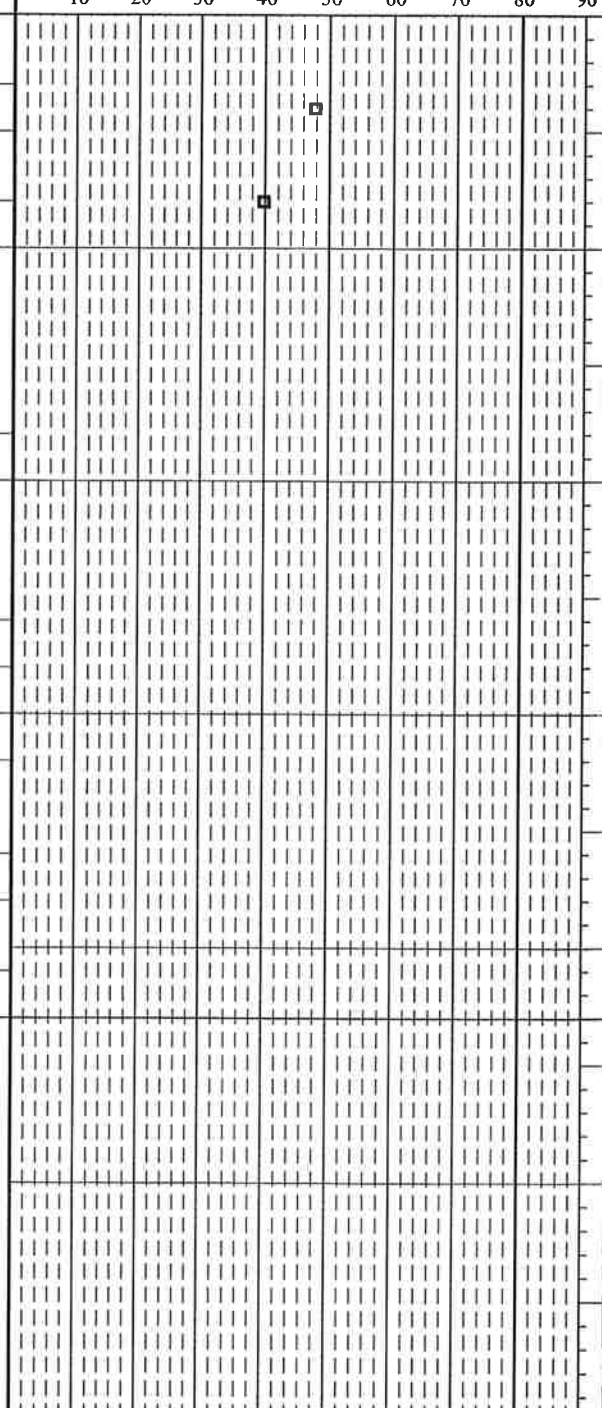
UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90



∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Jacques Whitford

TEST PIT RECORD

TP07-24

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

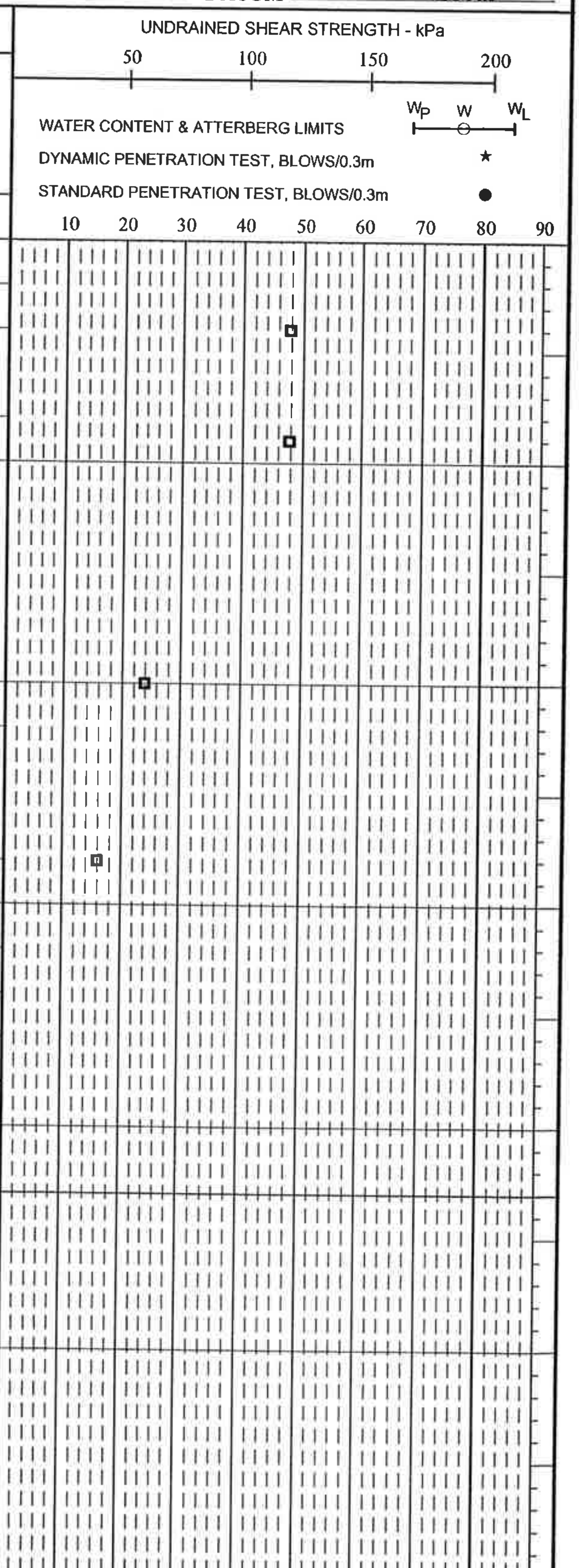
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-24

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	99.94							
	99.7	200 mm TOPSOIL			BS	1		
		Very stiff to stiff, greyish brown lean CLAY (CL)		∇	BS	2		
1					BS	3		
2					BS	4		
	97.4	Firm, grey lean CLAY (CL)						
3	96.9	Compact to dense, grey SANDY SILT (ML)			BS	5		
	96.6	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	6		
					BS	7		
4	95.6	End of Borehole Refusal on Inferred Bedrock			BS	8		
5								
6								



∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd

Date

Jacques Whitford

MONITORING WELL RECORD

MW07-25

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 14, 2007 WATER LEVEL June 20, 2007

BOREHOLE No. MW07-25
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLE TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	98.72					
	98.5	200 mm TOPSOIL				
		Firm to stiff, greyish brown lean CLAY (CL)	SS	1	320	19
1			SS	2	610	8
2			SS	3	610	7
3	95.7	Loose to compact, SANDY SILT (ML)	SS	4	610	14
4			SS	5	450	7
	93.9		SS	6	150	50/ 50 mm
5		End of Borehole Auger Refusal on Inferred Bedrock Monitoring Well Installed				

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

Jacques Whitford

TEST PIT RECORD

TP07-26

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-26
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.46					
	99.3	200 mm TOPSOIL				
		Very stiff to stiff, greyish brown lean CLAY (CL)	BS	1		
			BS	2		
			BS	3		
			BS	4		
	96.6	Dense, grey SANDY SILT (ML)	BS	5		
	95.5	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)	BS	6		
	95.1	End of Borehole Refusal on Inferred Bedrock				

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

Inferred Groundwater Level
Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd
Date

Jacques Whitford

BOREHOLE RECORD

BH07-27

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL
BOREHOLE No. BH07-27
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.64	Stiff to very stiff, greyish brown lean CLAY (CL)	SS	1	280	8
1			SS	2	30	8
2.3	97.3	Compact, brown SANDY SILT (ML)	SS	3	320	13
3			SS	4	350	18
3.6	96.0	End of Borehole Auger Refusal on Inferred Bedrock				

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd
Date

Jacques Whitford

BOREHOLE RECORD

BH07-28

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. BH07-28
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	100.04							
	99.9	100 mm TOPSOIL						
		Compact, greyish brown SANDY SILT (ML)			SS	1	150	7
1					SS	2	420	29
2				∇	SS	3	520	26
	97.8	Compact, brown SILTY SAND (SM)			SS	4	500	27
3	97.0	Compact, grey SILTY SAND (SM)			SS	5	420	25
	96.2				SS		100	50/ 0 mm
4		End of Borehole Auger Refusal on Inferred Bedrock						
5								
6								
7								
8								
9								
10								

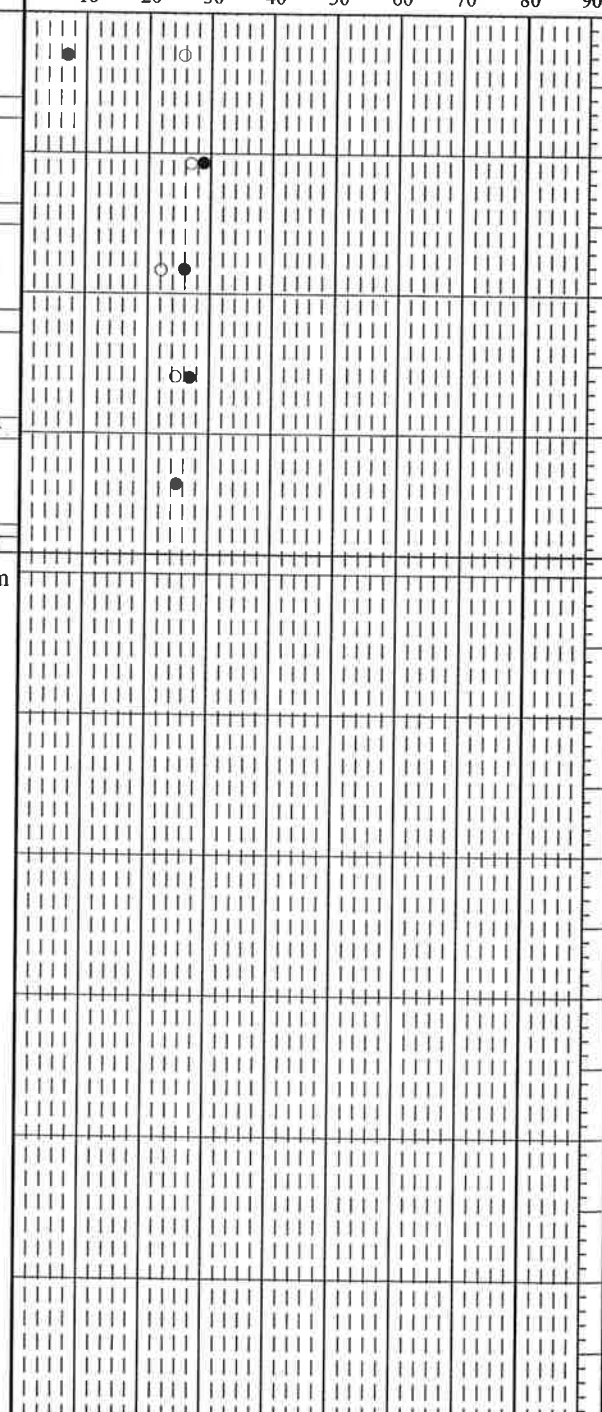
UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90



∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

Jacques Whitford

TEST PIT RECORD

TP07-29

CLIENT: Mattamy Homes

LOCATION: Proposed Subdivision, Richmond, ON

DATES: BORING: June 15, 2007 WATER LEVEL

BOREHOLE No.: TP07-29

PROJECT No.: 1026929

DATUM: Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE OR RQD
0	99.04							
	98.8	200 mm TOPSOIL						
		Very stiff to stiff, greyish brown lean CLAY (CL)		∇	BS	1		
1					BS	2		
2	96.8				BS	3		
		Dense, grey SANDY SILT (ML)			BS	4		
3	96.0	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	5		
	95.2				BS	6		
4		End of Borehole Refusal on Inferred Bedrock						
5								
6								

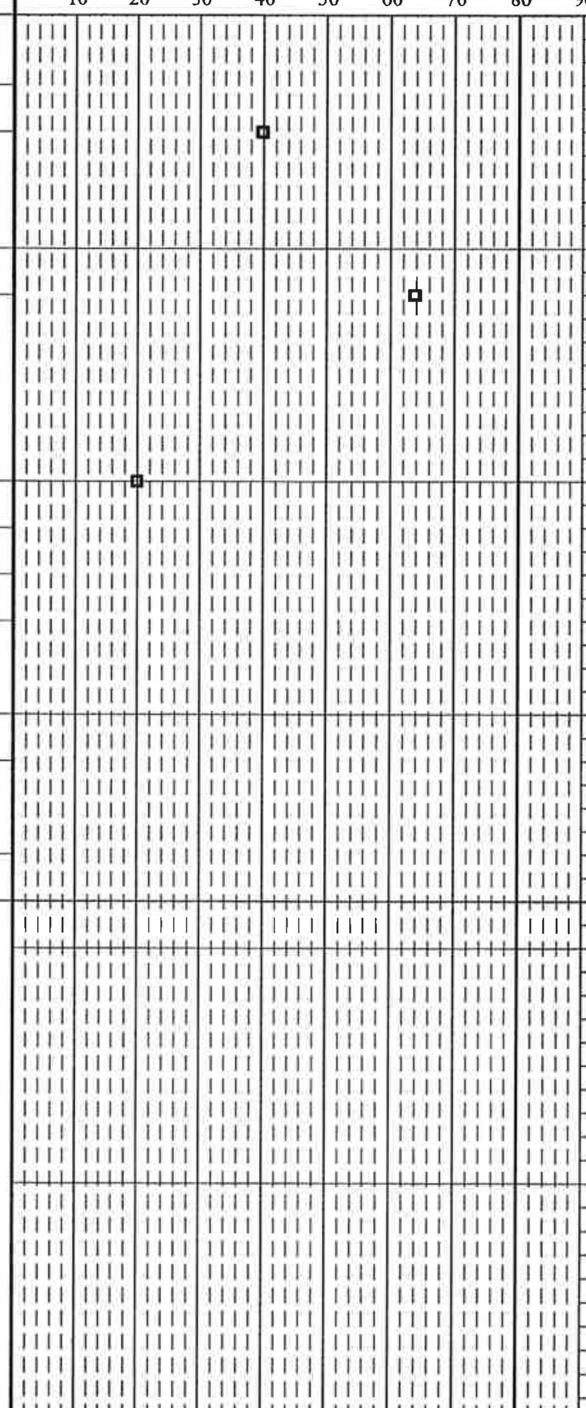
UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P, W, W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90



∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

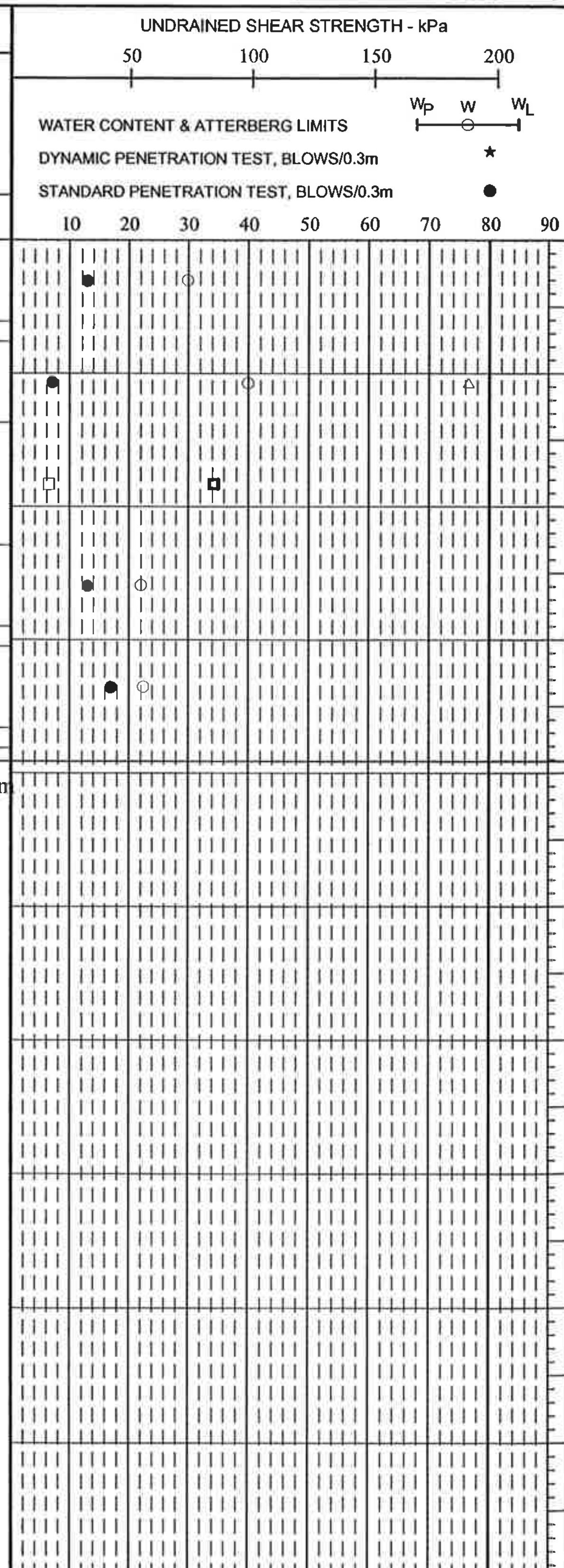
MONITORING WELL RECORD

MW07-30

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 14, 2007 WATER LEVEL June 20, 2007

BOREHOLE No. MW07-30
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.52					
	99.4	150 mm TOPSOIL				
		Firm to stiff, greyish brown lean CLAY (CL)	SS	1	100	13
1			SS	2	500	7
2	97.5	Compact, brown to grey SANDY SILT (ML)				
			SS	3	320	13
3			SS	4	420	17
	95.6		SS	5	150	50/ 100 mm
4		End of Borehole Auger Refusal on Inferred Bedrock Monitoring Well Installed				



Inferred Groundwater Level
Groundwater Level Measured in Standpipe

Field Vane Test, kPa
Remoulded Vane Test, kPa
Pocket Penetrometer Test, kPa

App'd ______
Date ______

Jacques Whitford

TEST PIT RECORD

TP07-31

CLIENT	Mattamy Homes	BOREHOLE No.	TP07-31
LOCATION	Proposed Subdivision, Richmond, ON	PROJECT No.	1026929
DATES: BORING	June 15, 2007 WATER LEVEL	DATUM	Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	WATER LEVEL	SAMPLE TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD	FIELD VANE (kPa)
0	99.82							
	99.6	200 mm TOPSOIL						
	99.4	Stiff, greyish brown lean CLAY (CL)		BS	1			~85
		Dense, grey SANDY SILT (ML)		BS	2			
			▽					
1				BS	3			
2				BS	4			
3	96.8			BS	5			
		Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)		BS	6			
	96.0	End of Borehole Refusal on Inferred Bedrock						

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Jacques Whitford

TEST PIT RECORD

TP07-32

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-32
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.92							
	99.8	150 mm TOPSOIL						
		Stiff, greyish brown lean CLAY (CL)		∇	BS	1		
1					BS	2		
	98.1	Compact to dense, grey SANDY SILT (ML)			BS	3		
2					BS	4		
					BS	5		
3	96.9	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	6		
	96.4	End of Borehole Refusal on Inferred Bedrock						
4								
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd
Date

Jacques Whitford

TEST PIT RECORD

TP07-33

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-33

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.45							
	99.3	150 mm TOPSOIL			BS	1		
		Stiff, brown lean CLAY (CL)			BS	2		
1	98.0				BS	3		
		Dense, brown SANDY SILT (ML)						
2					BS	4		
				∇				
3	96.2				BS	5		
		Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	6		
4	95.4				BS	7		
		End of Borehole Refusal on Inferred Bedrock						
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Jacques Whitford

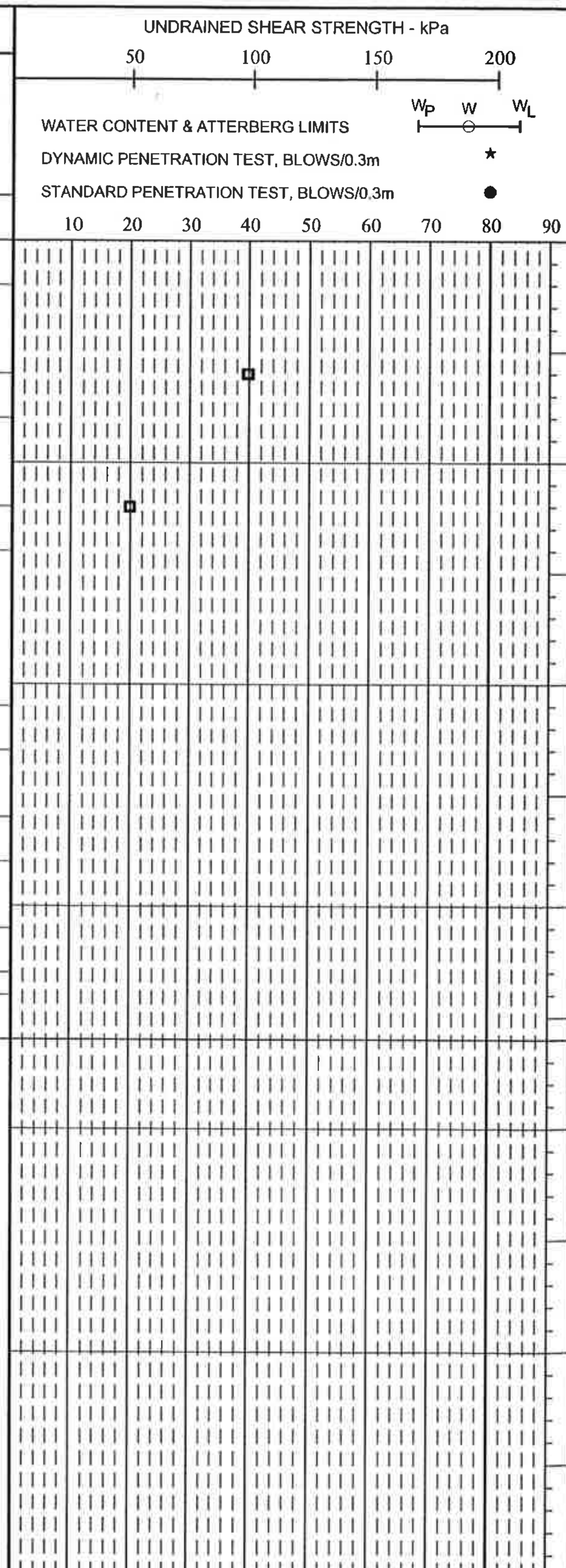
TEST PIT RECORD

TP07-34

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-34
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	WATER LEVEL	SAMPLE TYPE	SAMPLE NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.56	250 mm TOPSOIL		BS	1		
	99.3	Stiff, brown lean CLAY (CL)		BS	2		
1			∇	BS	3		
2	97.6	Dense, brown to grey SANDY SILT (ML)		BS	4		
				BS	5		
3	96.3	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)		BS	6		
	96.0			BS	7		
		End of Borehole Refusal on Inferred Bedrock					



∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

□ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

Jacques Whitford

TEST PIT RECORD

TP07-36

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-36

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE OR RQD
0	100.16							
	100.0	200 mm TOPSOIL			BS	1		
		Stiff, brown lean CLAY (CL)			BS	2		
1	99.1	Dense, brown SANDY SILT (ML)		∇	BS	3		
2					BS	4		
	97.3				BS	5		
3		End of Borehole Refusal on Inferred Bedrock						
4								
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd

Date

JWL-OLD 1026929.GPJ SMART.GDT 07/06/21

MONITORING WELL RECORD

MW07-37

CLIENT: Mattamy Homes
LOCATION: Proposed Subdivision, Richmond, ON
DATES: BORING June 14, 2007 WATER LEVEL June 20, 2007

BOREHOLE No. MW07-37
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.62					
	99.5	75 mm TOPSOIL				
		Firm, greyish brown lean CLAY (CL)	SS	1	150	6
1	98.4		SS	2	300	6
		Compact to dense, greyish brown SANDY SILT (ML)	SS	3	350	37
2			SS	4	320	27
3	96.4					
	96.2	Compact to dense, grey SANDY SILT (ML)	SS	5	280	50/ 75 mm
		End of Borehole				
4		Auger Refusal on Inferred Bedrock				
5		Monitoring Well Installed				

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m *
STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

Inferred Groundwater Level
Groundwater Level Measured in Standpipe

Field Vane Test, kPa
Remoulded Vane Test, kPa
Pocket Penetrometer Test, kPa

App'd ______
Date ______

Jacques Whitford

TEST PIT RECORD

TP07-38

CLIENT: Mattamy Homes
LOCATION: Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL
BOREHOLE No. TP07-38
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLE TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	99.75					
	99.6	200 mm TOPSOIL	BS	1		
		Stiff, brown lean CLAY (CL)	BS	2		
1			BS	3		
	98.2	Dense, brown SANDY SILT (ML)	BS	4		
2			BS	5		
3			BS	6		
	96.4	Dense, brown sandy silt, trace gravel, occasional cobbles: TILL (ML)	BS	7		
4	95.8	End of Borehole				
5						
6						

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS (W_P, W, W_L)
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

Jacques Whitford

TEST PIT RECORD

TP07-39

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL
BOREHOLE No. TP07-39
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	99.83	220 mm TOPSOIL			BS	1		
	99.6	Stiff, brown lean CLAY (CL)			BS	2		
1				∇	BS	3		
	98.1	Dense, brown SANDY SILT (ML)			BS	4		
2					BS	5		
	96.9				BS	6		
3		End of Borehole Refusal on Inferred Bedrock						
4								
5								
6								

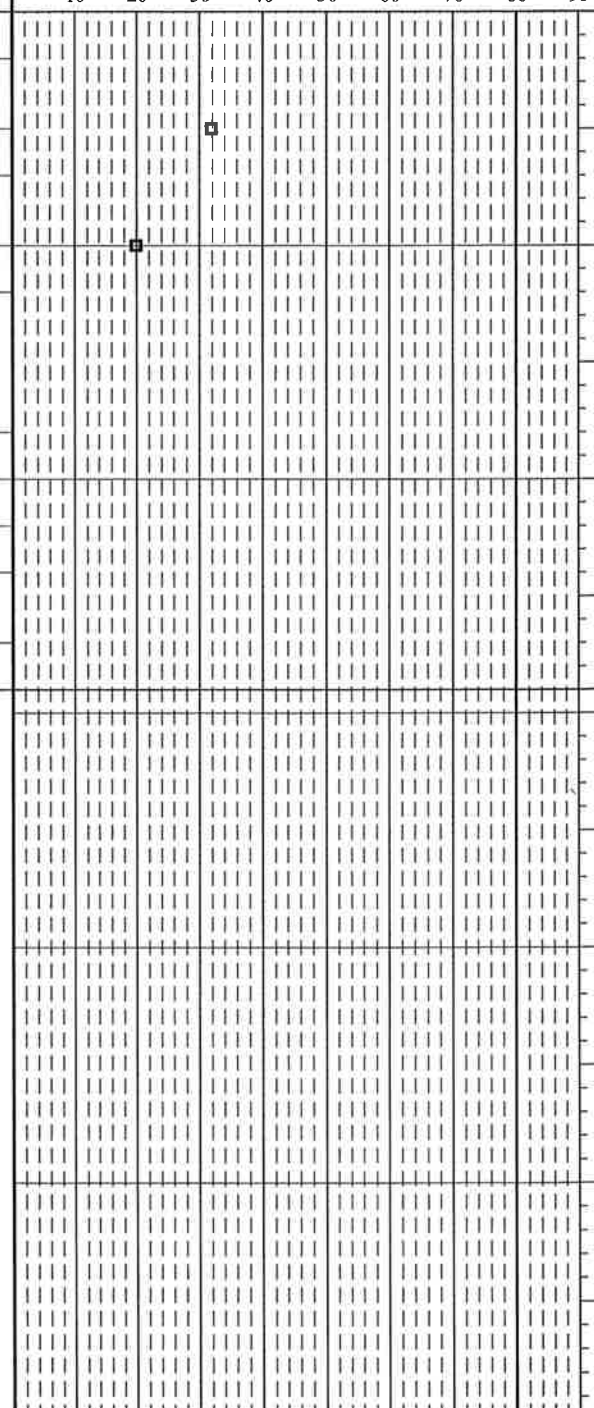
UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90



∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd

Date

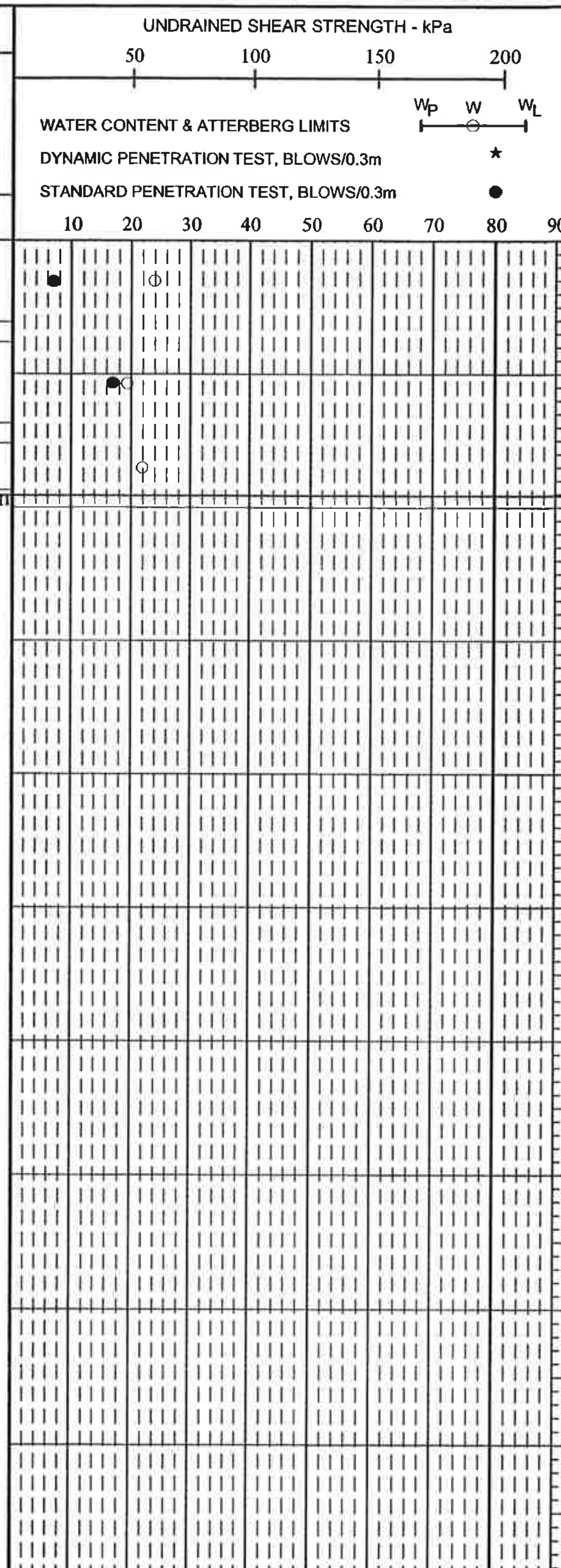
MONITORING WELL RECORD

MW07-40

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. MW07-40
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	100.26							
	100.1	150 mm TOPSOIL						
		Compact to dense, brownish grey SANDY SILT (ML)			SS	1	320	7
1				∇	SS	2	420	17
					SS	3	300	50/ 50 mm
2	98.3	End of Borehole Auger Refusal on Inferred Bedrock Monitoring Well Installed						
3								
4								
5								
6								
7								
8								
9								
10								



∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

Jacques Whitford

TEST PIT RECORD

TP07-41

CLIENT: Mattamy Homes
LOCATION: Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL
BOREHOLE No. TP07-41
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	99.77							
	99.6	200 mm TOPSOIL						
		Compact to dense, grey and brown SANDY SILT (ML)			BS	1		
				∇				
1					BS	2		
	98.0				BS	3		
2	97.6	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	4		
		End of Borehole Refusal on Inferred Bedrock						
3								
4								
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS — W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ________
Date ________

TEST PIT RECORD

TP07-42

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 14, 2007 WATER LEVEL

BOREHOLE No. TP07-42

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	100.05							
	99.8	200 mm TOPSOIL						
		Compact to dense, brown to grey SANDY SILT (ML)			BS	1		
				∇				
1					BS	2		
2	98.0	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	3		
					BS	4		
3	96.7				BS	5		
		End of Borehole Refusal on Inferred Bedrock						
4								
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

Jacques Whitford

TEST PIT RECORD

TP07-43

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 14, 2007 WATER LEVEL

BOREHOLE No. TP07-43
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	100.16							
	100.0	200 mm TOPSOIL			BS	1		
		Compact to dense, brown to grey SANDY SILT (ML)		∇	BS	2		
1					BS	3		
2					BS	4		
	97.5	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	5		
3	97.0				BS	6		
		End of Borehole						
4								
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ________
Date ________

Jacques Whitford

TEST PIT RECORD

TP07-44

CLIENT: Mattamy Homes

LOCATION: Proposed Subdivision, Richmond, ON

DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-44

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	100.41							
	100.2	200 mm TOPSOIL						
		Compact to dense, brown to grey SANDY SILT (ML)		∇	BS	1		
1					BS	2		
					BS	3		
	98.8	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	4		
2	98.1				BS	5		
		End of Borehole Refusal on Inferred Bedrock						
3								
4								
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P, W, W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

Jacques Whitford

TEST PIT RECORD

TP07-45

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 15, 2007 WATER LEVEL June 20, 2007

BOREHOLE No. TP07-45

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLES TYPE	SAMPLES NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	100.19					
	100.0	200 mm TOPSOIL				
		Compact to dense, brown to grey SANDY SILT (ML)	BS	1		
1			BS	2		
			BS	3		
2	98.3	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)				
	97.3		BS	4		
3		End of Borehole Refusal on Inferred Bedrock Standpipe Installed				
4						
5						
6						

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd

Date

Jacques Whitford

TEST PIT RECORD

TP07-46

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 14, 2007 WATER LEVEL

BOREHOLE No. TP07-46
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	WATER LEVEL	SAMPLE TYPE	SAMPLE NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	100.16	300 mm TOPSOIL					
	99.9	Compact to dense, brown to grey SANDY SILT (ML)		BS	1		
			▽	BS	2		
1				BS	3		
2				BS	4		
3				BS	5		
	96.8	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)		BS	6		
				BS	7		
4	96.2	End of Borehole Refusal on Inferred Bedrock					
5							
6							

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd
Date

Jacques Whitford

TEST PIT RECORD

TP07-47

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 14, 2007 WATER LEVEL June 20, 2007

BOREHOLE No. TP07-47

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	100.24							
	100.0	200 mm TOPSOIL			BS	1		
	99.6	Stiff, brown lean CLAY (CL)		▼	BS	2		
1		Compact to dense, brown and grey SANDY SILT (ML)			BS	3		
					BS	4		
2					BS	5		
3	97.0				BS	6		
		Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	7		
4					BS	8		
	95.7				BS	9		
		End of Borehole Standpipe Installed						
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

Jacques Whitford

TEST PIT RECORD

TP07-48

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-48
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLE TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	100.51					
	100.4	150 mm TOPSOIL				
		Compact to dense, brown and grey SANDY SILT (ML)	BS	1		
			BS	2		
1			BS	3		
			BS	4		
2			BS	5		
	98.0	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)	BS	6		
3						
	96.9		BS	7		
		End of Borehole Refusal on Inferred Bedrock				
4						
5						
6						

UNDRAINED SHEAR STRENGTH - kPa: 50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

TEST PIT RECORD

TP07-49

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 14, 2007 WATER LEVEL

BOREHOLE No. TP07-49

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	100.67							
	100.4	230 mm TOPSOIL						
		Compact to dense, brown and grey SANDY SILT (ML)			BS	1		
1					BS	2		
2	98.7				BS	3		
		End of Borehole						
		Refusal on Inferred Bedrock						
3								
4								
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

Jacques Whitford

TEST PIT RECORD

TP07-52

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 14, 2007 WATER LEVEL

BOREHOLE No. TP07-52

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
	100.59							
0		280 mm TOPSOIL			BS	1		
	100.3	Compact to dense, brown and grey SANDY SILT (ML)		∇	BS	2		
1					BS	3		
2					BS	4		
	98.1	Dense, grey SANDY SILT			BS	5		
3	97.4	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (ML)			BS	6		
4					BS	7		
	96.1				BS	8		
		End of Borehole						
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ________

Date ________

JWL-OLD 1026929.GPJ SMART.GDT 07/06/21

Jacques Whitford

TEST PIT RECORD

TP07-53

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

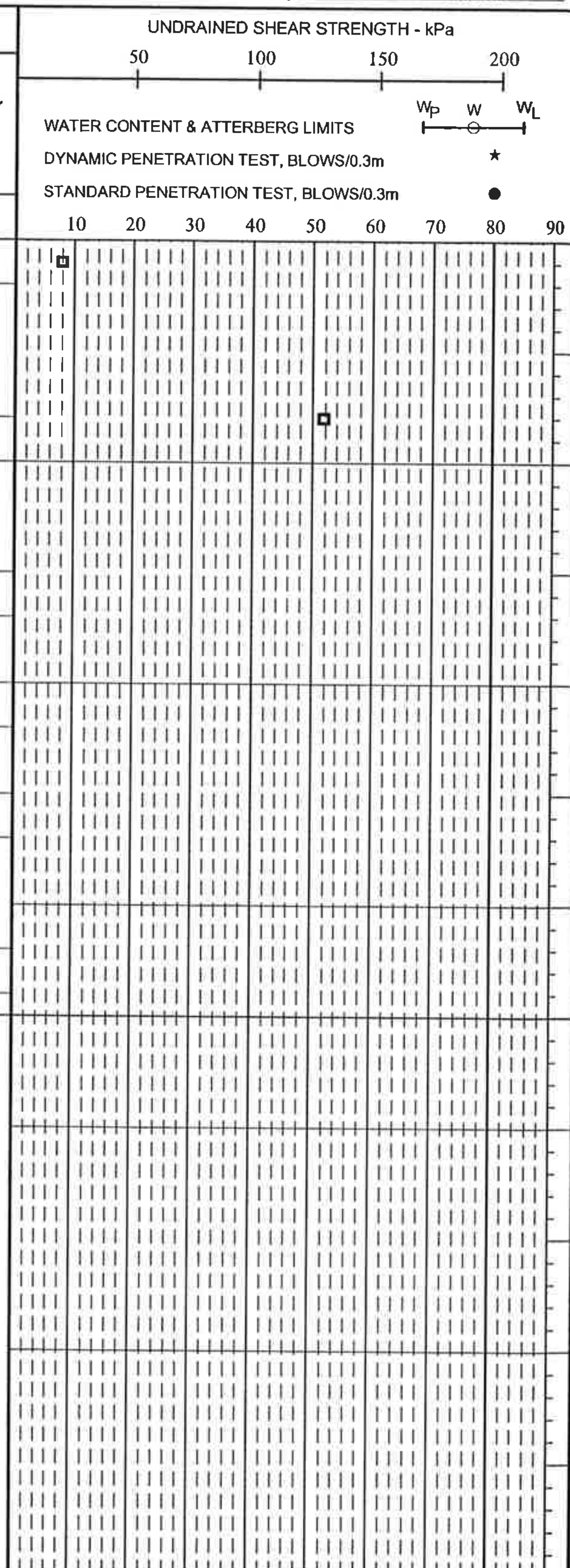
DATES: BORING June 15, 2007 WATER LEVEL

BOREHOLE No. TP07-53

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE OR RQD
0	100.94					
	100.7	200 mm TOPSOIL	BS	1		
1		Firm, brown lean CLAY (CL)	BS	2		
	99.4	Compact to dense, brown and grey SANDY SILT (ML)	BS	3		
2			BS	4		
	98.5	Dense, grey sandy silt, trace gravel, occasional cobbles and boulders: TILL (ML)	BS	5		
3			BS	6		
	97.4	End of Borehole Refusal on Inferred Boulders				
4						
5						
6						



▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

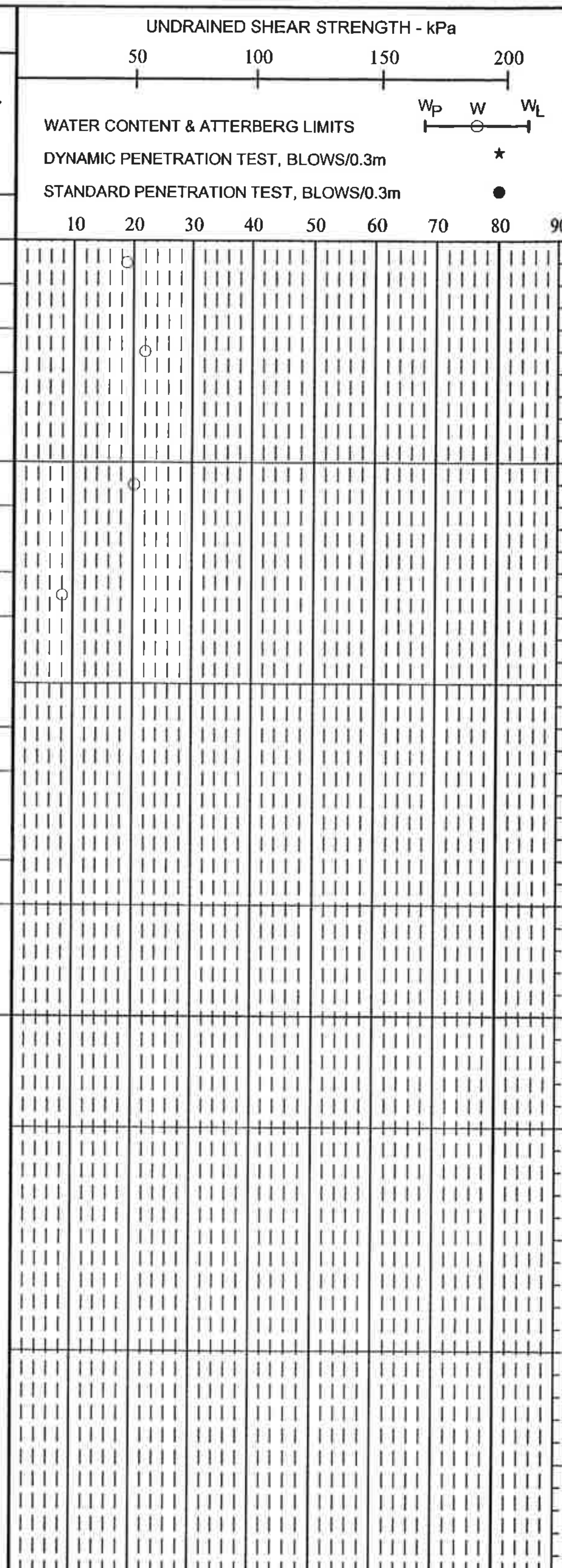
Jacques Whitford

TEST PIT RECORD

TP07-66

CLIENT: Mattamy Homes
LOCATION: Proposed Subdivision, Richmond, ON
DATES: BORING: June 14, 2007 WATER LEVEL: June 20, 2007
BOREHOLE No.: TP07-66
PROJECT No.: 1026929
DATUM: Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	100.48							
	100.4	100 mm TOPSOIL			BS	1		
		Compact to dense, brown to grey SILTY SAND (SM)			BS	2		
1				▽	BS	3		
	98.9	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (SM)			BS	4		
2					BS	5		
3					BS	6		
	97.0	End of Borehole Refusal on Inferred Boulders Standpipe Installed						
4								
5								
6								



▽ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ________
Date ________

JWL-OLD 1026929.GPJ SMART.GDT 07/06/21

Jacques Whitford

TEST PIT RECORD

TP07-67

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 14, 2007 WATER LEVEL

BOREHOLE No. TP07-67
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD
0	101.50					
	101.3	200 mm TOPSOIL	BS	1		
		Compact, brown SILTY SAND (SM)	BS	2		
1			BS	3		
	100.2	Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (SM)				
	99.9		BS	4		
		End of Borehole				
2		Refusal on Inferred Bedrock				
3						
4						
5						
6						

UNDRAINED SHEAR STRENGTH - kPa: 50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd ______
Date ______

Jacques Whitford

TEST PIT RECORD

TP07-70

CLIENT Mattamy Homes
LOCATION Proposed Subdivision, Richmond, ON
DATES: BORING June 20, 2007 WATER LEVEL

BOREHOLE No. TP07-70
PROJECT No. 1026929
DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE OR RQD
0		30 mm TOPSOIL						
		Compact, brown SILTY SAND (SM)						
		End of Hand Auger Hole						
1		Hand Auger Refusal						
2								
3								
4								
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

∇ Inferred Groundwater Level
▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa
□ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

App'd
Date

JWL-OLD 1026929.GPJ SMART.GDT 07/06/21

Jacques Whitford

TEST PIT RECORD

TP07-71

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 14, 2007 WATER LEVEL

BOREHOLE No. TP07-71

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	102.71	230 mm TOPSOIL			BS	1		
	102.5	Fractured Bedrock						
	102.1	End of Borehole Refusal on Inferred Bedrock						

UNDRAINED SHEAR STRENGTH - kPa: 50, 100, 150, 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m *

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

Depth scale: 0, 1, 2, 3, 4, 5, 6

∇ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd

Date

Jacques Whitford

TEST PIT RECORD

TP07-72

CLIENT Mattamy Homes

LOCATION Proposed Subdivision, Richmond, ON

DATES: BORING June 14, 2007 WATER LEVEL June 20, 2007

BOREHOLE No. TP07-72

PROJECT No. 1026929

DATUM Local

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD
0	102.44							
	102.2	200 mm TOPSOIL			BS	1		
		Dense, grey sandy silt, trace gravel, occasional cobbles: TILL (SM)			BS	2		
1				▽				
				▼	BS	3		
2					BS	4		
					BS	5		
3	98.9							
		End of Borehole						
		Refusal on Inferred Bedrock						
4		Standpipe Installed						
5								
6								

UNDRAINED SHEAR STRENGTH - kPa: 50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

◘ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

App'd ______

Date ______

APPENDIX C

Soil Grain Size Distribution Test Results

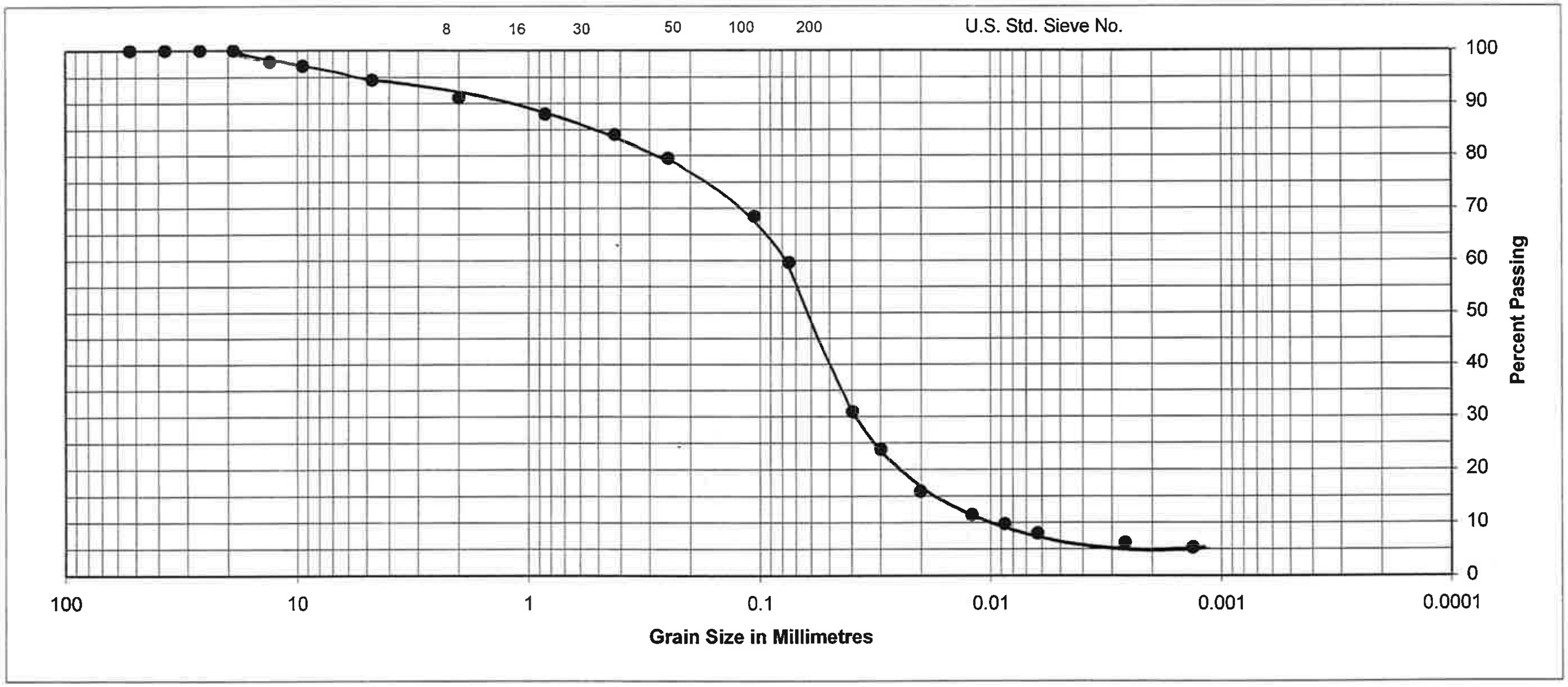
Jacques Whitford

2781 Lancaster Rd.
Ottawa, Ontario K1B 1A7

Tel: 613 738-0708
Fax: 613 738-0721

Hydrometer Analysis

Client:	**Mattamy Homes**	Project No.:	**1026929**
Project:	**Mattamy Homes, Rickmond**	Test Method:	**LS702**
Material Type:		Sample No.:	**N/A**
Source:	**BH07-18, SS-6**	Date Sampled:	**14-Jun-07**
Sampled From:	**17.5' to 19.5'**	Tested By:	**Blaine Miller**
Sampled By:	**Jeff Forrester**	Date Tested:	**21-Jun-07**



Remarks:

Reviewed By: Brian Prevost
Date: June 22/2007

2781 Lancaster Rd.
Ottawa ON, K1B 1A7

Wash Sieve Analysis

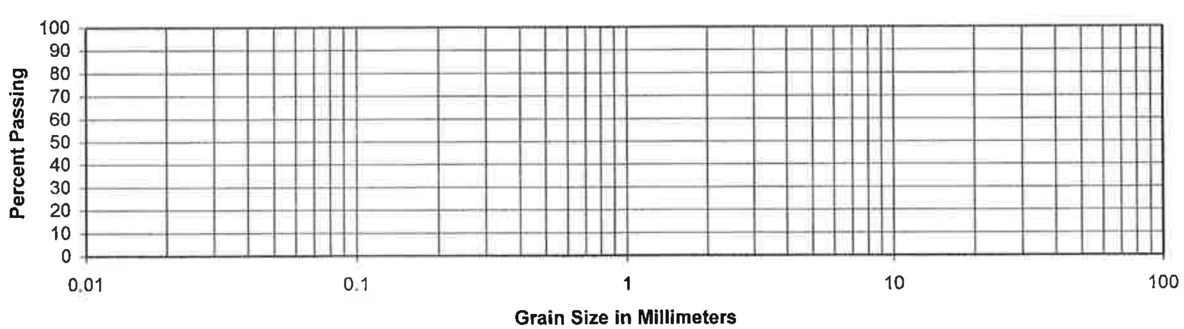
Client :	**Mattamy Homes**	Project No. :	**1026929**
Project :	**Mattamy Homes, Richmond**	Test Method :	**LS 602 (ASTM C136)**
Material Type :	**Soils / Aggregate:**		
Proposed Use :	**Fill / Granulars:**	Sample No. :	**N/A**
Supplier :	**N/A**		
Source :	**BH07-25**		
Sampled From :	**SS-5, 12.5' to 14.5'**		
Sampled By :	**Jeff Forrester**	Date Sampled :	**14-Jun-07**
Tested By :	**Eric Naylor**	Date Tested :	**20-Jun-07**

Wash Test Data

Sample Weight Before Sieve :		Sample Weight Before Wash :	**266.5**	
Sample Weight Aftter Sieve :		Sample Weight After Wash :	**37**	**Corrected**
% Loss In Sieve :		% Passing No.200	**86.1**	**N/A**

Sieve Analysis

Sieve No.	Size of Opening		Wt. Retained	Cum Wt. Retained	% Passing	Specifications	
	Inches	mm	grams	grams		Min	Max
	3	**76.2**					
	2	**53.0**					
	1	**26.5**					
	3/4	**19.0**					
	5/8	**16.0**					
	1/2	**13.2**					
	3/8	**9.5**					
+4	**0.187**	**4.75**		**3.2**	**98.8**		
		- 4.75		**37.0**			
8	**0.0937**	**2.36**					
16	**0.0469**	**1.18**					
30	**0.234**	**0.600**					
50	**0.0117**	**0.300**					
100	**0.0059**	**0.150**					
200	**0.0029**	**0.075**					
		Pan					
Classification of sample :		% Gravel :	**1.2**	% Sand :	**12.7**	% Silt and Clay :	**86.1**



Remarks :

Laboratory Supervisor : Brian Prevost

Date: June 21/2007

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2781 Lancaster Rd.
Ottawa ON, K1B 1A7

Wash Sieve Analysis

Client :	**Mattamy Homes**	Project No. :	**1026929**
Project :	**Mattamy Homes, Richmond**	Test Method :	**LS 602 (ASTM C136)**
Material Type :	**Soils / Aggregate:**		
Proposed Use :	**Fill / Granulars:**	Sample No. :	**N/A**
Supplier :	**N/A**		
Source :	**BH07-28**		
Sampled From :	**SS-3, 5' to 7'**		
Sampled By :	**Jeff Forrester**	Date Sampled :	**15-Jun-07**
Tested By :	**Eric Naylor**	Date Tested :	**20-Jun-07**

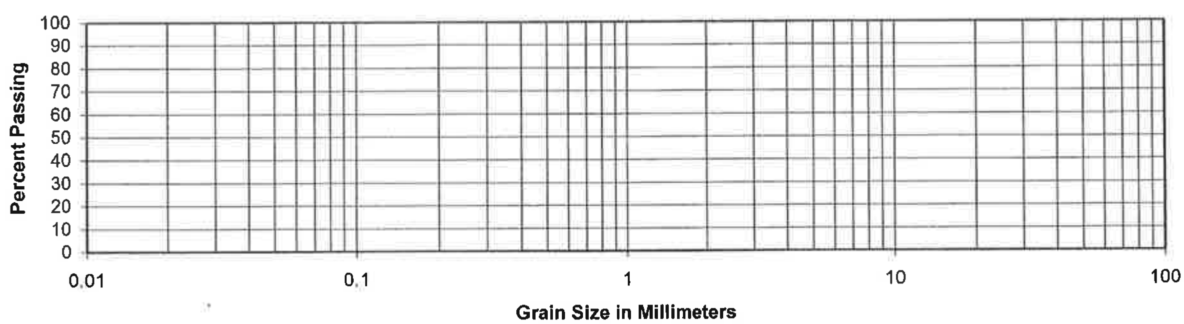
Wash Test Data

Sample Weight Before Sieve :		Sample Weight Before Wash :	**325.3**	
Sample Weight Afmter Sieve :		Sample Weight After Wash :	**180.6**	**Corrected**
% Loss In Sieve :		% Passing No.200	**44.5**	**N/A**

Sieve Analysis

Sieve No.	Size of Opening Inches	mm	Wt. Retained grams	Cum Wt. Retained grams	% Passing	Specifications Min	Max
	3	**76.2**					
	2	**53.0**					
	1	**26.5**					
	3/4	**19.0**					
	5/8	**16.0**					
	1/2	**13.2**					
	3/8	**9.5**					
+4	**0.187**	**4.75**		**1.0**	**99.7**		
		- 4.75		**180.5**			
8	**0.0937**	**2.36**					
16	**0.0469**	**1.18**					
30	**0.234**	**0.600**					
50	**0.0117**	**0.300**					
100	**0.0059**	**0.150**					
200	**0.0029**	**0.075**					
		Pan					

Classification of sample : % Gravel : **0.3** % Sand : **55.2** % Silt and Clay : **44.5**



Remarks :

Laboratory Supervisor : Brian Prevost **Date:** June 21/2007

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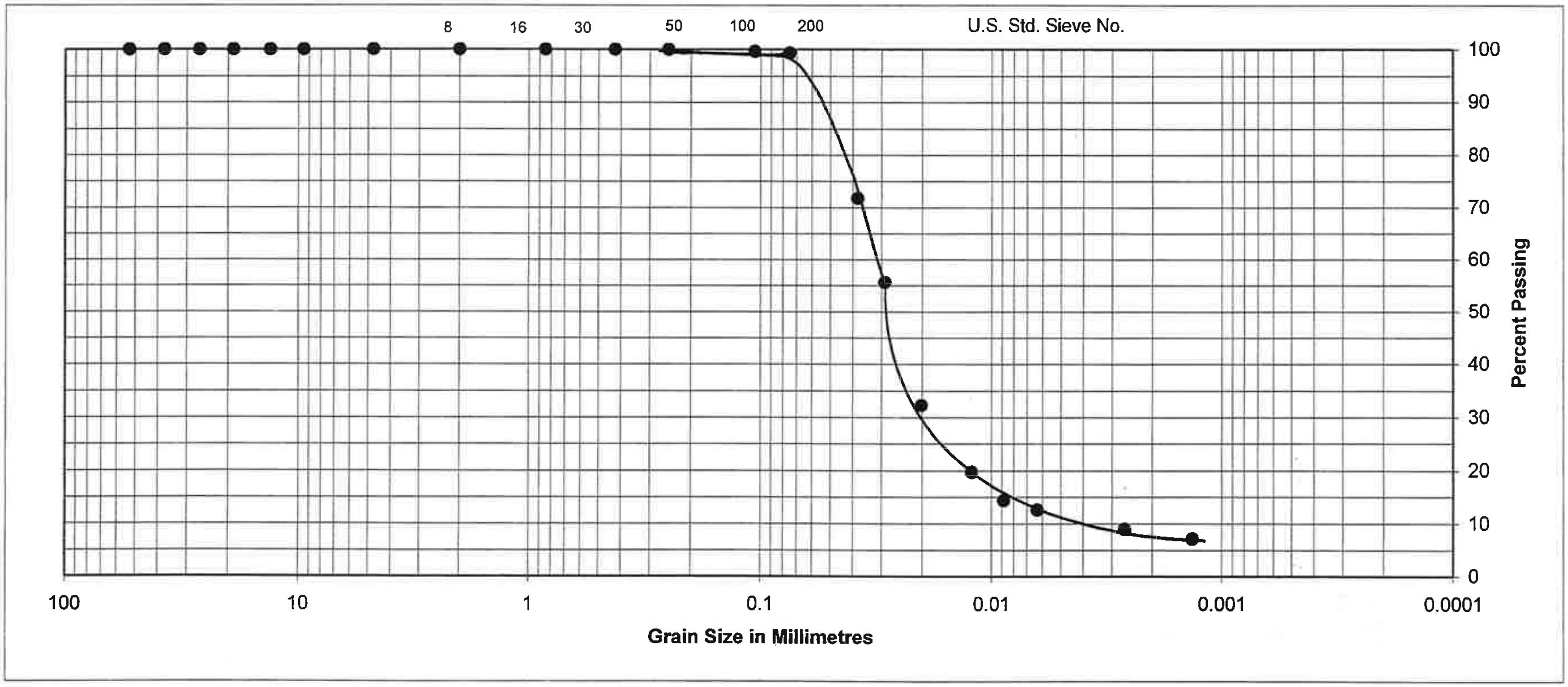
2781 Lancaster Rd.
Ottawa, Ontario K1B 1A7

Tel: 613 738-0708
Fax: 613 738-0721

Hydrometer Analysis

Client:	**Mattamy Homes**	Project No.:	**1026929**
Project:	**Mattamy Homes, Rickmond**	Test Method:	**LS702**
Material Type:		Sample No.:	**N/A**
Source:	**BH07-37, SS-3**	Date Sampled:	**14-Jun-07**
Sampled From:	**5' to 7'**	Tested By:	**Blaine Miller**
Sampled By:	**Jeff Forrester**	Date Tested:	**21-Jun-07**



Remarks:

Reviewed By: Brian Prevost

Date: June 22/2007

2781 Lancaster Rd.
Ottawa ON, K1B 1A7

Wash Sieve Analysis

Client :	Mattamy Homes	Project No. :	1026929
Project :	Mattamy Homes, Richmond	Test Method :	LS 602 (ASTM C136)
Material Type :	Soils / Aggregate:		
Proposed Use :	Fill / Granulars:	Sample No. :	N/A
Supplier :	N/A		
Source :	TP-48		
Sampled From :	BS-3		
Sampled By :	Jeff Forrester	Date Sampled :	14-Jun-07
Tested By :	Eric Naylor	Date Tested :	21-Jun-07

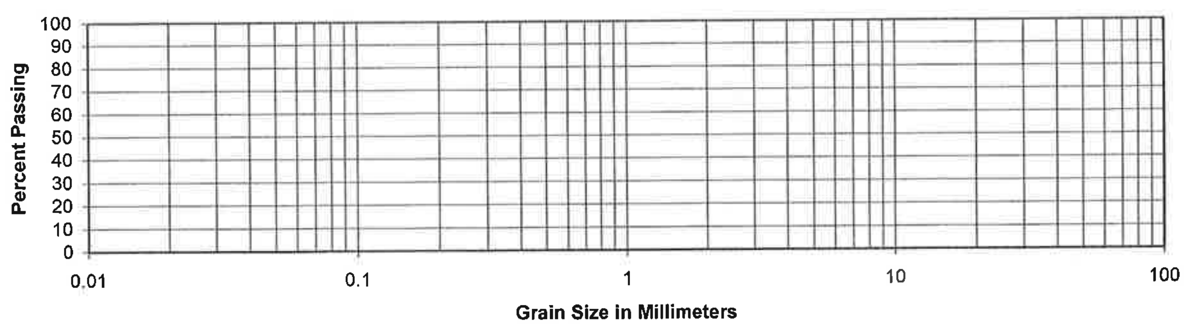
Wash Test Data

Sample Weight Before Sieve :		Sample Weight Before Wash :	254.2	
Sample Weight Aftter Sieve :		Sample Weight After Wash :	8.3	Corrected
% Loss In Sieve :		% Passing No.200	96.7	N/A

Sieve Analysis

Sieve No.	Size of Opening Inches	Size of Opening mm	Wt. Retained grams	Cum Wt. Retained grams	% Passing	Specifications Min	Specifications Max
	3	76.2					
	2	53.0					
	1	26.5					
	3/4	19.0					
	5/8	16.0					
	1/2	13.2					
	3/8	9.5					
+4	0.187	4.75		1.6	99.4		
		- 4.75		6.7			
8	0.0937	2.36					
16	0.0469	1.18					
30	0.234	0.600					
50	0.0117	0.300					
100	0.0059	0.150					
200	0.0029	0.075					
		Pan					

Classification of sample :	% Gravel :	0.6	% Sand :	2.6	% Silt and Clay :	96.7



Remarks :

Laboratory Supervisor : Brian Rewst

Date: June 22/2007

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2781 Lancaster Rd.
Ottawa ON, K1B 1A7

Wash Sieve Analysis

Client :	Mattamy Homes	Project No. :	1026929
Project :	Mattamy Homes, Richmond	Test Method :	LS 602 (ASTM C136)
Material Type :	Soils / Aggregate:		
Proposed Use :	Fill / Granulars:	Sample No. :	N/A
Supplier :	N/A		
Source :	TP-48		
Sampled From :	BS-7		
Sampled By :	Jeff Forrester	Date Sampled :	14-Jun-07
Tested By :	Eric Naylor	Date Tested :	20-Jun-07

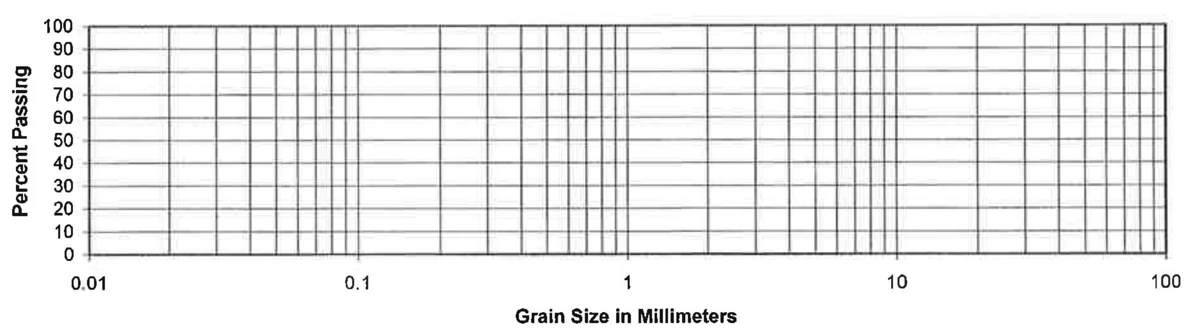
Wash Test Data

Sample Weight Before Sieve :		Sample Weight Before Wash :	385	
Sample Weight Aftter Sieve :		Sample Weight After Wash :	232	Corrected
% Loss In Sieve :		% Passing No.200	39.7	N/A

Sieve Analysis

Sieve No.	Size of Opening Inches	mm	Wt. Retained grams	Cum Wt. Retained grams	% Passing	Specifications Min	Max
	3	76.2					
	2	53.0					
	1	26.5					
	3/4	19.0					
	5/8	16.0					
	1/2	13.2					
	3/8	9.5					
+4	0.187	4.75		44.7	88.4		
		- 4.75		231.9			
8	0.0937	2.36					
16	0.0469	1.18					
30	0.234	0.600					
50	0.0117	0.300					
100	0.0059	0.150					
200	0.0029	0.075					
		Pan					

Classification of sample : % Gravel : 11.6 % Sand : 48.6 % Silt and Clay : 39.7



Remarks :

Laboratory Supervisor : Brian Prevost Date: June 21/2007

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2781 Lancaster Rd.
Ottawa ON, K1B 1A7

Wash Sieve Analysis

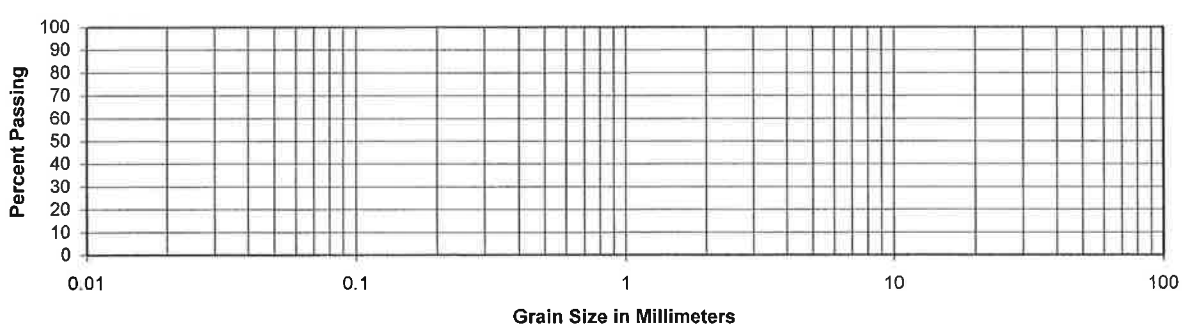
Client :	**Mattamy Homes**	Project No. :	**1026929**
Project :	**Mattamy Homes, Richmond**	Test Method :	**LS 602 (ASTM C136)**
Material Type :	**Soils / Aggregate:**		
Proposed Use :	**Fill / Granulars:**	Sample No. :	**N/A**
Supplier :	**N/A**		
Source :	**TP-54**		
Sampled From :	**BS-3**		
Sampled By :	**Jeff Forrester**	Date Sampled :	**14-Jun-07**
Tested By :	**Eric Naylor**	Date Tested :	**21-Jun-07**

Wash Test Data

Sample Weight Before Sieve :		Sample Weight Before Wash :	**259.3**	
Sample Weight Aftter Sieve :		Sample Weight After Wash :	**9.5**	**Corrected**
% Loss In Sieve :		% Passing No.200	**96.3**	**N/A**

Sieve Analysis

Sieve No.	Size of Opening		Wt. Retained	Cum Wt. Retained	% Passing	Specifications	
	Inches	mm	grams	grams		Min	Max
	3	**76.2**					
	2	**53.0**					
	1	**26.5**					
	3/4	**19.0**					
	5/8	**16.0**					
	1/2	**13.2**					
	3/8	**9.5**					
+4	**0.187**	**4.75**		**0.0**	**100.0**		
		- 4.75					
8	**0.0937**	**2.36**					
16	**0.0469**	**1.18**					
30	**0.234**	**0.600**					
50	**0.0117**	**0.300**					
100	**0.0059**	**0.150**					
200	**0.0029**	**0.075**					
		Pan					
Classification of sample :			% Gravel :	**0.0**	% Sand : **3.7**	% Silt and Clay :	**96.3**



Remarks :

Laboratory Supervisor : Brian Rust

Date: June 22/2007

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2781 Lancaster Rd.
Ottawa ON, K1B 1A7

Wash Sieve Analysis

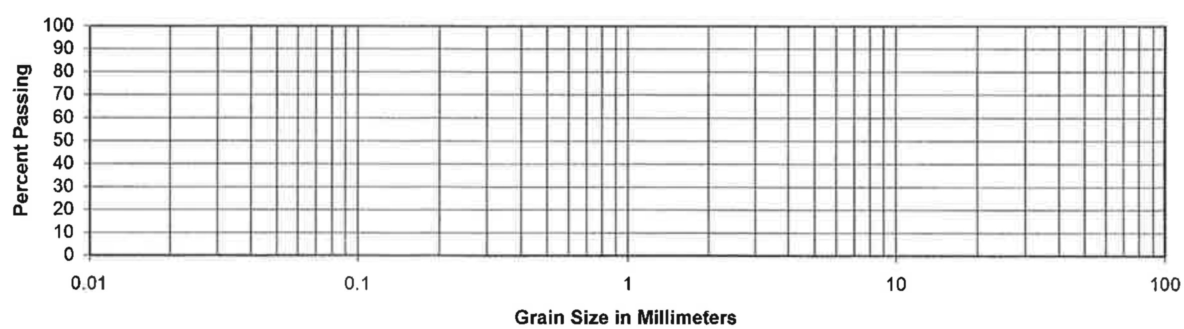
Client :	**Mattamy Homes**	Project No. :	**1026929**
Project :	**Mattamy Homes, Richmond**	Test Method :	**LS 602 (ASTM C136)**
Material Type :	**Soils / Aggregate:**		
Proposed Use :	**Fill / Granulars:**	Sample No. :	**N/A**
Supplier :	**N/A**		
Source :	**TP-66**		
Sampled From :	**SS-4**		
Sampled By :	**Jeff Forrester**	Date Sampled :	**14-Jun-07**
Tested By :	**Eric Naylor**	Date Tested :	**20-Jun-07**

Wash Test Data

Sample Weight Before Sieve :		Sample Weight Before Wash :	**2163.8**	
Sample Weight Aftter Sieve :		Sample Weight After Wash :	**1424.5**	**Corrected**
% Loss In Sieve :		% Passing No.200	**34.2**	**N/A**

Sieve Analysis

Sieve No.	Size of Opening		Wt. Retained	Cum Wt. Retained	% Passing	Specifications	
	Inches	mm	grams	grams		Min	Max
	3	**76.2**					
	2	**53.0**					
	1	**26.5**					
	3/4	**19.0**					
	5/8	**16.0**					
	1/2	**13.2**					
	3/8	**9.5**					
+4	**0.187**	**4.75**		**392.4**	**81.9**		
		- 4.75		**1424.3**			
8	**0.0937**	**2.36**					
16	**0.0469**	**1.18**					
30	**0.234**	**0.600**					
50	**0.0117**	**0.300**					
100	**0.0059**	**0.150**					
200	**0.0029**	**0.075**					
		Pan					
Classification of sample :			% Gravel :	**18.1**	% Sand : **47.7**	% Silt and Clay :	**34.2**



Remarks :

Laboratory Supervisor : Brian Prevost

Date: June 21 2007

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2781 Lancaster Rd.
Ottawa ON, K1B 1A7

Wash Sieve Analysis

Client :	**Mattamy Homes**	Project No. :	**1026929**
Project :	**Mattamy Homes, Richmond**	Test Method :	**LS 602 (ASTM C136)**
Material Type :	**Soils / Aggregate:**		
Proposed Use :	**Fill / Granulars:**	Sample No. :	**N/A**
Supplier :	**N/A**		
Source :	**TP-75**		
Sampled From :	**SS-4**		
Sampled By :	**Jeff Forrester**	Date Sampled :	**14-Jun-07**
Tested By :	**Eric Naylor**	Date Tested :	**20-Jun-07**

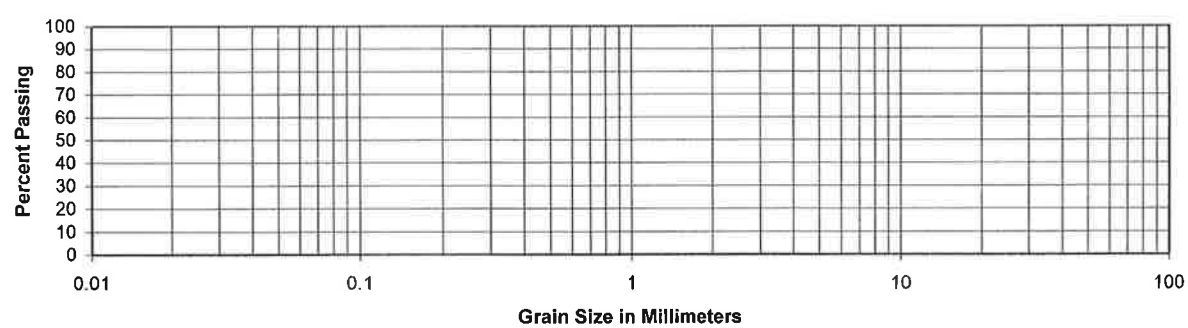
Wash Test Data

Sample Weight Before Sieve :		Sample Weight Before Wash :	**2454.1**	
Sample Weight Aftter Sieve :		Sample Weight After Wash :	**1688.2**	**Corrected**
% Loss In Sieve :		% Passing No.200	**31.2**	**N/A**

Sieve Analysis

Sieve No.	Size of Opening		Wt. Retained	Cum Wt. Retained	% Passing	Specifications	
	Inches	mm	grams	grams		Min	Max
	3	**76.2**					
	2	**53.0**					
	1	**26.5**					
	3/4	**19.0**					
	5/8	**16.0**					
	1/2	**13.2**					
	3/8	**9.5**					
+4	**0.187**	**4.75**		**669.2**	**72.7**		
		- 4.75		**1688.1**			
8	**0.0937**	**2.36**					
16	**0.0469**	**1.18**					
30	**0.234**	**0.600**					
50	**0.0117**	**0.300**					
100	**0.0059**	**0.150**					
200	**0.0029**	**0.075**					
		Pan					

Classification of sample :	% Gravel :	**27.3**	% Sand :	**41.5**	% Silt and Clay :	**31.2**



Remarks :

Laboratory Supervisor : Brian [illegible]

Date: June 21/2007

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APPENDIX D

Symbols and Terms Used on the SCPTu Records
SCPTu Probe Records

Jacques
Whitford

Terminology Used on SCPTu Records

Key Terminology and Principles

SCPTu:
- Seismic Piezocone (SCPTu);
- A piezocone (CPTu) is an enhanced cone penetration test (CPT) probe that is able to measure porewater pressure (u);
- A seismic piezocone (SCPTu) is further enhanced to measure surface generated compression and shear waves at depth; used to define the shear wave velocity of soils.

Equipment Type and Governing Standard:
- 10 cm^2 seismic piezocone;
- 150 cm^2 friction sleeve;
- manufactured by Applied Research Associates, Inc.;
- ASTM Specification D3441.

PCPT Investigation Objectives:
- evaluate soil type and soil stratigraphy;
- estimate the relative density of granular soils and in situ undrained shear strength of cohesive soils.

Soil Behaviour Type (SBT):
- The SBT is selected based on a soil's response to cone penetration, which is different from an explicit soil type defined by specified laboratory testing procedures, but is normally what the geotechnical engineer requires for design purposes.
- The SBT can be classified on the basis of the soil friction ratio, f_s; ratio between the side shear on the friction sleeve and cone tip resistance.
- The SBT can also be classified on the basis of the normalized pore pressure, Bq; a function of the pore water response and the cone tip resistance.
- The "CPT Soil Behaviour Type Legend" used for this project is attached.

Canadian Foundation Engineering Manual (3rd Edition) Statement on the CPT
- "The most significant advantage that the electric cone penetrometers offer is their repeatability and accuracy."
- "One of the most important applications of the cone penetration test is to accurately determine the soil profile."

Key References:

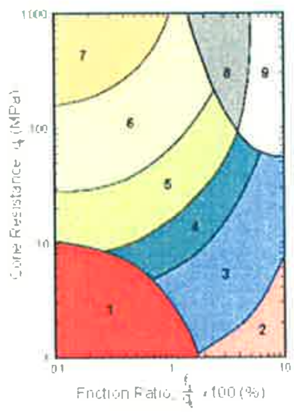
T. Lunne, P.K. Robertson, and J.J.M. Powell (1997). "Cone Penetration Testing in Geotechnical Practice"; Spon Press.

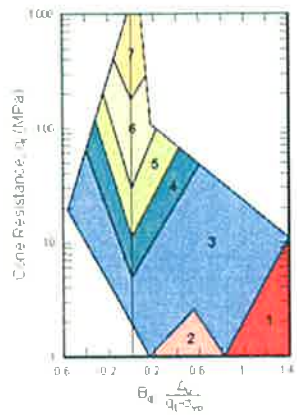
P.W. Mayne (1986). "CPT indexing of in situ OCR in Clays"; Proceedings of the ASCE Specialty Conference In Situ '86: Use of In Situ Tests in Geotechnical Engineering, Blacksburg, 780-93, ASCE.

P.K. Robertson and R.G. Campanella (1988). "Guidelines for geotechnical design using CPT and CPTU"; University of British Columbia, Vancouver, Department of Civil Engineering, Soil Mechanics Series 120.

Jacques Whitford

CPT Soil Behavior Type Legend
(Robertson et al. 1990)



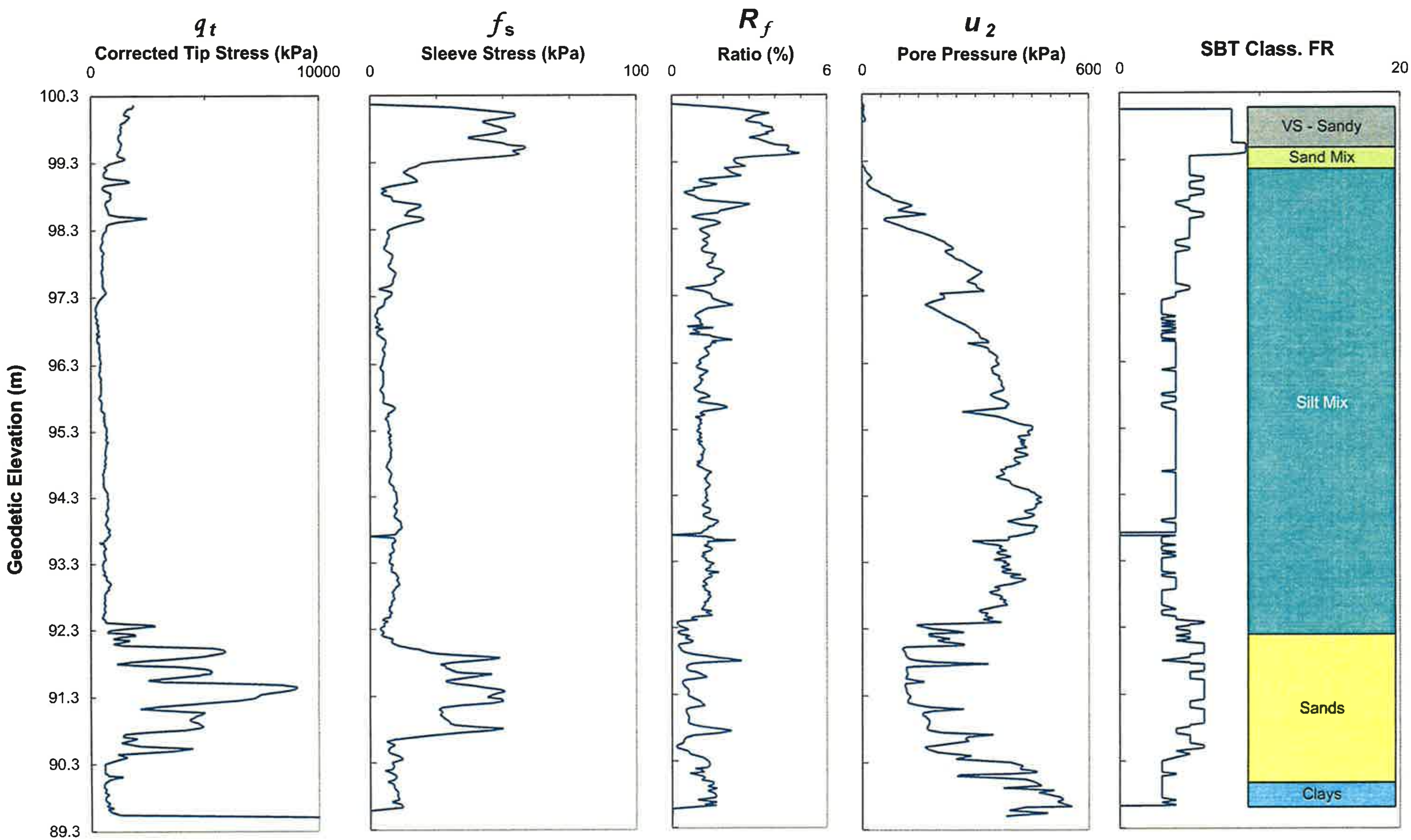


Zone	Soil Behavior Type
1	Sensitive, Fine Grained
2	Organic Soils-Peats
3	Clays; Clay to Silty Clay
4	Silt Mixtures; Clayey Silt to Silty Clay
5	Sand Mixtures; Silty Sand to Sandy Silt
6	Sands; Clean Sands to Silty Sands
7	Gravelly Sand to Sand
8	Very Stiff Sand to Clayey Sand*
9	Very Stiff Fine Grained*

*Overconsolidated or Cemented

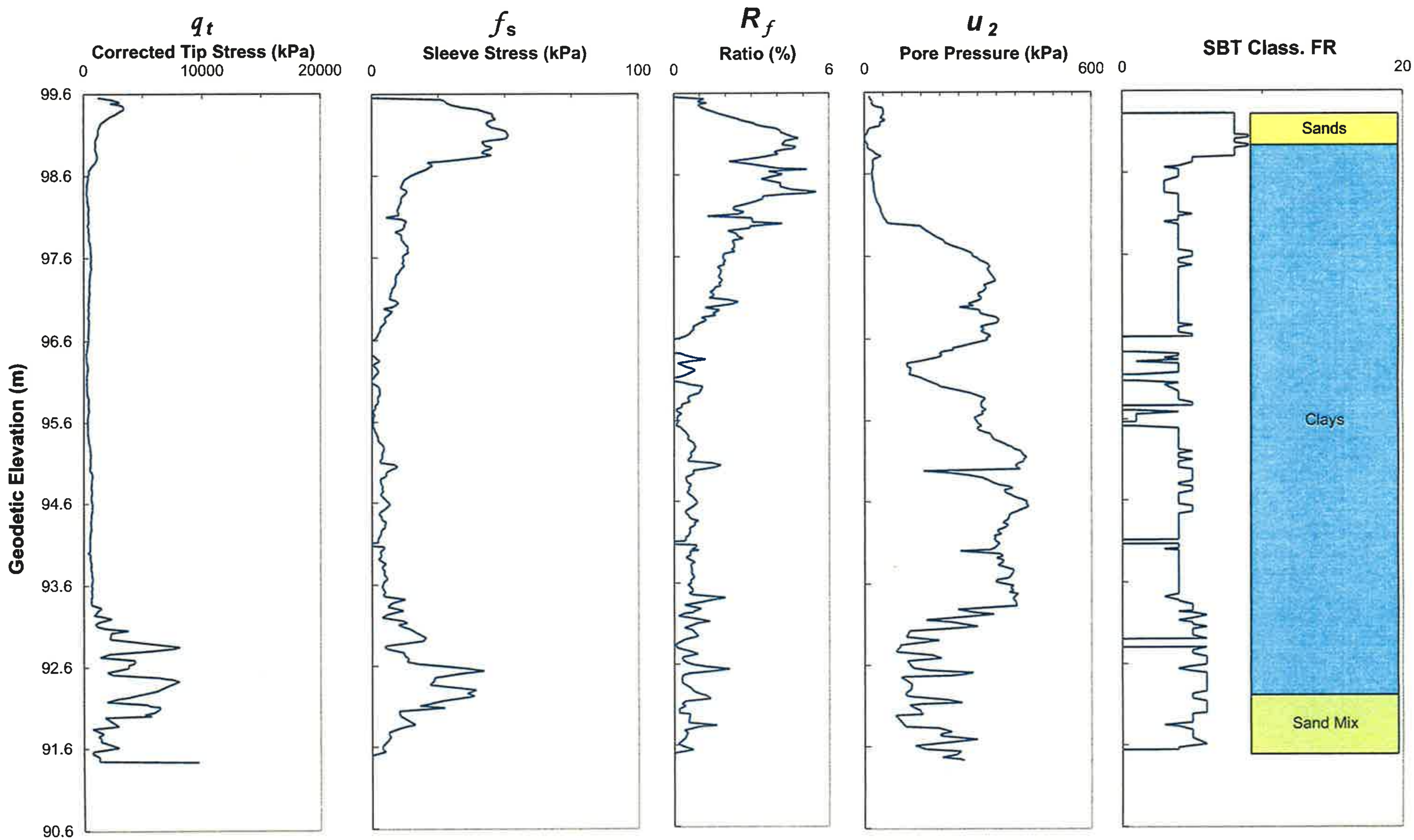
Jacques Whitford

Jacques Whitford	Elevation: 100.23 m SCPTu Start Elevation: 100.23 m Groundwater Elevation: 98.98 m	Test Date: June 15, 2007 Project No. 1026929	CPT 07-2
	Client: Mattamy Homes Project: Proposed Residential Subdivision, Richmond, ON		



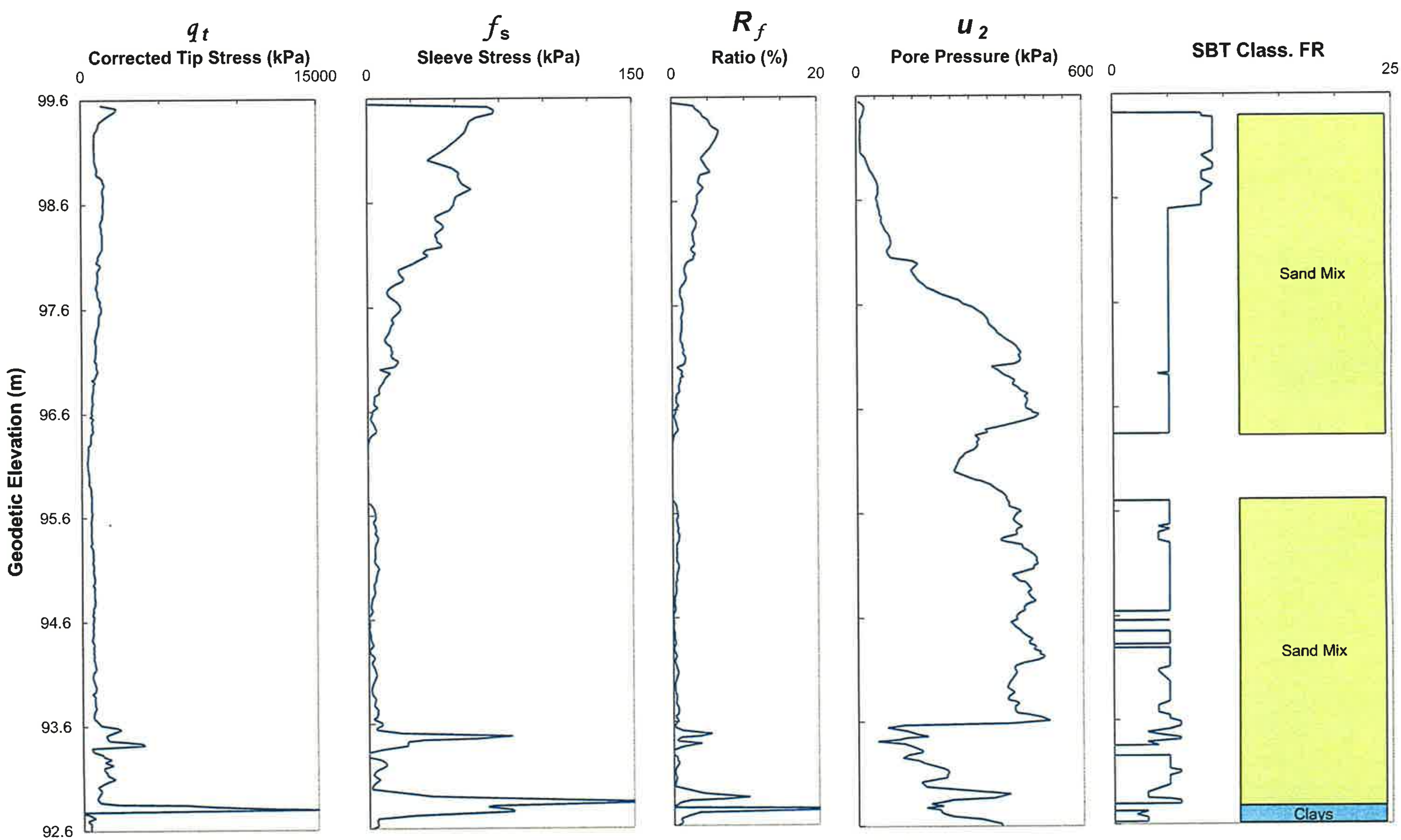
Class FR: Friction Ratio Classification (Robertson, 1990)

Jacques Whitford	Elevation: 99.60 m SCPTu Start Elevation: 99.60 m Groundwater Elevation: 98.51 m	Test Date: June 18, 2007 Project No. 1026929	CPT 07-9
	Client: Mattamy Homes Project: Proposed Residential Subdivision, Richmond, ON		



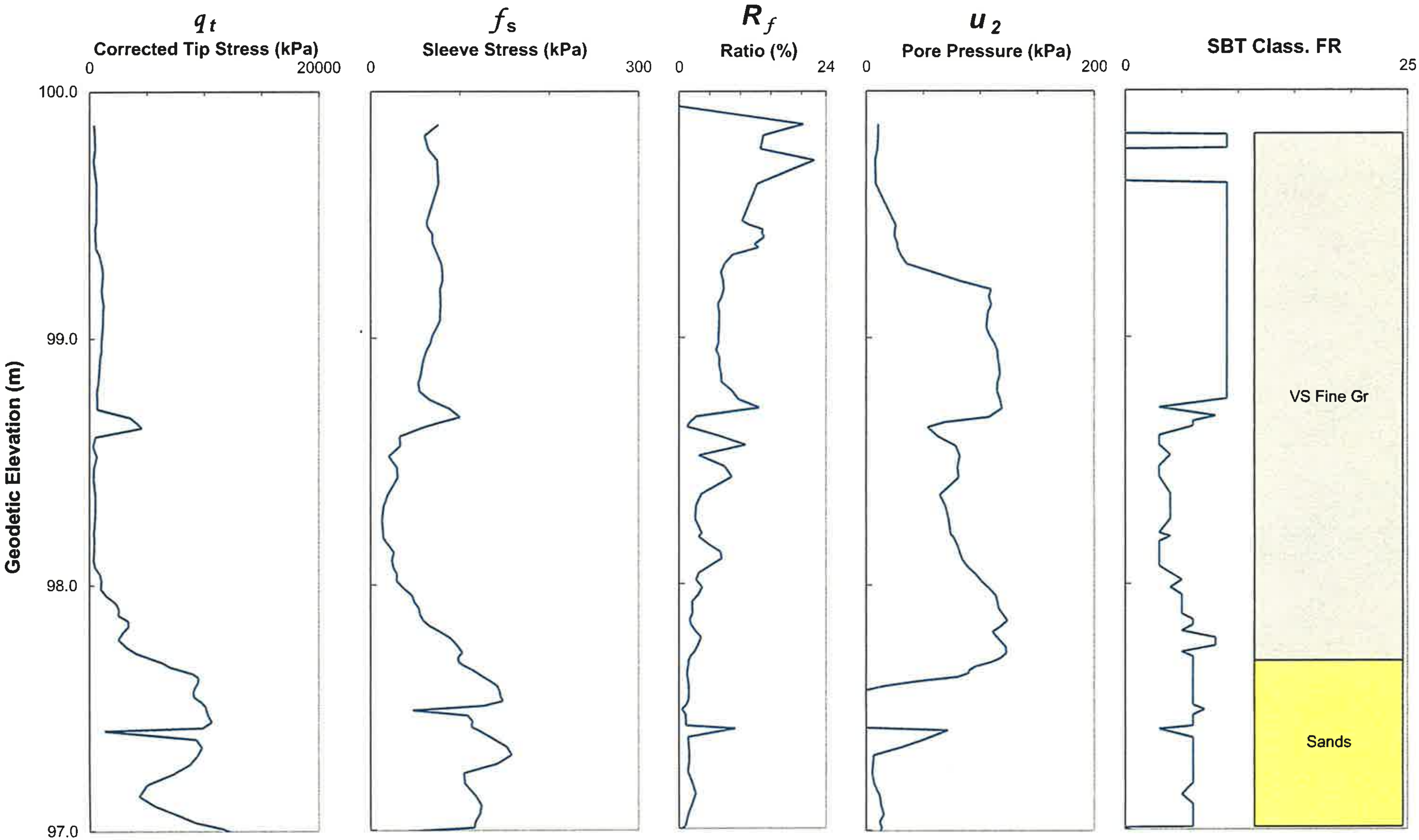
Class FR: Friction Ratio Classification (Robertson, 1990)

Jacques Whitford	Elevation: 99.59 m SCPTu Start Elevation: 99.59 m Groundwater Elevation: 98.38 m	Test Date: June 18, 2007 Project No. 1026929	CPT 07-15
	Client: Mattamy Homes Project: Proposed Residential Subdivision, Richmond, ON		



Class FR: Friction Ratio Classification (Robertson, 1990)

Jacques Whitford	Elevation: 99.94 m SCPTu Start Elevation: 99.94 m Groundwater Elevation: 98.62 m	Test Date: June 15, 2007 Project No. 1026929	CPT 07-20
	Client: Mattamy Homes Project: Proposed Residential Subdivision, Richmond, ON		



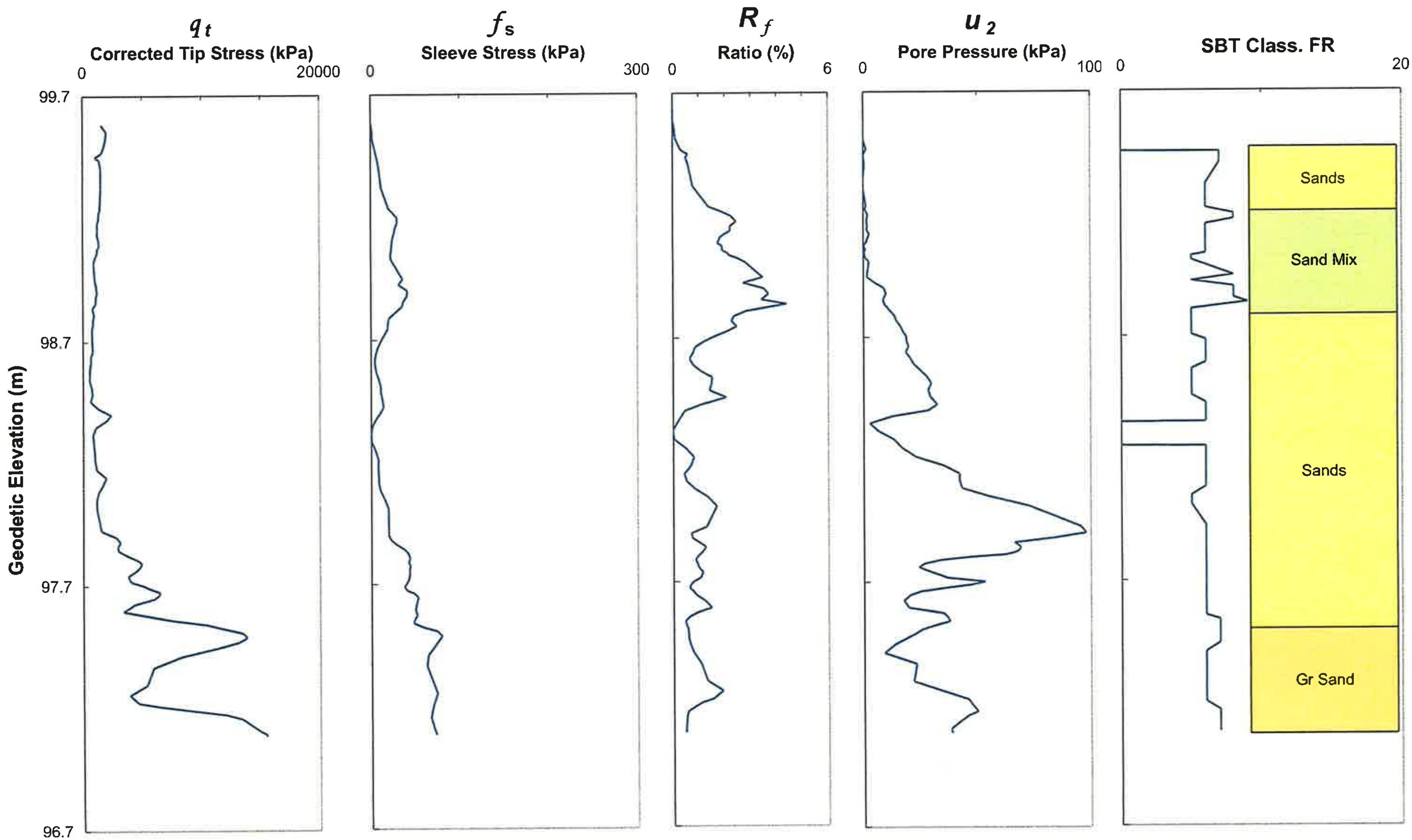
Class FR: Friction Ratio Classification (Robertson, 1990)

Jacques Whitford

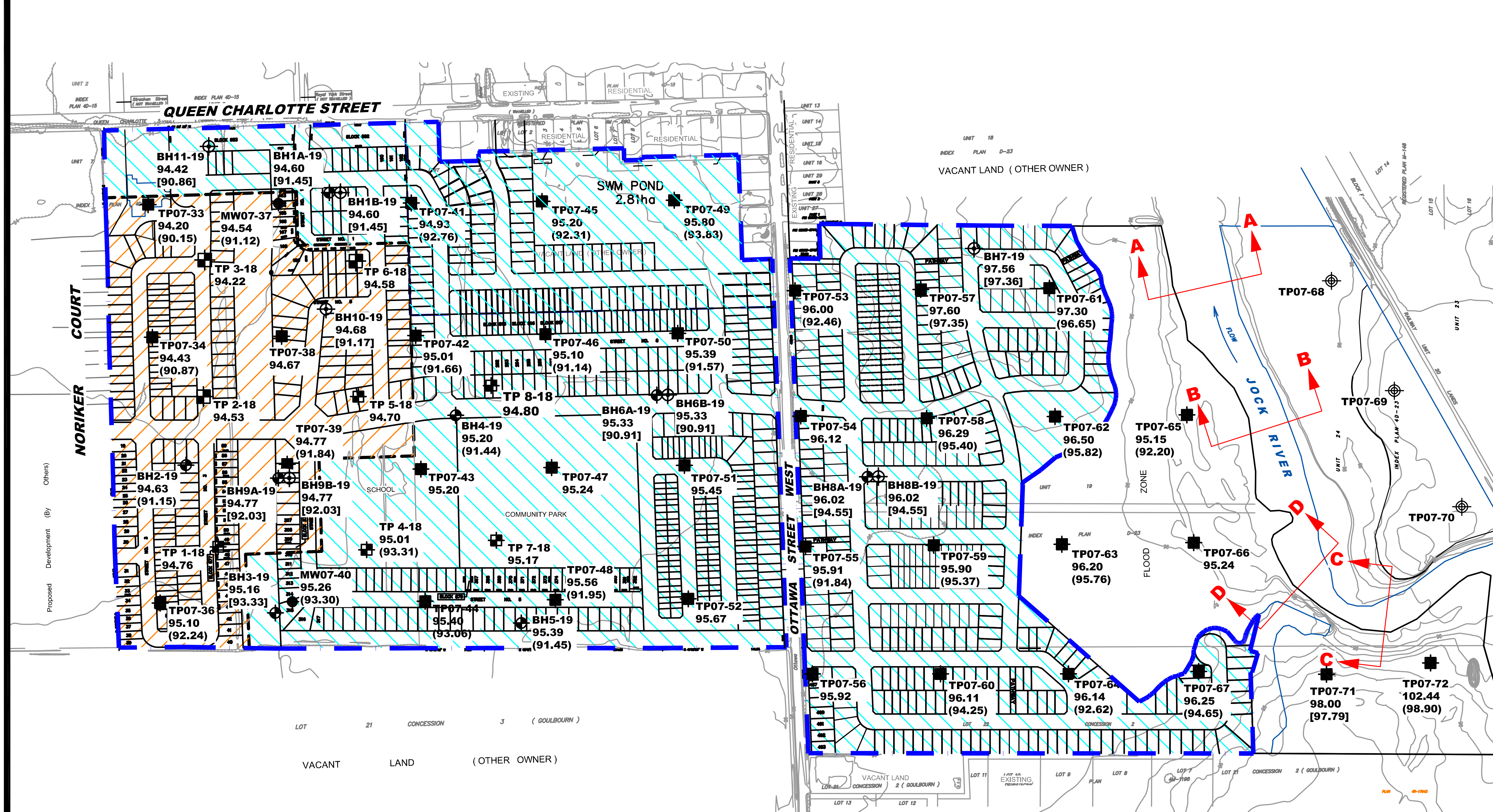
Elevation:	99.64 m	Test Date: June 15, 2007	CPT 07-35
SCPTu Start Elevation:	99.64 m	Project No. 1026929	
Groundwater Elevation:	98.19 m		

Client: Mattamy Homes

Project: Proposed Residential Subdivision, Richmond, ON



Class FR: Friction Ratio Classification (Robertson, 1990)



PERMISSIBLE GRADE RAISE AREAS:

- NO PERMISSIBLE GRADE RAISE REQUIRED
- UP TO 2.0m PERMISSIBLE GRADE RAISE ABOVE EXISTING GROUND SURFACE

LEGEND:

- MONITORING WELL WITH BEDROCK CORING, CURRENT INVESTIGATION
- MONITORING WELL DOWN TO BEDROCK SURFACE, CURRENT INVESTIGATION
- TEST PIT LOCATION, 2018
- TEST PIT LOCATION BY OTHERS
- MONITORING WELL LOCATION BY OTHERS
- HAND AUGER HOLE
- CROSS-SECTION LOCATION

95.01 GROUND SURFACE ELEV. (m)

(93.31) REFUSAL ON INFERRED BEDROCK SURFACE ELEV. (m)

[102.50] BEDROCK SURFACE ELEV. (m)

BASE PLAN, TEST HOLE LOCATIONS AND ELEVATIONS AT TEST HOLES BY PATERSONGROUP PROVIDED BY ANNIS, O'SULLIVAN, VOLLEBEKK LTD.

SCALE: 1:5000

0 50 100 150 200 250 300m

p:\autocad drawings\geotechnical\pg46xx\pg4683\pg4683-2 rev1 may30.dwg

patersongroup
consulting engineers

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Tel: (613) 226-7381 Fax: (613) 226-6344

NO.	REVISIONS	DATE	INITIAL
1	2019 BOREHOLES ADDED	07/05/2019	FA

MATTAMY HOMES

GEOTECHNICAL INVESTIGATION

PROPOSED RESIDENTIAL DEVELOPMENT - OTTAWA STREET - RICHMOND

OTTAWA, ONTARIO

Title:

TEST HOLE LOCATION PLAN

Scale: 1:5000	Date: 11/2018
Drawn by: RCG	Report No.: PG4683
Checked by: FA	Dwg. No.: PG4683-2
Approved by: DJG	Revision No.: 1

APPENDIX C

Regulatory Floodplain

RIDEAU VALLEY
CONSERVATION AUTHORITY

3889 Rideau Valley Drive, P.O. Box 599, Manotick, ON K4M 1A5
tel 613-692-3571 | 1-800-267-3504 | fax 613-692-0831 | www.rvca.ca

RVCA LETTER OF PERMISSION – ONT. REG. 174/06, S. 28 CONSERVATION AUTHORITIES ACT 1990, AS AMENDED.

Revised Date: March 3, 2009
Orig Date: February 17, 2009
File: RV5 0309

Mattamy Ltd. (Jock River)
123 Huntmar Drive
Ottawa, ON
K2S 1B9

Attention: Sean MacFarlane,

Subject: **Application for Development being the establishment of an earth berm on a property at part of Unit 19, Index Plan 4D-23 and part of Lot 2, Concession 2, former Township of Goulbourn, now in the City of Ottawa, bounded by Ottawa Street to the North and the Jock River to the south within the Village of Richmond.**

Dear Mr. MacFarlane,

The Rideau Valley Conservation Authority has reviewed the application submitted on behalf of Mattamy Ltd. and understands the proposal to be for:

1. The removal of fill associated with construction of a berm already on the property.
2. The establishment of a new berm closer to the municipal road and farther from the river.
3. The reinstatement of the land area at the existing/"*original*" berm site.
4. The placement of fill between the new berm and Ottawa Street to match existing surrounding grades.

This proposal was reviewed under Ontario Regulation 174/06, the "*Development, Interference with Wetlands, and Alteration to Watercourse and Shorelines*" regulation, which the Conservation Authority administers as well as the approved "Policies Regarding the Construction of Buildings and Structures, Placing of Fill and Alterations to Waterways" (Adopted by the Executive Committee, October 21, 1993 and last revised and approved by the Board of Directors, April 2006).

History

This proposal relates to two previous regulation application filings on the property, RV5-16/05 submitted and approved by the RVCA on December 9, 2005 under Ont. Regulation 166/90 and RV5-01/08 submitted by Mattamy relating to work undertaken in December 2007.

In 2005, a letter of permission was issued by the RVCA for the construction of a berm "to maintain flood risk mapping land levels as per (the 1980 Acres Floodplain) Mapping Study (96.0 metres)". The application indicated that the berm would be 15 cm to 30 cm in height and on site material would be used to construct the berm at a height of land determined in the field as the natural or high point of land, approximately the 96.0 metre contour. The berm as it exists today is 1-2 metres in height, 10-20 metres in width at the base, 2-100 metres from the Jock River and established more or less at the 95.5 metres contour.

On May 6, 2006, Ontario Regulation 166/90 (Fill, Construction and Alteration to Waterways Regulation) was rescinded and Ontario Regulation 174/06 was enacted. Both regulations were made pursuant to the provisions of Section 28 of the Conservation Authorities Act, and both gave responsibility for administration to the Rideau Valley Conservation Authority. The change in the regulatory legislation in May 2006 resulted in, amongst other things, incorporation of revised and extended hazard delineation along the Jock River (Jock River Floodplain Mapping Study completed in July 2005 by PSR). The new Mapping Study extended the hazard mapping upstream of the previous limit of study and provided for additional lands being subject to RVCA's regulatory jurisdiction; the 1:100 year flood level was considered to be 96.35 metres. A provincially mandated public process was followed in order for this new mapping to take effect.

The purpose of the 2005 application (previous property owner) was to establish a berm at the flood level, (96.0 metres – defined by the pre 2006 Flood Plain Mapping Study) thereby, preventing the remainder of the property from being subject to the floodplain regulations after incorporation of the New Mapping Study into the regulation in May 2006.

Project Scope

This application proposes removing the existing berm [established in Winter/Spring 2006, with further filling and reinforcement in December 2007] and locating it at the 2005 approved location. It is also proposed to remove the flapgate and culvert from the drainage easement until the issues relating to drainage for the property and greater surrounding area can be addressed. The berm will also be extended parallel along both sides of the drainage easement north up to Ottawa Street. The overall function of the drainage ditch/easement will be reviewed as part of a Storm Water Management and Drainage Plan to be completed by Mattamy respecting any future development applications.

The placing of fill for the berm and the associated filling behind the berm up to Ottawa Street is not expected to have a negative impact on the control of flooding. The filling operation and location of the "berm" should not impact the roadside conveyance of water and should not impact the conveyance of water through the Drainage Easement running through the centre of the subject property providing the work in undertaken as proposed.

This permission results in the re-location of the 2005 berm in the originally approved location. The filling between the relocated berm (maximum height 96.4 metres geodetic) and Ottawa Street will be to a maximum level of 96.5 and only to a level to taper to match existing grades.

Permission and Conditions

By this letter the Rideau Valley Conservation Authority hereby grants you permission to undertake the works on this property as outlined in the application, covering letter dated January 23, 2009 from David Schaeffer Engineering Ltd. and Drawings completed by same, Project 303, Figures 1-4, dated January 21, 2009 prepared for Mattamy Ltd. and all subject to the following conditions:

1. The existing berm will be removed from its current site. The material may be used for the construction of the new berm **if** deemed appropriate by a qualified Professional Engineer. Any excess material not required for the construction of the new berm may be used as fill in areas to the north of the relocated berm to a maximum elevation of 96.5 metres, noting the maximum berm height will be 96.4 metres. Any excess material will be disposed of in a suitable location outside all 1:100 year floodplains and regulated areas and not within a wetland.

2. The proposed berm shall be established as noted on the attached plan, (DSEL, Project 303, Figure 1-4 dated January 21, 2009) with the southern most boundary of the berm located no further south than the line denoted on the plan and established at an original grade no lower than 96. 1 metres

as depicted on the plan with the top of the berm at a maximum elevation of 96.4 metres or not greater than 0.3 metres in height. Grades along Ottawa Street will also be no higher than 96.4 metres.

3. The berm is to be located no closer than 3 metres to the drainage watercourse on both sides and/or **not** within the City of Ottawa's Drainage Easement, whichever is greater.

4. The culvert located in the drainage easement will be removed as the earthworks are completed and no fill or other obstruction will be placed in the drainage easement without approval from the City of Ottawa. The flap gate will be removed immediately from the culvert to ensure free flow of water.

5. The area of the original berm will be rehabilitated to original grade with plant material re-established as discussed in DSEL letter dated January 23, 2009.

6. A finished grading plan will be submitted as soon as the work is complete to confirm the height and location of the new berm and the grade height and location of the existing berm reinstated to original grade. A refundable deposit of $3000.00 is required to be submitted prior to commencement of the work.

7. No earthworks shall commence before May 1, 2009 and only if flows in the Jock River are considered at or lower than summer levels. Sediment control will be established as defined on Figure 3 prepared by David Schaeffer Engineering Ltd. (DSEL), dated January 21, 2009 and additional measures will be installed as deemed necessary.

8. Sediment and Erosion control Inspections will take place daily by DSEL or other appropriate and designated engineering staff while work is ongoing, and thereafter prior to and immediately following any forecasted rainfall event until such time as the site is revegetated, to ensure sediment control is operational and functional. This is ultimately the responsibility of the property owner and all persons associated with the construction/earthworks/grading on the property. Failure to comply may result in this permission being revoked and charges under other applicable law.

9. Any material excavated from the property and not required must be removed immediately and disposed of at a suitable disposal site outside the 100 year floodplain and regulated area.

10. The RVCA is to receive 48 hours notice of the proposed commencement of the proposed works to ensure compliance with all conditions.

11. There is to be **no** work at the bank or in the Jock River as part of this approval. The contractor will take all necessary measures to ensure no sediment migration into the river occurs and that no machinery, no grubbing and no further vegetation clearing takes place on the property as part of the proposed rehabilitation work. Failure to comply may result in this permission being revoked and charges under other applicable law.

12. It is acknowledged by all parties that the area of the fill operation between the new berm and Ottawa Street, when completed and confirmed, will be considered outside the 1:100 year flood plain of the Jock River. The Regulated Area of Ontario Regulation 174/06 nevertheless extends 15 metres from the 1:100 flood elevation which will be confirmed as the outer limit of the relocated berm. The portion of the property within the Regulated Area of Ontario Regulation 174/06 remains subject to the RVCA's regulatory jurisdiction regarding the *Development, Interference with Wetlands and Alteration to Watercourses"* regulation and associated implementation policies, as amended from time to time by the RVCA Board of Directors.

The regulatory mapping for Ontario Regulation 174/06 is reviewed once a year and amendments introduced as required. Once the works are completed, the Rideau Valley Conservation Authority agrees to pursue an amendment to the regulatory mapping to reflect the changes to the 1:100 floodplain contemplated in this approval.

Failure to comply with any or all conditions will result in the letter of permission being revoked with associated legal action to remedy the situation to the Conservation Authority's satisfaction.

By this letter, the Rideau Valley Conservation Authority assumes no responsibility or liability for any flood or erosion damage which may occur either to your property or the structures on it, or if any activity undertaken by you adversely affects the property or interests of adjacent landowners. This letter does not relieve you of the necessity or responsibility for obtaining any other federal or provincial permits including, but not limited to, approvals under the Public Lands Act, Ontario Water Resources Act, Building Code Act, Planning Act, Endangered Species Act etc.

Nothing in this letter of permission is intended to imply or confer any right of occupation or use of public land. This permission may not be transferred to any other party.

Should you have any questions, please contact Shelley Macpherson at our office.

Yours truly,

Donald A. Maciver, MCIP, RPP
Director of Planning

SM/DAM/sm

cc: Susan Murphy, Mattamy Ltd.
City of Ottawa, Guy Bourgon
City of Ottawa, Mike Wildman
City of Ottawa, Don Morse MCIP RPP
Helmut Brodmann LL.B. Bell, Baker
DSEL

NOTE: This letter of permission does not come into full force and effect until the attached copy of this letter is signed by the responsible corporate official, dated, and returned to the Authority offices in Manotick.

This letter's **return shall be taken as an acknowledgment and an acceptance of the conditions contained herein, as per the Authority's approval based on the application submitted.**

Pursuant to the provisions of S. 28 (12) of the Conservation Authorities Act (R.S.O. 1990, as amended) any or all of the conditions set out above may be appealed to the Executive Committee of the Conservation Authority in the event that they may be unsatisfactory or can not be met.

Name (printed) ______________________ **Date:** ______________

Corporate position / title: ______________________________

Signed: ______________________

Supplementary STAFF REPORT

To: **RVCA Board of Directors**

Prepared by: **Bruce A. Reid, P.Eng., Director, Watershed Science and Engineering Services**

Subject: **Van Gaal Drain Flood Plain Mapping – Final Report**

Date: **January 28, 2010**

At it's December 18, 2009 meeting, the Board postponed its decision with respect to the acceptance of the JF Sabourin and Associates Final Report on the Van Gaal Drain Flood Plain Mapping (item 6 on the December 18th agenda), in order to give "staff and proponent engineers a further chance to review and come to agreement on the methodology".

Staff met with representatives the City of Ottawa, and Mattamy Homes and their engineering consultants on January 14th. Minutes of that meeting are attached hereto.

There continues to be difference of opinion between Mattamy's consultants and RVCA's consultant with respect to the selection of the 1:100 year design flow (summer event) on the Van Gaal Drain. RVCA staff continue to be confident that using the JFSA design flows will be defensible before appeal tribunals (Mining and Lands Commissioner, OMB or the Courts) if and when necessary.

At the January 14th meeting we did achieve consensus on a step-by-step process to bring the matter to a successful conclusion, summarized as follows

1. RVCA will accept the JFSA flood plain mapping for original conditions of the land, and begin administering and enforcing O.Reg. 174/06 on the flood hazard areas defined in it.

2. Additional channel modifications will be done to increase the channel's conveyance capacity, compensating for the loss of conveyance capacity in overbank areas due to recent berm construction and returning the 1:100 year water surface profile to its pre-berm position. The work will be done by Mattamy, and will be subject to formal approval by the City's Drainage Superintendent as well as RVCA (under O.Reg. 174/06).

3. Grades will be raised in the areas behind (upland) of the existing berms, such that the finished grades will no longer be lower than the water surface profile

DSEL
david schaeffer engineering ltd
SMART SUBDIVISIONS™

120 Iber Road, Unit 203
Stittsville, Ontario, K2S 1E9
Tel. (613) 836-0856
Fax (613) 836-7183
www.DSEL.ca

September 14, 2012

Jocelyn Chandler M.Pl. MCIP, RPP
Rideau Valley Conservation Authority
3889 Rideau Valley Drive
Ottawa, ON K2C 3H1

Re: RVCA File No. 11-GOU-SUB
Richmond Village (South) Ltd.
Proposed Van Gaal Channel Re-Alignment

DSEL in collaboration with JFSA, nak design strategies, JTBES, and Kilgour and Associates have prepared a preliminary design in support of a Richmond Village (South) Ltd., proposal to realign and widen the Van Gaal Drain north of Perth Street in order to redefine the floodplain North of Perth Street. The following and attached supporting information was prepared to provide the Rideau Valley Conservation an opportunity provide preliminary feedback on the proposed re-alignment.

The supporting information is presented as a first step toward addressing the existing floodplain north of Perth Street. The following meetings and reports concerning the Van Gaal channel and associated floodplain north of Perth Street have taken place to date:

- January 28, 2010 – Supplemental Staff Report to the RVCA Board of directors, supporting a 2008 proposal to raise the grade of the subject property behind the existing constructed berms. The proposal to fill the area behind the berms was relying on fill generated from the development itself. To import fill specifically to raise the grade would have negative environmental impact (ie numerous trucks to import fill).

- May 19, 2011 – Representatives from Richmond Village (South) Ltd., met with RVCA staff to discuss a proposal to widen and realign and widen the Van Gaal drain north of Perth Street as a vehicle to remove the interim floodplain north of Perth Street.

- July 7, 2011 – DSEL submitted a preliminary design and supporting hydraulic analysis to realign and remove the interim floodplain north of Perth Street for RVCA review and input.

- August 5, 2011 – RVCA provided review comments by e-mail to be addressed and considered in the subsequent submission.

A new channel alignment has been contemplated to address the interim floodplain North of Perth Street and also addresses a number of additional issues. The current proposal is a deviation from the previously submitted channel re-alignment and as such, the consulting team felt it prudent to involve the RVCA prior to completing detailed design.

The following supporting information is attached:

- Site photographs of the existing Van Gaal Drain taken 2012-08-30.
    - At the time of the site visit, the existing drain was dry. Note that a total of 81.9mm of rain fell in the previous 30days leading to August 30, with 8.5mm of rain on August 25 (source: The Weather Network Online). The site photographs show that the existing channel has very few trees providing shade.
- Site photographs of the existing Todd Pond outlet taken 2012-08-30.
    - Nak design strategies was part of the team who created the Todd Pond outlet. This channel is fed by an upstream pond, and therefore has a consistent base flow. These photographs illustrate the desired end product for the proposed Van Gaal Drain outlet.
- nak design strategies Van Gaal Drain Re-Alignment and Channel Enhancement Plans
    - The attached plans illustrate a conceptual planting and meandering low flow channel. These plans were developed in coordination with JFSA, JTBES, and Kilgour and Assoc.
- J.F. Sabourin and Associates Inc – Technical Memo
    - Hydraulic Analysis of realigned drain. The channel hydrology considers the type and placement of the proposed landscaping treatment in predicting water levels along the realigned drain. The analysis shows that the 100-year event is contained within the channel. Some modest modifications to the inlet of the Perth Street culvert are required.
- JTBES – Technical memo
    - JTBES provided advice on the proposed re-aligned channel. Their office prepared additional investigations of the downstream water course and have noted areas of concern. The proposed re-aligned channel will reduce upstream velocities and will benefit the downstream system.
- Kilgour and Associates - Technical Memo
    - Kilgour and Associates were involved in discussions pertaining to the realigned drain and were asked for their feedback and input. Their technical memorandum comments on the proposed design and gives design advise.

The following summarizes additional benefits the re-aligned channel will have on the site as a whole.

1. Addresses and contains the interim floodplain north of Perth Street.

    a. Proposed channel realignment and widening meets the goals set forth to contain the 100-year flood elevations without increasing water levels.
    b. Eliminates the need to import soils to redefine floodplain per previous agreement. Importing additional soils would prevent continued agricultural practices from taking place. Would unnecessarily add numerous vehicles required to import soils, which would have a negative impact on the existing community. IE noise / traffic.

2. Fish Habitat
    a. Channel definition is greater in length and provides opportunity for natural channel design thus improving and adding to the total available habitat.
3. Potential for preservation of woodlot.
    a. Channel definition would potentially minimize the impact on the existing woodlot.
4. No road crossing
    a. Re-aligning channel to the eastern property line eliminates need for the proposed road crossing.
5. Potential for benefit to mitigate existing downstream erosion.
    a. Low flow channel definition may provide opportunities to reduce in stream velocities providing a benefit downstream (JTBES to confirm requirements, JFSA to review impact of greater friction in channel on predicted water levels.)
6. Removes Isolated Stormwater Management Facility
    a. The previous alignment required the introduction of a small stormwater management facility to service a 3.4ha area. The previously conceived facility was not optimal in that it serviced an area less than MOE recommendations (greater than 5ha). Eliminating this facility reduces infrastructure requirements for development. In turn potential reduction in capital expenditures as well as operation and maintenance.

We look forward to discussing the attached proposal and moving forward with detailed engineering plans.

Yours truly,
David Schaeffer Engineering Ltd.

Per: Adam D. Fobert, P.Eng.

Yours truly,
David Schaeffer Engineering Ltd.

Per: Stephen J. Pichette, P.Eng.

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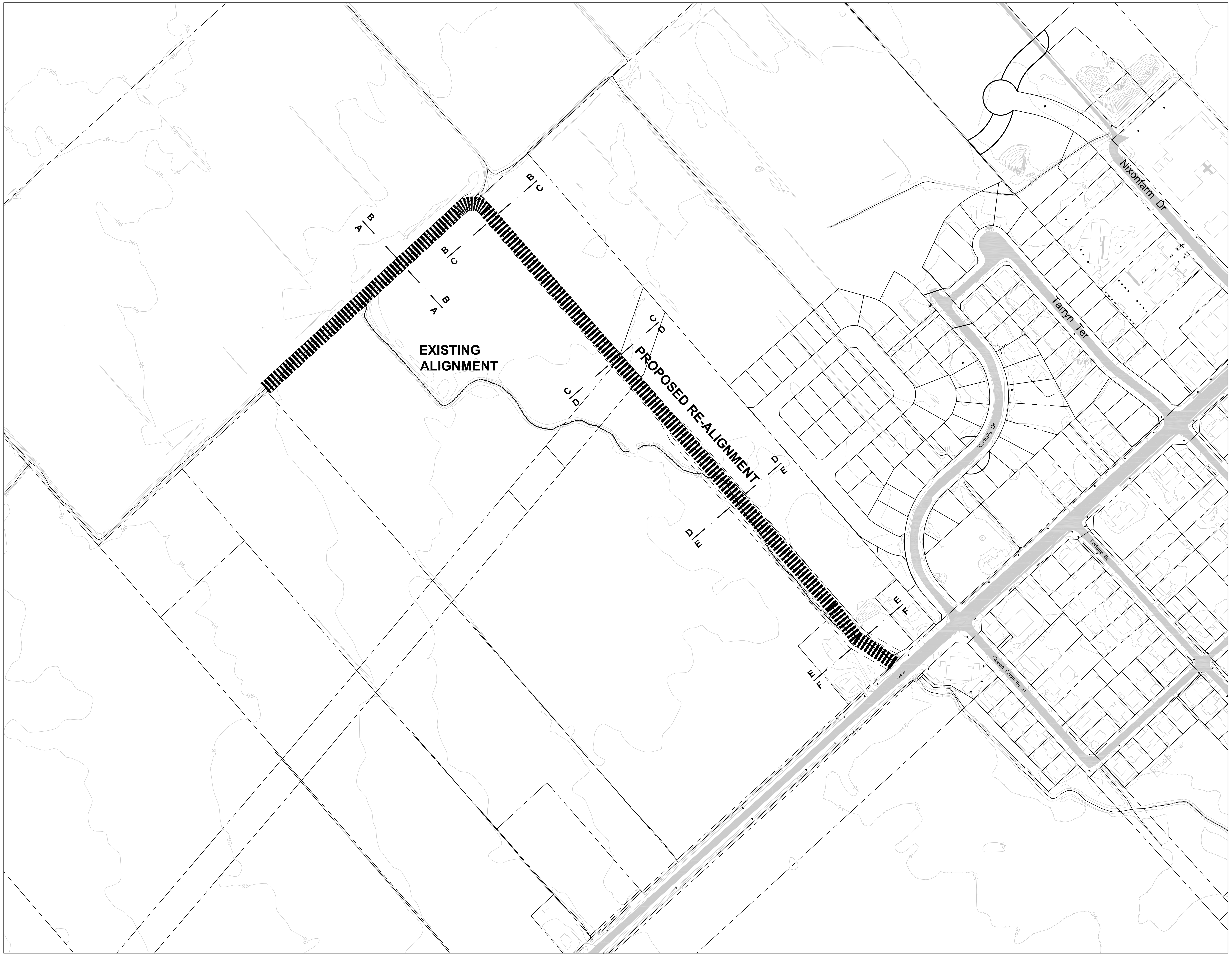


VAN GAAL DRAIN RE-ALIGNMENT & CHANNEL ENHANCEMENTS

Richmond Village Development Corporation

CONTEXT

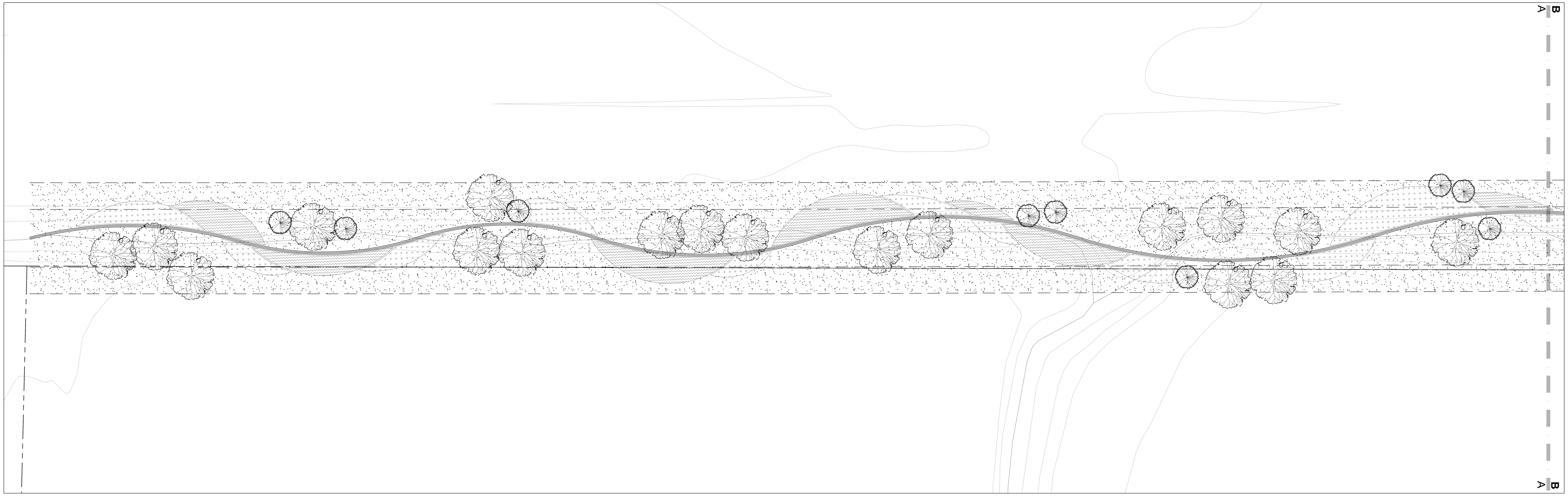
12.08.30

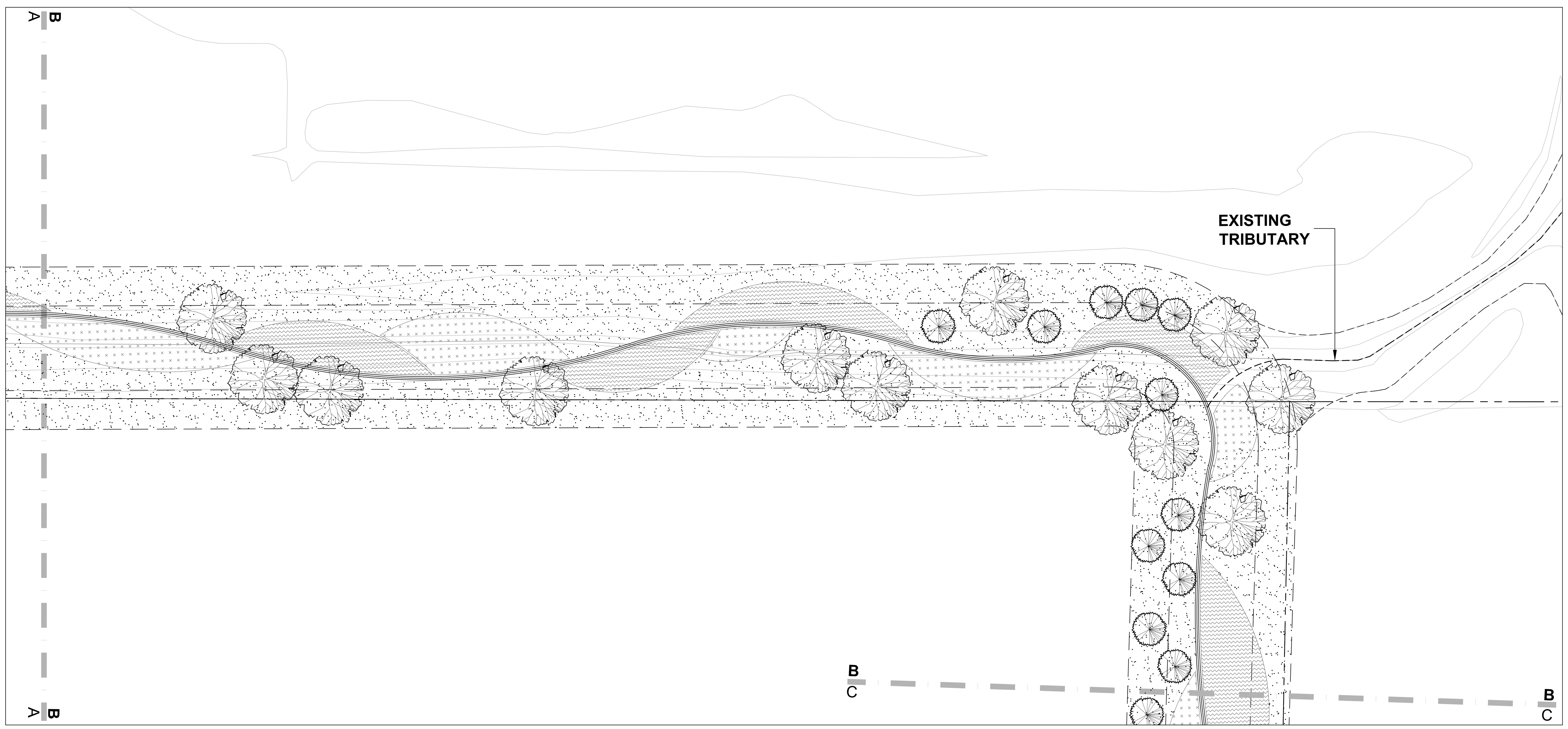
1:2000

Job No. 1-12__

nak design strategies

250 Besserer Street | Studio 100 | Ottawa, Ontario | K1N 6B3
tel: 613.237.2345 | fax: 613.237.6423 | nak@nak-design.com





PROPOSED PLANT LIST

DECIDUOUS TREES
SUGAR MAPLE
RED MAPLE
SILVER MAPLE
BUR OAK
RED OAK
TREMBLING ASPEN
BLACK WILLOW

CONIFEROUS TREES
TAMARACK
WHITE SPRUCE
WHITE PINE
WHITE CEDAR

SHRUBS
PEACH-LEAVED WILLOW
BEBB'S WILLOW
PUSSY WILLOW
STAGHORN SUMAC
COMMON ELDERBERRY
SERVICEBERRY
NANNYBERRY
HIGHBUSH CRANBERRY
RED OSIER DOGWOOD
GRAY DOGWOOD
CHOKECHERRY

WET MEADOW SEED MIX
25% CANADA BLUE JOINT GRASS
25% ROUGH-STALKED MEADOW GRASS
20% HIGHLAND COLONIAL BENTGRASS
15% CREEPING RED FESCUE
5% TALL WHITE ASTER
10% NEW ENGLAND ASTER

DRY-MESIC MEADOW SEED MIX
25% CANADA BLUE GRASS
25% CREEPING RED FESCUE
25% PERENNIAL RYEGRASS
10% RED CLOVER
10% BLACK-EYED SUSAN
5% NEW ENGLAND ASTER

LEGEND

DECIDUOUS TREE
CONIFEROUS TREE
TOP / BOTTOM OF SLOPE
EXISTING TRIBUTARY
SEEDING
SHRUB MIX 'A'
SHRUB MIX 'B'
STABILIZATION PLANTING

PLANTING KEY
XX # TREE SPECIES QUANTITY
X # SHRUB SPECIES QUANTITY

VAN GAAL DRAIN RE-ALIGNMENT & CHANNEL ENHANCEMENTS

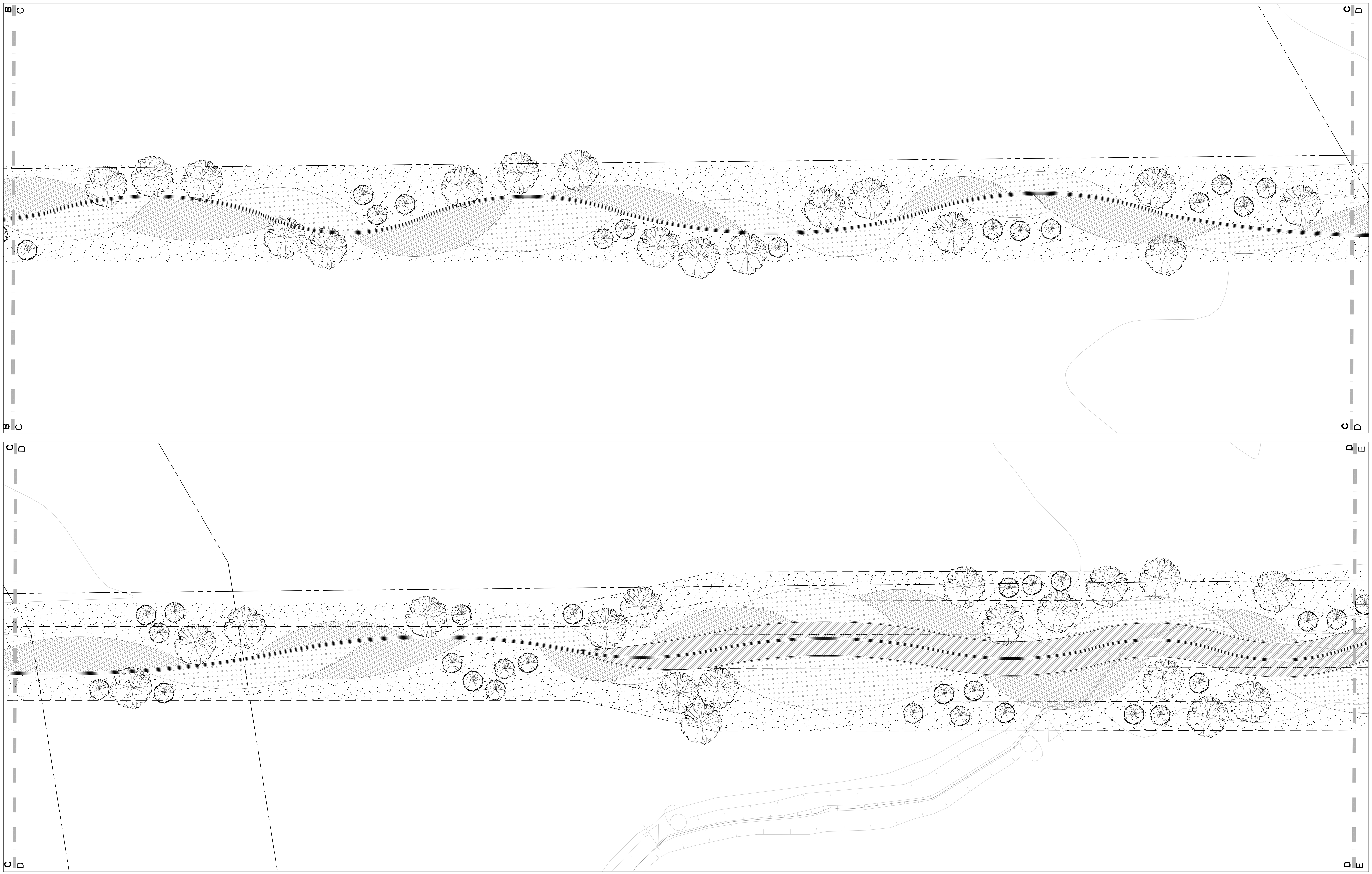
Richmond Village Development Corporation

LAYOUT PLANS

N

12.09.31
1:200
Job No. 1-12___

nak design strategies
250 Besserer Street | Studio 100 | Ottawa, Ontario | K1N 6B3
tel: 613.237.2345 | fax: 613.237.6423 | nak@nak-design.com



VAN GAAL DRAIN RE-ALIGNMENT & CHANNEL ENHANCEMENTS

Richmond Village Development Corporation

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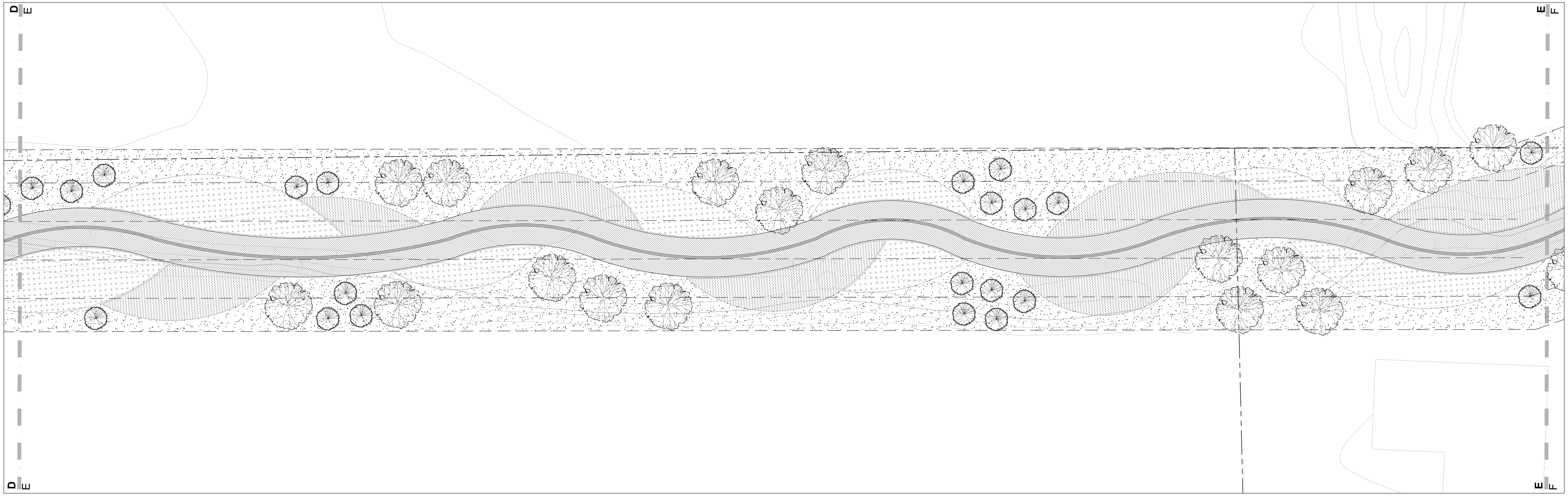

PROPOSED PLANT LIST

DECIDUOUS TREES
- SUGAR MAPLE
- RED MAPLE
- SILVER MAPLE
- BUR OAK
- RED OAK
- TREMBLING ASPEN
- BLACK WILLOW

CONIFEROUS TREES
- TAMARACK
- WHITE SPRUCE
- WHITE PINE
- WHITE CEDAR

SHRUBS
- PEACH-LEAVED WILLOW
- BEBB'S WILLOW
- PUSSY WILLOW
- STAGHORN SUMAC
- COMMON ELDERBERRY
- SERVICEBERRY
- NANNYBERRY
- HIGHBUSH CRANBERRY
- RED OSIER DOGWOOD
- GRAY DOGWOOD
- CHOKECHERRY

WET MEADOW SEED MIX
- 25% CANADA BLUE JOINT GRASS
- 25% ROUGH-STALKED MEADOW GRASS
- 20% HIGHLAND COLONIAL BENTGRASS
- 15% CREEPING RED FESCUE
- 5% TALL WHITE ASTER
- 10% NEW ENGLAND ASTER

DRY-MESIC MEADOW SEED MIX
- 25% CANADA BLUE GRASS
- 25% CREEPING RED FESCUE
- 25% PERENNIAL RYEGRASS
- 10% RED CLOVER
- 10% BLACK-EYED SUSAN
- 5% NEW ENGLAND ASTER

LEGEND

- DECIDUOUS TREE
- CONIFEROUS TREE
- TOP / BOTTOM OF SLOPE
- SEEDING
- SHRUB MIX 'A'
- SHRUB MIX 'B'
- STABILIZATION PLANTING

PLANTING KEY

- XX / # — TREE SPECIES / QUANTITY
- X / # — SHRUB SPECIES / QUANTITY

VAN GAAL DRAIN RE-ALIGNMENT & CHANNEL ENHANCEMENTS

Richmond Village Development Corporation

LAYOUT PLANS

12.09.31

1:200

Job No. 1-12___

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J.F. Sabourin and Associates Inc.
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WEB: www.jfsa.com

September 6, 2012

David Schaeffer Engineering Limited
120 Iber Road, Unit 203
Ottawa, Ontario K2S 1E9

Attention: Mr. Adam Forbert, P.Eng.

Subject: Richmond Village Development / Proposed Realignment of Van Gaal Drain *our file:922-11*

As requested by your office, we have evaluated, based on the available information as described below, the preliminary channel dimensions required to contain the 100-year design water levels within the proposed realignment of the Van Gaal Drain. It is understood that approximately 900 m of the existing Van Gaal Drain upstream of Perth Street will be realigned to follow the boundary of the Richmond Village Development Corporation site in the Village of Richmond.

In undertaking this work, the following information was considered:

1) HEC-RAS models of Van Gaal Drain under existing conditions (spring and summer) were obtained from the *Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond* (JFSA, November 2009). The November 2009 *Floodplain Mapping Report* defined the maximum flood levels in the Van Gaal Drain based on three scenarios: (1) the Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River; (2) The Van Gaal 100-year spring snowmelt plus rainfall peak flow reaches the Jock River; and (4) The Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain.

2) The HEC-RAS models of existing conditions were modified to reflect the proposed channel realignment based on information provided by DSEL. As noted above, it is proposed that approximately 900 m of the existing Van Gaal Drain upstream of Perth Street be realigned to follow the boundary of the Richmond Village Development Corporation site. Note that in order to best define the upstream limit of the channel realignment, existing conditions cross-sections were interpolated in HEC-RAS every 50 m between existing conditions cross-sections 2478 and 2157. The downstream limit of the channel realignment is defined by the Perth Street crossing. Refer to Figure 1 for the proposed channel realignment and cross-section locations.

3) Note that the proposed channel realignment will not impact flows in the Van Gaal Drain. As such, flows provided in the existing conditions HEC-RAS models were also used for the proposed conditions models.

4) The proposed channel dimensions were set to contain the 100-year flood levels within the channel for all three spring and summer scenarios, and to set the 100-year proposed conditions water levels at comparable cross-sections (2554, 2478, and 1615 - 1340) equal to or less than the maximum existing conditions flood levels defined in the November 2009 *Floodplain Mapping Report*. Note that 100-year water levels within the majority of the realigned channel are not comparable to existing conditions, given the different locations of the existing and proposed cross-sections.

5) The required low flow channel dimensions for the realigned channel are currently unknown. As such, a 0.3 m deep low flow channel with 0.3 m bottom width, 1H:1V side slopes and 0.9 m top width was assumed for the purposes of this analysis. The top of the low flow channel (beginning of the floodplain) was set to match existing minimum channel elevations at the upstream and downstream limits of the proposed channel

realignment. It should therefore be noted that the bottom of the proposed low flow channel is 0.3 m below the invert of the Perth Street culvert.

6) Two typical cross-sections were sized for the proposed channel realignment; Section A, from the upstream limit of the realignment to cross-section 1682; and Section B, from cross-section 1682 to the downstream limit of the realignment at Perth Street. Refer to Figure 2 for the typical proposed cross-section dimensions. Section A has a floodplain width of 7.5 m and a total depth of 1.7 m based on the existing grade of surrounding lands and the depth required to contain the 100-year design water levels in the channel. Section B has a floodplain width of 15.0 m and a variable depth; the top of the channel is set to match the existing grade of the surrounding land in order to ensure that the adjacent existing Cedarstone Subdivision is unaffected by the proposed channel realignment.

7) The existing conditions HEC-RAS models specify Manning's roughness coefficients of 0.035 for the low flow channel, 0.05 for the banks under spring conditions and 0.08 for the banks under summer conditions. These Manning's roughness coefficients are generally to be maintained in the proposed realigned channel. However, plantings are to be selected in Section B for a 5.0 m wide area of the proposed floodplain (centred around the low flow channel) to set a low Manning's roughness coefficient of 0.04 under both spring and summer conditions.

8) The entrance loss coefficient of Perth Street culvert was changed from 0.5 under existing conditions to 0.2 under proposed conditions, to represent proposed changes to the culvert entrance consisting of a headwall parallel to the embankment (no wingwalls) with three edges rounded to radius of 1/12 barrel dimension. This proposed conditions entrance loss coefficient is in accordance with the *HEC-RAS River Analysis System Hydraulic Reference Manual Version 4.1* (US Army Corps of Engineers, January 2010).

Based on the above information, 100-year design water levels for the proposed realignment of the Van Gaal Drain under the three spring and summer scenarios were determined using HEC-RAS and are presented in Table 1. The proposed conditions 100-year water levels are contained within the proposed channel for all scenarios. Furthermore, as may be seen in Table 1, the proposed conditions water levels at comparable cross-sections are equal to or less than the maximum existing conditions flood levels defined in the November 2009 *Floodplain Mapping Report*.

Yours truly,
J.F. Sabourin and Associates Inc.

Laura Pipkins, P.Eng.

cc: J.F. Sabourin, M.Eng, P.Eng.
Director of Water Resources Projects

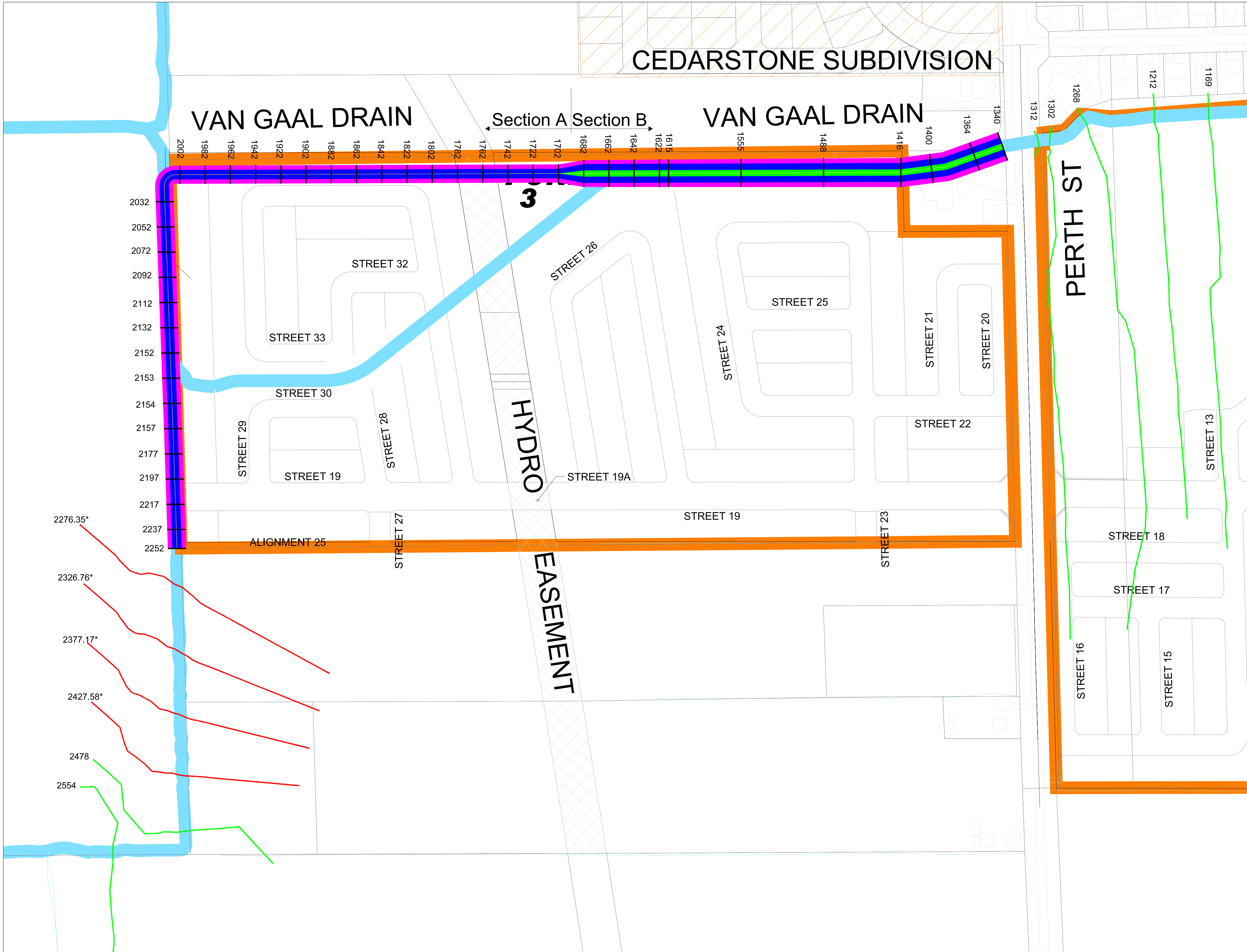
Table 1: Water Levels on Van Gaal Drain Reach 2 to Perth Street Under Proposed Conditions [1]

River Station	Scenario			
	1	*2*	*4*	*Max. Allowable* [2]
2554	96.26	96.28	95.86	96.28
2478	96.13	96.14	95.77	96.16
2427.58*	96.04	96.05	95.71	N/A
2377.17*	95.95	95.95	95.63	N/A
2326.76*	95.86	95.88	95.53	N/A
2276.35*	95.80	95.64	95.14	N/A
2252	95.77	95.59	95.04	N/A
2237	95.75	95.57	95.02	N/A
2217	95.72	95.55	94.99	N/A
2197	95.69	95.52	94.95	N/A
2177	95.67	95.49	94.92	N/A
2157	95.64	95.47	94.89	N/A
2154	95.62	95.44	94.85	N/A
2153	95.57	95.39	94.81	N/A
2152	95.52	95.35	94.77	N/A
2132	95.48	95.31	94.73	N/A
2112	95.44	95.26	94.69	N/A
2092	95.39	95.22	94.65	N/A
2072	95.35	95.18	94.61	N/A
2052	95.31	95.14	94.57	N/A
2032	95.26	95.10	94.53	N/A
2002	95.20	95.03	94.48	N/A
1982	95.15	94.99	94.44	N/A
1962	95.11	94.95	94.41	N/A
1942	95.06	94.90	94.38	N/A
1922	95.02	94.86	94.35	N/A
1902	94.97	94.82	94.32	N/A
1882	94.92	94.77	94.29	N/A
1862	94.87	94.73	94.27	N/A
1842	94.83	94.69	94.25	N/A
1822	94.78	94.64	94.23	N/A
1802	94.73	94.60	94.21	N/A
1782	94.67	94.56	94.19	N/A
1762	94.62	94.51	94.18	N/A
1742	94.56	94.47	94.17	N/A
1722	94.50	94.42	94.16	N/A
1702	94.44	94.37	94.15	N/A
1682	94.44	94.38	94.15	N/A
1662	94.42	94.37	94.15	N/A
1642	94.41	94.36	94.15	N/A
1622	94.40	94.35	94.14	N/A
1615	94.39	94.35	94.14	94.61
1555	94.37	94.33	94.14	94.55
1488	94.34	94.31	94.14	94.45
1416	94.32	94.30	94.14	94.41
1400	94.31	94.29	94.14	94.36
1364	94.30	94.29	94.13	94.31
1340	94.17	94.16	94.12	94.21

[1] Scenario Descriptions:

1. The Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River.
2. The Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River.
4. The Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain.

[2] Maximum water level at existing cross-sections as per "*Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond*" (JFSA, November 2009)



LEGEND :

- LIMITS OF SUBDIVISION
- PROPOSED CROSS-SECTION
- EXISTING CROSS-SECTION
- EXISTING (INTERPOLATED) CROSS-SECTION
- EXISTING CHANNEL ALIGNMENT

PROPOSED CHANNEL ALIGNMENT (SECTION A) :

- 2.5H:1V SECTION; 14.416 M TOTAL WIDTH
- 0.3 M WIDE LOW FLOW CHANNEL
- 7.5 M WIDE FLOODPLAIN SECTION

PROPOSED CHANNEL ALIGNMENT (SECTION B) :

- 2.5H:1V SECTION; VARIABLE TOTAL WIDTH
- 0.3 M WIDE LOW FLOW CHANNEL
- 5.0 M WIDE MINIMAL VEGETATION SECTION
- 15.0 M WIDE FLOODPLAIN SECTION

SCALE :

0 25 50 75 100 125 150m

J.F. Sabourin & Associates Inc.
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS
OTTAWA (613) 836-3884
GATINEAU (819) 243-6858

CLIENT :

DSEL
david schaeffer engineering ltd
120 IBER ROAD, UNIT 203
OTTAWA, ONTARIO, K2S 1E9
(613) 836-0856

PROJECT :

PROPOSED REALIGNMENT OF VAN GAAL DRAIN

BY	DATE	DESCRIPTION	BY

LOCATION OF PROPOSED CROSS-SECTIONS

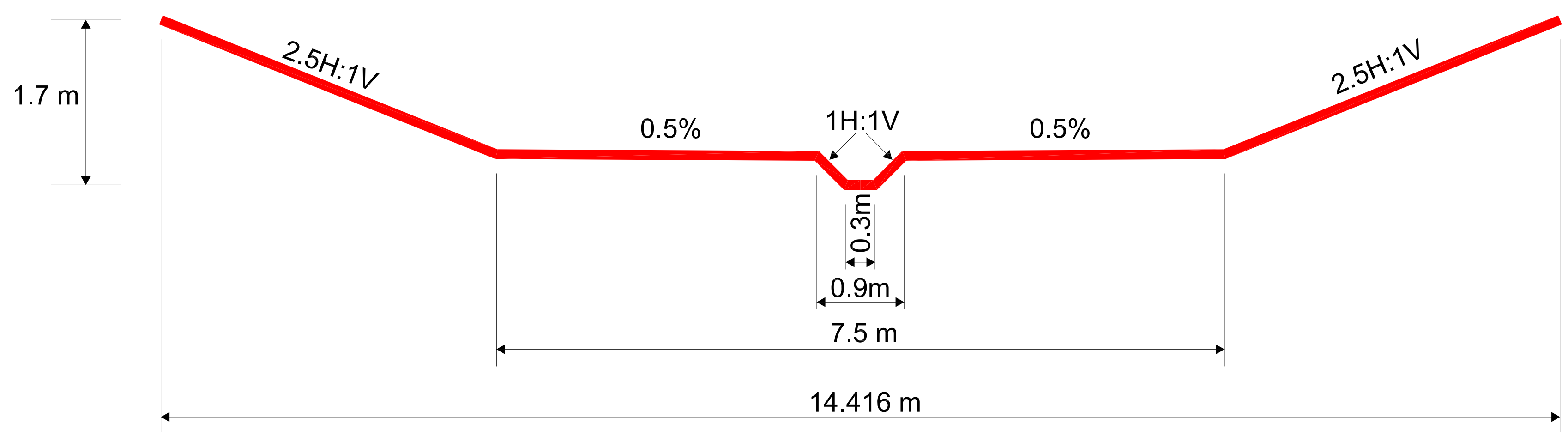
FIGURE 1

DESIGNED:	
DRAWN:	LP
VERIFIED:	JFS
APPROVED:	JFS

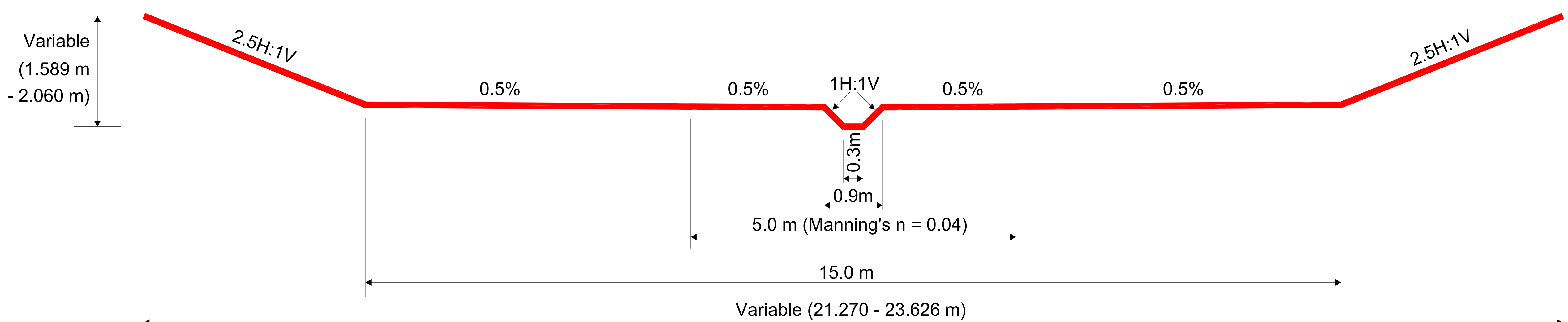
DRAWING REF.
922-11\201209 Channel Realignment\Design\CAD\JFSA Figures.dwg

DATE	PROJECT No.
Sep/12	922-11

SECTION A :



SECTION B :



LEGEND :

PROPOSED CROSS–SECTION

SCALE :

0 50 100 150 200 250 300 350 400cm

J.F. Sabourin & Associates Inc.
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS
OTTAWA (613) 836–3884
GATINEAU (819) 243–6858

CLIENT :

DSEL
david schaeffer engineering ltd
120 IBER ROAD, UNIT 203
OTTAWA, ONTARIO, K2S 1E9
(613) 836–0856

PROJECT :

PROPOSED REALIGNMENT OF VAN GAAL DRAIN

BY	DATE	DESCRIPTION	BY

DIMENSIONS OF PROPOSED CROSS–SECTIONS

FIGURE 2

DESIGNED:
DRAWN: LP
VERIFIED: JFS
APPROVED: JFS

DRAWING REF.
922–11\201209 Channel Realignment\ Design\CAD\JFSA Figures.dwg

DATE	PROJECT No.
Sep/12	922–11

September 6, 2012

David Schaeffer Engineering Limited
120 Iber Road, Unit 203,
OTTAWA, Ontario K2S 1E9

Attention: Mr. Adam Fobert, P. Eng

Subject: Richmond Village Development: Van Gaal Drain Geomorphology Assessment

---

JTBES was contacted by DSEL to complete an erosion threshold analysis for the Van Gaal drain. A previous erosion analysis did not appear to factor in sensitivity to erosion for the reach between Perth Street and Fortune Avenue, and it did not include any information between Fortune Avenue and the Jock River outlet.

Further, an assessment of the potential for realigning the existing drain upstream of Perth Street to accommodate site development has also been requested. The overall benefit of the realignment relative to maintaining the existing condition is discussed.

REALIGNMENT OF THE VAN GAAL DRAIN UPSTREAM OF PERTH STREET

A realignment concept has been provided which shows the drain shifting from its current alignment across the property to a position along the boundary of the property. This realignment will result in an overall straightening of the drain corridor; however the low flow function of the drain will be designed to show a sinuous path.

The result of this shift in position will be an increase in the overall stream length of the drain. Normally there would be concerns with sedimentation as energy budgets are affected by such realignments, particularly in low-gradient sections. However, based on our site visits in 2012 it is possible to create a series of steeper and gentler sections along the realigned drain to maintain sediment transport relationships and overall drain function.

A low flow channel will be incorporated into the design. The purpose of the low flow is to provide for fish habitat; the purpose of the overbank areas will be to provide velocity control which will aid in erosion protection. The overall design will be a positive outcome considering the existing condition of the drain. This is discussed further below.

CAUSES OF EXISTING EROSION ON THE VAN GAAL DRAIN

Erosion on the Drain is caused by a number of factors, some of which are natural and others which are induced as a result of changes in land use/hydrologic behaviour.

Natural erosion delivers sediment to the Drain through a number of possible mechanisms, including sheetwash, frost heave and desiccation fracturing, gravity failures due to oversteepening of the banks, and natural weathering of the clays (caused by repeated wet/dry cycles) which weakens the structural bonds in the clay matrix. Once operated upon by these mechanisms flowing water is easily able to erode and transport this weakened material. Large clumps of bank, once in the active channel, get quickly broken down into constituent clay particles which are cohesionless and very susceptible to erosion by flowing water.

Further, as banks become partly separated by slumps, flow from upstream can get behind the failing portion of the bank and hydraulic pressure forces the bank to fail more quickly. All of these processes (with the exception of frost heaving due to the time of year of the assessment) were visible along the drain.

Induced changes are the result of human activity upstream in the watershed. In this case, a recent small residential development along Rochelle Drive/Mira Court upstream of Perth Street may have changed the hydrologic properties of overland flow in the area. The increased impervious surface, and apparent lack of stormwater detention, delivers runoff quickly to the Drain during storms, creating a first pulse of fast flow through the Drain during storm events. When additional storm inlets are added to the mix (for instance the drain at Queen Charlotte Street) the cumulative effect of this fast rise in stage and velocity could result in erosion.

Finally, there is the construction of the Drain itself to consider. It is not known whether the Drain cross section was designed using flow analysis at the time of design (though the fact that the 2-year flow is well outside the cross-sectional area of the Drain under current conditions may be telling); if the necessary hydrologic calculations were not used to size the Drain then there is a chance it is undersized. This is currently evident as the Drain appears to be widening in response to flows, though it may be a combination of factors that is causing this to occur and, given the upstream development, may have sent the Drain past a stability threshold and initiated erosion at the scale which is evident today.

Results from the geomorphic analysis indicate the Van Gaal Drain system is a sediment rich as well as energy rich (at times of flowing water) system, which erodes, transports and deposits bed material under rising and falling hydrographs under existing conditions.

Mobilization of bed materials which have been deposited from upstream will occur under almost all flows and should be encouraged as the system needs to flush out these large deposits of silts and clays. Establishing a threshold discharge based on these surficial deposits is not appropriate as their transport requires very low velocities. Since the ‘bedrock’ layer is comprised of tight, cohesive clays and is highly resistant to erosion by flowing water, that material is also unsuitable for establishing thresholds. Therefore, given these two points and the fact that the Drain is eroding its banks in multiple locations, the most appropriate erosion threshold for use in this analysis is the bank erosion threshold.

Erosion along banks can be caused by flows that exceed the theoretical critical velocity for entrainment of the cohesive bank material. Assessment of the conditions of the creek show that the banks are comprised of consolidated clay materials, ranging from coarse to fine clay. When these materials are exposed to flowing water, velocities of between 0.225 metres per second (coarse clay) and 0.400 metres per second (fine clay) are required to entrain (erode) these materials (ref. Hjulstrom, 1935).

IMPLICATIONS

Existing Erosion

The analysis clearly shows that there are significant erosion sites on the Van Gaal Drain that have their cause in a number of areas. Addition of stormwater flows from the proposed site, even if controlled to the threshold rate, will not prevent existing erosion from continuing. It must be well understood that existing erosion will continue to occur for the simple reason that once erosion scars develop in banks they become weak points and as such are susceptible to continual erosion unless an intervention is undertaken. For those sites downstream of the stormwater connection point erosion will continue to occur, the rates of erosion may be lower as there will be some control on velocities which does not occur at present. For those sites upstream of the connection point, the degree and rates of erosion that are currently occurring will continue and that material which is eroded into the Drain will transport to the downstream reach. This continual influx of high sediment loads from upstream will complicate the erodibility of the downstream section.

OVERALL BENEFIT OF THE REALIGNMENT UPSTREAM OF PERTH STREET

Given erosion conditions in the drain downstream of Perth Street, application of the erosion thresholds and re-design of the drain upstream will provide the following benefit:

1. The existing erosive conditions in the drain upstream of Perth Street will be remediated in the design;and
2. Downstream erosion will be mitigated somewhat through the design upstream through the use of erosion thresholds and design principles tasked with controlling erosional velocities

Existing erosion along the Drain will continue once the site has been developed and while the degree of erosion may be somewhat addressed using the thresholds outlined in this study, the fact of the matter is that all erosion will not cease.

This condition assumes the Drain remains in its current configuration. With that condition in place, application of the erosion thresholds will not exacerbate erosion. There is an opportunity to mitigate some of the existing erosion in Reach 3 in a manner which will reduce some stress on reaches 2 and 1, which would be an overall benefit to the Drain system. Considering use of the Drain by aquatic species there is an added benefit to modification of the form and function of the Drain from the homogeneous nature it currently displays to a more diverse state. This can be done using natural channel design principles.

Natural Channel Design Principles

The purpose of natural channel design is to create/modify a system that is not properly functioning to a state where it is more in equilibrium with processes acting upon it. Doing so builds into the system a natural resilience to flow variability which is found in all stable, functioning watercourse systems. With respect to the Drain, and specifically Reach 3 from Perth Street to Fortune Street, it currently is classified as a straight channel with steep, vertical eroding banks that prevent connection to a floodplain during frequent flow events. Low flow events occupy the same channel width as high flow events which means that, as the Drain dries up, water depth is spread over a wide area resulting in shallow water which is not conducive to fish health. In addition, the concentration of flow during multiple events concentrates energy and erosion. This combination of factors acts to further entrench the Drain and create sidewall erosion as it tries to create a stable form over time.

JTBES has modelled a three-stage channel as described above at a coarse level and finds that through natural channel design it is possible to contain stormwater velocities below the threshold value through the site. Doing so lessens pressure on un-restored reaches downstream.

Details of the channel have also incorporated the channel dimensions used by JFSA in their floodplain analysis and findings support the notion that a stable, functioning system can be developed for the realigned sections of the Van Gaal Drain. Upon acceptance in principle by approval agencies JTBES will complete the full design for submission and will provide documentation with respect to function and lessening of downstream impacts.

If I can provide any further details please contact me directly.

Respectfully Submitted,

John T. Beebe, PhD
JTB Environmental Systems Inc.
CAMBRIDGE, ON

Kilgour & Associates Ltd.
Environmental Consultants
2285C St. Laurent Blvd., Unit 16, Ottawa, Ontario, K1G 4Z6, 613.260.5555

2012 September 7 **Our File: 156**

Mr. Adam Fobert
David Schaeffer Engineering Ltd.
120 Iber Road, Unit 203
Ottawa, Ontario, K2S 1E9

Dear Mr. Fobert,

Reference: Richmond Village Development, Van Gaal Drain Realignment.

Per your request, we have reviewed the proposed realignment of the Van Gaal Drain for the Richmond Village Development Corporation, as illustrated in Figures 1 and 2 provided by JF Sabourin and Associates, and in the illustrations of the landscaping plans prepared by NAK Design.

Under a prior assignment in support of development in the area, we demonstrated that the feature can contain up to 16 species of fish (Kilgour & Associates and Parish Geomorphic, 2010). Northern Pike (*Esox lucius*) are known to inhabit the feature, while a pike spawning was feature created near Perth Street. Pike are considered a key species for the area, and any works to the channel should consider the spawning requirements of the species.

We also understand that the Van Gaal Drain was dry this year associated with reduced precipitation in June and July. The feature was very dry in 2008 as well. The feature, therefore, is best described as providing intermittent fish habitat. The existing feature has a bankfull width of ~ 5 m, and has no riparian zone providing shade (Kilgour & Associates and Parish Geomorphic, 2010).

The proposed realignment will lengthen the channel, and increase the wetted area during periods of high flow. The realigned feature will also have a low-flow channel that will enhance the fish habitat value for a longer period of time through dry periods. The floor of the realigned channel will is to be planted with a mixture of plants including a mixture of grasses and sedges that are selected to grow under wet and dry conditions.

The realignment of the feature should be enhance ecological functions of the feature and broader area. Northern pike can be anticipated to use the flat shelves, planted with grasses and sedges, for spawning in the spring when the shelves are inundated with water. Riparian canopy will result in greater shade, and reduce heating of the channel. The improved riparian corridor associated with the realigned feature will increase the movements of larger wildlife like deer, from the Jock River corridor through and to the Richmond Wetland to the west of the study area (assuming that other connections are also made). The various plantings within the corridor will increase the diversity of plant life, thus providing a greater diversity of potential habitats for avifauna.

Realignment of the feature presents a minor risk to fishes in the system. Assuming that fish habitat features are provided for in the design, we anticipate that all of the fish species that were demonstrated to be using the Van Gaal Drain will continue to use the drain after the realignment.

Regards,

KILGOUR & ASSOCIATES LTD.

Bruce Kilgour, PhD

Literature Cited

Kilgour & Associates Ltd., and Parish Geomorphic. 2010. Mattamy Richmond Lands, Natural Environment and Impact Assessment Study.

RIDEAU VALLEY
CONSERVATION AUTHORITY

3889 Rideau Valley Dr, Box 599
Manotick, Ontario K4M 1A5
Ph: (613) 692-3571 fax: 692-0831

MEMO

Date: October 16, 2012

From: Jocelyn Chandler

To: Adam Fobert. P.Eng., Stephen J. Pichette, P.Eng. DSEL

RE: **Richmond Floodplain Lands, Proposed Van Gaal Channel Re-Alignment.**

RVCA staff have reviewed the submission dated September 14, 2012 which proposes a preliminary design to realign and widen the Van Gaal Drain north of Perth Street. The intent is to ultimately redefine the boundaries of the 1:100 year floodplain associated with the Van Gaal Drain.

Staff provide the following comments for your consideration prior to submitting an application for full technical and regulatory policy review under O.Reg 174/06.

- Provide details on corridor width and setbacks showing that applicable policies are being achieved.
- Provide cross sections showing the 3 tier channel as described in the text. It is the understanding of staff that a three tier channel should incorporate a low flow channel, bank full channel (more frequent events) and floodplain.
- Calculation showing loss of direct surface runoff within the subject reach of the Van Gaal Drain once the proposed municipal storm system is in place and overland run-off no longer contributes to instream flow. This comment arises out of the removal of the conceptual swm pond at the upstream location. A longer channel may not be beneficial if there are substantially reduced flows through urbanization of adjacent lands.
- Habitat features built into the new channel should consider all species of fish that have been recorded in the existing channel. For example if there are species that rely in riffle habitat to carry out their life processes then they should be included within the design. Once the detail design stage commences a review of the local fish species should be undertaken and measures to incorporate those habitat types should be incorporated into the design. If the channel is improved adequately it is conceivable that other species from the Jock River might access the new channel that have not in the past.
- Consider including re-use of existing stream bed materials to seed new bed etc.
- Provide status regarding municipal drain. The applicant must have support of the Drainage Superintendent to either abandon the drain or undertake these works.
- Provide information on how the groundwater recharge and base flow contributions will be maintained.

- A statement, supported by necessary analysis, from the consultant must be provided that the design will not adversely impact the control of upstream or downstream flooding.
- The design of the culvert modifications should be described in detail, with appropriate reference to standard manuals/texts.

Required documents for review under O.Reg 174/06:

- Application forms. One for each land owner. (One consultant may act as the agent for all owners provided a letter of authorization is submitted for each).
- Municipal Drain status paperwork if abandoned or comments/authorization from Municipal Drainage Dept.
- Location of works plan showing affected property parcels & ownership (for physical works and related setback influences).
- Documentation regarding the imposition of the setbacks, if applicable, on neighbouring properties must be provided and proof of such resolution (ie. signed documents acknowledging and accepting impact of the setbacks on adjacent property from property owners).
- This application will trigger a floodplain amendment therefore all technical calculations and modelling to support the amendment should be provided.
- Grading plan and cross sections of proposed design
- Design drawings for changes to culvert under Perth St.
- Any information on changes upstream or downstream of subject area.
- Natural Channel Design plans including:
  - Cross-section, profiles and plan view
  - Planting species, amounts, density, location
  - Pools, riffles, instream structures.
  - Description of materials (aggregates, stream bed materials, etc).
- Location of municipal pathway in the corridor and the width must be show on plans.
- Sediment and Erosion Control Plan
- Phasing and Implementation Plan – when will this work be undertaken? When will the new channel be established and the connection to the up and downstream connections be made.
- Fish rescue/relocation plan
- Post effectiveness monitoring plan (5 years)
- Fee Level 5 = $2140.00

This memo has been prepared in consultation with and on behalf of RVCA Watershed Science and Engineering, and Regulatory staff. Technical report review fees will be invoiced separately. Please contact me if you have any questions or require additional information.

JChandler

Jocelyn Chandler, M.Pl., RPP, MCIP
Planner, RVCA

J.F. Sabourin and Associates Inc.
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April 20, 2017

David Schaeffer Engineering Limited
120 Iber Road, Unit 103
Ottawa, Ontario K2S 1E9

Attention: **Mr. Kevin Murphy, P.Eng.**

Subject: **Richmond Village Development / Proposed Realignment of Van Gaal Drain** *our file:922-11*

As requested by your office, we have evaluated, based on the available information as described below, the channel dimensions required to contain the 100-year design water levels within the proposed realignment of the Van Gaal Drain. It is understood that approximately 900 m of the existing Van Gaal Drain upstream of Perth Street will be realigned to follow the boundary of the Richmond Village Development Corporation site in the Village of Richmond.

In undertaking this work, the following information was considered:

1) HEC-RAS models of Van Gaal Drain under existing conditions (spring and summer) were obtained from the *Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond* (JFSA, November 2009). The November 2009 report defined the maximum flood levels in the Van Gaal Drain based on three scenarios: (1) the Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River; (2) The Van Gaal 100-year spring snowmelt plus rainfall peak flow reaches the Jock River; and (4) The Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain.

2) In order to best define the upstream limit of the channel realignment, existing conditions cross-sections were interpolated in HEC-RAS every 50 m between existing conditions cross-sections 2478 and 2157. The downstream limit of the channel realignment is defined by the Perth Street crossing.

3) While the floodplain mapping study for the drain was in progress, a berm was constructed by Mattamy Homes on the Richmond Village Development Corporation lands north of Perth Street. Refer to the *Mattamy Homes Richmond - Channelization / Berm Modifications Analysis, North of Perth Street* memo (AECOM Canada Ltd., January 2010) for further details. The berm generally follows the Van Gaal Drain upstream of Perth Street at an offset of 30 m. However, the November 2009 *Floodplain Mapping Report* does not account for this berm in its modelling. As such, the HEC-RAS models obtained from the November 2009 *Floodplain Mapping Report* have been modified to include this berm in order to best represent existing conditions. The existing topography of the berm was provided by DSEL.

4) The HEC-RAS models were modified to reflect the proposed channel realignment based on information provided by DSEL. As noted above, it is proposed that approximately 900 m of the existing Van Gaal Drain upstream of Perth Street be realigned to follow the boundary of the Richmond Village Development Corporation site. Refer to Figure 1 for the proposed channel realignment and cross-section locations.

5) Note that the proposed channel realignment will not significantly impact flows in the Van Gaal Drain. As such, existing conditions flows provided were also used to model proposed conditions. The 2-, 5-, 10-, 25- and 100-year return periods were assessed, as per the flows provided in the March 26, 2010 *P709(02) Richmond 2, 5, 10, 25 Year WSEL Results* email from JFSA to the City of Ottawa (forwarded to RVCA on March 30, 2012).

The 25 mm 3-hour Chicago storm flows, as simulated using the March 26, 2010 SWMHYMO models, were also evaluated.

6) For the purpose of calculating floodplain elevations, all channel infrastructure was included in the existing and proposed conditions models. Conversely, for the purpose of calculating riparian storage volumes, all channel infrastructure was removed from the models. The existing flow profiles for the 25 mm and 2- to 100-year events were used to compare existing and proposed riparian storage volumes.

7) The proposed channel dimensions were set to contain the 100-year flood levels within the channel for all three spring and summer scenarios, and to set the 100-year proposed conditions water levels at comparable cross-sections (2554, 2478, 2157 and 1615 - 1340 in Van Gaal Drain Reach 2) equal to or less than the maximum existing conditions flood levels defined in the November 2009 *Floodplain Mapping Report*. Note that 100-year water levels within the majority of the realigned channel are not comparable to existing conditions, given the different locations of the existing and proposed cross-sections.

8) The required low flow channel dimensions for the realigned channel were provided by Coldwater Engineering. The proposed low flow channel is 0.5 m deep with a 1.0 m bottom width, 2H:1V side slopes and a 3.0 m top width. The top of the low flow channel (beginning of the floodplain) was set to match existing minimum channel elevations at the upstream and downstream limits of the proposed channel realignment. It should therefore be noted that the bottom of the proposed low flow channel is below the invert of the Perth Street culvert.

9) The typical cross-section for the proposed channel realignment is presented in Figure 2 and has a floodplain width of 10 m and a total depth between 1.8 m and 2.4 m based on the existing grade of surrounding lands and the depth required to contain the 100-year design water levels in the channel. Note that a berm will be constructed along the southwest side of the channel, from cross-section 1416 to the downstream limit of the realignment at Perth Street, in order to contain the 100-year flow within the channel through an existing residential lot. Additionally, note that a 6.7 m wide (5.0 m wide from cross-section 1416 to the downstream limit of the realignment at Perth Street) level area (at 0.6% cross-slope) has been included on one side of the channel for future maintenance access.

10) The existing conditions HEC-RAS models specify Manning's roughness coefficients of 0.035 for the low flow channel, 0.05 for the banks under spring conditions and 0.08 for the banks under summer conditions. These Manning's roughness coefficients are generally to be maintained in the proposed realigned channel. However, we understand that trees and shrubs are to be planted on the banks above the 25 mm water level; Manning's roughness coefficients for this area of the proposed channel have been set to 0.08 under spring conditions and 0.10 under summer conditions.

11) The low flow channel will widen into a 9.0 m wide and 1.0 m deep sediment detention pool, from Perth Street to approximately 50 m upstream, in order to ensure that the operation of the culvert is not adversely affected by overgrown vegetation or sediment accumulation.

12) The entrance loss coefficient of Perth Street culvert was changed from 0.5 under existing conditions to 0.2 under proposed conditions, to represent proposed changes to the culvert entrance consisting of a headwall parallel to the embankment (no wingwalls) with three edges rounded to radius of 1/12 barrel dimension. This proposed conditions entrance loss coefficient is in accordance with the *HEC-RAS River Analysis System Hydraulic Reference Manual Version 4.1* (US Army Corps of Engineers, January 2010).

Based on the above information, 25 mm and 2- to 100-year design water levels and velocities were determined using HEC-RAS under the three spring and summer scenarios and are presented in Attachments A for existing conditions and Attachment C for proposed conditions. The 25 mm "normal" water level and 100-year floodplain within the proposed channel are presented in plan view in Figure 3 for the most critical of the three scenarios.

The 100-year design water levels for the proposed realignment of the Van Gaal Drain are presented in Table 1 and are contained within the proposed channel for all scenarios. Furthermore, as may be seen in Table 1, the proposed conditions 100-year water levels at comparable cross-sections are equal to or less than the maximum existing conditions flood levels defined in the November 2009 *Floodplain Mapping Report*, except where the water level increases by 3 cm at cross-section 1340. However, the water level at this location is unreliable due to instabilities in the model through the downstream Perth Street culvert; for example, in comparing the energy gradeline elevations at this location, the existing conditions 100-year level is 4 cm higher than the proposed conditions level. At the next upstream cross-section, both the 100-year water level and 100-year energy gradeline elevations are higher under existing than under proposed conditions. It may therefore be concluded, excepting the instabilities at cross-section 1340, that the proposed realignment of the Van Gaal Drain upstream of Perth Street will not adversely impact upstream flooding.

Table 1: 100-Year Water Levels on Van Gaal Drain Reach 2 to Perth Street Under Proposed Conditions [(1)]

River Station	Scenario			
	1	*2*	*4*	*Max. Allowable* [(2)]
2554	96.26	96.28	95.86	96.28
2478	96.13	96.14	95.77	96.16
2427.58*	96.04	96.05	95.71	N/A
2377.17*	95.95	95.95	95.63	N/A
2326.76*	95.88	95.88	95.53	N/A
2276.35*	95.50	95.64	95.15	N/A
2261	94.89	94.98	94.35	N/A
2258	95.00	94.94	94.46	N/A
2256	94.98	94.92	94.44	N/A
2254	94.96	94.91	94.42	N/A
2235	94.95	94.89	94.40	N/A
2207	94.92	94.87	94.38	95.48
2188	94.88	94.83	94.36	N/A
2163	94.85	94.80	94.33	N/A
2141	94.82	94.77	94.31	N/A
2121	94.80	94.74	94.30	N/A
2101	94.77	94.72	94.28	N/A
2080	94.74	94.69	94.26	N/A
2059	94.71	94.66	94.25	N/A
2038	94.69	94.63	94.23	N/A
2017	94.67	94.62	94.23	N/A
2003	94.66	94.61	94.22	N/A
1982	94.63	94.58	94.21	N/A
1961	94.61	94.56	94.20	N/A
1940	94.58	94.54	94.19	N/A
1919	94.56	94.51	94.18	N/A
1898	94.54	94.49	94.18	N/A
1877	94.52	94.47	94.17	N/A
1857	94.50	94.45	94.17	N/A
1837	94.48	94.44	94.16	N/A
1817	94.46	94.42	94.16	N/A
1797	94.45	94.41	94.16	N/A
1777	94.43	94.39	94.15	N/A
1757	94.42	94.38	94.15	N/A
1736	94.41	94.37	94.15	N/A
1715	94.39	94.36	94.15	N/A
1694	94.38	94.35	94.15	N/A
1673	94.37	94.34	94.14	N/A
1653	94.36	94.33	94.14	N/A
1632	94.35	94.33	94.14	N/A
1615	94.35	94.32	94.14	94.61
1555	94.33	94.31	94.14	94.55
1488	94.31	94.29	94.14	94.45
1416	94.29	94.28	94.14	94.41
1400	94.28	94.27	94.13	94.36
1364	94.28	94.27	94.13	94.31
1340	94.24	94.22	94.13	94.21

[(1)] Scenarios:
1. The Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River.
2. The Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River.
4. The Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain.

[(2)] Maximum water level at existing cross-sections as per *Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond* (JFSA, November 2009).

An analysis of riparian storage in the channel under existing and proposed conditions was performed using the 25 mm and 2-, 5-, 10-, 25- and 100-year flows for the three scenarios. All drainage infrastructure was removed from the models for the purpose of this analysis. Refer to Attachments B and D for detailed results under existing and proposed conditions, respectively. Table 2 presents a summary of the riparian storage analysis results.

Table 2: Riparian Storage on Van Gaal Drain Reach 2 Under Existing and Proposed Conditions (1) (2)

Event	Existing Volume (m^3)			Proposed Volume (m^3)		
	Scenario 1	Scenario 2	Scenario 4	Scenario 1	Scenario 2	Scenario 4
25 mm	3570	N/A	N/A	6920	N/A	N/A
2-Year	7640	12550	11550	14460	19570	18310
5-Year	11950	16610	5890	19950	23710	11050
10-Year	15650	20280	5250	24070	26690	9110
25-Year	22190	26230	9590	29880	31360	15270
100-Year	38090	39190	36830	42020	41220	44480

(1) All channel infrastructure removed from the models for the purpose of calculating riparian storage volumes.
(2) Scenarios:
1. The Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River.
2. The Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River.
4. The Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain.

As may be seen from Table 1, riparian storage volumes under proposed conditions are equal to or greater than existing riparian storage volumes for all scenarios and return periods, and will not adversely impact downstream flooding.

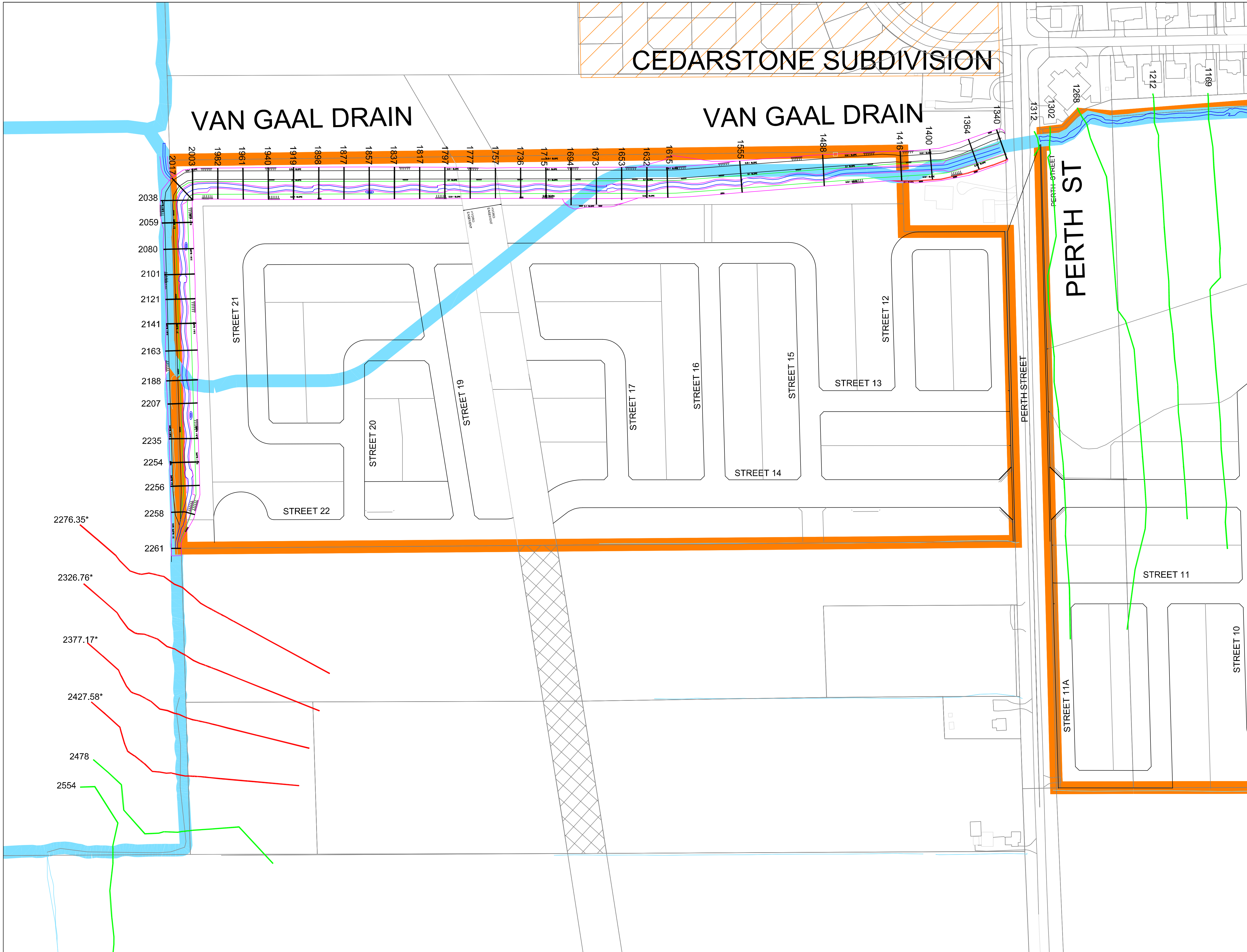
Yours truly,
J.F. Sabourin and Associates Inc.

Laura Pipkins, P.Eng.

cc: J.F. Sabourin, M.Eng, P.Eng.
Director of Water Resources Projects

Figure 1: Location of Proposed Cross-Sections
Figure 2: Dimensions of Proposed Cross-Sections
Figure 3: 25 mm and 100-Year Flood Extents in Proposed Channel

Attachment A: HEC-RAS Results for Van Gaal Drain Reach 2 Existing Conditions (Floodplain Analysis)
Attachment B: HEC-RAS Results for Van Gaal Drain Reach 2 Existing Conditions (Riparian Storage Analysis)
Attachment C: HEC-RAS Results for Van Gaal Drain Reach 2 Proposed Conditions (Floodplain Analysis)
Attachment D: HEC-RAS Results for Van Gaal Drain Reach 2 Proposed Conditions (Riparian Storage Analysis)



LEGEND :

LIMITS OF SUBDIVISION

PROPOSED CROSS–SECTION

EXISTING CROSS–SECTION

EXISTING (INTERPOLATED) CROSS–SECTION

EXISTING CHANNEL ALIGNMENT

SCALE :

0 25 50 75 100 125 150m

J.F. Sabourin & Associates Inc.

WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS

OTTAWA (613) 836–3884

GATINEAU (819) 243–6858

CLIENT :

DSEL

david schaeffer engineering ltd

120 IBER ROAD, UNIT 203

OTTAWA, ONTARIO, K2S 1E9

(613) 836–0856

PROJECT :

PROPOSED REALIGNMENT OF VAN GAAL DRAIN

BY	DATE	DESCRIPTION	BY

LOCATION OF PROPOSED CROSS–SECTIONS

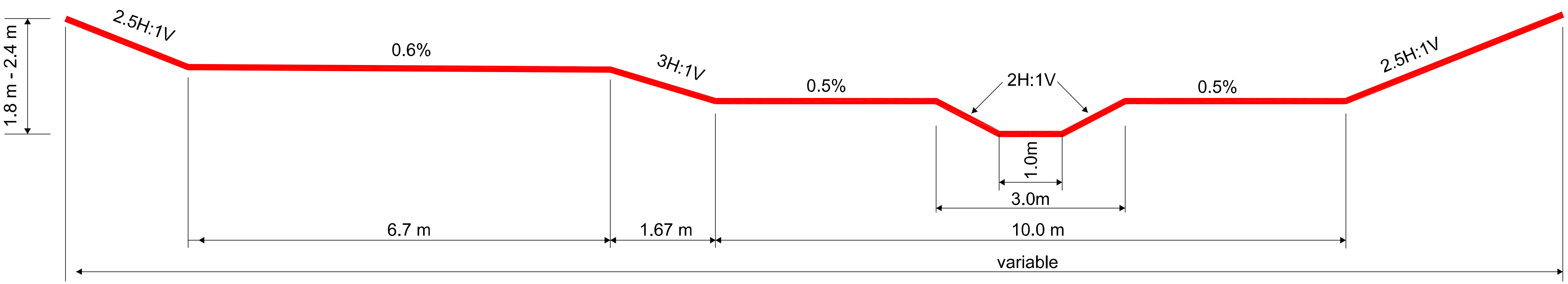
FIGURE 1

DESIGNED:	
DRAWN:	LP
VERIFIED:	JFS
APPROVED:	JFS

DRAWING REF.

922–11\201701 Channel\Design\CAD\JFSA Figures.dwg

DATE	PROJECT No.
Apr/17	922–11



LEGEND :

PROPOSED CROSS-SECTION

SCALE :

0 100 200 300 400cm

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(613) 836-0856

PROJECT :

PROPOSED REALIGNMENT OF VAN GAAL DRAIN

BY	DATE	DESCRIPTION	BY

DIMENSIONS OF PROPOSED CROSS-SECTIONS

FIGURE 2

DESIGNED:	
DRAWN:	LP
VERIFIED:	JFS
APPROVED:	JFS
DATE	PROJECT No.
Apr/17	922-11

DRAWING REF.
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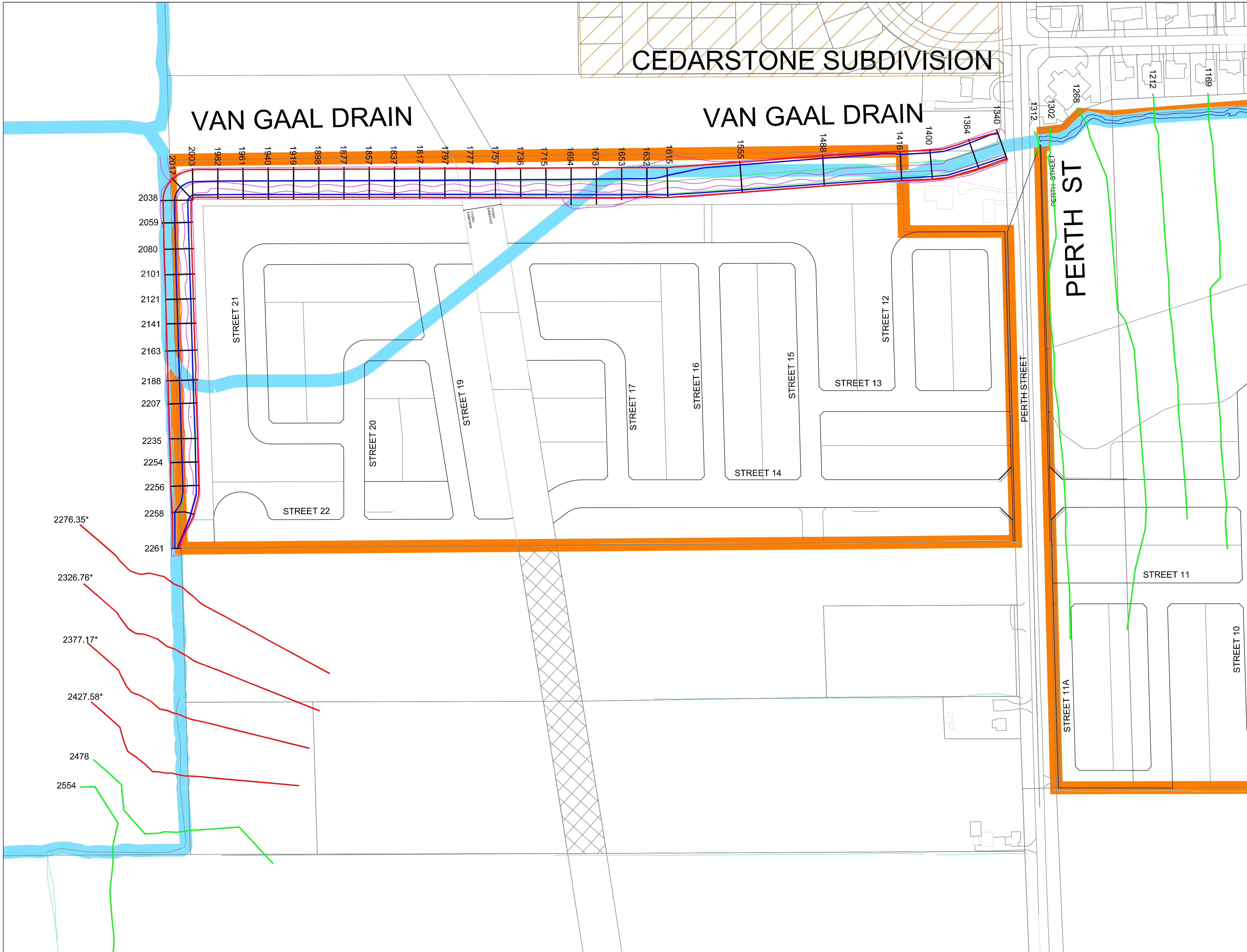

LEGEND :

LIMITS OF SUBDIVISION

PROPOSED CROSS–SECTION

EXISTING CROSS–SECTION

EXISTING (INTERPOLATED) CROSS–SECTION

EXISTING CHANNEL ALIGNMENT

25 MM FLOODPLAIN

100–YEAR FLOODPLAIN (CRITICAL SCENARIO)

SCALE :

0 25 50 75 100 125 150m

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PROJECT :

PROPOSED REALIGNMENT OF VAN GAAL DRAIN

BY	DATE	DESCRIPTION	BY

25 MM AND 100–YEAR FLOOD EXTENTS IN PROPOSED CHANNEL

FIGURE 3

DESIGNED:	
DRAWN:	LP
VERIFIED:	JFS
APPROVED:	JFS

DRAWING REF.
922–11\201701 Channel\Design\CAD\JFSA Figures.dwg

DATE	PROJECT No.
Apr/17	922–11

ATTACHMENT

A

HEC- RAS Results for Van Gaal Drain Reach 2
Existing Conditions (Floodplain Analysis)

JFSA Water Resources and Environmental Consultants

Table A-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) (1)

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2554	(1) 25 mm	0.72	94.75	95.41	0.41	0.85
2554	(1) 2-Year	1.95	94.75	95.72	0.56	0.70
2554	(1) 5-Year	3.20	94.75	95.93	0.65	0.61
2554	(1) 10-Year	4.11	94.75	96.04	0.71	0.57
2554	(1) 25-Year	5.28	94.75	96.14	0.78	0.55
2554	(1) 100-Year	7.27	94.75	96.26	0.84	0.58
2478	(1) 25 mm	0.72	94.75	95.35	0.42	0.80
2478	(1) 2-Year	1.95	94.75	95.65	0.59	0.66
2478	(1) 5-Year	3.20	94.75	95.85	0.72	0.58
2478	(1) 10-Year	4.11	94.75	95.94	0.82	0.54
2478	(1) 25-Year	5.28	94.75	96.03	0.93	0.53
2478	(1) 100-Year	7.27	94.75	96.12	1.10	0.56
2427.58*	(1) 25 mm	0.72	94.68	95.30	0.43	0.76
2427.58*	(1) 2-Year	1.95	94.68	95.60	0.61	0.64
2427.58*	(1) 5-Year	3.20	94.68	95.79	0.74	0.56
2427.58*	(1) 10-Year	4.11	94.68	95.87	0.84	0.53
2427.58*	(1) 25-Year	5.28	94.68	95.95	0.95	0.52
2427.58*	(1) 100-Year	7.27	94.68	96.04	1.11	0.54
2377.17*	(1) 25 mm	0.72	94.61	95.25	0.44	0.73
2377.17*	(1) 2-Year	1.95	94.61	95.54	0.62	0.61
2377.17*	(1) 5-Year	3.20	94.61	95.72	0.76	0.55
2377.17*	(1) 10-Year	4.11	94.61	95.80	0.86	0.51
2377.17*	(1) 25-Year	5.28	94.61	95.87	0.97	0.50
2377.17*	(1) 100-Year	7.27	94.61	95.95	1.09	0.53
2326.76*	(1) 25 mm	0.72	94.54	95.19	0.46	0.70
2326.76*	(1) 2-Year	1.95	94.54	95.48	0.64	0.59
2326.76*	(1) 5-Year	3.20	94.54	95.65	0.78	0.53
2326.76*	(1) 10-Year	4.11	94.54	95.72	0.88	0.50
2326.76*	(1) 25-Year	5.28	94.54	95.78	0.97	0.49
2326.76*	(1) 100-Year	7.27	94.54	95.85	1.07	0.52
2276.35*	(1) 25 mm	0.72	94.48	95.13	0.49	0.67
2276.35*	(1) 2-Year	1.95	94.48	95.41	0.68	0.57
2276.35*	(1) 5-Year	3.20	94.48	95.57	0.80	0.51
2276.35*	(1) 10-Year	4.11	94.48	95.63	0.89	0.48
2276.35*	(1) 25-Year	5.28	94.48	95.69	0.96	0.47
2276.35*	(1) 100-Year	7.27	94.48	95.77	0.98	0.50
2225.94*	(1) 25 mm	0.72	94.41	95.05	0.54	0.65
2225.94*	(1) 2-Year	1.95	94.41	95.33	0.74	0.55
2225.94*	(1) 5-Year	3.20	94.41	95.48	0.84	0.49
2225.94*	(1) 10-Year	4.11	94.41	95.54	0.88	0.46
2225.94*	(1) 25-Year	5.28	94.41	95.59	0.95	0.46
2225.94*	(1) 100-Year	7.27	94.41	95.66	1.05	0.49
2175.53*	(1) 25 mm	0.72	94.34	94.93	0.68	0.62
2175.53*	(1) 2-Year	1.95	94.34	95.18	0.92	0.53
2175.53*	(1) 5-Year	3.20	94.34	95.33	1.04	0.48

Table A-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) (1)

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2175.53*	(1) 10-Year	4.11	94.34	95.42	0.95	0.45
2175.53*	(1) 25-Year	5.28	94.34	95.47	1.01	0.44
2175.53*	(1) 100-Year	7.27	94.34	95.54	1.07	0.48
2157	(1) 25 mm	0.72	94.31	94.72	1.45	0.62
2157	(1) 2-Year	1.95	94.31	94.93	1.76	0.53
2157	(1) 5-Year	3.20	94.31	95.13	1.64	0.47
2157	(1) 10-Year	4.11	94.31	95.25	1.54	0.44
2157	(1) 25-Year	5.28	94.31	95.37	1.28	0.44
2157	(1) 100-Year	7.27	94.31	95.48	1.13	0.47
2076	(1) 25 mm	1.16	93.86	94.39	0.64	0.60
2076	(1) 2-Year	2.80	93.86	94.74	0.76	0.51
2076	(1) 5-Year	4.41	93.86	94.99	0.82	0.46
2076	(1) 10-Year	5.53	93.86	95.10	0.90	0.43
2076	(1) 25-Year	6.96	93.86	95.20	0.96	0.42
2076	(1) 100-Year	9.54	93.86	95.33	0.99	0.45
1974	(1) 25 mm	1.16	93.68	94.22	0.62	0.55
1974	(1) 2-Year	2.80	93.68	94.61	0.70	0.48
1974	(1) 5-Year	4.41	93.68	94.87	0.75	0.42
1974	(1) 10-Year	5.53	93.68	94.96	0.84	0.39
1974	(1) 25-Year	6.96	93.68	95.05	0.93	0.39
1974	(1) 100-Year	9.54	93.68	95.17	1.02	0.42
1922	(1) 25 mm	1.16	93.59	94.14	0.61	0.53
1922	(1) 2-Year	2.80	93.59	94.56	0.67	0.46
1922	(1) 5-Year	4.41	93.59	94.82	0.74	0.40
1922	(1) 10-Year	5.53	93.59	94.90	0.84	0.38
1922	(1) 25-Year	6.96	93.59	94.97	0.96	0.38
1922	(1) 100-Year	9.54	93.59	95.06	1.11	0.41
1833	(1) 25 mm	1.16	93.44	94.02	0.56	0.49
1833	(1) 2-Year	2.80	93.44	94.48	0.59	0.42
1833	(1) 5-Year	4.41	93.44	94.74	0.61	0.37
1833	(1) 10-Year	5.53	93.44	94.80	0.69	0.35
1833	(1) 25-Year	6.96	93.44	94.86	0.76	0.35
1833	(1) 100-Year	9.54	93.44	94.95	0.85	0.39
1796	(1) 25 mm	1.16	93.37	93.97	0.54	0.47
1796	(1) 2-Year	2.80	93.37	94.45	0.57	0.40
1796	(1) 5-Year	4.41	93.37	94.71	0.64	0.35
1796	(1) 10-Year	5.53	93.37	94.76	0.76	0.33
1796	(1) 25-Year	6.96	93.37	94.80	0.90	0.33
1796	(1) 100-Year	9.54	93.37	94.86	1.13	0.38
1735	(1) 25 mm	1.16	93.26	93.93	0.47	0.44
1735	(1) 2-Year	2.80	93.26	94.42	0.48	0.37
1735	(1) 5-Year	4.41	93.26	94.68	0.51	0.32
1735	(1) 10-Year	5.53	93.26	94.73	0.58	0.31
1735	(1) 25-Year	6.96	93.26	94.77	0.66	0.31
1735	(1) 100-Year	9.54	93.26	94.82	0.79	0.36

Table A-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1728	(1) 25 mm	1.16	93.25	93.91	0.56	0.44
1728	(1) 2-Year	2.80	93.25	94.41	0.60	0.37
1728	(1) 5-Year	4.41	93.25	94.67	0.68	0.32
1728	(1) 10-Year	5.53	93.25	94.71	0.80	0.31
1728	(1) 25-Year	6.96	93.25	94.73	0.96	0.31
1728	(1) 100-Year	9.54	93.25	94.75	1.25	0.36
1727		Culvert				
1717	(1) 25 mm	1.16	93.24	93.79	0.70	0.43
1717	(1) 2-Year	2.80	93.24	94.17	0.85	0.36
1717	(1) 5-Year	4.41	93.24	94.39	0.97	0.32
1717	(1) 10-Year	5.53	93.24	94.51	1.03	0.30
1717	(1) 25-Year	6.96	93.24	94.62	1.13	0.31
1717	(1) 100-Year	9.54	93.24	94.74	1.28	0.35
1615	(1) 25 mm	1.16	93.05	93.64	0.56	0.39
1615	(1) 2-Year	2.80	93.05	94.04	0.64	0.32
1615	(1) 5-Year	4.41	93.05	94.24	0.77	0.28
1615	(1) 10-Year	5.53	93.05	94.36	0.84	0.27
1615	(1) 25-Year	6.96	93.05	94.47	0.87	0.28
1615	(1) 100-Year	9.54	93.05	94.61	0.87	0.33
1555	(1) 25 mm	1.16	92.94	93.58	0.50	0.35
1555	(1) 2-Year	2.80	92.94	93.99	0.59	0.30
1555	(1) 5-Year	4.41	92.94	94.19	0.72	0.26
1555	(1) 10-Year	5.53	92.94	94.29	0.80	0.25
1555	(1) 25-Year	6.96	92.94	94.40	0.86	0.26
1555	(1) 100-Year	9.54	92.94	94.53	0.94	0.31
1488	(1) 25 mm	1.16	92.82	93.53	0.43	0.31
1488	(1) 2-Year	2.80	92.82	93.96	0.53	0.26
1488	(1) 5-Year	4.41	92.82	94.13	0.66	0.23
1488	(1) 10-Year	5.53	92.82	94.23	0.73	0.23
1488	(1) 25-Year	6.96	92.82	94.33	0.82	0.24
1488	(1) 100-Year	9.54	92.82	94.46	0.92	0.29
1416	(1) 25 mm	1.16	92.71	93.48	0.54	0.28
1416	(1) 2-Year	2.80	92.71	93.89	0.73	0.23
1416	(1) 5-Year	4.41	92.71	94.03	0.96	0.21
1416	(1) 10-Year	5.53	92.71	94.10	1.07	0.21
1416	(1) 25-Year	6.96	92.71	94.20	1.13	0.22
1416	(1) 100-Year	9.54	92.71	94.38	0.94	0.27
1400	(1) 25 mm	1.16	92.68	93.47	0.39	0.27
1400	(1) 2-Year	2.80	92.68	93.89	0.47	0.23
1400	(1) 5-Year	4.41	92.68	94.03	0.60	0.20
1400	(1) 10-Year	5.53	92.68	94.11	0.67	0.20
1400	(1) 25-Year	6.96	92.68	94.20	0.75	0.22
1400	(1) 100-Year	9.54	92.68	94.36	0.86	0.27

Table A-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1364	(1) 25 mm	1.16	92.62	93.46	0.34	0.24
1364	(1) 2-Year	2.80	92.62	93.87	0.46	0.20
1364	(1) 5-Year	4.41	92.62	94.00	0.61	0.19
1364	(1) 10-Year	5.53	92.62	94.07	0.71	0.19
1364	(1) 25-Year	6.96	92.62	94.16	0.81	0.20
1364	(1) 100-Year	9.54	92.62	94.31	0.92	0.25
1340	(1) 25 mm	1.53	92.61	93.45	0.37	0.22
1340	(1) 2-Year	3.64	92.61	93.85	0.60	0.19
1340	(1) 5-Year	5.57	92.61	93.97	0.84	0.18
1340	(1) 10-Year	6.92	92.61	94.03	1.00	0.18
1340	(1) 25-Year	8.58	92.61	94.09	1.18	0.20
1340	(1) 100-Year	11.43	92.61	94.21	1.46	0.25
1339		Culvert				
1312	(1) 25 mm	1.53	92.47	93.45	0.32	0.20
1312	(1) 2-Year	3.87	92.47	93.84	0.57	0.18
1312	(1) 5-Year	5.93	92.47	93.95	0.82	0.17
1312	(1) 10-Year	7.38	92.47	94.00	0.99	0.17
1312	(1) 25-Year	9.17	92.47	94.05	1.19	0.19
1312	(1) 100-Year	12.20	92.47	94.14	1.50	0.24
1302	(1) 25 mm	1.53	92.57	93.41	0.83	0.19
1302	(1) 2-Year	3.87	92.57	93.81	0.88	0.17
1302	(1) 5-Year	5.93	92.57	93.92	1.05	0.17
1302	(1) 10-Year	7.38	92.57	93.98	1.15	0.17
1302	(1) 25-Year	9.17	92.57	94.04	1.26	0.19
1302	(1) 100-Year	12.20	92.57	94.15	1.23	0.24
1268	(1) 25 mm	1.53	92.47	93.33	0.79	0.18
1268	(1) 2-Year	3.87	92.47	93.75	0.56	0.16
1268	(1) 5-Year	5.93	92.47	93.88	0.57	0.16
1268	(1) 10-Year	7.38	92.47	93.94	0.60	0.16
1268	(1) 25-Year	9.17	92.47	94.01	0.61	0.18
1268	(1) 100-Year	12.20	92.47	94.14	0.52	0.23
1212	(1) 25 mm	1.53	92.36	93.18	0.86	0.16
1212	(1) 2-Year	3.87	92.36	93.61	0.89	0.14
1212	(1) 5-Year	5.93	92.36	93.78	0.91	0.13
1212	(1) 10-Year	7.38	92.36	93.85	0.93	0.14
1212	(1) 25-Year	9.17	92.36	93.93	0.91	0.16
1212	(1) 100-Year	12.20	92.36	94.10	0.76	0.21
1169	(1) 25 mm	1.53	92.30	93.10	0.69	0.15
1169	(1) 2-Year	3.87	92.30	93.53	0.77	0.13
1169	(1) 5-Year	5.93	92.30	93.70	0.86	0.12
1169	(1) 10-Year	7.38	92.30	93.77	0.91	0.12
1169	(1) 25-Year	9.17	92.30	93.85	0.95	0.14
1169	(1) 100-Year	12.20	92.30	94.04	0.88	0.19
1091	(1) 25 mm	1.53	92.15	92.98	0.65	0.11

Table A-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) (1)

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1091	(1) 2-Year	3.87	92.15	93.40	0.75	0.10
1091	(1) 5-Year	5.93	92.15	93.57	0.82	0.09
1091	(1) 10-Year	7.38	92.15	93.65	0.85	0.10
1091	(1) 25-Year	9.17	92.15	93.75	0.85	0.12
1091	(1) 100-Year	12.20	92.15	93.97	0.83	0.17
1002	(1) 25 mm	1.53	92.06	92.81	0.76	0.08
1002	(1) 2-Year	3.87	92.06	93.21	0.90	0.07
1002	(1) 5-Year	5.93	92.06	93.39	0.98	0.07
1002	(1) 10-Year	7.38	92.06	93.50	0.93	0.07
1002	(1) 25-Year	9.17	92.06	93.65	0.83	0.09
1002	(1) 100-Year	12.20	92.06	93.93	0.65	0.13
961	(1) 25 mm	1.53	91.96	92.77	0.54	0.06
961	(1) 2-Year	3.87	91.96	93.14	0.71	0.05
961	(1) 5-Year	5.93	91.96	93.31	0.76	0.05
961	(1) 10-Year	7.38	91.96	93.44	0.71	0.06
961	(1) 25-Year	9.17	91.96	93.61	0.52	0.07
961	(1) 100-Year	12.20	91.96	93.92	0.35	0.11
910	(1) 25 mm	1.53	91.93	92.72	0.57	0.04
910	(1) 2-Year	3.87	91.93	93.07	0.72	0.03
910	(1) 5-Year	5.93	91.93	93.25	0.73	0.04
910	(1) 10-Year	7.38	91.93	93.40	0.69	0.04
910	(1) 25-Year	9.17	91.93	93.59	0.53	0.05
910	(1) 100-Year	12.20	91.93	93.91	0.33	0.07
840	(1) 25 mm	1.53	91.86	92.64	0.50	0.00
840	(1) 2-Year	3.87	91.86	93.00	0.44	0.00
840	(1) 5-Year	5.93	91.86	93.22	0.37	0.00
840	(1) 10-Year	7.38	91.86	93.38	0.33	0.00
840	(1) 25-Year	9.17	91.86	93.58	0.30	0.00
840	(1) 100-Year	12.20	91.86	93.91	0.25	0.00

(1) All channel infrastructure included in the HEC-RAS model for floodplain analysis.
For Scenario 1 (the Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River).

Table A-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2554	(2) 2-Year	4.13	94.75	96.03	0.71	0.58
2554	(2) 5-Year	5.24	94.75	96.13	0.78	0.55
2554	(2) 10-Year	6.01	94.75	96.18	0.81	0.54
2554	(2) 25-Year	6.94	94.75	96.23	0.83	0.57
2554	(2) 100-Year	8.32	94.75	96.28	0.82	0.68
2554	(4) 2-Year	3.97	94.75	96.02	0.70	0.58
2554	(4) 5-Year	2.02	94.75	95.74	0.56	0.71
2554	(4) 10-Year	1.57	94.75	95.64	0.52	0.82
2554	(4) 25-Year	2.25	94.75	95.78	0.58	0.93
2554	(4) 100-Year	2.86	94.75	95.88	0.63	2.01
2478	(2) 2-Year	4.13	94.75	95.93	0.83	0.55
2478	(2) 5-Year	5.24	94.75	96.02	0.93	0.52
2478	(2) 10-Year	6.01	94.75	96.06	1.00	0.52
2478	(2) 25-Year	6.94	94.75	96.10	1.09	0.55
2478	(2) 100-Year	8.32	94.75	96.14	1.17	0.66
2478	(4) 2-Year	3.97	94.75	95.92	0.81	0.56
2478	(4) 5-Year	2.02	94.75	95.67	0.60	0.67
2478	(4) 10-Year	1.57	94.75	95.57	0.55	0.78
2478	(4) 25-Year	2.25	94.75	95.71	0.63	0.89
2478	(4) 100-Year	2.86	94.75	95.80	0.69	1.98
2427.58*	(2) 2-Year	4.13	94.68	95.86	0.85	0.53
2427.58*	(2) 5-Year	5.24	94.68	95.94	0.95	0.51
2427.58*	(2) 10-Year	6.01	94.68	95.97	1.04	0.51
2427.58*	(2) 25-Year	6.94	94.68	96.01	1.09	0.53
2427.58*	(2) 100-Year	8.32	94.68	96.05	1.16	0.65
2427.58*	(4) 2-Year	3.97	94.68	95.85	0.83	0.54
2427.58*	(4) 5-Year	2.02	94.68	95.61	0.61	0.65
2427.58*	(4) 10-Year	1.57	94.68	95.52	0.56	0.75
2427.58*	(4) 25-Year	2.25	94.68	95.65	0.64	0.87
2427.58*	(4) 100-Year	2.86	94.68	95.74	0.70	1.96
2377.17*	(2) 2-Year	4.13	94.61	95.79	0.87	0.52
2377.17*	(2) 5-Year	5.24	94.61	95.85	0.97	0.49
2377.17*	(2) 10-Year	6.01	94.61	95.88	1.03	0.49
2377.17*	(2) 25-Year	6.94	94.61	95.91	1.08	0.52
2377.17*	(2) 100-Year	8.32	94.61	95.95	1.13	0.63
2377.17*	(4) 2-Year	3.97	94.61	95.78	0.85	0.52
2377.17*	(4) 5-Year	2.02	94.61	95.56	0.63	0.63
2377.17*	(4) 10-Year	1.57	94.61	95.47	0.58	0.73
2377.17*	(4) 25-Year	2.25	94.61	95.60	0.65	0.85
2377.17*	(4) 100-Year	2.86	94.61	95.68	0.72	1.94
2326.76*	(2) 2-Year	4.13	94.54	95.71	0.88	0.50
2326.76*	(2) 5-Year	5.24	94.54	95.76	0.98	0.48
2326.76*	(2) 10-Year	6.01	94.54	95.79	1.02	0.48
2326.76*	(2) 25-Year	6.94	94.54	95.82	1.06	0.51
2326.76*	(2) 100-Year	8.32	94.54	95.85	1.11	0.62
2326.76*	(4) 2-Year	3.97	94.54	95.70	0.87	0.51
2326.76*	(4) 5-Year	2.02	94.54	95.50	0.65	0.61
2326.76*	(4) 10-Year	1.57	94.54	95.41	0.60	0.70

Table A-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2326.76*	(4) 25-Year	2.25	94.54	95.54	0.68	0.83
2326.76*	(4) 100-Year	2.86	94.54	95.61	0.75	1.92
2276.35*	(2) 2-Year	4.13	94.48	95.62	0.90	0.49
2276.35*	(2) 5-Year	5.24	94.48	95.66	0.98	0.46
2276.35*	(2) 10-Year	6.01	94.48	95.69	1.00	0.47
2276.35*	(2) 25-Year	6.94	94.48	95.72	1.00	0.50
2276.35*	(2) 100-Year	8.32	94.48	95.76	0.99	0.61
2276.35*	(4) 2-Year	3.97	94.48	95.61	0.89	0.49
2276.35*	(4) 5-Year	2.02	94.48	95.43	0.69	0.58
2276.35*	(4) 10-Year	1.57	94.48	95.34	0.63	0.68
2276.35*	(4) 25-Year	2.25	94.48	95.46	0.71	0.81
2276.35*	(4) 100-Year	2.86	94.48	95.53	0.77	1.91
2225.94*	(2) 2-Year	4.13	94.41	95.52	0.87	0.47
2225.94*	(2) 5-Year	5.24	94.41	95.56	0.93	0.45
2225.94*	(2) 10-Year	6.01	94.41	95.59	0.97	0.45
2225.94*	(2) 25-Year	6.94	94.41	95.62	1.01	0.48
2225.94*	(2) 100-Year	8.32	94.41	95.65	1.06	0.59
2225.94*	(4) 2-Year	3.97	94.41	95.52	0.86	0.47
2225.94*	(4) 5-Year	2.02	94.41	95.34	0.75	0.57
2225.94*	(4) 10-Year	1.57	94.41	95.26	0.69	0.66
2225.94*	(4) 25-Year	2.25	94.41	95.37	0.77	0.79
2225.94*	(4) 100-Year	2.86	94.41	95.44	0.81	1.89
2175.53*	(2) 2-Year	4.13	94.34	95.43	0.83	0.45
2175.53*	(2) 5-Year	5.24	94.34	95.46	0.92	0.44
2175.53*	(2) 10-Year	6.01	94.34	95.47	0.99	0.44
2175.53*	(2) 25-Year	6.94	94.34	95.49	1.02	0.47
2175.53*	(2) 100-Year	8.32	94.34	95.54	1.02	0.58
2175.53*	(4) 2-Year	3.97	94.34	95.41	0.85	0.46
2175.53*	(4) 5-Year	2.02	94.34	95.19	0.93	0.55
2175.53*	(4) 10-Year	1.57	94.34	95.12	0.86	0.64
2175.53*	(4) 25-Year	2.25	94.34	95.23	0.96	0.77
2175.53*	(4) 100-Year	2.86	94.34	95.30	0.98	1.87
2157	(2) 2-Year	4.13	94.31	95.20	1.80	0.45
2157	(2) 5-Year	5.24	94.31	95.34	1.36	0.43
2157	(2) 10-Year	6.01	94.31	95.38	1.22	0.43
2157	(2) 25-Year	6.94	94.31	95.43	1.14	0.46
2157	(2) 100-Year	8.32	94.31	95.49	1.02	0.58
2157	(4) 2-Year	3.97	94.31	95.17	1.85	0.45
2157	(4) 5-Year	2.02	94.31	94.94	1.78	0.54
2157	(4) 10-Year	1.57	94.31	94.88	1.70	0.64
2157	(4) 25-Year	2.25	94.31	94.97	1.81	0.77
2157	(4) 100-Year	2.86	94.31	95.03	1.89	1.87
2076	(2) 2-Year	5.00	93.86	95.05	0.86	0.43
2076	(2) 5-Year	6.32	93.86	95.16	0.93	0.41
2076	(2) 10-Year	7.24	93.86	95.21	0.95	0.41
2076	(2) 25-Year	8.38	93.86	95.27	0.95	0.44
2076	(2) 100-Year	10.81	93.86	95.35	0.96	0.55

Table A-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2076	(4) 2-Year	4.78	93.86	95.03	0.85	0.44
2076	(4) 5-Year	2.34	93.86	94.65	0.75	0.53
2076	(4) 10-Year	1.78	93.86	94.53	0.71	0.62
2076	(4) 25-Year	2.60	93.86	94.70	0.76	0.75
2076	(4) 100-Year	3.29	93.86	94.85	0.76	1.85
1974	(2) 2-Year	5.00	93.68	94.92	0.80	0.40
1974	(2) 5-Year	6.32	93.68	95.01	0.90	0.38
1974	(2) 10-Year	7.24	93.68	95.06	0.94	0.38
1974	(2) 25-Year	8.38	93.68	95.11	0.98	0.41
1974	(2) 100-Year	10.81	93.68	95.20	1.01	0.53
1974	(4) 2-Year	4.78	93.68	94.90	0.78	0.40
1974	(4) 5-Year	2.34	93.68	94.51	0.70	0.49
1974	(4) 10-Year	1.78	93.68	94.37	0.67	0.58
1974	(4) 25-Year	2.60	93.68	94.57	0.70	0.71
1974	(4) 100-Year	3.29	93.68	94.74	0.68	1.81
1922	(2) 2-Year	5.00	93.59	94.86	0.79	0.38
1922	(2) 5-Year	6.32	93.59	94.93	0.91	0.37
1922	(2) 10-Year	7.24	93.59	94.97	0.99	0.37
1922	(2) 25-Year	8.38	93.59	95.01	1.07	0.40
1922	(2) 100-Year	10.81	93.59	95.08	1.18	0.51
1922	(4) 2-Year	4.78	93.59	94.84	0.77	0.39
1922	(4) 5-Year	2.34	93.59	94.44	0.67	0.47
1922	(4) 10-Year	1.78	93.59	94.30	0.66	0.56
1922	(4) 25-Year	2.60	93.59	94.51	0.67	0.69
1922	(4) 100-Year	3.29	93.59	94.69	0.65	1.79
1833	(2) 2-Year	5.00	93.44	94.78	0.65	0.35
1833	(2) 5-Year	6.32	93.44	94.84	0.71	0.34
1833	(2) 10-Year	7.24	93.44	94.87	0.75	0.34
1833	(2) 25-Year	8.38	93.44	94.90	0.78	0.37
1833	(2) 100-Year	10.81	93.44	94.97	0.82	0.49
1833	(4) 2-Year	4.78	93.44	94.76	0.64	0.35
1833	(4) 5-Year	2.34	93.44	94.35	0.60	0.43
1833	(4) 10-Year	1.78	93.44	94.20	0.59	0.52
1833	(4) 25-Year	2.60	93.44	94.42	0.60	0.65
1833	(4) 100-Year	3.29	93.44	94.63	0.55	1.75
1796	(2) 2-Year	5.00	93.37	94.74	0.70	0.33
1796	(2) 5-Year	6.32	93.37	94.79	0.83	0.32
1796	(2) 10-Year	7.24	93.37	94.80	0.93	0.33
1796	(2) 25-Year	8.38	93.37	94.83	1.04	0.36
1796	(2) 100-Year	10.81	93.37	94.87	1.23	0.48
1796	(4) 2-Year	4.78	93.37	94.73	0.68	0.34
1796	(4) 5-Year	2.34	93.37	94.33	0.57	0.41
1796	(4) 10-Year	1.78	93.37	94.17	0.56	0.50
1796	(4) 25-Year	2.60	93.37	94.40	0.57	0.64
1796	(4) 100-Year	3.29	93.37	94.60	0.55	1.73
1735	(2) 2-Year	5.00	93.26	94.71	0.53	0.31
1735	(2) 5-Year	6.32	93.26	94.76	0.57	0.30

Table A-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1735	(2) 10-Year	7.24	93.26	94.77	0.63	0.31
1735	(2) 25-Year	8.38	93.26	94.79	0.68	0.34
1735	(2) 100-Year	10.81	93.26	94.84	0.74	0.46
1735	(4) 2-Year	4.78	93.26	94.70	0.53	0.31
1735	(4) 5-Year	2.34	93.26	94.29	0.49	0.38
1735	(4) 10-Year	1.78	93.26	94.13	0.49	0.47
1735	(4) 25-Year	2.60	93.26	94.36	0.49	0.61
1735	(4) 100-Year	3.29	93.26	94.58	0.45	1.70
1728	(2) 2-Year	5.00	93.25	94.69	0.73	0.31
1728	(2) 5-Year	6.32	93.25	94.74	0.84	0.30
1728	(2) 10-Year	7.24	93.25	94.74	0.95	0.31
1728	(2) 25-Year	8.38	93.25	94.75	1.07	0.34
1728	(2) 100-Year	10.81	93.25	94.76	1.32	0.46
1728	(4) 2-Year	4.78	93.25	94.68	0.72	0.31
1728	(4) 5-Year	2.34	93.25	94.28	0.61	0.38
1728	(4) 10-Year	1.78	93.25	94.11	0.60	0.47
1728	(4) 25-Year	2.60	93.25	94.35	0.61	0.60
1728	(4) 100-Year	3.29	93.25	94.57	0.58	1.70
1727		Culvert				
1717	(2) 2-Year	5.00	93.24	94.45	1.02	0.30
1717	(2) 5-Year	6.32	93.24	94.57	1.10	0.29
1717	(2) 10-Year	7.24	93.24	94.62	1.17	0.30
1717	(2) 25-Year	8.38	93.24	94.67	1.26	0.34
1717	(2) 100-Year	10.81	93.24	94.74	1.39	0.46
1717	(4) 2-Year	4.78	93.24	94.42	1.01	0.30
1717	(4) 5-Year	2.34	93.24	94.06	0.84	0.37
1717	(4) 10-Year	1.78	93.24	93.94	0.80	0.46
1717	(4) 25-Year	2.60	93.24	94.12	0.86	0.60
1717	(4) 100-Year	3.29	93.24	94.32	0.79	1.69
1615	(2) 2-Year	5.00	93.05	94.29	0.83	0.27
1615	(2) 5-Year	6.32	93.05	94.40	0.88	0.26
1615	(2) 10-Year	7.24	93.05	94.47	0.87	0.28
1615	(2) 25-Year	8.38	93.05	94.53	0.87	0.31
1615	(2) 100-Year	10.81	93.05	94.62	0.82	0.43
1615	(4) 2-Year	4.78	93.05	94.26	0.82	0.27
1615	(4) 5-Year	2.34	93.05	93.92	0.65	0.34
1615	(4) 10-Year	1.78	93.05	93.78	0.63	0.42
1615	(4) 25-Year	2.60	93.05	93.98	0.66	0.56
1615	(4) 100-Year	3.29	93.05	94.24	0.58	1.65
1555	(2) 2-Year	5.00	92.94	94.22	0.79	0.25
1555	(2) 5-Year	6.32	92.94	94.33	0.85	0.25
1555	(2) 10-Year	7.24	92.94	94.39	0.88	0.26
1555	(2) 25-Year	8.38	92.94	94.45	0.91	0.29
1555	(2) 100-Year	10.81	92.94	94.55	0.96	0.41
1555	(4) 2-Year	4.78	92.94	94.19	0.78	0.25
1555	(4) 5-Year	2.34	92.94	93.87	0.59	0.31
1555	(4) 10-Year	1.78	92.94	93.72	0.58	0.40

Table A-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1555	(4) 25-Year	2.60	92.94	93.93	0.60	0.54
1555	(4) 100-Year	3.29	92.94	94.21	0.53	1.62
1488	(2) 2-Year	5.00	92.82	94.16	0.72	0.23
1488	(2) 5-Year	6.32	92.82	94.26	0.81	0.22
1488	(2) 10-Year	7.24	92.82	94.31	0.86	0.24
1488	(2) 25-Year	8.38	92.82	94.37	0.91	0.27
1488	(2) 100-Year	10.81	92.82	94.46	1.00	0.40
1488	(4) 2-Year	4.78	92.82	94.13	0.72	0.23
1488	(4) 5-Year	2.34	92.82	93.82	0.53	0.28
1488	(4) 10-Year	1.78	92.82	93.66	0.51	0.36
1488	(4) 25-Year	2.60	92.82	93.88	0.54	0.50
1488	(4) 100-Year	3.29	92.82	94.18	0.46	1.59
1416	(2) 2-Year	5.00	92.71	94.02	1.09	0.21
1416	(2) 5-Year	6.32	92.71	94.10	1.21	0.20
1416	(2) 10-Year	7.24	92.71	94.17	1.21	0.22
1416	(2) 25-Year	8.38	92.71	94.25	1.12	0.25
1416	(2) 100-Year	10.81	92.71	94.40	0.82	0.37
1416	(4) 2-Year	4.78	92.71	93.99	1.08	0.21
1416	(4) 5-Year	2.34	92.71	93.74	0.74	0.25
1416	(4) 10-Year	1.78	92.71	93.58	0.71	0.33
1416	(4) 25-Year	2.60	92.71	93.81	0.76	0.47
1416	(4) 100-Year	3.29	92.71	94.14	0.58	1.55
1400	(2) 2-Year	5.00	92.68	94.02	0.68	0.20
1400	(2) 5-Year	6.32	92.68	94.11	0.77	0.20
1400	(2) 10-Year	7.24	92.68	94.16	0.82	0.21
1400	(2) 25-Year	8.38	92.68	94.23	0.87	0.25
1400	(2) 100-Year	10.81	92.68	94.36	0.96	0.37
1400	(4) 2-Year	4.78	92.68	93.99	0.68	0.20
1400	(4) 5-Year	2.34	92.68	93.74	0.50	0.24
1400	(4) 10-Year	1.78	92.68	93.58	0.50	0.32
1400	(4) 25-Year	2.60	92.68	93.80	0.50	0.47
1400	(4) 100-Year	3.29	92.68	94.14	0.38	1.54
1364	(2) 2-Year	5.00	92.62	93.99	0.71	0.19
1364	(2) 5-Year	6.32	92.62	94.06	0.82	0.19
1364	(2) 10-Year	7.24	92.62	94.11	0.88	0.20
1364	(2) 25-Year	8.38	92.62	94.18	0.95	0.24
1364	(2) 100-Year	10.81	92.62	94.29	1.06	0.36
1364	(4) 2-Year	4.78	92.62	93.96	0.70	0.19
1364	(4) 5-Year	2.34	92.62	93.72	0.46	0.22
1364	(4) 10-Year	1.78	92.62	93.56	0.44	0.30
1364	(4) 25-Year	2.60	92.62	93.79	0.47	0.45
1364	(4) 100-Year	3.29	92.62	94.13	0.39	1.51
1340	(2) 2-Year	5.79	92.61	93.96	0.88	0.18
1340	(2) 5-Year	7.32	92.61	94.01	1.06	0.18
1340	(2) 10-Year	8.34	92.61	94.05	1.18	0.19
1340	(2) 25-Year	9.65	92.61	94.10	1.33	0.23
1340	(2) 100-Year	11.62	92.61	94.19	1.50	0.35

Table A-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1340	(4) 2-Year	5.26	92.61	93.93	0.81	0.18
1340	(4) 5-Year	2.44	92.61	93.71	0.45	0.21
1340	(4) 10-Year	1.86	92.61	93.55	0.40	0.29
1340	(4) 25-Year	2.71	92.61	93.78	0.47	0.43
1340	(4) 100-Year	3.43	92.61	94.13	0.46	1.50
1339		Culvert				
1312	(2) 2-Year	6.08	92.47	93.94	0.85	0.17
1312	(2) 5-Year	7.69	92.47	93.98	1.04	0.17
1312	(2) 10-Year	8.76	92.47	94.01	1.16	0.19
1312	(2) 25-Year	10.15	92.47	94.04	1.32	0.23
1312	(2) 100-Year	12.20	92.47	94.12	1.51	0.35
1312	(4) 2-Year	5.46	92.47	93.91	0.77	0.17
1312	(4) 5-Year	2.47	92.47	93.71	0.41	0.19
1312	(4) 10-Year	1.87	92.47	93.55	0.35	0.27
1312	(4) 25-Year	2.73	92.47	93.77	0.43	0.41
1312	(4) 100-Year	3.44	92.47	94.12	0.43	1.48
1302	(2) 2-Year	6.08	92.57	93.91	1.03	0.17
1302	(2) 5-Year	7.69	92.57	93.97	1.12	0.17
1302	(2) 10-Year	8.76	92.57	94.00	1.18	0.19
1302	(2) 25-Year	10.15	92.57	94.04	1.26	0.23
1302	(2) 100-Year	12.20	92.57	94.14	1.07	0.35
1302	(4) 2-Year	5.46	92.57	93.89	0.98	0.17
1302	(4) 5-Year	2.47	92.57	93.68	0.77	0.18
1302	(4) 10-Year	1.87	92.57	93.51	0.84	0.26
1302	(4) 25-Year	2.73	92.57	93.75	0.72	0.41
1302	(4) 100-Year	3.44	92.57	94.12	0.33	1.47
1268	(2) 2-Year	6.08	92.47	93.87	0.59	0.15
1268	(2) 5-Year	7.69	92.47	93.93	0.62	0.16
1268	(2) 10-Year	8.76	92.47	93.96	0.64	0.18
1268	(2) 25-Year	10.15	92.47	94.00	0.65	0.22
1268	(2) 100-Year	12.20	92.47	94.14	0.45	0.34
1268	(4) 2-Year	5.46	92.47	93.84	0.57	0.15
1268	(4) 5-Year	2.47	92.47	93.59	0.68	0.17
1268	(4) 10-Year	1.87	92.47	93.44	0.79	0.25
1268	(4) 25-Year	2.73	92.47	93.69	0.51	0.39
1268	(4) 100-Year	3.44	92.47	94.12	0.14	1.43
1212	(2) 2-Year	6.08	92.36	93.78	0.84	0.13
1212	(2) 5-Year	7.69	92.36	93.85	0.85	0.14
1212	(2) 10-Year	8.76	92.36	93.89	0.85	0.15
1212	(2) 25-Year	10.15	92.36	93.94	0.80	0.19
1212	(2) 100-Year	12.20	92.36	94.11	0.56	0.30
1212	(4) 2-Year	5.46	92.36	93.74	0.83	0.13
1212	(4) 5-Year	2.47	92.36	93.41	0.89	0.15
1212	(4) 10-Year	1.87	92.36	93.32	0.81	0.23
1212	(4) 25-Year	2.73	92.36	93.58	0.66	0.37
1212	(4) 100-Year	3.44	92.36	94.12	0.15	1.32

Table A-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1169	(2) 2-Year	6.08	92.30	93.70	0.85	0.12
1169	(2) 5-Year	7.69	92.30	93.76	0.91	0.13
1169	(2) 10-Year	8.76	92.30	93.80	0.94	0.14
1169	(2) 25-Year	10.15	92.30	93.87	0.94	0.18
1169	(2) 100-Year	12.20	92.30	94.08	0.73	0.29
1169	(4) 2-Year	5.46	92.30	93.67	0.83	0.12
1169	(4) 5-Year	2.47	92.30	93.32	0.73	0.13
1169	(4) 10-Year	1.87	92.30	93.26	0.62	0.21
1169	(4) 25-Year	2.73	92.30	93.54	0.53	0.35
1169	(4) 100-Year	3.44	92.30	94.12	0.17	1.25
1091	(2) 2-Year	6.08	92.15	93.57	0.82	0.09
1091	(2) 5-Year	7.69	92.15	93.64	0.85	0.10
1091	(2) 10-Year	8.76	92.15	93.69	0.84	0.12
1091	(2) 25-Year	10.15	92.15	93.78	0.78	0.15
1091	(2) 100-Year	12.20	92.15	94.04	0.57	0.25
1091	(4) 2-Year	5.46	92.15	93.54	0.82	0.09
1091	(4) 5-Year	2.47	92.15	93.19	0.70	0.10
1091	(4) 10-Year	1.87	92.15	93.17	0.55	0.18
1091	(4) 25-Year	2.73	92.15	93.50	0.45	0.30
1091	(4) 100-Year	3.44	92.15	94.12	0.13	1.10
1002	(2) 2-Year	6.08	92.06	93.38	1.02	0.07
1002	(2) 5-Year	7.69	92.06	93.49	0.94	0.07
1002	(2) 10-Year	8.76	92.06	93.59	0.82	0.09
1002	(2) 25-Year	10.15	92.06	93.71	0.70	0.12
1002	(2) 100-Year	12.20	92.06	94.02	0.41	0.20
1002	(4) 2-Year	5.46	92.06	93.33	1.01	0.06
1002	(4) 5-Year	2.47	92.06	93.01	0.83	0.07
1002	(4) 10-Year	1.87	92.06	93.09	0.55	0.13
1002	(4) 25-Year	2.73	92.06	93.47	0.36	0.24
1002	(4) 100-Year	3.44	92.06	94.12	0.09	0.88
961	(2) 2-Year	6.08	91.96	93.28	0.83	0.05
961	(2) 5-Year	7.69	91.96	93.41	0.78	0.06
961	(2) 10-Year	8.76	91.96	93.52	0.65	0.07
961	(2) 25-Year	10.15	91.96	93.69	0.43	0.10
961	(2) 100-Year	12.20	91.96	94.02	0.24	0.17
961	(4) 2-Year	5.46	91.96	93.23	0.82	0.05
961	(4) 5-Year	2.47	91.96	92.97	0.62	0.06
961	(4) 10-Year	1.87	91.96	93.06	0.40	0.11
961	(4) 25-Year	2.73	91.96	93.46	0.25	0.21
961	(4) 100-Year	3.44	91.96	94.12	0.05	0.72
910	(2) 2-Year	6.08	91.93	93.22	0.70	0.03
910	(2) 5-Year	7.69	91.93	93.38	0.63	0.04
910	(2) 10-Year	8.76	91.93	93.49	0.52	0.05
910	(2) 25-Year	10.15	91.93	93.68	0.34	0.06
910	(2) 100-Year	12.20	91.93	94.02	0.20	0.10
910	(4) 2-Year	5.46	91.93	93.17	0.73	0.03
910	(4) 5-Year	2.47	91.93	92.91	0.64	0.03
910	(4) 10-Year	1.87	91.93	93.05	0.35	0.07

Table A-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
910	(4) 25-Year	2.73	91.93	93.46	0.18	0.14
910	(4) 100-Year	3.44	91.93	94.12	0.05	0.44
840	(2) 2-Year	6.08	91.86	93.18	0.41	0.00
840	(2) 5-Year	7.69	91.86	93.35	0.34	0.00
840	(2) 10-Year	8.76	91.86	93.48	0.30	0.00
840	(2) 25-Year	10.15	91.86	93.67	0.26	0.00
840	(2) 100-Year	12.20	91.86	94.02	0.18	0.00
840	(4) 2-Year	5.46	91.86	93.11	0.44	0.00
840	(4) 5-Year	2.47	91.86	92.83	0.47	0.00
840	(4) 10-Year	1.87	91.86	93.03	0.19	0.00
840	(4) 25-Year	2.73	91.86	93.45	0.10	0.00
840	(4) 100-Year	3.44	91.86	94.12	0.04	0.00

[(1)] All channel infrastructure included in the HEC-RAS model for floodplain analysis.
For Scenario 2 (the Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River) and Scenario 4 (the Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain).

ATTACHMENT

B

HEC- RAS Results for Van Gaal Drain Reach 2
Existing Conditions (Riparian Storage Analysis)

JFSA Water Resources and Environmental Consultants

Table B-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) (1)

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2554	(1) 25 mm	0.72	94.75	95.41	0.41	3.57
2554	(1) 2-Year	1.95	94.75	95.72	0.56	7.64
2554	(1) 5-Year	3.20	94.75	95.93	0.65	11.95
2554	(1) 10-Year	4.11	94.75	96.04	0.71	15.65
2554	(1) 25-Year	5.28	94.75	96.14	0.78	22.19
2554	(1) 100-Year	7.27	94.75	96.26	0.84	38.09
2478	(1) 25 mm	0.72	94.75	95.35	0.42	3.44
2478	(1) 2-Year	1.95	94.75	95.65	0.59	7.39
2478	(1) 5-Year	3.20	94.75	95.85	0.72	11.60
2478	(1) 10-Year	4.11	94.75	95.94	0.82	15.23
2478	(1) 25-Year	5.28	94.75	96.03	0.93	21.64
2478	(1) 100-Year	7.27	94.75	96.12	1.10	37.03
2427.58*	(1) 25 mm	0.72	94.68	95.30	0.43	3.36
2427.58*	(1) 2-Year	1.95	94.68	95.60	0.61	7.23
2427.58*	(1) 5-Year	3.20	94.68	95.79	0.74	11.38
2427.58*	(1) 10-Year	4.11	94.68	95.87	0.84	14.96
2427.58*	(1) 25-Year	5.28	94.68	95.95	0.95	21.30
2427.58*	(1) 100-Year	7.27	94.68	96.04	1.11	36.45
2377.17*	(1) 25 mm	0.72	94.61	95.25	0.44	3.28
2377.17*	(1) 2-Year	1.95	94.61	95.54	0.62	7.07
2377.17*	(1) 5-Year	3.20	94.61	95.72	0.76	11.16
2377.17*	(1) 10-Year	4.11	94.61	95.80	0.86	14.68
2377.17*	(1) 25-Year	5.28	94.61	95.87	0.97	20.90
2377.17*	(1) 100-Year	7.27	94.61	95.95	1.09	35.75
2326.76*	(1) 25 mm	0.72	94.54	95.19	0.46	3.20
2326.76*	(1) 2-Year	1.95	94.54	95.48	0.64	6.91
2326.76*	(1) 5-Year	3.20	94.54	95.65	0.78	10.93
2326.76*	(1) 10-Year	4.11	94.54	95.72	0.88	14.37
2326.76*	(1) 25-Year	5.28	94.54	95.78	0.97	20.42
2326.76*	(1) 100-Year	7.27	94.54	95.85	1.07	34.92
2276.35*	(1) 25 mm	0.72	94.48	95.13	0.49	3.12
2276.35*	(1) 2-Year	1.95	94.48	95.41	0.68	6.77
2276.35*	(1) 5-Year	3.20	94.48	95.57	0.80	10.67
2276.35*	(1) 10-Year	4.11	94.48	95.63	0.89	14.00
2276.35*	(1) 25-Year	5.28	94.48	95.69	0.96	19.84
2276.35*	(1) 100-Year	7.27	94.48	95.77	0.98	33.90
2225.94*	(1) 25 mm	0.72	94.41	95.05	0.54	3.05
2225.94*	(1) 2-Year	1.95	94.41	95.33	0.74	6.63
2225.94*	(1) 5-Year	3.20	94.41	95.48	0.84	10.38
2225.94*	(1) 10-Year	4.11	94.41	95.54	0.88	13.58
2225.94*	(1) 25-Year	5.28	94.41	95.59	0.95	19.24
2225.94*	(1) 100-Year	7.27	94.41	95.66	1.05	32.94
2175.53*	(1) 25 mm	0.72	94.34	94.93	0.68	2.99
2175.53*	(1) 2-Year	1.95	94.34	95.18	0.92	6.51
2175.53*	(1) 5-Year	3.20	94.34	95.33	1.03	10.12

Table B-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2175.53*	(1) 10-Year	4.11	94.34	95.42	0.94	13.14
2175.53*	(1) 25-Year	5.28	94.34	95.47	1.01	18.68
2175.53*	(1) 100-Year	7.27	94.34	95.54	1.07	32.14
2157	(1) 25 mm	0.72	94.31	94.72	1.45	2.98
2157	(1) 2-Year	1.95	94.31	94.93	1.77	6.48
2157	(1) 5-Year	3.20	94.31	95.12	1.71	10.06
2157	(1) 10-Year	4.11	94.31	95.24	1.59	13.03
2157	(1) 25-Year	5.28	94.31	95.37	1.29	18.50
2157	(1) 100-Year	7.27	94.31	95.48	1.13	31.84
2076	(1) 25 mm	1.16	93.86	94.39	0.64	2.89
2076	(1) 2-Year	2.80	93.86	94.71	0.81	6.30
2076	(1) 5-Year	4.41	93.86	94.94	0.89	9.79
2076	(1) 10-Year	5.53	93.86	95.07	0.93	12.67
2076	(1) 25-Year	6.96	93.86	95.19	0.97	17.86
2076	(1) 100-Year	9.54	93.86	95.33	0.99	30.64
1974	(1) 25 mm	1.16	93.68	94.21	0.63	2.71
1974	(1) 2-Year	2.80	93.68	94.54	0.78	5.95
1974	(1) 5-Year	4.41	93.68	94.77	0.86	9.29
1974	(1) 10-Year	5.53	93.68	94.92	0.89	12.06
1974	(1) 25-Year	6.96	93.68	95.04	0.95	16.97
1974	(1) 100-Year	9.54	93.68	95.17	1.02	28.90
1922	(1) 25 mm	1.16	93.59	94.12	0.63	2.62
1922	(1) 2-Year	2.80	93.59	94.46	0.78	5.77
1922	(1) 5-Year	4.41	93.59	94.70	0.87	9.04
1922	(1) 10-Year	5.53	93.59	94.84	0.91	11.76
1922	(1) 25-Year	6.96	93.59	94.95	0.98	16.58
1922	(1) 100-Year	9.54	93.59	95.07	1.10	28.19
1833	(1) 25 mm	1.16	93.44	93.97	0.62	2.45
1833	(1) 2-Year	2.80	93.44	94.33	0.75	5.45
1833	(1) 5-Year	4.41	93.44	94.56	0.81	8.57
1833	(1) 10-Year	5.53	93.44	94.70	0.82	11.18
1833	(1) 25-Year	6.96	93.44	94.82	0.83	15.73
1833	(1) 100-Year	9.54	93.44	94.95	0.84	26.54
1796	(1) 25 mm	1.16	93.37	93.91	0.62	2.38
1796	(1) 2-Year	2.80	93.37	94.28	0.73	5.31
1796	(1) 5-Year	4.41	93.37	94.51	0.83	8.38
1796	(1) 10-Year	5.53	93.37	94.64	0.88	10.95
1796	(1) 25-Year	6.96	93.37	94.75	0.96	15.39
1796	(1) 100-Year	9.54	93.37	94.87	1.11	25.93
1735	(1) 25 mm	1.16	93.26	93.83	0.58	2.27
1735	(1) 2-Year	2.80	93.26	94.21	0.67	5.08
1735	(1) 5-Year	4.41	93.26	94.44	0.74	8.05
1735	(1) 10-Year	5.53	93.26	94.57	0.77	10.56
1735	(1) 25-Year	6.96	93.26	94.69	0.80	14.83
1735	(1) 100-Year	9.54	93.26	94.83	0.76	24.60

Table B-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) (1)

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1728	(1) 25 mm	1.16	93.25	93.81	0.68	2.26
1728	(1) 2-Year	2.80	93.25	94.19	0.84	5.05
1728	(1) 5-Year	4.41	93.25	94.41	0.95	8.01
1728	(1) 10-Year	5.53	93.25	94.53	1.01	10.51
1728	(1) 25-Year	6.96	93.25	94.64	1.11	14.76
1728	(1) 100-Year	9.54	93.25	94.78	1.17	24.43
1717	(1) 25 mm	1.16	93.24	93.79	0.71	2.24
1717	(1) 2-Year	2.80	93.24	94.16	0.86	5.01
1717	(1) 5-Year	4.41	93.24	94.38	0.98	7.96
1717	(1) 10-Year	5.53	93.24	94.50	1.04	10.45
1717	(1) 25-Year	6.96	93.24	94.61	1.14	14.69
1717	(1) 100-Year	9.54	93.24	94.73	1.32	24.28
1615	(1) 25 mm	1.16	93.05	93.63	0.56	2.05
1615	(1) 2-Year	2.80	93.05	94.03	0.65	4.63
1615	(1) 5-Year	4.41	93.05	94.24	0.78	7.45
1615	(1) 10-Year	5.53	93.05	94.35	0.85	9.83
1615	(1) 25-Year	6.96	93.05	94.46	0.89	13.75
1615	(1) 100-Year	9.54	93.05	94.59	0.90	22.47
1555	(1) 25 mm	1.16	92.94	93.57	0.50	1.92
1555	(1) 2-Year	2.80	92.94	93.99	0.60	4.36
1555	(1) 5-Year	4.41	92.94	94.18	0.73	7.10
1555	(1) 10-Year	5.53	92.94	94.28	0.81	9.41
1555	(1) 25-Year	6.96	92.94	94.39	0.88	13.09
1555	(1) 100-Year	9.54	92.94	94.51	0.97	21.28
1488	(1) 25 mm	1.16	92.82	93.53	0.43	1.76
1488	(1) 2-Year	2.80	92.82	93.95	0.53	4.04
1488	(1) 5-Year	4.41	92.82	94.12	0.67	6.69
1488	(1) 10-Year	5.53	92.82	94.22	0.75	8.93
1488	(1) 25-Year	6.96	92.82	94.31	0.83	12.45
1488	(1) 100-Year	9.54	92.82	94.43	0.97	20.32
1416	(1) 25 mm	1.16	92.71	93.47	0.55	1.59
1416	(1) 2-Year	2.80	92.71	93.88	0.74	3.73
1416	(1) 5-Year	4.41	92.71	94.01	0.98	6.31
1416	(1) 10-Year	5.53	92.71	94.08	1.11	8.48
1416	(1) 25-Year	6.96	92.71	94.16	1.22	11.83
1416	(1) 100-Year	9.54	92.71	94.28	1.29	19.29
1400	(1) 25 mm	1.16	92.68	93.46	0.39	1.55
1400	(1) 2-Year	2.80	92.68	93.87	0.48	3.65
1400	(1) 5-Year	4.41	92.68	94.01	0.61	6.21
1400	(1) 10-Year	5.53	92.68	94.08	0.69	8.37
1400	(1) 25-Year	6.96	92.68	94.16	0.79	11.69
1400	(1) 100-Year	9.54	92.68	94.27	0.95	19.07
1364	(1) 25 mm	1.16	92.62	93.45	0.35	1.44
1364	(1) 2-Year	2.80	92.62	93.86	0.46	3.44

Table B-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1364	(1) 5-Year	4.41	92.62	93.98	0.63	5.96
1364	(1) 10-Year	5.53	92.62	94.04	0.73	8.09
1364	(1) 25-Year	6.96	92.62	94.11	0.85	11.37
1364	(1) 100-Year	9.54	92.62	94.20	1.05	18.72
1340	(1) 25 mm	1.53	92.61	93.45	0.19	1.30
1340	(1) 2-Year	3.64	92.61	93.86	0.29	3.22
1340	(1) 5-Year	5.57	92.61	93.98	0.41	5.71
1340	(1) 10-Year	6.92	92.61	94.05	0.48	7.82
1340	(1) 25-Year	8.58	92.61	94.12	0.57	11.09
1340	(1) 100-Year	11.43	92.61	94.21	0.71	18.39
1312	(1) 25 mm	1.53	92.47	93.45	0.29	1.10
1312	(1) 2-Year	3.87	92.47	93.84	0.51	2.91
1312	(1) 5-Year	5.93	92.47	93.96	0.71	5.36
1312	(1) 10-Year	7.38	92.47	94.01	0.84	7.45
1312	(1) 25-Year	9.17	92.47	94.07	1.01	10.69
1312	(1) 100-Year	12.20	92.47	94.13	1.29	17.96
1302	(1) 25 mm	1.53	92.57	93.41	0.83	1.07
1302	(1) 2-Year	3.87	92.57	93.81	0.88	2.84
1302	(1) 5-Year	5.93	92.57	93.92	1.05	5.28
1302	(1) 10-Year	7.38	92.57	93.98	1.15	7.35
1302	(1) 25-Year	9.17	92.57	94.03	1.27	10.58
1302	(1) 100-Year	12.20	92.57	94.11	1.41	17.81
1268	(1) 25 mm	1.53	92.47	93.33	0.79	1.00
1268	(1) 2-Year	3.87	92.47	93.75	0.56	2.62
1268	(1) 5-Year	5.93	92.47	93.88	0.57	4.91
1268	(1) 10-Year	7.38	92.47	93.94	0.60	6.88
1268	(1) 25-Year	9.17	92.47	94.01	0.62	9.89
1268	(1) 100-Year	12.20	92.47	94.10	0.60	16.63
1212	(1) 25 mm	1.53	92.36	93.18	0.86	0.90
1212	(1) 2-Year	3.87	92.36	93.61	0.89	2.25
1212	(1) 5-Year	5.93	92.36	93.77	0.91	4.21
1212	(1) 10-Year	7.38	92.36	93.85	0.93	5.90
1212	(1) 25-Year	9.17	92.36	93.92	0.94	8.43
1212	(1) 100-Year	12.20	92.36	94.04	0.90	14.29
1169	(1) 25 mm	1.53	92.30	93.10	0.69	0.81
1169	(1) 2-Year	3.87	92.30	93.53	0.78	2.01
1169	(1) 5-Year	5.93	92.30	93.70	0.86	3.67
1169	(1) 10-Year	7.38	92.30	93.77	0.92	5.11
1169	(1) 25-Year	9.17	92.30	93.84	0.98	7.33
1169	(1) 100-Year	12.20	92.30	93.94	1.09	12.63
1091	(1) 25 mm	1.53	92.15	92.98	0.65	0.63
1091	(1) 2-Year	3.87	92.15	93.40	0.75	1.62
1091	(1) 5-Year	5.93	92.15	93.57	0.83	2.89
1091	(1) 10-Year	7.38	92.15	93.64	0.87	4.03
1091	(1) 25-Year	9.17	92.15	93.71	0.92	5.91

Table B-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1091	(1) 100-Year	12.20	92.15	93.82	0.97	10.61
1002	(1) 25 mm	1.53	92.06	92.81	0.76	0.44
1002	(1) 2-Year	3.87	92.06	93.21	0.91	1.21
1002	(1) 5-Year	5.93	92.06	93.37	1.02	2.15
1002	(1) 10-Year	7.38	92.06	93.46	1.04	2.97
1002	(1) 25-Year	9.17	92.06	93.55	1.03	4.45
1002	(1) 100-Year	12.20	92.06	93.69	1.02	8.49
961	(1) 25 mm	1.53	91.96	92.77	0.54	0.34
961	(1) 2-Year	3.87	91.96	93.13	0.72	1.01
961	(1) 5-Year	5.93	91.96	93.28	0.80	1.85
961	(1) 10-Year	7.38	91.96	93.37	0.83	2.56
961	(1) 25-Year	9.17	91.96	93.47	0.82	3.85
961	(1) 100-Year	12.20	91.96	93.64	0.64	7.42
910	(1) 25 mm	1.53	91.93	92.72	0.57	0.20
910	(1) 2-Year	3.87	91.93	93.06	0.74	0.62
910	(1) 5-Year	5.93	91.93	93.20	0.81	1.16
910	(1) 10-Year	7.38	91.93	93.30	0.82	1.62
910	(1) 25-Year	9.17	91.93	93.41	0.83	2.38
910	(1) 100-Year	12.20	91.93	93.60	0.68	4.32
840	(1) 25 mm	1.53	91.86	92.65	0.50	0.00
840	(1) 2-Year	3.87	91.86	92.98	0.47	0.00
840	(1) 5-Year	5.93	91.86	93.16	0.43	0.00
840	(1) 10-Year	7.38	91.86	93.26	0.41	0.00
840	(1) 25-Year	9.17	91.86	93.38	0.41	0.00
840	(1) 100-Year	12.20	91.86	93.58	0.39	0.00

[(1)] All channel infrastructure removed from the HEC-RAS model for riparian storage analysis.
For Scenario 1 (the Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River).

Table B-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2554	(2) 2-Year	4.13	94.75	96.03	0.71	12.55
2554	(2) 5-Year	5.24	94.75	96.13	0.78	16.61
2554	(2) 10-Year	6.01	94.75	96.18	0.81	20.28
2554	(2) 25-Year	6.94	94.75	96.23	0.83	26.23
2554	(2) 100-Year	8.32	94.75	96.28	0.82	39.19
2554	(4) 2-Year	3.97	94.75	96.02	0.70	11.55
2554	(4) 5-Year	2.02	94.75	95.74	0.56	5.89
2554	(4) 10-Year	1.57	94.75	95.64	0.52	5.25
2554	(4) 25-Year	2.25	94.75	95.78	0.58	9.59
2554	(4) 100-Year	2.86	94.75	95.88	0.63	36.83
2478	(2) 2-Year	4.13	94.75	95.93	0.83	12.14
2478	(2) 5-Year	5.24	94.75	96.02	0.93	16.08
2478	(2) 10-Year	6.01	94.75	96.06	1.00	19.63
2478	(2) 25-Year	6.94	94.75	96.10	1.09	25.37
2478	(2) 100-Year	8.32	94.75	96.14	1.17	37.97
2478	(4) 2-Year	3.97	94.75	95.92	0.81	11.15
2478	(4) 5-Year	2.02	94.75	95.67	0.60	5.63
2478	(4) 10-Year	1.57	94.75	95.57	0.55	5.03
2478	(4) 25-Year	2.25	94.75	95.71	0.63	9.31
2478	(4) 100-Year	2.86	94.75	95.80	0.69	36.50
2427.58*	(2) 2-Year	4.13	94.68	95.86	0.85	11.88
2427.58*	(2) 5-Year	5.24	94.68	95.94	0.95	15.75
2427.58*	(2) 10-Year	6.01	94.68	95.97	1.04	19.25
2427.58*	(2) 25-Year	6.94	94.68	96.01	1.09	24.89
2427.58*	(2) 100-Year	8.32	94.68	96.05	1.16	37.34
2427.58*	(4) 2-Year	3.97	94.68	95.85	0.83	10.90
2427.58*	(4) 5-Year	2.02	94.68	95.61	0.61	5.47
2427.58*	(4) 10-Year	1.57	94.68	95.52	0.56	4.88
2427.58*	(4) 25-Year	2.25	94.68	95.65	0.64	9.13
2427.58*	(4) 100-Year	2.86	94.68	95.74	0.70	36.30
2377.17*	(2) 2-Year	4.13	94.61	95.79	0.87	11.60
2377.17*	(2) 5-Year	5.24	94.61	95.85	0.97	15.39
2377.17*	(2) 10-Year	6.01	94.61	95.88	1.03	18.81
2377.17*	(2) 25-Year	6.94	94.61	95.91	1.08	24.33
2377.17*	(2) 100-Year	8.32	94.61	95.95	1.13	36.61
2377.17*	(4) 2-Year	3.97	94.61	95.78	0.85	10.63
2377.17*	(4) 5-Year	2.02	94.61	95.56	0.63	5.30
2377.17*	(4) 10-Year	1.57	94.61	95.47	0.58	4.75
2377.17*	(4) 25-Year	2.25	94.61	95.60	0.65	8.96
2377.17*	(4) 100-Year	2.86	94.61	95.68	0.72	36.10
2326.76*	(2) 2-Year	4.13	94.54	95.71	0.88	11.31
2326.76*	(2) 5-Year	5.24	94.54	95.76	0.98	14.98
2326.76*	(2) 10-Year	6.01	94.54	95.79	1.02	18.30
2326.76*	(2) 25-Year	6.94	94.54	95.82	1.06	23.69
2326.76*	(2) 100-Year	8.32	94.54	95.85	1.11	35.80
2326.76*	(4) 2-Year	3.97	94.54	95.70	0.87	10.35
2326.76*	(4) 5-Year	2.02	94.54	95.50	0.65	5.14
2326.76*	(4) 10-Year	1.57	94.54	95.41	0.60	4.61

Table B-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2326.76*	(4) 25-Year	2.25	94.54	95.54	0.68	8.79
2326.76*	(4) 100-Year	2.86	94.54	95.61	0.75	35.90
2276.35*	(2) 2-Year	4.13	94.48	95.62	0.90	10.97
2276.35*	(2) 5-Year	5.24	94.48	95.66	0.98	14.50
2276.35*	(2) 10-Year	6.01	94.48	95.69	1.00	17.70
2276.35*	(2) 25-Year	6.94	94.48	95.72	1.00	22.95
2276.35*	(2) 100-Year	8.32	94.48	95.76	0.99	34.83
2276.35*	(4) 2-Year	3.97	94.48	95.61	0.89	10.03
2276.35*	(4) 5-Year	2.02	94.48	95.43	0.69	4.99
2276.35*	(4) 10-Year	1.57	94.48	95.34	0.63	4.48
2276.35*	(4) 25-Year	2.25	94.48	95.46	0.71	8.62
2276.35*	(4) 100-Year	2.86	94.48	95.53	0.77	35.68
2225.94*	(2) 2-Year	4.13	94.41	95.52	0.87	10.59
2225.94*	(2) 5-Year	5.24	94.41	95.56	0.93	14.00
2225.94*	(2) 10-Year	6.01	94.41	95.59	0.97	17.11
2225.94*	(2) 25-Year	6.94	94.41	95.62	1.01	22.24
2225.94*	(2) 100-Year	8.32	94.41	95.65	1.06	33.93
2225.94*	(4) 2-Year	3.97	94.41	95.52	0.86	9.67
2225.94*	(4) 5-Year	2.02	94.41	95.34	0.75	4.85
2225.94*	(4) 10-Year	1.57	94.41	95.26	0.69	4.36
2225.94*	(4) 25-Year	2.25	94.41	95.37	0.77	8.46
2225.94*	(4) 100-Year	2.86	94.41	95.44	0.81	35.46
2175.53*	(2) 2-Year	4.13	94.34	95.43	0.83	10.17
2175.53*	(2) 5-Year	5.24	94.34	95.46	0.92	13.49
2175.53*	(2) 10-Year	6.01	94.34	95.47	0.99	16.55
2175.53*	(2) 25-Year	6.94	94.34	95.49	1.02	21.61
2175.53*	(2) 100-Year	8.32	94.34	95.54	1.02	33.17
2175.53*	(4) 2-Year	3.97	94.34	95.42	0.85	9.27
2175.53*	(4) 5-Year	2.02	94.34	95.19	0.93	4.73
2175.53*	(4) 10-Year	1.57	94.34	95.12	0.86	4.26
2175.53*	(4) 25-Year	2.25	94.34	95.23	0.96	8.33
2175.53*	(4) 100-Year	2.86	94.34	95.30	0.98	35.25
2157	(2) 2-Year	4.13	94.31	95.18	1.86	10.06
2157	(2) 5-Year	5.24	94.31	95.34	1.37	13.33
2157	(2) 10-Year	6.01	94.31	95.38	1.22	16.37
2157	(2) 25-Year	6.94	94.31	95.43	1.14	21.39
2157	(2) 100-Year	8.32	94.31	95.49	1.02	32.87
2157	(4) 2-Year	3.97	94.31	95.16	1.91	9.17
2157	(4) 5-Year	2.02	94.31	94.94	1.78	4.70
2157	(4) 10-Year	1.57	94.31	94.88	1.70	4.24
2157	(4) 25-Year	2.25	94.31	94.97	1.81	8.29
2157	(4) 100-Year	2.86	94.31	95.03	1.90	35.20
2076	(2) 2-Year	5.00	93.86	95.01	0.91	9.75
2076	(2) 5-Year	6.32	93.86	95.14	0.95	12.81
2076	(2) 10-Year	7.24	93.86	95.21	0.96	15.68
2076	(2) 25-Year	8.38	93.86	95.27	0.95	20.49
2076	(2) 100-Year	10.81	93.86	95.35	0.96	31.59

Table B-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2076	(4) 2-Year	4.78	93.86	94.98	0.91	8.88
2076	(4) 5-Year	2.34	93.86	94.63	0.77	4.53
2076	(4) 10-Year	1.78	93.86	94.52	0.72	4.10
2076	(4) 25-Year	2.60	93.86	94.67	0.79	8.11
2076	(4) 100-Year	3.29	93.86	94.79	0.83	34.98
1974	(2) 2-Year	5.00	93.68	94.85	0.88	9.20
1974	(2) 5-Year	6.32	93.68	94.99	0.93	12.10
1974	(2) 10-Year	7.24	93.68	95.05	0.96	14.73
1974	(2) 25-Year	8.38	93.68	95.11	0.98	19.20
1974	(2) 100-Year	10.81	93.68	95.20	1.00	29.64
1974	(4) 2-Year	4.78	93.68	94.82	0.88	8.35
1974	(4) 5-Year	2.34	93.68	94.46	0.76	4.23
1974	(4) 10-Year	1.78	93.68	94.35	0.71	3.86
1974	(4) 25-Year	2.60	93.68	94.51	0.78	7.79
1974	(4) 100-Year	3.29	93.68	94.62	0.80	34.59
1922	(2) 2-Year	5.00	93.59	94.77	0.89	8.92
1922	(2) 5-Year	6.32	93.59	94.90	0.94	11.76
1922	(2) 10-Year	7.24	93.59	94.96	1.00	14.32
1922	(2) 25-Year	8.38	93.59	95.01	1.07	18.67
1922	(2) 100-Year	10.81	93.59	95.08	1.18	28.85
1922	(4) 2-Year	4.78	93.59	94.74	0.89	8.08
1922	(4) 5-Year	2.34	93.59	94.37	0.76	4.08
1922	(4) 10-Year	1.78	93.59	94.26	0.71	3.73
1922	(4) 25-Year	2.60	93.59	94.42	0.77	7.62
1922	(4) 100-Year	3.29	93.59	94.55	0.80	34.38
1833	(2) 2-Year	5.00	93.44	94.63	0.82	8.40
1833	(2) 5-Year	6.32	93.44	94.77	0.84	11.10
1833	(2) 10-Year	7.24	93.44	94.83	0.82	13.41
1833	(2) 25-Year	8.38	93.44	94.89	0.80	17.44
1833	(2) 100-Year	10.81	93.44	94.98	0.81	27.04
1833	(4) 2-Year	4.78	93.44	94.60	0.82	7.58
1833	(4) 5-Year	2.34	93.44	94.24	0.73	3.80
1833	(4) 10-Year	1.78	93.44	94.12	0.69	3.51
1833	(4) 25-Year	2.60	93.44	94.29	0.74	7.31
1833	(4) 100-Year	3.29	93.44	94.42	0.76	34.01
1796	(2) 2-Year	5.00	93.37	94.57	0.87	8.19
1796	(2) 5-Year	6.32	93.37	94.70	0.93	10.83
1796	(2) 10-Year	7.24	93.37	94.76	0.99	13.05
1796	(2) 25-Year	8.38	93.37	94.81	1.06	16.97
1796	(2) 100-Year	10.81	93.37	94.88	1.20	26.38
1796	(4) 2-Year	4.78	93.37	94.54	0.86	7.38
1796	(4) 5-Year	2.34	93.37	94.19	0.71	3.68
1796	(4) 10-Year	1.78	93.37	94.06	0.68	3.41
1796	(4) 25-Year	2.60	93.37	94.24	0.73	7.19
1796	(4) 100-Year	3.29	93.37	94.37	0.75	33.85
1735	(2) 2-Year	5.00	93.26	94.50	0.77	7.83
1735	(2) 5-Year	6.32	93.26	94.63	0.80	10.38

Table B-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1735	(2) 10-Year	7.24	93.26	94.70	0.80	12.45
1735	(2) 25-Year	8.38	93.26	94.77	0.74	16.06
1735	(2) 100-Year	10.81	93.26	94.85	0.69	24.90
1735	(4) 2-Year	4.78	93.26	94.47	0.76	7.04
1735	(4) 5-Year	2.34	93.26	94.11	0.66	3.49
1735	(4) 10-Year	1.78	93.26	93.98	0.64	3.26
1735	(4) 25-Year	2.60	93.26	94.17	0.67	6.97
1735	(4) 100-Year	3.29	93.26	94.31	0.67	33.58
1728	(2) 2-Year	5.00	93.25	94.47	1.00	7.79
1728	(2) 5-Year	6.32	93.25	94.59	1.07	10.33
1728	(2) 10-Year	7.24	93.25	94.65	1.14	12.38
1728	(2) 25-Year	8.38	93.25	94.71	1.19	15.95
1728	(2) 100-Year	10.81	93.25	94.81	1.12	24.69
1728	(4) 2-Year	4.78	93.25	94.44	0.99	7.00
1728	(4) 5-Year	2.34	93.25	94.09	0.82	3.46
1728	(4) 10-Year	1.78	93.25	93.96	0.78	3.24
1728	(4) 25-Year	2.60	93.25	94.14	0.84	6.94
1728	(4) 100-Year	3.29	93.25	94.29	0.85	33.55
1717	(2) 2-Year	5.00	93.24	94.44	1.03	7.74
1717	(2) 5-Year	6.32	93.24	94.56	1.11	10.26
1717	(2) 10-Year	7.24	93.24	94.61	1.18	12.30
1717	(2) 25-Year	8.38	93.24	94.66	1.28	15.86
1717	(2) 100-Year	10.81	93.24	94.73	1.45	24.52
1717	(4) 2-Year	4.78	93.24	94.41	1.02	6.94
1717	(4) 5-Year	2.34	93.24	94.06	0.85	3.43
1717	(4) 10-Year	1.78	93.24	93.93	0.81	3.21
1717	(4) 25-Year	2.60	93.24	94.11	0.87	6.91
1717	(4) 100-Year	3.29	93.24	94.26	0.87	33.51
1615	(2) 2-Year	5.00	93.05	94.28	0.84	7.18
1615	(2) 5-Year	6.32	93.05	94.40	0.89	9.52
1615	(2) 10-Year	7.24	93.05	94.46	0.88	11.35
1615	(2) 25-Year	8.38	93.05	94.52	0.88	14.62
1615	(2) 100-Year	10.81	93.05	94.62	0.84	22.57
1615	(4) 2-Year	4.78	93.05	94.25	0.83	6.41
1615	(4) 5-Year	2.34	93.05	93.92	0.65	3.11
1615	(4) 10-Year	1.78	93.05	93.77	0.64	2.96
1615	(4) 25-Year	2.60	93.05	93.97	0.66	6.56
1615	(4) 100-Year	3.29	93.05	94.15	0.65	33.06
1555	(2) 2-Year	5.00	92.94	94.21	0.79	6.82
1555	(2) 5-Year	6.32	92.94	94.33	0.86	9.01
1555	(2) 10-Year	7.24	92.94	94.39	0.89	10.68
1555	(2) 25-Year	8.38	92.94	94.45	0.92	13.73
1555	(2) 100-Year	10.81	92.94	94.54	0.98	21.28
1555	(4) 2-Year	4.78	92.94	94.19	0.79	6.06
1555	(4) 5-Year	2.34	92.94	93.86	0.60	2.89
1555	(4) 10-Year	1.78	92.94	93.71	0.59	2.79
1555	(4) 25-Year	2.60	92.94	93.92	0.61	6.32
1555	(4) 100-Year	3.29	92.94	94.11	0.59	32.74

Table B-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1488	(2) 2-Year	5.00	92.82	94.15	0.73	6.39
1488	(2) 5-Year	6.32	92.82	94.25	0.82	8.47
1488	(2) 10-Year	7.24	92.82	94.31	0.87	10.04
1488	(2) 25-Year	8.38	92.82	94.36	0.93	12.96
1488	(2) 100-Year	10.81	92.82	94.43	1.06	20.28
1488	(4) 2-Year	4.78	92.82	94.12	0.73	5.64
1488	(4) 5-Year	2.34	92.82	93.81	0.54	2.62
1488	(4) 10-Year	1.78	92.82	93.65	0.52	2.58
1488	(4) 25-Year	2.60	92.82	93.88	0.55	6.02
1488	(4) 100-Year	3.29	92.82	94.07	0.53	32.36
1416	(2) 2-Year	5.00	92.71	94.00	1.11	6.00
1416	(2) 5-Year	6.32	92.71	94.08	1.27	8.01
1416	(2) 10-Year	7.24	92.71	94.12	1.34	9.48
1416	(2) 25-Year	8.38	92.71	94.18	1.35	12.25
1416	(2) 100-Year	10.81	92.71	94.28	1.32	19.24
1416	(4) 2-Year	4.78	92.71	93.98	1.11	5.27
1416	(4) 5-Year	2.34	92.71	93.73	0.75	2.36
1416	(4) 10-Year	1.78	92.71	93.57	0.73	2.38
1416	(4) 25-Year	2.60	92.71	93.80	0.77	5.74
1416	(4) 100-Year	3.29	92.71	94.01	0.73	31.99
1400	(2) 2-Year	5.00	92.68	94.00	0.70	5.91
1400	(2) 5-Year	6.32	92.68	94.08	0.80	7.90
1400	(2) 10-Year	7.24	92.68	94.12	0.86	9.35
1400	(2) 25-Year	8.38	92.68	94.17	0.93	12.10
1400	(2) 100-Year	10.81	92.68	94.25	1.10	19.02
1400	(4) 2-Year	4.78	92.68	93.97	0.70	5.18
1400	(4) 5-Year	2.34	92.68	93.73	0.51	2.30
1400	(4) 10-Year	1.78	92.68	93.56	0.51	2.33
1400	(4) 25-Year	2.60	92.68	93.79	0.51	5.67
1400	(4) 100-Year	3.29	92.68	94.01	0.46	31.90
1364	(2) 2-Year	5.00	92.62	93.97	0.73	5.66
1364	(2) 5-Year	6.32	92.62	94.03	0.85	7.62
1364	(2) 10-Year	7.24	92.62	94.06	0.93	9.06
1364	(2) 25-Year	8.38	92.62	94.10	1.03	11.79
1364	(2) 100-Year	10.81	92.62	94.15	1.27	18.68
1364	(4) 2-Year	4.78	92.62	93.94	0.72	4.94
1364	(4) 5-Year	2.34	92.62	93.71	0.47	2.13
1364	(4) 10-Year	1.78	92.62	93.54	0.46	2.20
1364	(4) 25-Year	2.60	92.62	93.77	0.48	5.48
1364	(4) 100-Year	3.29	92.62	93.99	0.46	31.64
1340	(2) 2-Year	5.79	92.61	93.97	0.42	5.41
1340	(2) 5-Year	7.32	92.61	94.04	0.51	7.36
1340	(2) 10-Year	8.34	92.61	94.07	0.57	8.79
1340	(2) 25-Year	9.65	92.61	94.11	0.64	11.50
1340	(2) 100-Year	11.62	92.61	94.16	0.74	18.38
1340	(4) 2-Year	5.26	92.61	93.94	0.40	4.70
1340	(4) 5-Year	2.44	92.61	93.71	0.22	1.94

Table B-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) (1)

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1340	(4) 10-Year	1.86	92.61	93.54	0.20	2.05
1340	(4) 25-Year	2.71	92.61	93.78	0.23	5.28
1340	(4) 100-Year	3.43	92.61	93.99	0.25	31.39
1312	(2) 2-Year	6.08	92.47	93.95	0.71	5.07
1312	(2) 5-Year	7.69	92.47	94.00	0.85	7.00
1312	(2) 10-Year	8.76	92.47	94.03	0.95	8.41
1312	(2) 25-Year	10.15	92.47	94.06	1.08	11.11
1312	(2) 100-Year	12.20	92.47	94.09	1.27	17.96
1312	(4) 2-Year	5.46	92.47	93.92	0.65	4.37
1312	(4) 5-Year	2.47	92.47	93.71	0.36	1.67
1312	(4) 10-Year	1.87	92.47	93.54	0.32	1.82
1312	(4) 25-Year	2.73	92.47	93.77	0.37	4.99
1312	(4) 100-Year	3.44	92.47	93.99	0.39	31.03
1302	(2) 2-Year	6.08	92.57	93.91	1.03	4.98
1302	(2) 5-Year	7.69	92.57	93.97	1.13	6.90
1302	(2) 10-Year	8.76	92.57	94.00	1.18	8.31
1302	(2) 25-Year	10.15	92.57	94.04	1.26	11.00
1302	(2) 100-Year	12.20	92.57	94.07	1.39	17.84
1302	(4) 2-Year	5.46	92.57	93.89	0.98	4.28
1302	(4) 5-Year	2.47	92.57	93.68	0.77	1.62
1302	(4) 10-Year	1.87	92.57	93.50	0.85	1.79
1302	(4) 25-Year	2.73	92.57	93.74	0.73	4.94
1302	(4) 100-Year	3.44	92.57	93.98	0.49	30.93
1268	(2) 2-Year	6.08	92.47	93.87	0.59	4.63
1268	(2) 5-Year	7.69	92.47	93.93	0.62	6.46
1268	(2) 10-Year	8.76	92.47	93.96	0.64	7.77
1268	(2) 25-Year	10.15	92.47	94.00	0.67	10.34
1268	(2) 100-Year	12.20	92.47	94.05	0.64	16.97
1268	(4) 2-Year	5.46	92.47	93.84	0.57	3.96
1268	(4) 5-Year	2.47	92.47	93.59	0.68	1.50
1268	(4) 10-Year	1.87	92.47	93.43	0.81	1.71
1268	(4) 25-Year	2.73	92.47	93.67	0.53	4.78
1268	(4) 100-Year	3.44	92.47	93.98	0.24	30.37
1212	(2) 2-Year	6.08	92.36	93.78	0.84	3.93
1212	(2) 5-Year	7.69	92.36	93.85	0.85	5.52
1212	(2) 10-Year	8.76	92.36	93.88	0.86	6.62
1212	(2) 25-Year	10.15	92.36	93.93	0.84	8.90
1212	(2) 100-Year	12.20	92.36	94.00	0.80	15.05
1212	(4) 2-Year	5.46	92.36	93.74	0.83	3.36
1212	(4) 5-Year	2.47	92.36	93.41	0.89	1.32
1212	(4) 10-Year	1.87	92.36	93.30	0.83	1.58
1212	(4) 25-Year	2.73	92.36	93.54	0.74	4.52
1212	(4) 100-Year	3.44	92.36	93.97	0.24	28.89
1169	(2) 2-Year	6.08	92.30	93.70	0.86	3.39
1169	(2) 5-Year	7.69	92.30	93.76	0.91	4.74
1169	(2) 10-Year	8.76	92.30	93.80	0.95	5.69
1169	(2) 25-Year	10.15	92.30	93.84	0.99	7.77

Table B-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1169	(2) 100-Year	12.20	92.30	93.91	1.04	13.62
1169	(4) 2-Year	5.46	92.30	93.67	0.83	2.90
1169	(4) 5-Year	2.47	92.30	93.32	0.73	1.19
1169	(4) 10-Year	1.87	92.30	93.24	0.65	1.47
1169	(4) 25-Year	2.73	92.30	93.49	0.59	4.33
1169	(4) 100-Year	3.44	92.30	93.97	0.28	27.39
1091	(2) 2-Year	6.08	92.15	93.57	0.83	2.61
1091	(2) 5-Year	7.69	92.15	93.64	0.85	3.66
1091	(2) 10-Year	8.76	92.15	93.68	0.88	4.46
1091	(2) 25-Year	10.15	92.15	93.72	0.91	6.34
1091	(2) 100-Year	12.20	92.15	93.80	0.88	11.79
1091	(4) 2-Year	5.46	92.15	93.53	0.82	2.26
1091	(4) 5-Year	2.47	92.15	93.18	0.71	0.93
1091	(4) 10-Year	1.87	92.15	93.14	0.58	1.23
1091	(4) 25-Year	2.73	92.15	93.42	0.51	3.94
1091	(4) 100-Year	3.44	92.15	93.96	0.19	24.73
1002	(2) 2-Year	6.08	92.06	93.36	1.05	1.89
1002	(2) 5-Year	7.69	92.06	93.45	1.07	2.63
1002	(2) 10-Year	8.76	92.06	93.50	1.06	3.23
1002	(2) 25-Year	10.15	92.06	93.57	0.99	4.82
1002	(2) 100-Year	12.20	92.06	93.70	0.86	9.70
1002	(4) 2-Year	5.46	92.06	93.32	1.03	1.66
1002	(4) 5-Year	2.47	92.06	93.00	0.85	0.65
1002	(4) 10-Year	1.87	92.06	93.04	0.60	0.95
1002	(4) 25-Year	2.73	92.06	93.37	0.47	3.41
1002	(4) 100-Year	3.44	92.06	93.96	0.14	20.76
961	(2) 2-Year	6.08	91.96	93.25	0.88	1.61
961	(2) 5-Year	7.69	91.96	93.33	0.93	2.25
961	(2) 10-Year	8.76	91.96	93.39	0.95	2.77
961	(2) 25-Year	10.15	91.96	93.48	0.88	4.19
961	(2) 100-Year	12.20	91.96	93.67	0.55	8.56
961	(4) 2-Year	5.46	91.96	93.22	0.85	1.41
961	(4) 5-Year	2.47	91.96	92.95	0.64	0.51
961	(4) 10-Year	1.87	91.96	93.02	0.43	0.80
961	(4) 25-Year	2.73	91.96	93.35	0.32	3.09
961	(4) 100-Year	3.44	91.96	93.96	0.08	18.01
910	(2) 2-Year	6.08	91.93	93.17	0.79	0.99
910	(2) 5-Year	7.69	91.93	93.26	0.80	1.41
910	(2) 10-Year	8.76	91.93	93.32	0.77	1.75
910	(2) 25-Year	10.15	91.93	93.43	0.70	2.59
910	(2) 100-Year	12.20	91.93	93.65	0.44	4.99
910	(4) 2-Year	5.46	91.93	93.14	0.78	0.86
910	(4) 5-Year	2.47	91.93	92.89	0.67	0.31
910	(4) 10-Year	1.87	91.93	93.00	0.40	0.51
910	(4) 25-Year	2.73	91.93	93.35	0.24	2.01
910	(4) 100-Year	3.44	91.93	93.96	0.06	10.36
840	(2) 2-Year	6.08	91.86	93.10	0.50	0.00

Table B-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Existing Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
840	(2) 5-Year	7.69	91.86	93.21	0.48	0.00
840	(2) 10-Year	8.76	91.86	93.28	0.46	0.00
840	(2) 25-Year	10.15	91.86	93.41	0.41	0.00
840	(2) 100-Year	12.20	91.86	93.64	0.34	0.00
840	(4) 2-Year	5.46	91.86	93.06	0.51	0.00
840	(4) 5-Year	2.47	91.86	92.80	0.52	0.00
840	(4) 10-Year	1.87	91.86	92.97	0.23	0.00
840	(4) 25-Year	2.73	91.86	93.34	0.12	0.00
840	(4) 100-Year	3.44	91.86	93.96	0.05	0.00

[1] All channel infrastructure removed from the HEC-RAS model for riparian storage analysis.
For Scenario 2 (the Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River) and
Scenario 4 (the Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain).

ATTACHMENT C

HEC- RAS Results for Van Gaal Drain Reach 2
Proposed Conditions (Floodplain Analysis)

JFSA Water Resources and Environmental Consultants

Table C-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2554	(1) 25 mm	0.72	94.75	95.41	0.41	1.10
2554	(1) 2-Year	1.95	94.75	95.71	0.57	0.85
2554	(1) 5-Year	3.20	94.75	95.91	0.67	0.69
2554	(1) 10-Year	4.11	94.75	96.03	0.72	0.64
2554	(1) 25-Year	5.28	94.75	96.14	0.78	0.60
2554	(1) 100-Year	7.27	94.75	96.26	0.84	0.60
2478	(1) 25 mm	0.72	94.75	95.34	0.43	1.05
2478	(1) 2-Year	1.95	94.75	95.63	0.62	0.81
2478	(1) 5-Year	3.20	94.75	95.82	0.75	0.67
2478	(1) 10-Year	4.11	94.75	95.93	0.83	0.61
2478	(1) 25-Year	5.28	94.75	96.03	0.93	0.58
2478	(1) 100-Year	7.27	94.75	96.13	1.10	0.58
2427.58*	(1) 25 mm	0.72	94.68	95.29	0.45	1.02
2427.58*	(1) 2-Year	1.95	94.68	95.57	0.65	0.79
2427.58*	(1) 5-Year	3.20	94.68	95.75	0.77	0.65
2427.58*	(1) 10-Year	4.11	94.68	95.85	0.86	0.59
2427.58*	(1) 25-Year	5.28	94.68	95.95	0.95	0.56
2427.58*	(1) 100-Year	7.27	94.68	96.04	1.10	0.57
2377.17*	(1) 25 mm	0.72	94.61	95.23	0.47	0.99
2377.17*	(1) 2-Year	1.95	94.61	95.50	0.68	0.77
2377.17*	(1) 5-Year	3.20	94.61	95.68	0.82	0.63
2377.17*	(1) 10-Year	4.11	94.61	95.77	0.90	0.58
2377.17*	(1) 25-Year	5.28	94.61	95.86	0.99	0.55
2377.17*	(1) 100-Year	7.27	94.61	95.95	1.07	0.56
2326.76*	(1) 25 mm	0.72	94.54	95.15	0.52	0.97
2326.76*	(1) 2-Year	1.95	94.54	95.41	0.75	0.75
2326.76*	(1) 5-Year	3.20	94.54	95.57	0.90	0.61
2326.76*	(1) 10-Year	4.11	94.54	95.67	0.97	0.56
2326.76*	(1) 25-Year	5.28	94.54	95.77	1.02	0.54
2326.76*	(1) 100-Year	7.27	94.54	95.88	0.95	0.54
2276.35*	(1) 25 mm	0.72	94.48	94.86	1.40	0.95
2276.35*	(1) 2-Year	1.95	94.48	95.05	1.72	0.74
2276.35*	(1) 5-Year	3.20	94.48	95.18	1.92	0.60
2276.35*	(1) 10-Year	4.11	94.48	95.25	2.02	0.55
2276.35*	(1) 25-Year	5.28	94.48	95.34	2.14	0.53
2276.35*	(1) 100-Year	7.27	94.48	95.50	2.13	0.53
2261	(1) 25 mm	0.72	93.57	94.17	0.86	0.94
2261	(1) 2-Year	1.95	93.57	94.39	1.57	0.74
2261	(1) 5-Year	3.20	93.57	94.51	2.15	0.60
2261	(1) 10-Year	4.11	93.57	94.55	2.61	0.55
2261	(1) 25-Year	5.28	93.57	94.68	2.87	0.53
2261	(1) 100-Year	7.27	93.57	94.89	3.13	0.53
2258	(1) 25 mm	0.72	93.52	94.14	0.47	0.93
2258	(1) 2-Year	1.95	93.52	94.41	0.61	0.73
2258	(1) 5-Year	3.20	93.52	94.60	0.71	0.59

Table C-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) (1)

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2258	(1) 10-Year	4.11	93.52	94.70	0.79	0.55
2258	(1) 25-Year	5.28	93.52	94.82	0.87	0.52
2258	(1) 100-Year	7.27	93.52	95.00	0.99	0.53
2256	(1) 25 mm	0.72	93.49	94.12	0.46	0.92
2256	(1) 2-Year	1.95	93.49	94.39	0.63	0.72
2256	(1) 5-Year	3.20	93.49	94.58	0.75	0.59
2256	(1) 10-Year	4.11	93.49	94.68	0.81	0.54
2256	(1) 25-Year	5.28	93.49	94.80	0.88	0.51
2256	(1) 100-Year	7.27	93.49	94.98	0.96	0.52
2254	(1) 25 mm	0.72	93.46	94.11	0.44	0.91
2254	(1) 2-Year	1.95	93.46	94.38	0.62	0.71
2254	(1) 5-Year	3.20	93.46	94.57	0.73	0.58
2254	(1) 10-Year	4.11	93.46	94.67	0.80	0.53
2254	(1) 25-Year	5.28	93.46	94.78	0.87	0.51
2254	(1) 100-Year	7.27	93.46	94.96	0.95	0.52
2235	(1) 25 mm	0.72	93.44	94.10	0.43	0.90
2235	(1) 2-Year	1.95	93.44	94.36	0.60	0.70
2235	(1) 5-Year	3.20	93.44	94.55	0.72	0.57
2235	(1) 10-Year	4.11	93.44	94.65	0.78	0.53
2235	(1) 25-Year	5.28	93.44	94.77	0.85	0.50
2235	(1) 100-Year	7.27	93.44	94.95	0.94	0.51
2207	(1) 25 mm	0.72	93.40	94.08	0.40	0.88
2207	(1) 2-Year	1.95	93.40	94.35	0.59	0.69
2207	(1) 5-Year	3.20	93.40	94.53	0.71	0.56
2207	(1) 10-Year	4.11	93.40	94.63	0.78	0.52
2207	(1) 25-Year	5.28	93.40	94.74	0.85	0.49
2207	(1) 100-Year	7.27	93.40	94.92	0.94	0.50
2188	(1) 25 mm	1.16	93.37	94.05	0.65	0.87
2188	(1) 2-Year	2.80	93.37	94.31	0.84	0.68
2188	(1) 5-Year	4.41	93.37	94.50	0.98	0.56
2188	(1) 10-Year	5.53	93.37	94.60	1.05	0.51
2188	(1) 25-Year	6.96	93.37	94.71	1.12	0.49
2188	(1) 100-Year	9.54	93.37	94.88	1.23	0.50
2163	(1) 25 mm	1.16	93.34	94.02	0.65	0.86
2163	(1) 2-Year	2.80	93.34	94.28	0.84	0.67
2163	(1) 5-Year	4.41	93.34	94.46	0.97	0.55
2163	(1) 10-Year	5.53	93.34	94.56	1.04	0.50
2163	(1) 25-Year	6.96	93.34	94.67	1.11	0.48
2163	(1) 100-Year	9.54	93.34	94.85	1.22	0.49
2141	(1) 25 mm	1.16	93.31	93.99	0.65	0.85
2141	(1) 2-Year	2.80	93.31	94.25	0.83	0.67
2141	(1) 5-Year	4.41	93.31	94.43	0.97	0.54
2141	(1) 10-Year	5.53	93.31	94.53	1.04	0.50
2141	(1) 25-Year	6.96	93.31	94.65	1.11	0.48
2141	(1) 100-Year	9.54	93.31	94.82	1.22	0.49

Table C-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2121	(1) 25 mm	1.16	93.28	93.97	0.64	0.84
2121	(1) 2-Year	2.80	93.28	94.23	0.83	0.66
2121	(1) 5-Year	4.41	93.28	94.41	0.96	0.54
2121	(1) 10-Year	5.53	93.28	94.51	1.03	0.49
2121	(1) 25-Year	6.96	93.28	94.62	1.11	0.47
2121	(1) 100-Year	9.54	93.28	94.80	1.22	0.48
2101	(1) 25 mm	1.16	93.26	93.94	0.66	0.83
2101	(1) 2-Year	2.80	93.26	94.20	0.84	0.65
2101	(1) 5-Year	4.41	93.26	94.38	0.97	0.53
2101	(1) 10-Year	5.53	93.26	94.48	1.04	0.49
2101	(1) 25-Year	6.96	93.26	94.59	1.12	0.47
2101	(1) 100-Year	9.54	93.26	94.77	1.23	0.48
2080	(1) 25 mm	1.16	93.24	93.90	0.68	0.82
2080	(1) 2-Year	2.80	93.24	94.17	0.85	0.65
2080	(1) 5-Year	4.41	93.24	94.35	0.99	0.52
2080	(1) 10-Year	5.53	93.24	94.45	1.06	0.48
2080	(1) 25-Year	6.96	93.24	94.56	1.14	0.46
2080	(1) 100-Year	9.54	93.24	94.74	1.24	0.47
2059	(1) 25 mm	1.16	93.21	93.87	0.69	0.81
2059	(1) 2-Year	2.80	93.21	94.14	0.85	0.64
2059	(1) 5-Year	4.41	93.21	94.32	0.99	0.52
2059	(1) 10-Year	5.53	93.21	94.42	1.06	0.48
2059	(1) 25-Year	6.96	93.21	94.53	1.14	0.46
2059	(1) 100-Year	9.54	93.21	94.71	1.24	0.47
2038	(1) 25 mm	1.16	93.18	93.84	0.70	0.81
2038	(1) 2-Year	2.80	93.18	94.12	0.84	0.63
2038	(1) 5-Year	4.41	93.18	94.30	0.98	0.51
2038	(1) 10-Year	5.53	93.18	94.40	1.05	0.47
2038	(1) 25-Year	6.96	93.18	94.51	1.12	0.45
2038	(1) 100-Year	9.54	93.18	94.69	1.23	0.46
2017	(1) 25 mm	1.16	93.17	93.82	0.71	0.80
2017	(1) 2-Year	2.80	93.17	94.11	0.85	0.63
2017	(1) 5-Year	4.41	93.17	94.28	1.00	0.51
2017	(1) 10-Year	5.53	93.17	94.38	1.07	0.47
2017	(1) 25-Year	6.96	93.17	94.49	1.14	0.45
2017	(1) 100-Year	9.54	93.17	94.67	1.25	0.46
2003	(1) 25 mm	1.16	93.16	93.81	0.73	0.80
2003	(1) 2-Year	2.80	93.16	94.10	0.86	0.63
2003	(1) 5-Year	4.41	93.16	94.27	1.00	0.51
2003	(1) 10-Year	5.53	93.16	94.37	1.07	0.47
2003	(1) 25-Year	6.96	93.16	94.48	1.15	0.45
2003	(1) 100-Year	9.54	93.16	94.66	1.26	0.46
1982	(1) 25 mm	1.16	93.12	93.77	0.71	0.79
1982	(1) 2-Year	2.80	93.12	94.07	0.82	0.62

Table C-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1982	(1) 5-Year	4.41	93.12	94.25	0.97	0.50
1982	(1) 10-Year	5.53	93.12	94.35	1.04	0.46
1982	(1) 25-Year	6.96	93.12	94.46	1.11	0.44
1982	(1) 100-Year	9.54	93.12	94.63	1.22	0.46
1961	(1) 25 mm	1.16	93.08	93.74	0.70	0.78
1961	(1) 2-Year	2.80	93.08	94.05	0.80	0.62
1961	(1) 5-Year	4.41	93.08	94.22	0.94	0.50
1961	(1) 10-Year	5.53	93.08	94.32	1.01	0.46
1961	(1) 25-Year	6.96	93.08	94.43	1.09	0.44
1961	(1) 100-Year	9.54	93.08	94.61	1.20	0.45
1940	(1) 25 mm	1.16	93.04	93.70	0.68	0.78
1940	(1) 2-Year	2.80	93.04	94.03	0.77	0.61
1940	(1) 5-Year	4.41	93.04	94.20	0.92	0.49
1940	(1) 10-Year	5.53	93.04	94.30	0.99	0.45
1940	(1) 25-Year	6.96	93.04	94.41	1.07	0.43
1940	(1) 100-Year	9.54	93.04	94.58	1.18	0.45
1919	(1) 25 mm	1.16	93.01	93.67	0.68	0.77
1919	(1) 2-Year	2.80	93.01	94.01	0.75	0.60
1919	(1) 5-Year	4.41	93.01	94.18	0.90	0.49
1919	(1) 10-Year	5.53	93.01	94.27	0.97	0.45
1919	(1) 25-Year	6.96	93.01	94.38	1.05	0.43
1919	(1) 100-Year	9.54	93.01	94.56	1.16	0.44
1898	(1) 25 mm	1.16	92.97	93.64	0.66	0.76
1898	(1) 2-Year	2.80	92.97	93.99	0.72	0.59
1898	(1) 5-Year	4.41	92.97	94.16	0.87	0.48
1898	(1) 10-Year	5.53	92.97	94.25	0.94	0.44
1898	(1) 25-Year	6.96	92.97	94.36	1.03	0.42
1898	(1) 100-Year	9.54	92.97	94.54	1.14	0.44
1877	(1) 25 mm	1.16	92.93	93.61	0.64	0.75
1877	(1) 2-Year	2.80	92.93	93.97	0.70	0.59
1877	(1) 5-Year	4.41	92.93	94.14	0.84	0.47
1877	(1) 10-Year	5.53	92.93	94.24	0.91	0.43
1877	(1) 25-Year	6.96	92.93	94.34	1.00	0.42
1877	(1) 100-Year	9.54	92.93	94.52	1.12	0.43
1857	(1) 25 mm	1.16	92.89	93.59	0.62	0.74
1857	(1) 2-Year	2.80	92.89	93.96	0.67	0.58
1857	(1) 5-Year	4.41	92.89	94.12	0.81	0.47
1857	(1) 10-Year	5.53	92.89	94.22	0.89	0.43
1857	(1) 25-Year	6.96	92.89	94.32	0.98	0.41
1857	(1) 100-Year	9.54	92.89	94.50	1.10	0.43
1837	(1) 25 mm	1.16	92.86	93.57	0.60	0.73
1837	(1) 2-Year	2.80	92.86	93.95	0.65	0.57
1837	(1) 5-Year	4.41	92.86	94.11	0.79	0.46
1837	(1) 10-Year	5.53	92.86	94.20	0.87	0.42
1837	(1) 25-Year	6.96	92.86	94.31	0.96	0.40

Table C-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1837	(1) 100-Year	9.54	92.86	94.48	1.08	0.42
1817	(1) 25 mm	1.16	92.81	93.55	0.56	0.72
1817	(1) 2-Year	2.80	92.81	93.94	0.62	0.56
1817	(1) 5-Year	4.41	92.81	94.10	0.76	0.45
1817	(1) 10-Year	5.53	92.81	94.19	0.84	0.41
1817	(1) 25-Year	6.96	92.81	94.29	0.93	0.40
1817	(1) 100-Year	9.54	92.81	94.46	1.05	0.42
1797	(1) 25 mm	1.16	92.77	93.53	0.52	0.71
1797	(1) 2-Year	2.80	92.77	93.93	0.58	0.55
1797	(1) 5-Year	4.41	92.77	94.08	0.73	0.44
1797	(1) 10-Year	5.53	92.77	94.17	0.81	0.41
1797	(1) 25-Year	6.96	92.77	94.28	0.90	0.39
1797	(1) 100-Year	9.54	92.77	94.45	1.03	0.41
1777	(1) 25 mm	1.16	92.73	93.52	0.48	0.70
1777	(1) 2-Year	2.80	92.73	93.92	0.55	0.54
1777	(1) 5-Year	4.41	92.73	94.07	0.69	0.44
1777	(1) 10-Year	5.53	92.73	94.16	0.78	0.40
1777	(1) 25-Year	6.96	92.73	94.26	0.87	0.39
1777	(1) 100-Year	9.54	92.73	94.43	0.99	0.41
1757	(1) 25 mm	1.16	92.69	93.51	0.46	0.69
1757	(1) 2-Year	2.80	92.69	93.91	0.53	0.53
1757	(1) 5-Year	4.41	92.69	94.07	0.67	0.43
1757	(1) 10-Year	5.53	92.69	94.15	0.75	0.39
1757	(1) 25-Year	6.96	92.69	94.25	0.85	0.38
1757	(1) 100-Year	9.54	92.69	94.42	0.98	0.40
1736	(1) 25 mm	1.16	92.66	93.50	0.43	0.68
1736	(1) 2-Year	2.80	92.66	93.91	0.50	0.52
1736	(1) 5-Year	4.41	92.66	94.06	0.65	0.42
1736	(1) 10-Year	5.53	92.66	94.14	0.73	0.39
1736	(1) 25-Year	6.96	92.66	94.24	0.82	0.37
1736	(1) 100-Year	9.54	92.66	94.41	0.95	0.40
1715	(1) 25 mm	1.16	92.62	93.50	0.40	0.66
1715	(1) 2-Year	2.80	92.62	93.90	0.48	0.51
1715	(1) 5-Year	4.41	92.62	94.05	0.61	0.41
1715	(1) 10-Year	5.53	92.62	94.13	0.70	0.38
1715	(1) 25-Year	6.96	92.62	94.23	0.79	0.37
1715	(1) 100-Year	9.54	92.62	94.39	0.92	0.39
1694	(1) 25 mm	1.16	92.58	93.49	0.38	0.65
1694	(1) 2-Year	2.80	92.58	93.90	0.46	0.50
1694	(1) 5-Year	4.41	92.58	94.04	0.59	0.40
1694	(1) 10-Year	5.53	92.58	94.13	0.68	0.37
1694	(1) 25-Year	6.96	92.58	94.22	0.77	0.36
1694	(1) 100-Year	9.54	92.58	94.38	0.90	0.38
1673	(1) 25 mm	1.16	92.53	93.49	0.35	0.63

Table C-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1673	(1) 2-Year	2.80	92.53	93.89	0.43	0.48
1673	(1) 5-Year	4.41	92.53	94.04	0.57	0.39
1673	(1) 10-Year	5.53	92.53	94.12	0.65	0.36
1673	(1) 25-Year	6.96	92.53	94.21	0.74	0.35
1673	(1) 100-Year	9.54	92.53	94.37	0.87	0.38
1653	(1) 25 mm	1.16	92.50	93.48	0.33	0.62
1653	(1) 2-Year	2.80	92.50	93.89	0.41	0.47
1653	(1) 5-Year	4.41	92.50	94.03	0.55	0.38
1653	(1) 10-Year	5.53	92.50	94.11	0.63	0.35
1653	(1) 25-Year	6.96	92.50	94.20	0.72	0.34
1653	(1) 100-Year	9.54	92.50	94.36	0.85	0.37
1632	(1) 25 mm	1.16	92.46	93.48	0.31	0.60
1632	(1) 2-Year	2.80	92.46	93.89	0.40	0.46
1632	(1) 5-Year	4.41	92.46	94.03	0.53	0.37
1632	(1) 10-Year	5.53	92.46	94.11	0.61	0.34
1632	(1) 25-Year	6.96	92.46	94.20	0.71	0.34
1632	(1) 100-Year	9.54	92.46	94.35	0.84	0.36
1615	(1) 25 mm	1.16	92.43	93.48	0.31	0.58
1615	(1) 2-Year	2.80	92.43	93.89	0.38	0.45
1615	(1) 5-Year	4.41	92.43	94.02	0.51	0.36
1615	(1) 10-Year	5.53	92.43	94.10	0.59	0.34
1615	(1) 25-Year	6.96	92.43	94.19	0.68	0.33
1615	(1) 100-Year	9.54	92.43	94.35	0.81	0.36
1555	(1) 25 mm	1.16	92.35	93.47	0.28	0.53
1555	(1) 2-Year	2.80	92.35	93.88	0.35	0.40
1555	(1) 5-Year	4.41	92.35	94.01	0.47	0.33
1555	(1) 10-Year	5.53	92.35	94.09	0.55	0.31
1555	(1) 25-Year	6.96	92.35	94.17	0.64	0.30
1555	(1) 100-Year	9.54	92.35	94.33	0.76	0.34
1488	(1) 25 mm	1.16	92.28	93.46	0.24	0.46
1488	(1) 2-Year	2.80	92.28	93.87	0.32	0.35
1488	(1) 5-Year	4.41	92.28	94.00	0.44	0.29
1488	(1) 10-Year	5.53	92.28	94.08	0.51	0.27
1488	(1) 25-Year	6.96	92.28	94.16	0.60	0.27
1488	(1) 100-Year	9.54	92.28	94.31	0.72	0.31
1416	(1) 25 mm	1.16	92.20	93.46	0.21	0.38
1416	(1) 2-Year	2.80	92.20	93.87	0.30	0.29
1416	(1) 5-Year	4.41	92.20	94.00	0.41	0.25
1416	(1) 10-Year	5.53	92.20	94.07	0.48	0.24
1416	(1) 25-Year	6.96	92.20	94.15	0.57	0.25
1416	(1) 100-Year	9.54	92.20	94.29	0.70	0.29
1400	(1) 25 mm	1.16	92.17	93.46	0.20	0.35
1400	(1) 2-Year	2.80	92.17	93.87	0.29	0.27
1400	(1) 5-Year	4.41	92.17	93.99	0.40	0.23
1400	(1) 10-Year	5.53	92.17	94.06	0.47	0.22

Table C-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1400	(1) 25-Year	6.96	92.17	94.14	0.55	0.23
1400	(1) 100-Year	9.54	92.17	94.28	0.68	0.28
1364	(1) 25 mm	1.16	91.63	93.46	0.08	0.28
1364	(1) 2-Year	2.80	91.63	93.87	0.15	0.22
1364	(1) 5-Year	4.41	91.63	93.99	0.22	0.20
1364	(1) 10-Year	5.53	91.63	94.06	0.26	0.20
1364	(1) 25-Year	6.96	91.63	94.14	0.31	0.21
1364	(1) 100-Year	9.54	91.63	94.28	0.39	0.26
1340	(1) 25 mm	1.53	91.60	93.46	0.18	0.23
1340	(1) 2-Year	3.64	91.60	93.86	0.35	0.20
1340	(1) 5-Year	5.57	91.60	93.98	0.50	0.18
1340	(1) 10-Year	6.92	91.60	94.04	0.61	0.18
1340	(1) 25-Year	8.58	91.60	94.11	0.73	0.20
1340	(1) 100-Year	11.43	91.60	94.24	0.93	0.25
1339		Culvert				
1312	(1) 25 mm	1.53	92.47	93.45	0.32	0.20
1312	(1) 2-Year	3.87	92.47	93.84	0.57	0.18
1312	(1) 5-Year	5.93	92.47	93.95	0.82	0.17
1312	(1) 10-Year	7.38	92.47	94.00	0.99	0.17
1312	(1) 25-Year	9.17	92.47	94.05	1.19	0.19
1312	(1) 100-Year	12.20	92.47	94.14	1.50	0.24
1302	(1) 25 mm	1.53	92.57	93.41	0.83	0.19
1302	(1) 2-Year	3.87	92.57	93.81	0.88	0.17
1302	(1) 5-Year	5.93	92.57	93.92	1.05	0.17
1302	(1) 10-Year	7.38	92.57	93.98	1.15	0.17
1302	(1) 25-Year	9.17	92.57	94.04	1.26	0.19
1302	(1) 100-Year	12.20	92.57	94.15	1.23	0.24
1268	(1) 25 mm	1.53	92.47	93.33	0.79	0.18
1268	(1) 2-Year	3.87	92.47	93.75	0.56	0.16
1268	(1) 5-Year	5.93	92.47	93.88	0.57	0.16
1268	(1) 10-Year	7.38	92.47	93.94	0.60	0.16
1268	(1) 25-Year	9.17	92.47	94.01	0.61	0.18
1268	(1) 100-Year	12.20	92.47	94.14	0.52	0.23
1212	(1) 25 mm	1.53	92.36	93.18	0.86	0.16
1212	(1) 2-Year	3.87	92.36	93.61	0.89	0.14
1212	(1) 5-Year	5.93	92.36	93.78	0.91	0.13
1212	(1) 10-Year	7.38	92.36	93.85	0.93	0.14
1212	(1) 25-Year	9.17	92.36	93.93	0.91	0.16
1212	(1) 100-Year	12.20	92.36	94.10	0.76	0.21
1169	(1) 25 mm	1.53	92.30	93.10	0.69	0.15
1169	(1) 2-Year	3.87	92.30	93.53	0.77	0.13
1169	(1) 5-Year	5.93	92.30	93.70	0.86	0.12
1169	(1) 10-Year	7.38	92.30	93.77	0.91	0.12
1169	(1) 25-Year	9.17	92.30	93.85	0.95	0.14

Table C-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1169	(1) 100-Year	12.20	92.30	94.04	0.88	0.19
1091	(1) 25 mm	1.53	92.15	92.98	0.65	0.11
1091	(1) 2-Year	3.87	92.15	93.40	0.75	0.10
1091	(1) 5-Year	5.93	92.15	93.57	0.82	0.09
1091	(1) 10-Year	7.38	92.15	93.65	0.85	0.10
1091	(1) 25-Year	9.17	92.15	93.75	0.85	0.12
1091	(1) 100-Year	12.20	92.15	93.97	0.82	0.17
1002	(1) 25 mm	1.53	92.06	92.81	0.76	0.08
1002	(1) 2-Year	3.87	92.06	93.21	0.90	0.07
1002	(1) 5-Year	5.93	92.06	93.39	0.98	0.07
1002	(1) 10-Year	7.38	92.06	93.50	0.93	0.07
1002	(1) 25-Year	9.17	92.06	93.65	0.83	0.09
1002	(1) 100-Year	12.20	92.06	93.93	0.64	0.13
961	(1) 25 mm	1.53	91.96	92.77	0.54	0.06
961	(1) 2-Year	3.87	91.96	93.14	0.71	0.05
961	(1) 5-Year	5.93	91.96	93.31	0.76	0.05
961	(1) 10-Year	7.38	91.96	93.44	0.71	0.06
961	(1) 25-Year	9.17	91.96	93.61	0.52	0.07
961	(1) 100-Year	12.20	91.96	93.92	0.35	0.11
910	(1) 25 mm	1.53	91.93	92.72	0.57	0.04
910	(1) 2-Year	3.87	91.93	93.07	0.72	0.03
910	(1) 5-Year	5.93	91.93	93.25	0.73	0.04
910	(1) 10-Year	7.38	91.93	93.40	0.69	0.04
910	(1) 25-Year	9.17	91.93	93.59	0.53	0.05
910	(1) 100-Year	12.20	91.93	93.91	0.33	0.07
840	(1) 25 mm	1.53	91.86	92.64	0.50	0.00
840	(1) 2-Year	3.87	91.86	93.00	0.44	0.00
840	(1) 5-Year	5.93	91.86	93.22	0.36	0.00
840	(1) 10-Year	7.38	91.86	93.38	0.33	0.00
840	(1) 25-Year	9.17	91.86	93.58	0.30	0.00
840	(1) 100-Year	12.20	91.86	93.91	0.25	0.00

[1] All channel infrastructure included in the HEC-RAS model for floodplain analysis.
For Scenario 1 (the Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River).

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2554	(2) 2-Year	4.13	94.75	96.03	0.72	0.71
2554	(2) 5-Year	5.24	94.75	96.13	0.78	0.65
2554	(2) 10-Year	6.00	94.75	96.18	0.81	0.64
2554	(2) 25-Year	6.94	94.75	96.23	0.83	0.65
2554	(2) 100-Year	8.32	94.75	96.28	0.82	0.73
2554	(4) 2-Year	3.97	94.75	96.01	0.71	0.72
2554	(4) 5-Year	2.02	94.75	95.72	0.58	0.95
2554	(4) 10-Year	1.57	94.75	95.63	0.54	1.06
2554	(4) 25-Year	2.25	94.75	95.76	0.60	1.16
2554	(4) 100-Year	2.86	94.75	95.86	0.65	2.34
2478	(2) 2-Year	4.13	94.75	95.93	0.83	0.68
2478	(2) 5-Year	5.24	94.75	96.02	0.93	0.63
2478	(2) 10-Year	6.00	94.75	96.06	1.00	0.61
2478	(2) 25-Year	6.94	94.75	96.10	1.09	0.63
2478	(2) 100-Year	8.32	94.75	96.14	1.17	0.71
2478	(4) 2-Year	3.97	94.75	95.91	0.82	0.69
2478	(4) 5-Year	2.02	94.75	95.64	0.63	0.92
2478	(4) 10-Year	1.57	94.75	95.55	0.58	1.03
2478	(4) 25-Year	2.25	94.75	95.68	0.66	1.13
2478	(4) 100-Year	2.86	94.75	95.77	0.71	2.30
2427.58*	(2) 2-Year	4.13	94.68	95.85	0.86	0.67
2427.58*	(2) 5-Year	5.24	94.68	95.94	0.95	0.61
2427.58*	(2) 10-Year	6.00	94.68	95.97	1.03	0.60
2427.58*	(2) 25-Year	6.94	94.68	96.01	1.09	0.61
2427.58*	(2) 100-Year	8.32	94.68	96.05	1.16	0.70
2427.58*	(4) 2-Year	3.97	94.68	95.84	0.85	0.67
2427.58*	(4) 5-Year	2.02	94.68	95.58	0.65	0.90
2427.58*	(4) 10-Year	1.57	94.68	95.49	0.60	1.00
2427.58*	(4) 25-Year	2.25	94.68	95.62	0.68	1.11
2427.58*	(4) 100-Year	2.86	94.68	95.71	0.74	2.29
2377.17*	(2) 2-Year	4.13	94.61	95.77	0.90	0.65
2377.17*	(2) 5-Year	5.24	94.61	95.85	0.97	0.60
2377.17*	(2) 10-Year	6.00	94.61	95.89	1.02	0.59
2377.17*	(2) 25-Year	6.94	94.61	95.92	1.05	0.60
2377.17*	(2) 100-Year	8.32	94.61	95.95	1.13	0.69
2377.17*	(4) 2-Year	3.97	94.61	95.76	0.88	0.66
2377.17*	(4) 5-Year	2.02	94.61	95.51	0.69	0.88
2377.17*	(4) 10-Year	1.57	94.61	95.43	0.63	0.98
2377.17*	(4) 25-Year	2.25	94.61	95.54	0.72	1.09
2377.17*	(4) 100-Year	2.86	94.61	95.63	0.78	2.27
2326.76*	(2) 2-Year	4.13	94.54	95.67	0.96	0.64
2326.76*	(2) 5-Year	5.24	94.54	95.76	0.98	0.59
2326.76*	(2) 10-Year	6.00	94.54	95.81	0.94	0.57
2326.76*	(2) 25-Year	6.94	94.54	95.85	0.89	0.59
2326.76*	(2) 100-Year	8.32	94.54	95.88	0.95	0.68
2326.76*	(4) 2-Year	3.97	94.54	95.66	0.95	0.64
2326.76*	(4) 5-Year	2.02	94.54	95.42	0.76	0.86
2326.76*	(4) 10-Year	1.57	94.54	95.34	0.69	0.96

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2326.76*	(4) 25-Year	2.25	94.54	95.45	0.79	1.07
2326.76*	(4) 100-Year	2.86	94.54	95.53	0.86	2.25
2276.35*	(2) 2-Year	4.13	94.48	95.25	2.02	0.63
2276.35*	(2) 5-Year	5.24	94.48	95.33	2.16	0.58
2276.35*	(2) 10-Year	6.00	94.48	95.38	2.23	0.56
2276.35*	(2) 25-Year	6.94	94.48	95.49	2.09	0.58
2276.35*	(2) 100-Year	8.32	94.48	95.64	1.66	0.66
2276.35*	(4) 2-Year	3.97	94.48	95.24	2.02	0.63
2276.35*	(4) 5-Year	2.02	94.48	95.06	1.73	0.85
2276.35*	(4) 10-Year	1.57	94.48	95.00	1.64	0.95
2276.35*	(4) 25-Year	2.25	94.48	95.08	1.78	1.06
2276.35*	(4) 100-Year	2.86	94.48	95.14	1.87	2.24
2261	(2) 2-Year	4.13	93.57	94.53	2.64	0.62
2261	(2) 5-Year	5.24	93.57	94.66	2.81	0.57
2261	(2) 10-Year	6.00	93.57	94.74	2.92	0.56
2261	(2) 25-Year	6.94	93.57	94.84	3.02	0.58
2261	(2) 100-Year	8.32	93.57	94.95	3.19	0.66
2261	(4) 2-Year	3.97	93.57	94.51	2.61	0.63
2261	(4) 5-Year	2.02	93.57	94.30	1.87	0.84
2261	(4) 10-Year	1.57	93.57	94.26	1.56	0.94
2261	(4) 25-Year	2.25	93.57	94.31	2.05	1.06
2261	(4) 100-Year	2.86	93.57	94.36	2.40	2.24
2258	(2) 2-Year	4.13	93.52	94.59	0.80	0.62
2258	(2) 5-Year	5.24	93.52	94.68	0.87	0.57
2258	(2) 10-Year	6.00	93.52	94.74	0.91	0.56
2258	(2) 25-Year	6.94	93.52	94.81	0.96	0.57
2258	(2) 100-Year	8.32	93.52	94.94	0.99	0.66
2258	(4) 2-Year	3.97	93.52	94.57	0.79	0.62
2258	(4) 5-Year	2.02	93.52	94.33	0.68	0.84
2258	(4) 10-Year	1.57	93.52	94.26	0.65	0.93
2258	(4) 25-Year	2.25	93.52	94.36	0.70	1.05
2258	(4) 100-Year	2.86	93.52	94.46	0.71	2.23
2256	(2) 2-Year	4.13	93.49	94.56	0.83	0.61
2256	(2) 5-Year	5.24	93.49	94.66	0.88	0.56
2256	(2) 10-Year	6.00	93.49	94.72	0.91	0.55
2256	(2) 25-Year	6.94	93.49	94.79	0.95	0.57
2256	(2) 100-Year	8.32	93.49	94.92	0.95	0.65
2256	(4) 2-Year	3.97	93.49	94.55	0.82	0.62
2256	(4) 5-Year	2.02	93.49	94.30	0.69	0.83
2256	(4) 10-Year	1.57	93.49	94.23	0.66	0.93
2256	(4) 25-Year	2.25	93.49	94.34	0.71	1.04
2256	(4) 100-Year	2.86	93.49	94.44	0.72	2.22
2254	(2) 2-Year	4.13	93.46	94.54	0.81	0.60
2254	(2) 5-Year	5.24	93.46	94.64	0.87	0.56
2254	(2) 10-Year	6.00	93.46	94.70	0.90	0.55
2254	(2) 25-Year	6.94	93.46	94.77	0.94	0.56
2254	(2) 100-Year	8.32	93.46	94.91	0.94	0.65

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2254	(4) 2-Year	3.97	93.46	94.53	0.81	0.61
2254	(4) 5-Year	2.02	93.46	94.28	0.68	0.82
2254	(4) 10-Year	1.57	93.46	94.21	0.65	0.92
2254	(4) 25-Year	2.25	93.46	94.31	0.70	1.04
2254	(4) 100-Year	2.86	93.46	94.42	0.71	2.22
2235	(2) 2-Year	4.13	93.44	94.53	0.80	0.60
2235	(2) 5-Year	5.24	93.44	94.62	0.86	0.55
2235	(2) 10-Year	6.00	93.44	94.68	0.89	0.54
2235	(2) 25-Year	6.94	93.44	94.76	0.92	0.55
2235	(2) 100-Year	8.32	93.44	94.89	0.92	0.64
2235	(4) 2-Year	3.97	93.44	94.51	0.80	0.60
2235	(4) 5-Year	2.02	93.44	94.26	0.68	0.81
2235	(4) 10-Year	1.57	93.44	94.19	0.64	0.91
2235	(4) 25-Year	2.25	93.44	94.29	0.70	1.03
2235	(4) 100-Year	2.86	93.44	94.40	0.69	2.21
2207	(2) 2-Year	4.13	93.40	94.50	0.80	0.59
2207	(2) 5-Year	5.24	93.40	94.60	0.86	0.54
2207	(2) 10-Year	6.00	93.40	94.66	0.89	0.53
2207	(2) 25-Year	6.94	93.40	94.73	0.93	0.55
2207	(2) 100-Year	8.32	93.40	94.87	0.92	0.63
2207	(4) 2-Year	3.97	93.40	94.48	0.80	0.59
2207	(4) 5-Year	2.02	93.40	94.23	0.68	0.80
2207	(4) 10-Year	1.57	93.40	94.16	0.65	0.90
2207	(4) 25-Year	2.25	93.40	94.26	0.70	1.02
2207	(4) 100-Year	2.86	93.40	94.38	0.69	2.20
2188	(2) 2-Year	5.00	93.37	94.47	0.96	0.58
2188	(2) 5-Year	6.32	93.37	94.56	1.03	0.54
2188	(2) 10-Year	7.24	93.37	94.62	1.07	0.53
2188	(2) 25-Year	8.38	93.37	94.69	1.11	0.54
2188	(2) 100-Year	10.81	93.37	94.83	1.20	0.63
2188	(4) 2-Year	4.78	93.37	94.45	0.95	0.59
2188	(4) 5-Year	2.33	93.37	94.20	0.77	0.79
2188	(4) 10-Year	1.78	93.37	94.13	0.71	0.89
2188	(4) 25-Year	2.60	93.37	94.24	0.79	1.01
2188	(4) 100-Year	3.29	93.37	94.36	0.77	2.19
2163	(2) 2-Year	5.00	93.34	94.44	0.95	0.58
2163	(2) 5-Year	6.32	93.34	94.53	1.02	0.53
2163	(2) 10-Year	7.24	93.34	94.59	1.06	0.52
2163	(2) 25-Year	8.38	93.34	94.66	1.10	0.53
2163	(2) 100-Year	10.81	93.34	94.80	1.18	0.62
2163	(4) 2-Year	4.78	93.34	94.42	0.94	0.58
2163	(4) 5-Year	2.33	93.34	94.17	0.77	0.78
2163	(4) 10-Year	1.78	93.34	94.10	0.71	0.88
2163	(4) 25-Year	2.60	93.34	94.20	0.79	1.00
2163	(4) 100-Year	3.29	93.34	94.33	0.75	2.18
2141	(2) 2-Year	5.00	93.31	94.41	0.95	0.57
2141	(2) 5-Year	6.32	93.31	94.50	1.01	0.52

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2141	(2) 10-Year	7.24	93.31	94.56	1.05	0.51
2141	(2) 25-Year	8.38	93.31	94.63	1.10	0.53
2141	(2) 100-Year	10.81	93.31	94.77	1.18	0.62
2141	(4) 2-Year	4.78	93.31	94.39	0.94	0.57
2141	(4) 5-Year	2.33	93.31	94.14	0.76	0.78
2141	(4) 10-Year	1.78	93.31	94.07	0.71	0.87
2141	(4) 25-Year	2.60	93.31	94.17	0.78	0.99
2141	(4) 100-Year	3.29	93.31	94.31	0.74	2.17
2121	(2) 2-Year	5.00	93.28	94.38	0.94	0.56
2121	(2) 5-Year	6.32	93.28	94.48	1.01	0.52
2121	(2) 10-Year	7.24	93.28	94.54	1.05	0.51
2121	(2) 25-Year	8.38	93.28	94.61	1.09	0.52
2121	(2) 100-Year	10.81	93.28	94.74	1.18	0.61
2121	(4) 2-Year	4.78	93.28	94.36	0.93	0.57
2121	(4) 5-Year	2.33	93.28	94.12	0.76	0.77
2121	(4) 10-Year	1.78	93.28	94.04	0.70	0.86
2121	(4) 25-Year	2.60	93.28	94.15	0.78	0.99
2121	(4) 100-Year	3.29	93.28	94.30	0.72	2.17
2101	(2) 2-Year	5.00	93.26	94.35	0.95	0.56
2101	(2) 5-Year	6.32	93.26	94.45	1.02	0.51
2101	(2) 10-Year	7.24	93.26	94.51	1.06	0.50
2101	(2) 25-Year	8.38	93.26	94.58	1.10	0.52
2101	(2) 100-Year	10.81	93.26	94.72	1.19	0.61
2101	(4) 2-Year	4.78	93.26	94.33	0.95	0.56
2101	(4) 5-Year	2.33	93.26	94.09	0.77	0.76
2101	(4) 10-Year	1.78	93.26	94.01	0.72	0.86
2101	(4) 25-Year	2.60	93.26	94.12	0.79	0.98
2101	(4) 100-Year	3.29	93.26	94.28	0.71	2.16
2080	(2) 2-Year	5.00	93.24	94.32	0.97	0.55
2080	(2) 5-Year	6.32	93.24	94.42	1.04	0.51
2080	(2) 10-Year	7.24	93.24	94.48	1.08	0.50
2080	(2) 25-Year	8.38	93.24	94.55	1.12	0.51
2080	(2) 100-Year	10.81	93.24	94.69	1.20	0.60
2080	(4) 2-Year	4.78	93.24	94.30	0.97	0.56
2080	(4) 5-Year	2.33	93.24	94.06	0.80	0.75
2080	(4) 10-Year	1.78	93.24	93.98	0.75	0.85
2080	(4) 25-Year	2.60	93.24	94.09	0.81	0.97
2080	(4) 100-Year	3.29	93.24	94.26	0.71	2.15
2059	(2) 2-Year	5.00	93.21	94.29	0.98	0.55
2059	(2) 5-Year	6.32	93.21	94.39	1.04	0.50
2059	(2) 10-Year	7.24	93.21	94.45	1.08	0.49
2059	(2) 25-Year	8.38	93.21	94.52	1.12	0.51
2059	(2) 100-Year	10.81	93.21	94.66	1.20	0.60
2059	(4) 2-Year	4.78	93.21	94.27	0.97	0.55
2059	(4) 5-Year	2.33	93.21	94.02	0.80	0.75
2059	(4) 10-Year	1.78	93.21	93.95	0.76	0.84
2059	(4) 25-Year	2.60	93.21	94.06	0.81	0.97
2059	(4) 100-Year	3.29	93.21	94.25	0.70	2.14

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
2038	(2) 2-Year	5.00	93.18	94.27	0.96	0.54
2038	(2) 5-Year	6.32	93.18	94.36	1.03	0.50
2038	(2) 10-Year	7.24	93.18	94.43	1.07	0.49
2038	(2) 25-Year	8.38	93.18	94.50	1.11	0.50
2038	(2) 100-Year	10.81	93.18	94.63	1.19	0.59
2038	(4) 2-Year	4.78	93.18	94.25	0.96	0.55
2038	(4) 5-Year	2.33	93.18	94.00	0.80	0.74
2038	(4) 10-Year	1.78	93.18	93.92	0.76	0.83
2038	(4) 25-Year	2.60	93.18	94.03	0.80	0.96
2038	(4) 100-Year	3.29	93.18	94.23	0.67	2.13
2017	(2) 2-Year	5.00	93.17	94.26	0.98	0.54
2017	(2) 5-Year	6.32	93.17	94.35	1.05	0.49
2017	(2) 10-Year	7.24	93.17	94.41	1.09	0.49
2017	(2) 25-Year	8.38	93.17	94.48	1.13	0.50
2017	(2) 100-Year	10.81	93.17	94.62	1.21	0.59
2017	(4) 2-Year	4.78	93.17	94.23	0.98	0.54
2017	(4) 5-Year	2.33	93.17	93.98	0.81	0.74
2017	(4) 10-Year	1.78	93.17	93.90	0.78	0.83
2017	(4) 25-Year	2.60	93.17	94.02	0.82	0.96
2017	(4) 100-Year	3.29	93.17	94.23	0.68	2.13
2003	(2) 2-Year	5.00	93.16	94.25	0.99	0.54
2003	(2) 5-Year	6.32	93.16	94.34	1.06	0.49
2003	(2) 10-Year	7.24	93.16	94.40	1.10	0.48
2003	(2) 25-Year	8.38	93.16	94.47	1.14	0.50
2003	(2) 100-Year	10.81	93.16	94.61	1.22	0.59
2003	(4) 2-Year	4.78	93.16	94.22	0.98	0.54
2003	(4) 5-Year	2.33	93.16	93.97	0.83	0.74
2003	(4) 10-Year	1.78	93.16	93.88	0.81	0.83
2003	(4) 25-Year	2.60	93.16	94.01	0.83	0.95
2003	(4) 100-Year	3.29	93.16	94.22	0.68	2.13
1982	(2) 2-Year	5.00	93.12	94.22	0.95	0.53
1982	(2) 5-Year	6.32	93.12	94.31	1.02	0.49
1982	(2) 10-Year	7.24	93.12	94.38	1.06	0.48
1982	(2) 25-Year	8.38	93.12	94.45	1.10	0.50
1982	(2) 100-Year	10.81	93.12	94.58	1.18	0.59
1982	(4) 2-Year	4.78	93.12	94.20	0.95	0.54
1982	(4) 5-Year	2.33	93.12	93.94	0.79	0.73
1982	(4) 10-Year	1.78	93.12	93.85	0.78	0.82
1982	(4) 25-Year	2.60	93.12	93.98	0.79	0.95
1982	(4) 100-Year	3.29	93.12	94.21	0.63	2.12
1961	(2) 2-Year	5.00	93.08	94.19	0.92	0.52
1961	(2) 5-Year	6.32	93.08	94.29	0.99	0.48
1961	(2) 10-Year	7.24	93.08	94.35	1.03	0.47
1961	(2) 25-Year	8.38	93.08	94.42	1.08	0.49
1961	(2) 100-Year	10.81	93.08	94.56	1.16	0.58
1961	(4) 2-Year	4.78	93.08	94.17	0.92	0.53
1961	(4) 5-Year	2.33	93.08	93.91	0.77	0.72

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1961	(4) 10-Year	1.78	93.08	93.82	0.76	0.81
1961	(4) 25-Year	2.60	93.08	93.96	0.76	0.94
1961	(4) 100-Year	3.29	93.08	94.20	0.60	2.11
1940	(2) 2-Year	5.00	93.04	94.17	0.90	0.52
1940	(2) 5-Year	6.32	93.04	94.27	0.97	0.48
1940	(2) 10-Year	7.24	93.04	94.33	1.01	0.47
1940	(2) 25-Year	8.38	93.04	94.40	1.05	0.48
1940	(2) 100-Year	10.81	93.04	94.54	1.13	0.58
1940	(4) 2-Year	4.78	93.04	94.15	0.89	0.52
1940	(4) 5-Year	2.33	93.04	93.89	0.74	0.71
1940	(4) 10-Year	1.78	93.04	93.78	0.74	0.81
1940	(4) 25-Year	2.60	93.04	93.93	0.73	0.93
1940	(4) 100-Year	3.29	93.04	94.19	0.57	2.10
1919	(2) 2-Year	5.00	93.01	94.15	0.87	0.51
1919	(2) 5-Year	6.32	93.01	94.24	0.94	0.47
1919	(2) 10-Year	7.24	93.01	94.31	0.98	0.46
1919	(2) 25-Year	8.38	93.01	94.38	1.03	0.48
1919	(2) 100-Year	10.81	93.01	94.51	1.11	0.57
1919	(4) 2-Year	4.78	93.01	94.13	0.87	0.52
1919	(4) 5-Year	2.33	93.01	93.86	0.72	0.71
1919	(4) 10-Year	1.78	93.01	93.75	0.73	0.80
1919	(4) 25-Year	2.60	93.01	93.91	0.71	0.93
1919	(4) 100-Year	3.29	93.01	94.18	0.54	2.09
1898	(2) 2-Year	5.00	92.97	94.13	0.84	0.51
1898	(2) 5-Year	6.32	92.97	94.22	0.91	0.46
1898	(2) 10-Year	7.24	92.97	94.29	0.95	0.46
1898	(2) 25-Year	8.38	92.97	94.36	1.00	0.47
1898	(2) 100-Year	10.81	92.97	94.49	1.09	0.57
1898	(4) 2-Year	4.78	92.97	94.11	0.84	0.51
1898	(4) 5-Year	2.33	92.97	93.84	0.69	0.70
1898	(4) 10-Year	1.78	92.97	93.73	0.71	0.79
1898	(4) 25-Year	2.60	92.97	93.90	0.68	0.92
1898	(4) 100-Year	3.29	92.97	94.18	0.51	2.08
1877	(2) 2-Year	5.00	92.93	94.11	0.81	0.50
1877	(2) 5-Year	6.32	92.93	94.21	0.88	0.46
1877	(2) 10-Year	7.24	92.93	94.27	0.92	0.45
1877	(2) 25-Year	8.38	92.93	94.34	0.97	0.47
1877	(2) 100-Year	10.81	92.93	94.47	1.06	0.56
1877	(4) 2-Year	4.78	92.93	94.09	0.81	0.50
1877	(4) 5-Year	2.33	92.93	93.82	0.65	0.69
1877	(4) 10-Year	1.78	92.93	93.70	0.68	0.78
1877	(4) 25-Year	2.60	92.93	93.88	0.64	0.91
1877	(4) 100-Year	3.29	92.93	94.17	0.48	2.07
1857	(2) 2-Year	5.00	92.89	94.10	0.78	0.49
1857	(2) 5-Year	6.32	92.89	94.19	0.86	0.45
1857	(2) 10-Year	7.24	92.89	94.25	0.90	0.44
1857	(2) 25-Year	8.38	92.89	94.32	0.95	0.46

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1857	(2) 100-Year	10.81	92.89	94.45	1.04	0.55
1857	(4) 2-Year	4.78	92.89	94.07	0.78	0.50
1857	(4) 5-Year	2.33	92.89	93.81	0.62	0.68
1857	(4) 10-Year	1.78	92.89	93.68	0.65	0.78
1857	(4) 25-Year	2.60	92.89	93.87	0.62	0.90
1857	(4) 100-Year	3.29	92.89	94.17	0.46	2.06
1837	(2) 2-Year	5.00	92.86	94.08	0.75	0.48
1837	(2) 5-Year	6.32	92.86	94.17	0.83	0.44
1837	(2) 10-Year	7.24	92.86	94.23	0.87	0.44
1837	(2) 25-Year	8.38	92.86	94.30	0.92	0.46
1837	(2) 100-Year	10.81	92.86	94.44	1.01	0.55
1837	(4) 2-Year	4.78	92.86	94.06	0.75	0.49
1837	(4) 5-Year	2.33	92.86	93.80	0.59	0.67
1837	(4) 10-Year	1.78	92.86	93.66	0.63	0.77
1837	(4) 25-Year	2.60	92.86	93.85	0.59	0.89
1837	(4) 100-Year	3.29	92.86	94.16	0.44	2.04
1817	(2) 2-Year	5.00	92.81	94.07	0.72	0.48
1817	(2) 5-Year	6.32	92.81	94.16	0.80	0.44
1817	(2) 10-Year	7.24	92.81	94.22	0.85	0.43
1817	(2) 25-Year	8.38	92.81	94.29	0.90	0.45
1817	(2) 100-Year	10.81	92.81	94.42	0.99	0.54
1817	(4) 2-Year	4.78	92.81	94.04	0.72	0.48
1817	(4) 5-Year	2.33	92.81	93.78	0.56	0.66
1817	(4) 10-Year	1.78	92.81	93.64	0.59	0.76
1817	(4) 25-Year	2.60	92.81	93.84	0.56	0.88
1817	(4) 100-Year	3.29	92.81	94.16	0.42	2.03
1797	(2) 2-Year	5.00	92.77	94.06	0.69	0.47
1797	(2) 5-Year	6.32	92.77	94.15	0.77	0.43
1797	(2) 10-Year	7.24	92.77	94.21	0.82	0.42
1797	(2) 25-Year	8.38	92.77	94.27	0.87	0.44
1797	(2) 100-Year	10.81	92.77	94.41	0.96	0.54
1797	(4) 2-Year	4.78	92.77	94.03	0.69	0.47
1797	(4) 5-Year	2.33	92.77	93.77	0.53	0.65
1797	(4) 10-Year	1.78	92.77	93.63	0.55	0.75
1797	(4) 25-Year	2.60	92.77	93.84	0.53	0.87
1797	(4) 100-Year	3.29	92.77	94.16	0.40	2.02
1777	(2) 2-Year	5.00	92.73	94.05	0.65	0.46
1777	(2) 5-Year	6.32	92.73	94.14	0.73	0.42
1777	(2) 10-Year	7.24	92.73	94.20	0.78	0.42
1777	(2) 25-Year	8.38	92.73	94.26	0.83	0.44
1777	(2) 100-Year	10.81	92.73	94.39	0.93	0.53
1777	(4) 2-Year	4.78	92.73	94.02	0.65	0.47
1777	(4) 5-Year	2.33	92.73	93.77	0.49	0.64
1777	(4) 10-Year	1.78	92.73	93.62	0.51	0.74
1777	(4) 25-Year	2.60	92.73	93.83	0.49	0.86
1777	(4) 100-Year	3.29	92.73	94.15	0.37	2.00
1757	(2) 2-Year	5.00	92.69	94.04	0.63	0.45

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1757	(2) 5-Year	6.32	92.69	94.13	0.71	0.42
1757	(2) 10-Year	7.24	92.69	94.18	0.76	0.41
1757	(2) 25-Year	8.38	92.69	94.25	0.81	0.43
1757	(2) 100-Year	10.81	92.69	94.38	0.90	0.53
1757	(4) 2-Year	4.78	92.69	94.02	0.63	0.46
1757	(4) 5-Year	2.33	92.69	93.76	0.47	0.63
1757	(4) 10-Year	1.78	92.69	93.61	0.48	0.73
1757	(4) 25-Year	2.60	92.69	93.82	0.47	0.85
1757	(4) 100-Year	3.29	92.69	94.15	0.36	1.99
1736	(2) 2-Year	5.00	92.66	94.04	0.60	0.44
1736	(2) 5-Year	6.32	92.66	94.12	0.68	0.41
1736	(2) 10-Year	7.24	92.66	94.18	0.73	0.40
1736	(2) 25-Year	8.38	92.66	94.24	0.78	0.42
1736	(2) 100-Year	10.81	92.66	94.37	0.88	0.52
1736	(4) 2-Year	4.78	92.66	94.01	0.60	0.45
1736	(4) 5-Year	2.33	92.66	93.75	0.44	0.62
1736	(4) 10-Year	1.78	92.66	93.60	0.45	0.71
1736	(4) 25-Year	2.60	92.66	93.82	0.44	0.84
1736	(4) 100-Year	3.29	92.66	94.15	0.34	1.97
1715	(2) 2-Year	5.00	92.62	94.03	0.57	0.43
1715	(2) 5-Year	6.32	92.62	94.11	0.65	0.40
1715	(2) 10-Year	7.24	92.62	94.17	0.69	0.39
1715	(2) 25-Year	8.38	92.62	94.23	0.75	0.42
1715	(2) 100-Year	10.81	92.62	94.36	0.84	0.51
1715	(4) 2-Year	4.78	92.62	94.00	0.57	0.44
1715	(4) 5-Year	2.33	92.62	93.75	0.41	0.60
1715	(4) 10-Year	1.78	92.62	93.59	0.42	0.70
1715	(4) 25-Year	2.60	92.62	93.81	0.41	0.82
1715	(4) 100-Year	3.29	92.62	94.15	0.32	1.95
1694	(2) 2-Year	5.00	92.58	94.03	0.55	0.42
1694	(2) 5-Year	6.32	92.58	94.11	0.63	0.39
1694	(2) 10-Year	7.24	92.58	94.16	0.67	0.39
1694	(2) 25-Year	8.38	92.58	94.22	0.73	0.41
1694	(2) 100-Year	10.81	92.58	94.35	0.82	0.51
1694	(4) 2-Year	4.78	92.58	94.00	0.55	0.43
1694	(4) 5-Year	2.33	92.58	93.75	0.39	0.59
1694	(4) 10-Year	1.78	92.58	93.59	0.40	0.69
1694	(4) 25-Year	2.60	92.58	93.81	0.39	0.81
1694	(4) 100-Year	3.29	92.58	94.15	0.31	1.94
1673	(2) 2-Year	5.00	92.53	94.02	0.52	0.41
1673	(2) 5-Year	6.32	92.53	94.10	0.60	0.38
1673	(2) 10-Year	7.24	92.53	94.15	0.65	0.38
1673	(2) 25-Year	8.38	92.53	94.22	0.70	0.40
1673	(2) 100-Year	10.81	92.53	94.34	0.80	0.50
1673	(4) 2-Year	4.78	92.53	93.99	0.52	0.42
1673	(4) 5-Year	2.33	92.53	93.74	0.37	0.57
1673	(4) 10-Year	1.78	92.53	93.58	0.37	0.67
1673	(4) 25-Year	2.60	92.53	93.81	0.37	0.79

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1673	(4) 100-Year	3.29	92.53	94.14	0.30	1.92
1653	(2) 2-Year	5.00	92.50	94.02	0.50	0.40
1653	(2) 5-Year	6.32	92.50	94.09	0.58	0.37
1653	(2) 10-Year	7.24	92.50	94.15	0.62	0.37
1653	(2) 25-Year	8.38	92.50	94.21	0.68	0.39
1653	(2) 100-Year	10.81	92.50	94.33	0.77	0.49
1653	(4) 2-Year	4.78	92.50	93.99	0.50	0.41
1653	(4) 5-Year	2.33	92.50	93.74	0.35	0.56
1653	(4) 10-Year	1.78	92.50	93.58	0.35	0.66
1653	(4) 25-Year	2.60	92.50	93.80	0.35	0.78
1653	(4) 100-Year	3.29	92.50	94.14	0.28	1.90
1632	(2) 2-Year	5.00	92.46	94.01	0.49	0.39
1632	(2) 5-Year	6.32	92.46	94.09	0.56	0.36
1632	(2) 10-Year	7.24	92.46	94.14	0.61	0.36
1632	(2) 25-Year	8.38	92.46	94.20	0.66	0.38
1632	(2) 100-Year	10.81	92.46	94.33	0.76	0.49
1632	(4) 2-Year	4.78	92.46	93.98	0.48	0.39
1632	(4) 5-Year	2.33	92.46	93.74	0.33	0.54
1632	(4) 10-Year	1.78	92.46	93.58	0.33	0.64
1632	(4) 25-Year	2.60	92.46	93.80	0.33	0.76
1632	(4) 100-Year	3.29	92.46	94.14	0.28	1.88
1615	(2) 2-Year	5.00	92.43	94.01	0.46	0.38
1615	(2) 5-Year	6.32	92.43	94.09	0.53	0.35
1615	(2) 10-Year	7.24	92.43	94.14	0.57	0.35
1615	(2) 25-Year	8.38	92.43	94.20	0.62	0.38
1615	(2) 100-Year	10.81	92.43	94.32	0.71	0.48
1615	(4) 2-Year	4.78	92.43	93.98	0.46	0.38
1615	(4) 5-Year	2.33	92.43	93.73	0.32	0.53
1615	(4) 10-Year	1.78	92.43	93.58	0.32	0.63
1615	(4) 25-Year	2.60	92.43	93.80	0.32	0.75
1615	(4) 100-Year	3.29	92.43	94.14	0.26	1.86
1555	(2) 2-Year	5.00	92.35	94.00	0.42	0.34
1555	(2) 5-Year	6.32	92.35	94.08	0.48	0.32
1555	(2) 10-Year	7.24	92.35	94.13	0.53	0.32
1555	(2) 25-Year	8.38	92.35	94.19	0.57	0.35
1555	(2) 100-Year	10.81	92.35	94.31	0.66	0.45
1555	(4) 2-Year	4.78	92.35	93.97	0.41	0.35
1555	(4) 5-Year	2.33	92.35	93.73	0.28	0.47
1555	(4) 10-Year	1.78	92.35	93.57	0.29	0.57
1555	(4) 25-Year	2.60	92.35	93.79	0.29	0.69
1555	(4) 100-Year	3.29	92.35	94.14	0.24	1.80
1488	(2) 2-Year	5.00	92.28	93.99	0.38	0.30
1488	(2) 5-Year	6.32	92.28	94.07	0.45	0.28
1488	(2) 10-Year	7.24	92.28	94.12	0.49	0.29
1488	(2) 25-Year	8.38	92.28	94.17	0.53	0.32
1488	(2) 100-Year	10.81	92.28	94.29	0.62	0.43
1488	(4) 2-Year	4.78	92.28	93.96	0.38	0.30

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1488	(4) 5-Year	2.33	92.28	93.73	0.25	0.41
1488	(4) 10-Year	1.78	92.28	93.56	0.25	0.50
1488	(4) 25-Year	2.60	92.28	93.79	0.26	0.63
1488	(4) 100-Year	3.29	92.28	94.14	0.22	1.71
1416	(2) 2-Year	5.00	92.20	93.99	0.36	0.25
1416	(2) 5-Year	6.32	92.20	94.06	0.42	0.24
1416	(2) 10-Year	7.24	92.20	94.11	0.46	0.25
1416	(2) 25-Year	8.38	92.20	94.16	0.51	0.28
1416	(2) 100-Year	10.81	92.20	94.28	0.59	0.40
1416	(4) 2-Year	4.78	92.20	93.96	0.35	0.25
1416	(4) 5-Year	2.33	92.20	93.72	0.22	0.33
1416	(4) 10-Year	1.78	92.20	93.56	0.22	0.43
1416	(4) 25-Year	2.60	92.20	93.79	0.23	0.55
1416	(4) 100-Year	3.29	92.20	94.14	0.20	1.63
1400	(2) 2-Year	5.00	92.17	93.99	0.34	0.23
1400	(2) 5-Year	6.32	92.17	94.06	0.41	0.23
1400	(2) 10-Year	7.24	92.17	94.10	0.45	0.23
1400	(2) 25-Year	8.38	92.17	94.16	0.49	0.27
1400	(2) 100-Year	10.81	92.17	94.27	0.58	0.39
1400	(4) 2-Year	4.78	92.17	93.96	0.34	0.23
1400	(4) 5-Year	2.33	92.17	93.72	0.21	0.30
1400	(4) 10-Year	1.78	92.17	93.56	0.20	0.40
1400	(4) 25-Year	2.60	92.17	93.79	0.22	0.52
1400	(4) 100-Year	3.29	92.17	94.13	0.20	1.60
1364	(2) 2-Year	5.00	91.63	93.98	0.23	0.20
1364	(2) 5-Year	6.32	91.63	94.05	0.28	0.20
1364	(2) 10-Year	7.24	91.63	94.10	0.31	0.21
1364	(2) 25-Year	8.38	91.63	94.16	0.35	0.25
1364	(2) 100-Year	10.81	91.63	94.27	0.42	0.37
1364	(4) 2-Year	4.78	91.63	93.95	0.23	0.20
1364	(4) 5-Year	2.33	91.63	93.72	0.13	0.25
1364	(4) 10-Year	1.78	91.63	93.56	0.12	0.34
1364	(4) 25-Year	2.60	91.63	93.79	0.14	0.47
1364	(4) 100-Year	3.29	91.63	94.13	0.14	1.54
1340	(2) 2-Year	5.79	91.60	93.97	0.53	0.18
1340	(2) 5-Year	7.32	91.60	94.03	0.65	0.18
1340	(2) 10-Year	8.33	91.60	94.07	0.72	0.20
1340	(2) 25-Year	9.65	91.60	94.12	0.82	0.23
1340	(2) 100-Year	11.62	91.60	94.22	0.95	0.36
1340	(4) 2-Year	5.26	91.60	93.94	0.48	0.18
1340	(4) 5-Year	2.44	91.60	93.72	0.25	0.21
1340	(4) 10-Year	1.86	91.60	93.56	0.21	0.30
1340	(4) 25-Year	2.71	91.60	93.78	0.27	0.44
1340	(4) 100-Year	3.43	91.60	94.13	0.29	1.51
1339		Culvert				
1312	(2) 2-Year	6.08	92.47	93.94	0.85	0.17

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1312	(2) 5-Year	7.69	92.47	93.98	1.04	0.17
1312	(2) 10-Year	8.76	92.47	94.01	1.16	0.19
1312	(2) 25-Year	10.15	92.47	94.04	1.32	0.23
1312	(2) 100-Year	12.20	92.47	94.12	1.51	0.35
1312	(4) 2-Year	5.46	92.47	93.91	0.77	0.17
1312	(4) 5-Year	2.47	92.47	93.71	0.41	0.19
1312	(4) 10-Year	1.87	92.47	93.55	0.35	0.27
1312	(4) 25-Year	2.73	92.47	93.77	0.43	0.42
1312	(4) 100-Year	3.44	92.47	94.12	0.42	1.49
1302	(2) 2-Year	6.08	92.57	93.91	1.03	0.17
1302	(2) 5-Year	7.69	92.57	93.97	1.12	0.17
1302	(2) 10-Year	8.76	92.57	94.00	1.18	0.19
1302	(2) 25-Year	10.15	92.57	94.04	1.26	0.23
1302	(2) 100-Year	12.20	92.57	94.14	1.07	0.35
1302	(4) 2-Year	5.46	92.57	93.89	0.98	0.17
1302	(4) 5-Year	2.47	92.57	93.68	0.77	0.18
1302	(4) 10-Year	1.87	92.57	93.51	0.84	0.26
1302	(4) 25-Year	2.73	92.57	93.75	0.72	0.41
1302	(4) 100-Year	3.44	92.57	94.12	0.33	1.48
1268	(2) 2-Year	6.08	92.47	93.87	0.59	0.15
1268	(2) 5-Year	7.69	92.47	93.93	0.62	0.16
1268	(2) 10-Year	8.76	92.47	93.96	0.64	0.18
1268	(2) 25-Year	10.15	92.47	94.00	0.65	0.22
1268	(2) 100-Year	12.20	92.47	94.14	0.45	0.34
1268	(4) 2-Year	5.46	92.47	93.84	0.57	0.15
1268	(4) 5-Year	2.47	92.47	93.59	0.68	0.17
1268	(4) 10-Year	1.87	92.47	93.44	0.79	0.25
1268	(4) 25-Year	2.73	92.47	93.69	0.51	0.40
1268	(4) 100-Year	3.44	92.47	94.12	0.13	1.44
1212	(2) 2-Year	6.08	92.36	93.78	0.84	0.13
1212	(2) 5-Year	7.69	92.36	93.85	0.85	0.14
1212	(2) 10-Year	8.76	92.36	93.89	0.85	0.15
1212	(2) 25-Year	10.15	92.36	93.94	0.80	0.19
1212	(2) 100-Year	12.20	92.36	94.11	0.56	0.30
1212	(4) 2-Year	5.46	92.36	93.74	0.83	0.13
1212	(4) 5-Year	2.47	92.36	93.41	0.89	0.15
1212	(4) 10-Year	1.87	92.36	93.32	0.81	0.23
1212	(4) 25-Year	2.73	92.36	93.58	0.66	0.37
1212	(4) 100-Year	3.44	92.36	94.12	0.15	1.33
1169	(2) 2-Year	6.08	92.30	93.70	0.85	0.12
1169	(2) 5-Year	7.69	92.30	93.76	0.91	0.13
1169	(2) 10-Year	8.76	92.30	93.80	0.94	0.14
1169	(2) 25-Year	10.15	92.30	93.87	0.94	0.18
1169	(2) 100-Year	12.20	92.30	94.08	0.72	0.29
1169	(4) 2-Year	5.46	92.30	93.67	0.83	0.12
1169	(4) 5-Year	2.47	92.30	93.32	0.73	0.13
1169	(4) 10-Year	1.87	92.30	93.26	0.62	0.22
1169	(4) 25-Year	2.73	92.30	93.54	0.53	0.35

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
1169	(4) 100-Year	3.44	92.30	94.12	0.17	1.26
1091	(2) 2-Year	6.08	92.15	93.57	0.82	0.09
1091	(2) 5-Year	7.69	92.15	93.64	0.85	0.10
1091	(2) 10-Year	8.76	92.15	93.69	0.84	0.12
1091	(2) 25-Year	10.15	92.15	93.78	0.78	0.15
1091	(2) 100-Year	12.20	92.15	94.04	0.57	0.25
1091	(4) 2-Year	5.46	92.15	93.54	0.82	0.09
1091	(4) 5-Year	2.47	92.15	93.19	0.70	0.10
1091	(4) 10-Year	1.87	92.15	93.17	0.55	0.18
1091	(4) 25-Year	2.73	92.15	93.50	0.45	0.30
1091	(4) 100-Year	3.44	92.15	94.12	0.13	1.11
1002	(2) 2-Year	6.08	92.06	93.38	1.02	0.07
1002	(2) 5-Year	7.69	92.06	93.49	0.94	0.07
1002	(2) 10-Year	8.76	92.06	93.59	0.82	0.09
1002	(2) 25-Year	10.15	92.06	93.71	0.70	0.12
1002	(2) 100-Year	12.20	92.06	94.03	0.41	0.20
1002	(4) 2-Year	5.46	92.06	93.33	1.01	0.06
1002	(4) 5-Year	2.47	92.06	93.01	0.83	0.07
1002	(4) 10-Year	1.87	92.06	93.09	0.55	0.13
1002	(4) 25-Year	2.73	92.06	93.47	0.36	0.24
1002	(4) 100-Year	3.44	92.06	94.12	0.09	0.88
961	(2) 2-Year	6.08	91.96	93.28	0.83	0.05
961	(2) 5-Year	7.69	91.96	93.41	0.78	0.06
961	(2) 10-Year	8.76	91.96	93.52	0.65	0.07
961	(2) 25-Year	10.15	91.96	93.69	0.43	0.10
961	(2) 100-Year	12.20	91.96	94.02	0.24	0.17
961	(4) 2-Year	5.46	91.96	93.23	0.82	0.05
961	(4) 5-Year	2.47	91.96	92.97	0.62	0.06
961	(4) 10-Year	1.87	91.96	93.06	0.40	0.11
961	(4) 25-Year	2.73	91.96	93.46	0.25	0.21
961	(4) 100-Year	3.44	91.96	94.12	0.05	0.72
910	(2) 2-Year	6.08	91.93	93.22	0.70	0.04
910	(2) 5-Year	7.69	91.93	93.38	0.63	0.04
910	(2) 10-Year	8.76	91.93	93.49	0.52	0.05
910	(2) 25-Year	10.15	91.93	93.68	0.34	0.06
910	(2) 100-Year	12.20	91.93	94.02	0.20	0.10
910	(4) 2-Year	5.46	91.93	93.17	0.73	0.03
910	(4) 5-Year	2.47	91.93	92.91	0.64	0.03
910	(4) 10-Year	1.87	91.93	93.05	0.35	0.07
910	(4) 25-Year	2.73	91.93	93.46	0.18	0.14
910	(4) 100-Year	3.44	91.93	94.12	0.05	0.44
840	(2) 2-Year	6.08	91.86	93.18	0.41	0.00
840	(2) 5-Year	7.69	91.86	93.35	0.34	0.00
840	(2) 10-Year	8.76	91.86	93.48	0.30	0.00
840	(2) 25-Year	10.15	91.86	93.67	0.26	0.00
840	(2) 100-Year	12.20	91.86	94.02	0.18	0.00
840	(4) 2-Year	5.46	91.86	93.11	0.44	0.00

Table C-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Floodplain) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Channel Travel Time (h)
840	(4) 5-Year	2.47	91.86	92.83	0.47	0.00
840	(4) 10-Year	1.87	91.86	93.03	0.19	0.00
840	(4) 25-Year	2.73	91.86	93.45	0.10	0.00
840	(4) 100-Year	3.44	91.86	94.12	0.04	0.00

[(1)] All channel infrastructure included in the HEC-RAS model for floodplain analysis.
For Scenario 2 (the Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River) and
Scenario 4 (the Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain).

ATTACHMENT D

HEC- RAS Results for Van Gaal Drain Reach 2
Proposed Conditions (Riparian Storage Analysis)

JFSA Water Resources and Environmental Consultants

Table D-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2554	(1) 25 mm	0.72	94.75	95.41	0.41	6.92
2554	(1) 2-Year	1.95	94.75	95.71	0.57	14.46
2554	(1) 5-Year	3.20	94.75	95.91	0.67	19.95
2554	(1) 10-Year	4.11	94.75	96.03	0.72	24.07
2554	(1) 25-Year	5.28	94.75	96.14	0.78	29.88
2554	(1) 100-Year	7.27	94.75	96.26	0.84	42.02
2478	(1) 25 mm	0.72	94.75	95.34	0.43	6.79
2478	(1) 2-Year	1.95	94.75	95.63	0.62	14.21
2478	(1) 5-Year	3.20	94.75	95.82	0.75	19.61
2478	(1) 10-Year	4.11	94.75	95.93	0.83	23.66
2478	(1) 25-Year	5.28	94.75	96.03	0.93	29.33
2478	(1) 100-Year	7.27	94.75	96.13	1.10	40.96
2427.58*	(1) 25 mm	0.72	94.68	95.29	0.45	6.71
2427.58*	(1) 2-Year	1.95	94.68	95.57	0.65	14.06
2427.58*	(1) 5-Year	3.20	94.68	95.75	0.77	19.40
2427.58*	(1) 10-Year	4.11	94.68	95.85	0.86	23.40
2427.58*	(1) 25-Year	5.28	94.68	95.95	0.95	28.99
2427.58*	(1) 100-Year	7.27	94.68	96.04	1.10	40.37
2377.17*	(1) 25 mm	0.72	94.61	95.23	0.47	6.63
2377.17*	(1) 2-Year	1.95	94.61	95.50	0.68	13.91
2377.17*	(1) 5-Year	3.20	94.61	95.68	0.82	19.20
2377.17*	(1) 10-Year	4.11	94.61	95.77	0.90	23.14
2377.17*	(1) 25-Year	5.28	94.61	95.86	0.99	28.61
2377.17*	(1) 100-Year	7.27	94.61	95.95	1.07	39.64
2326.76*	(1) 25 mm	0.72	94.54	95.15	0.52	6.56
2326.76*	(1) 2-Year	1.95	94.54	95.41	0.75	13.77
2326.76*	(1) 5-Year	3.20	94.54	95.57	0.90	19.01
2326.76*	(1) 10-Year	4.11	94.54	95.67	0.97	22.88
2326.76*	(1) 25-Year	5.28	94.54	95.77	1.02	28.17
2326.76*	(1) 100-Year	7.27	94.54	95.88	0.95	38.69
2276.35*	(1) 25 mm	0.72	94.48	94.86	1.40	6.51
2276.35*	(1) 2-Year	1.95	94.48	95.05	1.72	13.68
2276.35*	(1) 5-Year	3.20	94.48	95.18	1.92	18.88
2276.35*	(1) 10-Year	4.11	94.48	95.25	2.02	22.70
2276.35*	(1) 25-Year	5.28	94.48	95.34	2.14	27.87
2276.35*	(1) 100-Year	7.27	94.48	95.50	2.13	38.05
2261	(1) 25 mm	0.72	93.57	94.17	0.86	6.49
2261	(1) 2-Year	1.95	93.57	94.39	1.57	13.65
2261	(1) 5-Year	3.20	93.57	94.51	2.15	18.84
2261	(1) 10-Year	4.11	93.57	94.55	2.62	22.65
2261	(1) 25-Year	5.28	93.57	94.68	2.87	27.82
2261	(1) 100-Year	7.27	93.57	94.89	3.13	37.96
2258	(1) 25 mm	0.72	93.52	94.14	0.47	6.44
2258	(1) 2-Year	1.95	93.52	94.41	0.61	13.54
2258	(1) 5-Year	3.20	93.52	94.60	0.72	18.68

Table D-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2258	(1) 10-Year	4.11	93.52	94.70	0.79	22.47
2258	(1) 25-Year	5.28	93.52	94.82	0.87	27.60
2258	(1) 100-Year	7.27	93.52	94.99	0.99	37.69
2256	(1) 25 mm	0.72	93.49	94.12	0.46	6.40
2256	(1) 2-Year	1.95	93.49	94.39	0.63	13.42
2256	(1) 5-Year	3.20	93.49	94.58	0.75	18.50
2256	(1) 10-Year	4.11	93.49	94.68	0.81	22.25
2256	(1) 25-Year	5.28	93.49	94.80	0.88	27.34
2256	(1) 100-Year	7.27	93.49	94.97	0.97	37.35
2254	(1) 25 mm	0.72	93.46	94.11	0.44	6.35
2254	(1) 2-Year	1.95	93.46	94.38	0.62	13.32
2254	(1) 5-Year	3.20	93.46	94.56	0.73	18.35
2254	(1) 10-Year	4.11	93.46	94.67	0.80	22.06
2254	(1) 25-Year	5.28	93.46	94.78	0.87	27.10
2254	(1) 100-Year	7.27	93.46	94.96	0.96	37.05
2235	(1) 25 mm	0.72	93.44	94.10	0.43	6.30
2235	(1) 2-Year	1.95	93.44	94.36	0.60	13.21
2235	(1) 5-Year	3.20	93.44	94.55	0.72	18.20
2235	(1) 10-Year	4.11	93.44	94.65	0.79	21.87
2235	(1) 25-Year	5.28	93.44	94.77	0.86	26.87
2235	(1) 100-Year	7.27	93.44	94.94	0.95	36.74
2207	(1) 25 mm	0.72	93.40	94.08	0.40	6.23
2207	(1) 2-Year	1.95	93.40	94.35	0.59	13.06
2207	(1) 5-Year	3.20	93.40	94.53	0.71	17.96
2207	(1) 10-Year	4.11	93.40	94.63	0.78	21.58
2207	(1) 25-Year	5.28	93.40	94.74	0.85	26.51
2207	(1) 100-Year	7.27	93.40	94.92	0.94	36.28
2188	(1) 25 mm	1.16	93.37	94.05	0.65	6.18
2188	(1) 2-Year	2.80	93.37	94.31	0.84	12.95
2188	(1) 5-Year	4.41	93.37	94.49	0.98	17.80
2188	(1) 10-Year	5.53	93.37	94.59	1.05	21.38
2188	(1) 25-Year	6.96	93.37	94.70	1.13	26.27
2188	(1) 100-Year	9.54	93.37	94.88	1.25	35.98
2163	(1) 25 mm	1.16	93.34	94.02	0.65	6.12
2163	(1) 2-Year	2.80	93.34	94.28	0.84	12.81
2163	(1) 5-Year	4.41	93.34	94.46	0.97	17.60
2163	(1) 10-Year	5.53	93.34	94.56	1.04	21.13
2163	(1) 25-Year	6.96	93.34	94.67	1.12	25.97
2163	(1) 100-Year	9.54	93.34	94.84	1.23	35.59
2141	(1) 25 mm	1.16	93.31	93.99	0.65	6.06
2141	(1) 2-Year	2.80	93.31	94.25	0.84	12.69
2141	(1) 5-Year	4.41	93.31	94.43	0.97	17.42
2141	(1) 10-Year	5.53	93.31	94.53	1.04	20.91
2141	(1) 25-Year	6.96	93.31	94.64	1.11	25.69
2141	(1) 100-Year	9.54	93.31	94.81	1.23	35.23

Table D-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) (1)

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2121	(1) 25 mm	1.16	93.28	93.97	0.64	6.00
2121	(1) 2-Year	2.80	93.28	94.23	0.83	12.58
2121	(1) 5-Year	4.41	93.28	94.41	0.96	17.25
2121	(1) 10-Year	5.53	93.28	94.51	1.03	20.70
2121	(1) 25-Year	6.96	93.28	94.62	1.11	25.44
2121	(1) 100-Year	9.54	93.28	94.79	1.23	34.91
2101	(1) 25 mm	1.16	93.26	93.94	0.66	5.95
2101	(1) 2-Year	2.80	93.26	94.20	0.84	12.46
2101	(1) 5-Year	4.41	93.26	94.38	0.98	17.08
2101	(1) 10-Year	5.53	93.26	94.48	1.05	20.49
2101	(1) 25-Year	6.96	93.26	94.59	1.12	25.18
2101	(1) 100-Year	9.54	93.26	94.76	1.24	34.58
2080	(1) 25 mm	1.16	93.24	93.90	0.68	5.89
2080	(1) 2-Year	2.80	93.24	94.17	0.86	12.34
2080	(1) 5-Year	4.41	93.24	94.35	0.99	16.91
2080	(1) 10-Year	5.53	93.24	94.45	1.06	20.28
2080	(1) 25-Year	6.96	93.24	94.56	1.14	24.93
2080	(1) 100-Year	9.54	93.24	94.73	1.26	34.25
2059	(1) 25 mm	1.16	93.21	93.87	0.70	5.84
2059	(1) 2-Year	2.80	93.21	94.14	0.86	12.23
2059	(1) 5-Year	4.41	93.21	94.32	0.99	16.73
2059	(1) 10-Year	5.53	93.21	94.42	1.06	20.06
2059	(1) 25-Year	6.96	93.21	94.53	1.14	24.66
2059	(1) 100-Year	9.54	93.21	94.69	1.27	33.91
2038	(1) 25 mm	1.16	93.18	93.84	0.70	5.80
2038	(1) 2-Year	2.80	93.18	94.12	0.84	12.12
2038	(1) 5-Year	4.41	93.18	94.29	0.98	16.58
2038	(1) 10-Year	5.53	93.18	94.39	1.05	19.87
2038	(1) 25-Year	6.96	93.18	94.50	1.13	24.44
2038	(1) 100-Year	9.54	93.18	94.67	1.25	33.62
2017	(1) 25 mm	1.16	93.17	93.82	0.71	5.78
2017	(1) 2-Year	2.80	93.17	94.10	0.86	12.08
2017	(1) 5-Year	4.41	93.17	94.28	1.00	16.52
2017	(1) 10-Year	5.53	93.17	94.38	1.07	19.79
2017	(1) 25-Year	6.96	93.17	94.49	1.15	24.33
2017	(1) 100-Year	9.54	93.17	94.65	1.28	33.49
2003	(1) 25 mm	1.16	93.16	93.81	0.73	5.76
2003	(1) 2-Year	2.80	93.16	94.09	0.86	12.04
2003	(1) 5-Year	4.41	93.16	94.27	1.01	16.46
2003	(1) 10-Year	5.53	93.16	94.37	1.08	19.72
2003	(1) 25-Year	6.96	93.16	94.48	1.16	24.24
2003	(1) 100-Year	9.54	93.16	94.64	1.28	33.37
1982	(1) 25 mm	1.16	93.12	93.77	0.71	5.71
1982	(1) 2-Year	2.80	93.12	94.07	0.83	11.93

Table D-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1982	(1) 5-Year	4.41	93.12	94.24	0.97	16.29
1982	(1) 10-Year	5.53	93.12	94.34	1.04	19.51
1982	(1) 25-Year	6.96	93.12	94.45	1.12	23.99
1982	(1) 100-Year	9.54	93.12	94.61	1.25	33.04
1961	(1) 25 mm	1.16	93.08	93.74	0.70	5.66
1961	(1) 2-Year	2.80	93.08	94.04	0.80	11.81
1961	(1) 5-Year	4.41	93.08	94.22	0.95	16.11
1961	(1) 10-Year	5.53	93.08	94.32	1.02	19.29
1961	(1) 25-Year	6.96	93.08	94.42	1.10	23.73
1961	(1) 100-Year	9.54	93.08	94.59	1.24	32.71
1940	(1) 25 mm	1.16	93.04	93.70	0.68	5.61
1940	(1) 2-Year	2.80	93.04	94.02	0.78	11.68
1940	(1) 5-Year	4.41	93.04	94.19	0.92	15.93
1940	(1) 10-Year	5.53	93.04	94.29	1.00	19.07
1940	(1) 25-Year	6.96	93.04	94.40	1.08	23.46
1940	(1) 100-Year	9.54	93.04	94.56	1.22	32.38
1919	(1) 25 mm	1.16	93.01	93.67	0.69	5.56
1919	(1) 2-Year	2.80	93.01	94.00	0.76	11.55
1919	(1) 5-Year	4.41	93.01	94.17	0.90	15.74
1919	(1) 10-Year	5.53	93.01	94.27	0.98	18.84
1919	(1) 25-Year	6.96	93.01	94.38	1.06	23.19
1919	(1) 100-Year	9.54	93.01	94.53	1.20	32.04
1898	(1) 25 mm	1.16	92.97	93.64	0.67	5.51
1898	(1) 2-Year	2.80	92.97	93.99	0.73	11.42
1898	(1) 5-Year	4.41	92.97	94.15	0.87	15.55
1898	(1) 10-Year	5.53	92.97	94.25	0.95	18.61
1898	(1) 25-Year	6.96	92.97	94.35	1.04	22.91
1898	(1) 100-Year	9.54	92.97	94.51	1.18	31.69
1877	(1) 25 mm	1.16	92.93	93.61	0.64	5.45
1877	(1) 2-Year	2.80	92.93	93.97	0.70	11.28
1877	(1) 5-Year	4.41	92.93	94.13	0.84	15.34
1877	(1) 10-Year	5.53	92.93	94.23	0.92	18.36
1877	(1) 25-Year	6.96	92.93	94.33	1.01	22.62
1877	(1) 100-Year	9.54	92.93	94.49	1.16	31.33
1857	(1) 25 mm	1.16	92.89	93.59	0.62	5.39
1857	(1) 2-Year	2.80	92.89	93.96	0.68	11.13
1857	(1) 5-Year	4.41	92.89	94.12	0.82	15.13
1857	(1) 10-Year	5.53	92.89	94.21	0.90	18.11
1857	(1) 25-Year	6.96	92.89	94.31	0.99	22.33
1857	(1) 100-Year	9.54	92.89	94.46	1.14	30.97
1837	(1) 25 mm	1.16	92.86	93.56	0.60	5.33
1837	(1) 2-Year	2.80	92.86	93.94	0.65	10.98
1837	(1) 5-Year	4.41	92.86	94.10	0.80	14.91
1837	(1) 10-Year	5.53	92.86	94.19	0.88	17.86
1837	(1) 25-Year	6.96	92.86	94.30	0.97	22.02

Table D-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1837	(1) 100-Year	9.54	92.86	94.44	1.12	30.60
1817	(1) 25 mm	1.16	92.81	93.54	0.56	5.27
1817	(1) 2-Year	2.80	92.81	93.93	0.62	10.81
1817	(1) 5-Year	4.41	92.81	94.09	0.77	14.68
1817	(1) 10-Year	5.53	92.81	94.18	0.85	17.59
1817	(1) 25-Year	6.96	92.81	94.28	0.94	21.71
1817	(1) 100-Year	9.54	92.81	94.42	1.10	30.23
1797	(1) 25 mm	1.16	92.77	93.53	0.53	5.20
1797	(1) 2-Year	2.80	92.77	93.92	0.59	10.64
1797	(1) 5-Year	4.41	92.77	94.08	0.74	14.44
1797	(1) 10-Year	5.53	92.77	94.17	0.82	17.31
1797	(1) 25-Year	6.96	92.77	94.26	0.92	21.39
1797	(1) 100-Year	9.54	92.77	94.41	1.07	29.85
1777	(1) 25 mm	1.16	92.73	93.52	0.49	5.13
1777	(1) 2-Year	2.80	92.73	93.91	0.56	10.45
1777	(1) 5-Year	4.41	92.73	94.07	0.70	14.19
1777	(1) 10-Year	5.53	92.73	94.15	0.78	17.02
1777	(1) 25-Year	6.96	92.73	94.25	0.88	21.06
1777	(1) 100-Year	9.54	92.73	94.39	1.04	29.45
1757	(1) 25 mm	1.16	92.69	93.51	0.46	5.04
1757	(1) 2-Year	2.80	92.69	93.91	0.53	10.24
1757	(1) 5-Year	4.41	92.69	94.06	0.68	13.92
1757	(1) 10-Year	5.53	92.69	94.14	0.76	16.72
1757	(1) 25-Year	6.96	92.69	94.24	0.86	20.72
1757	(1) 100-Year	9.54	92.69	94.37	1.02	29.05
1736	(1) 25 mm	1.16	92.66	93.50	0.44	4.96
1736	(1) 2-Year	2.80	92.66	93.90	0.51	10.03
1736	(1) 5-Year	4.41	92.66	94.05	0.65	13.65
1736	(1) 10-Year	5.53	92.66	94.13	0.74	16.40
1736	(1) 25-Year	6.96	92.66	94.23	0.83	20.36
1736	(1) 100-Year	9.54	92.66	94.36	1.00	28.63
1715	(1) 25 mm	1.16	92.62	93.49	0.40	4.86
1715	(1) 2-Year	2.80	92.62	93.90	0.48	9.80
1715	(1) 5-Year	4.41	92.62	94.04	0.62	13.35
1715	(1) 10-Year	5.53	92.62	94.13	0.70	16.07
1715	(1) 25-Year	6.96	92.62	94.22	0.80	20.00
1715	(1) 100-Year	9.54	92.62	94.35	0.96	28.20
1694	(1) 25 mm	1.16	92.58	93.48	0.38	4.76
1694	(1) 2-Year	2.80	92.58	93.89	0.46	9.56
1694	(1) 5-Year	4.41	92.58	94.03	0.60	13.05
1694	(1) 10-Year	5.53	92.58	94.12	0.68	15.73
1694	(1) 25-Year	6.96	92.58	94.21	0.78	19.61
1694	(1) 100-Year	9.54	92.58	94.33	0.94	27.76
1673	(1) 25 mm	1.16	92.53	93.48	0.35	4.64

Table D-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) (1)

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1673	(1) 2-Year	2.80	92.53	93.89	0.44	9.30
1673	(1) 5-Year	4.41	92.53	94.03	0.57	12.73
1673	(1) 10-Year	5.53	92.53	94.11	0.66	15.38
1673	(1) 25-Year	6.96	92.53	94.20	0.75	19.22
1673	(1) 100-Year	9.54	92.53	94.32	0.92	27.31
1653	(1) 25 mm	1.16	92.50	93.48	0.33	4.52
1653	(1) 2-Year	2.80	92.50	93.88	0.42	9.02
1653	(1) 5-Year	4.41	92.50	94.02	0.55	12.39
1653	(1) 10-Year	5.53	92.50	94.10	0.64	15.01
1653	(1) 25-Year	6.96	92.50	94.19	0.73	18.81
1653	(1) 100-Year	9.54	92.50	94.31	0.89	26.85
1632	(1) 25 mm	1.16	92.46	93.47	0.31	4.39
1632	(1) 2-Year	2.80	92.46	93.88	0.40	8.74
1632	(1) 5-Year	4.41	92.46	94.02	0.54	12.05
1632	(1) 10-Year	5.53	92.46	94.10	0.62	14.63
1632	(1) 25-Year	6.96	92.46	94.18	0.72	18.39
1632	(1) 100-Year	9.54	92.46	94.30	0.88	26.37
1615	(1) 25 mm	1.16	92.43	93.47	0.31	4.28
1615	(1) 2-Year	2.80	92.43	93.88	0.39	8.49
1615	(1) 5-Year	4.41	92.43	94.02	0.52	11.75
1615	(1) 10-Year	5.53	92.43	94.09	0.60	14.30
1615	(1) 25-Year	6.96	92.43	94.18	0.69	18.04
1615	(1) 100-Year	9.54	92.43	94.29	0.85	25.97
1555	(1) 25 mm	1.16	92.35	93.46	0.28	3.83
1555	(1) 2-Year	2.80	92.35	93.87	0.36	7.55
1555	(1) 5-Year	4.41	92.35	94.00	0.48	10.64
1555	(1) 10-Year	5.53	92.35	94.08	0.56	13.09
1555	(1) 25-Year	6.96	92.35	94.16	0.64	16.71
1555	(1) 100-Year	9.54	92.35	94.27	0.80	24.49
1488	(1) 25 mm	1.16	92.28	93.46	0.25	3.24
1488	(1) 2-Year	2.80	92.28	93.87	0.33	6.40
1488	(1) 5-Year	4.41	92.28	93.99	0.44	9.30
1488	(1) 10-Year	5.53	92.28	94.07	0.52	11.64
1488	(1) 25-Year	6.96	92.28	94.14	0.61	15.14
1488	(1) 100-Year	9.54	92.28	94.24	0.76	22.76
1416	(1) 25 mm	1.16	92.20	93.45	0.21	2.59
1416	(1) 2-Year	2.80	92.20	93.86	0.30	5.23
1416	(1) 5-Year	4.41	92.20	93.99	0.42	7.96
1416	(1) 10-Year	5.53	92.20	94.06	0.49	10.20
1416	(1) 25-Year	6.96	92.20	94.13	0.58	13.61
1416	(1) 100-Year	9.54	92.20	94.22	0.73	21.09
1400	(1) 25 mm	1.16	92.17	93.45	0.20	2.31
1400	(1) 2-Year	2.80	92.17	93.86	0.29	4.76
1400	(1) 5-Year	4.41	92.17	93.98	0.40	7.42
1400	(1) 10-Year	5.53	92.17	94.05	0.48	9.63

Table D-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1400	(1) 25-Year	6.96	92.17	94.12	0.56	12.99
1400	(1) 100-Year	9.54	92.17	94.22	0.72	20.42
1364	(1) 25 mm	1.16	91.63	93.45	0.09	1.80
1364	(1) 2-Year	2.80	91.63	93.86	0.15	3.97
1364	(1) 5-Year	4.41	91.63	93.98	0.22	6.53
1364	(1) 10-Year	5.53	91.63	94.05	0.27	8.69
1364	(1) 25-Year	6.96	91.63	94.12	0.32	12.00
1364	(1) 100-Year	9.54	91.63	94.22	0.41	19.35
1340	(1) 25 mm	1.53	91.60	93.45	0.11	1.42
1340	(1) 2-Year	3.64	91.60	93.86	0.20	3.39
1340	(1) 5-Year	5.57	91.60	93.98	0.28	5.90
1340	(1) 10-Year	6.92	91.60	94.05	0.33	8.02
1340	(1) 25-Year	8.58	91.60	94.12	0.39	11.29
1340	(1) 100-Year	11.43	91.60	94.21	0.50	18.60
1312	(1) 25 mm	1.53	92.47	93.45	0.29	1.10
1312	(1) 2-Year	3.87	92.47	93.84	0.51	2.91
1312	(1) 5-Year	5.93	92.47	93.96	0.71	5.36
1312	(1) 10-Year	7.38	92.47	94.01	0.84	7.45
1312	(1) 25-Year	9.17	92.47	94.07	1.01	10.69
1312	(1) 100-Year	12.20	92.47	94.13	1.29	17.96
1302	(1) 25 mm	1.53	92.57	93.41	0.83	1.07
1302	(1) 2-Year	3.87	92.57	93.81	0.88	2.84
1302	(1) 5-Year	5.93	92.57	93.92	1.05	5.28
1302	(1) 10-Year	7.38	92.57	93.98	1.15	7.35
1302	(1) 25-Year	9.17	92.57	94.03	1.27	10.58
1302	(1) 100-Year	12.20	92.57	94.11	1.41	17.81
1268	(1) 25 mm	1.53	92.47	93.33	0.79	1.00
1268	(1) 2-Year	3.87	92.47	93.75	0.56	2.62
1268	(1) 5-Year	5.93	92.47	93.88	0.57	4.91
1268	(1) 10-Year	7.38	92.47	93.94	0.60	6.88
1268	(1) 25-Year	9.17	92.47	94.01	0.62	9.89
1268	(1) 100-Year	12.20	92.47	94.10	0.60	16.64
1212	(1) 25 mm	1.53	92.36	93.18	0.86	0.90
1212	(1) 2-Year	3.87	92.36	93.61	0.89	2.25
1212	(1) 5-Year	5.93	92.36	93.77	0.91	4.21
1212	(1) 10-Year	7.38	92.36	93.85	0.93	5.90
1212	(1) 25-Year	9.17	92.36	93.92	0.94	8.43
1212	(1) 100-Year	12.20	92.36	94.04	0.90	14.29
1169	(1) 25 mm	1.53	92.30	93.10	0.69	0.81
1169	(1) 2-Year	3.87	92.30	93.53	0.78	2.02
1169	(1) 5-Year	5.93	92.30	93.70	0.86	3.67
1169	(1) 10-Year	7.38	92.30	93.77	0.92	5.11
1169	(1) 25-Year	9.17	92.30	93.84	0.98	7.33
1169	(1) 100-Year	12.20	92.30	93.94	1.09	12.64

Table D-1: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1091	(1) 25 mm	1.53	92.15	92.98	0.65	0.63
1091	(1) 2-Year	3.87	92.15	93.40	0.75	1.62
1091	(1) 5-Year	5.93	92.15	93.57	0.83	2.89
1091	(1) 10-Year	7.38	92.15	93.64	0.87	4.03
1091	(1) 25-Year	9.17	92.15	93.71	0.92	5.91
1091	(1) 100-Year	12.20	92.15	93.82	0.97	10.62
1002	(1) 25 mm	1.53	92.06	92.81	0.76	0.44
1002	(1) 2-Year	3.87	92.06	93.21	0.91	1.21
1002	(1) 5-Year	5.93	92.06	93.37	1.02	2.15
1002	(1) 10-Year	7.38	92.06	93.46	1.04	2.97
1002	(1) 25-Year	9.17	92.06	93.55	1.03	4.45
1002	(1) 100-Year	12.20	92.06	93.69	1.02	8.49
961	(1) 25 mm	1.53	91.96	92.77	0.54	0.34
961	(1) 2-Year	3.87	91.96	93.13	0.72	1.01
961	(1) 5-Year	5.93	91.96	93.28	0.80	1.86
961	(1) 10-Year	7.38	91.96	93.37	0.83	2.56
961	(1) 25-Year	9.17	91.96	93.47	0.82	3.85
961	(1) 100-Year	12.20	91.96	93.64	0.64	7.42
910	(1) 25 mm	1.53	91.93	92.72	0.57	0.20
910	(1) 2-Year	3.87	91.93	93.06	0.74	0.62
910	(1) 5-Year	5.93	91.93	93.20	0.81	1.16
910	(1) 10-Year	7.38	91.93	93.30	0.82	1.62
910	(1) 25-Year	9.17	91.93	93.41	0.83	2.38
910	(1) 100-Year	12.20	91.93	93.60	0.68	4.32
840	(1) 25 mm	1.53	91.86	92.65	0.50	
840	(1) 2-Year	3.87	91.86	92.98	0.47	
840	(1) 5-Year	5.93	91.86	93.16	0.42	
840	(1) 10-Year	7.38	91.86	93.26	0.41	
840	(1) 25-Year	9.17	91.86	93.38	0.41	
840	(1) 100-Year	12.20	91.86	93.58	0.39	

[(1)] All channel infrastructure removed from the HEC-RAS model for riparian storage analysis.
For Scenario 1 (the Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River).

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2554	(2) 2-Year	4.13	94.75	96.03	0.72	19.57
2554	(2) 5-Year	5.24	94.75	96.13	0.78	23.71
2554	(2) 10-Year	6.00	94.75	96.18	0.81	26.69
2554	(2) 25-Year	6.94	94.75	96.23	0.83	31.36
2554	(2) 100-Year	8.32	94.75	96.28	0.82	41.22
2554	(4) 2-Year	3.97	94.75	96.01	0.71	18.31
2554	(4) 5-Year	2.02	94.75	95.72	0.58	11.05
2554	(4) 10-Year	1.57	94.75	95.63	0.54	9.11
2554	(4) 25-Year	2.25	94.75	95.76	0.60	15.27
2554	(4) 100-Year	2.86	94.75	95.86	0.65	44.48
2478	(2) 2-Year	4.13	94.75	95.93	0.83	19.16
2478	(2) 5-Year	5.24	94.75	96.02	0.93	23.18
2478	(2) 10-Year	6.00	94.75	96.06	1.00	26.04
2478	(2) 25-Year	6.94	94.75	96.10	1.09	30.49
2478	(2) 100-Year	8.32	94.75	96.14	1.17	40.01
2478	(4) 2-Year	3.97	94.75	95.91	0.82	17.92
2478	(4) 5-Year	2.02	94.75	95.64	0.63	10.80
2478	(4) 10-Year	1.57	94.75	95.55	0.58	8.89
2478	(4) 25-Year	2.25	94.75	95.68	0.66	15.00
2478	(4) 100-Year	2.86	94.75	95.77	0.71	44.17
2427.58*	(2) 2-Year	4.13	94.68	95.85	0.86	18.91
2427.58*	(2) 5-Year	5.24	94.68	95.94	0.95	22.85
2427.58*	(2) 10-Year	6.00	94.68	95.97	1.03	25.66
2427.58*	(2) 25-Year	6.94	94.68	96.01	1.09	30.01
2427.58*	(2) 100-Year	8.32	94.68	96.05	1.16	39.37
2427.58*	(4) 2-Year	3.97	94.68	95.84	0.85	17.67
2427.58*	(4) 5-Year	2.02	94.68	95.58	0.65	10.65
2427.58*	(4) 10-Year	1.57	94.68	95.49	0.60	8.76
2427.58*	(4) 25-Year	2.25	94.68	95.62	0.68	14.83
2427.58*	(4) 100-Year	2.86	94.68	95.71	0.74	43.97
2377.17*	(2) 2-Year	4.13	94.61	95.77	0.90	18.65
2377.17*	(2) 5-Year	5.24	94.61	95.85	0.97	22.49
2377.17*	(2) 10-Year	6.00	94.61	95.89	1.02	25.20
2377.17*	(2) 25-Year	6.94	94.61	95.92	1.05	29.43
2377.17*	(2) 100-Year	8.32	94.61	95.95	1.13	38.64
2377.17*	(4) 2-Year	3.97	94.61	95.76	0.88	17.42
2377.17*	(4) 5-Year	2.02	94.61	95.51	0.69	10.49
2377.17*	(4) 10-Year	1.57	94.61	95.43	0.63	8.63
2377.17*	(4) 25-Year	2.25	94.61	95.54	0.72	14.67
2377.17*	(4) 100-Year	2.86	94.61	95.63	0.78	43.78
2326.76*	(2) 2-Year	4.13	94.54	95.67	0.96	18.38
2326.76*	(2) 5-Year	5.24	94.54	95.76	0.98	22.08
2326.76*	(2) 10-Year	6.00	94.54	95.81	0.94	24.63
2326.76*	(2) 25-Year	6.94	94.54	95.85	0.89	28.66
2326.76*	(2) 100-Year	8.32	94.54	95.88	0.95	37.72
2326.76*	(4) 2-Year	3.97	94.54	95.66	0.95	17.17
2326.76*	(4) 5-Year	2.02	94.54	95.42	0.76	10.36
2326.76*	(4) 10-Year	1.57	94.54	95.34	0.69	8.51

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2326.76*	(4) 25-Year	2.25	94.54	95.45	0.79	14.52
2326.76*	(4) 100-Year	2.86	94.54	95.53	0.86	43.61
2276.35*	(2) 2-Year	4.13	94.48	95.25	2.02	18.20
2276.35*	(2) 5-Year	5.24	94.48	95.33	2.16	21.79
2276.35*	(2) 10-Year	6.00	94.48	95.38	2.23	24.23
2276.35*	(2) 25-Year	6.94	94.48	95.49	2.09	28.12
2276.35*	(2) 100-Year	8.32	94.48	95.64	1.66	36.98
2276.35*	(4) 2-Year	3.97	94.48	95.24	2.02	17.00
2276.35*	(4) 5-Year	2.02	94.48	95.06	1.73	10.26
2276.35*	(4) 10-Year	1.57	94.48	95.00	1.64	8.43
2276.35*	(4) 25-Year	2.25	94.48	95.08	1.78	14.42
2276.35*	(4) 100-Year	2.86	94.48	95.14	1.87	43.49
2261	(2) 2-Year	4.13	93.57	94.53	2.64	18.16
2261	(2) 5-Year	5.24	93.57	94.66	2.81	21.74
2261	(2) 10-Year	6.00	93.57	94.74	2.92	24.17
2261	(2) 25-Year	6.94	93.57	94.84	3.02	28.04
2261	(2) 100-Year	8.32	93.57	94.95	3.19	36.83
2261	(4) 2-Year	3.97	93.57	94.51	2.61	16.96
2261	(4) 5-Year	2.02	93.57	94.30	1.87	10.23
2261	(4) 10-Year	1.57	93.57	94.26	1.56	8.41
2261	(4) 25-Year	2.25	93.57	94.31	2.05	14.39
2261	(4) 100-Year	2.86	93.57	94.36	2.40	43.46
2258	(2) 2-Year	4.13	93.52	94.59	0.80	18.00
2258	(2) 5-Year	5.24	93.52	94.68	0.87	21.55
2258	(2) 10-Year	6.00	93.52	94.74	0.91	23.97
2258	(2) 25-Year	6.94	93.52	94.81	0.96	27.82
2258	(2) 100-Year	8.32	93.52	94.93	1.00	36.57
2258	(4) 2-Year	3.97	93.52	94.57	0.79	16.81
2258	(4) 5-Year	2.02	93.52	94.33	0.68	10.14
2258	(4) 10-Year	1.57	93.52	94.26	0.65	8.33
2258	(4) 25-Year	2.25	93.52	94.36	0.70	14.29
2258	(4) 100-Year	2.86	93.52	94.44	0.73	43.34
2256	(2) 2-Year	4.13	93.49	94.56	0.83	17.83
2256	(2) 5-Year	5.24	93.49	94.66	0.88	21.34
2256	(2) 10-Year	6.00	93.49	94.72	0.92	23.73
2256	(2) 25-Year	6.94	93.49	94.79	0.95	27.55
2256	(2) 100-Year	8.32	93.49	94.91	0.96	36.26
2256	(4) 2-Year	3.97	93.49	94.55	0.82	16.64
2256	(4) 5-Year	2.02	93.49	94.30	0.69	10.04
2256	(4) 10-Year	1.57	93.49	94.23	0.66	8.25
2256	(4) 25-Year	2.25	93.49	94.34	0.71	14.19
2256	(4) 100-Year	2.86	93.49	94.42	0.75	43.21
2254	(2) 2-Year	4.13	93.46	94.54	0.82	17.68
2254	(2) 5-Year	5.24	93.46	94.64	0.87	21.16
2254	(2) 10-Year	6.00	93.46	94.70	0.91	23.53
2254	(2) 25-Year	6.94	93.46	94.77	0.94	27.32
2254	(2) 100-Year	8.32	93.46	94.90	0.95	35.98

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2254	(4) 2-Year	3.97	93.46	94.53	0.81	16.50
2254	(4) 5-Year	2.02	93.46	94.28	0.69	9.96
2254	(4) 10-Year	1.57	93.46	94.21	0.65	8.19
2254	(4) 25-Year	2.25	93.46	94.31	0.70	14.10
2254	(4) 100-Year	2.86	93.46	94.40	0.74	43.10
2235	(2) 2-Year	4.13	93.44	94.53	0.80	17.54
2235	(2) 5-Year	5.24	93.44	94.62	0.86	20.98
2235	(2) 10-Year	6.00	93.44	94.68	0.89	23.32
2235	(2) 25-Year	6.94	93.44	94.75	0.93	27.09
2235	(2) 100-Year	8.32	93.44	94.88	0.93	35.69
2235	(4) 2-Year	3.97	93.44	94.51	0.80	16.36
2235	(4) 5-Year	2.02	93.44	94.26	0.68	9.88
2235	(4) 10-Year	1.57	93.44	94.19	0.64	8.12
2235	(4) 25-Year	2.25	93.44	94.29	0.70	14.01
2235	(4) 100-Year	2.86	93.44	94.38	0.73	42.99
2207	(2) 2-Year	4.13	93.40	94.50	0.80	17.32
2207	(2) 5-Year	5.24	93.40	94.60	0.86	20.70
2207	(2) 10-Year	6.00	93.40	94.66	0.89	23.01
2207	(2) 25-Year	6.94	93.40	94.73	0.93	26.74
2207	(2) 100-Year	8.32	93.40	94.86	0.93	35.27
2207	(4) 2-Year	3.97	93.40	94.48	0.80	16.15
2207	(4) 5-Year	2.02	93.40	94.23	0.68	9.76
2207	(4) 10-Year	1.57	93.40	94.16	0.65	8.02
2207	(4) 25-Year	2.25	93.40	94.26	0.70	13.88
2207	(4) 100-Year	2.86	93.40	94.35	0.73	42.83
2188	(2) 2-Year	5.00	93.37	94.47	0.96	17.17
2188	(2) 5-Year	6.32	93.37	94.56	1.03	20.52
2188	(2) 10-Year	7.24	93.37	94.62	1.07	22.81
2188	(2) 25-Year	8.38	93.37	94.69	1.12	26.51
2188	(2) 100-Year	10.81	93.37	94.82	1.21	34.99
2188	(4) 2-Year	4.78	93.37	94.45	0.95	16.01
2188	(4) 5-Year	2.33	93.37	94.20	0.77	9.68
2188	(4) 10-Year	1.78	93.37	94.13	0.71	7.96
2188	(4) 25-Year	2.60	93.37	94.24	0.79	13.79
2188	(4) 100-Year	3.29	93.37	94.33	0.82	42.72
2163	(2) 2-Year	5.00	93.34	94.44	0.95	16.98
2163	(2) 5-Year	6.32	93.34	94.53	1.02	20.29
2163	(2) 10-Year	7.24	93.34	94.59	1.06	22.54
2163	(2) 25-Year	8.38	93.34	94.66	1.11	26.21
2163	(2) 100-Year	10.81	93.34	94.79	1.20	34.62
2163	(4) 2-Year	4.78	93.34	94.42	0.94	15.83
2163	(4) 5-Year	2.33	93.34	94.17	0.77	9.57
2163	(4) 10-Year	1.78	93.34	94.10	0.71	7.87
2163	(4) 25-Year	2.60	93.34	94.20	0.79	13.67
2163	(4) 100-Year	3.29	93.34	94.30	0.81	42.58
2141	(2) 2-Year	5.00	93.31	94.41	0.95	16.81
2141	(2) 5-Year	6.32	93.31	94.50	1.02	20.07

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2141	(2) 10-Year	7.24	93.31	94.56	1.06	22.30
2141	(2) 25-Year	8.38	93.31	94.63	1.11	25.94
2141	(2) 100-Year	10.81	93.31	94.76	1.20	34.30
2141	(4) 2-Year	4.78	93.31	94.39	0.94	15.66
2141	(4) 5-Year	2.33	93.31	94.14	0.77	9.48
2141	(4) 10-Year	1.78	93.31	94.07	0.71	7.79
2141	(4) 25-Year	2.60	93.31	94.17	0.79	13.57
2141	(4) 100-Year	3.29	93.31	94.27	0.80	42.45
2121	(2) 2-Year	5.00	93.28	94.38	0.94	16.65
2121	(2) 5-Year	6.32	93.28	94.48	1.01	19.88
2121	(2) 10-Year	7.24	93.28	94.54	1.05	22.08
2121	(2) 25-Year	8.38	93.28	94.60	1.10	25.70
2121	(2) 100-Year	10.81	93.28	94.73	1.20	34.00
2121	(4) 2-Year	4.78	93.28	94.36	0.94	15.51
2121	(4) 5-Year	2.33	93.28	94.12	0.76	9.39
2121	(4) 10-Year	1.78	93.28	94.04	0.70	7.72
2121	(4) 25-Year	2.60	93.28	94.15	0.78	13.48
2121	(4) 100-Year	3.29	93.28	94.25	0.79	42.34
2101	(2) 2-Year	5.00	93.26	94.35	0.96	16.49
2101	(2) 5-Year	6.32	93.26	94.45	1.03	19.68
2101	(2) 10-Year	7.24	93.26	94.51	1.07	21.86
2101	(2) 25-Year	8.38	93.26	94.57	1.12	25.45
2101	(2) 100-Year	10.81	93.26	94.70	1.21	33.69
2101	(4) 2-Year	4.78	93.26	94.33	0.95	15.36
2101	(4) 5-Year	2.33	93.26	94.09	0.77	9.30
2101	(4) 10-Year	1.78	93.26	94.01	0.72	7.65
2101	(4) 25-Year	2.60	93.26	94.12	0.79	13.38
2101	(4) 100-Year	3.29	93.26	94.23	0.79	42.22
2080	(2) 2-Year	5.00	93.24	94.32	0.98	16.33
2080	(2) 5-Year	6.32	93.24	94.42	1.05	19.48
2080	(2) 10-Year	7.24	93.24	94.48	1.09	21.64
2080	(2) 25-Year	8.38	93.24	94.54	1.14	25.20
2080	(2) 100-Year	10.81	93.24	94.67	1.23	33.39
2080	(4) 2-Year	4.78	93.24	94.30	0.97	15.21
2080	(4) 5-Year	2.33	93.24	94.05	0.80	9.21
2080	(4) 10-Year	1.78	93.24	93.98	0.75	7.58
2080	(4) 25-Year	2.60	93.24	94.09	0.81	13.28
2080	(4) 100-Year	3.29	93.24	94.20	0.80	42.09
2059	(2) 2-Year	5.00	93.21	94.29	0.98	16.17
2059	(2) 5-Year	6.32	93.21	94.39	1.05	19.28
2059	(2) 10-Year	7.24	93.21	94.45	1.09	21.41
2059	(2) 25-Year	8.38	93.21	94.51	1.14	24.94
2059	(2) 100-Year	10.81	93.21	94.64	1.24	33.08
2059	(4) 2-Year	4.78	93.21	94.27	0.97	15.05
2059	(4) 5-Year	2.33	93.21	94.02	0.81	9.13
2059	(4) 10-Year	1.78	93.21	93.94	0.76	7.51
2059	(4) 25-Year	2.60	93.21	94.06	0.82	13.19
2059	(4) 100-Year	3.29	93.21	94.18	0.79	41.96

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
2038	(2) 2-Year	5.00	93.18	94.27	0.97	16.03
2038	(2) 5-Year	6.32	93.18	94.36	1.03	19.10
2038	(2) 10-Year	7.24	93.18	94.42	1.08	21.22
2038	(2) 25-Year	8.38	93.18	94.49	1.13	24.72
2038	(2) 100-Year	10.81	93.18	94.61	1.23	32.81
2038	(4) 2-Year	4.78	93.18	94.24	0.96	14.92
2038	(4) 5-Year	2.33	93.18	93.99	0.80	9.05
2038	(4) 10-Year	1.78	93.18	93.91	0.76	7.45
2038	(4) 25-Year	2.60	93.18	94.03	0.81	13.10
2038	(4) 100-Year	3.29	93.18	94.16	0.77	41.85
2017	(2) 2-Year	5.00	93.17	94.25	0.99	15.96
2017	(2) 5-Year	6.32	93.17	94.35	1.06	19.03
2017	(2) 10-Year	7.24	93.17	94.41	1.10	21.13
2017	(2) 25-Year	8.38	93.17	94.47	1.15	24.62
2017	(2) 100-Year	10.81	93.17	94.59	1.25	32.69
2017	(4) 2-Year	4.78	93.17	94.23	0.98	14.87
2017	(4) 5-Year	2.33	93.17	93.98	0.82	9.02
2017	(4) 10-Year	1.78	93.17	93.90	0.79	7.42
2017	(4) 25-Year	2.60	93.17	94.02	0.82	13.07
2017	(4) 100-Year	3.29	93.17	94.15	0.78	41.81
2003	(2) 2-Year	5.00	93.16	94.24	1.00	15.91
2003	(2) 5-Year	6.32	93.16	94.34	1.07	18.96
2003	(2) 10-Year	7.24	93.16	94.40	1.11	21.05
2003	(2) 25-Year	8.38	93.16	94.46	1.16	24.53
2003	(2) 100-Year	10.81	93.16	94.58	1.26	32.58
2003	(4) 2-Year	4.78	93.16	94.22	0.99	14.81
2003	(4) 5-Year	2.33	93.16	93.97	0.83	8.99
2003	(4) 10-Year	1.78	93.16	93.88	0.81	7.40
2003	(4) 25-Year	2.60	93.16	94.01	0.84	13.03
2003	(4) 100-Year	3.29	93.16	94.14	0.78	41.76
1982	(2) 2-Year	5.00	93.12	94.22	0.96	15.75
1982	(2) 5-Year	6.32	93.12	94.31	1.03	18.76
1982	(2) 10-Year	7.24	93.12	94.37	1.07	20.83
1982	(2) 25-Year	8.38	93.12	94.43	1.12	24.28
1982	(2) 100-Year	10.81	93.12	94.55	1.23	32.28
1982	(4) 2-Year	4.78	93.12	94.19	0.95	14.67
1982	(4) 5-Year	2.33	93.12	93.94	0.79	8.90
1982	(4) 10-Year	1.78	93.12	93.85	0.78	7.34
1982	(4) 25-Year	2.60	93.12	93.98	0.80	12.94
1982	(4) 100-Year	3.29	93.12	94.12	0.74	41.63
1961	(2) 2-Year	5.00	93.08	94.19	0.93	15.59
1961	(2) 5-Year	6.32	93.08	94.28	1.00	18.56
1961	(2) 10-Year	7.24	93.08	94.34	1.05	20.60
1961	(2) 25-Year	8.38	93.08	94.41	1.10	24.03
1961	(2) 100-Year	10.81	93.08	94.53	1.21	31.98
1961	(4) 2-Year	4.78	93.08	94.17	0.93	14.51
1961	(4) 5-Year	2.33	93.08	93.91	0.77	8.82

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1961	(4) 10-Year	1.78	93.08	93.81	0.77	7.27
1961	(4) 25-Year	2.60	93.08	93.95	0.77	12.84
1961	(4) 100-Year	3.29	93.08	94.11	0.71	41.50
1940	(2) 2-Year	5.00	93.04	94.17	0.90	15.42
1940	(2) 5-Year	6.32	93.04	94.26	0.97	18.35
1940	(2) 10-Year	7.24	93.04	94.32	1.02	20.37
1940	(2) 25-Year	8.38	93.04	94.38	1.07	23.77
1940	(2) 100-Year	10.81	93.04	94.50	1.19	31.67
1940	(4) 2-Year	4.78	93.04	94.14	0.90	14.35
1940	(4) 5-Year	2.33	93.04	93.88	0.74	8.72
1940	(4) 10-Year	1.78	93.04	93.78	0.75	7.20
1940	(4) 25-Year	2.60	93.04	93.93	0.74	12.74
1940	(4) 100-Year	3.29	93.04	94.09	0.68	41.36
1919	(2) 2-Year	5.00	93.01	94.15	0.88	15.24
1919	(2) 5-Year	6.32	93.01	94.24	0.95	18.14
1919	(2) 10-Year	7.24	93.01	94.30	1.00	20.13
1919	(2) 25-Year	8.38	93.01	94.36	1.05	23.50
1919	(2) 100-Year	10.81	93.01	94.47	1.17	31.35
1919	(4) 2-Year	4.78	93.01	94.12	0.88	14.18
1919	(4) 5-Year	2.33	93.01	93.86	0.72	8.63
1919	(4) 10-Year	1.78	93.01	93.75	0.74	7.13
1919	(4) 25-Year	2.60	93.01	93.91	0.72	12.63
1919	(4) 100-Year	3.29	93.01	94.08	0.65	41.21
1898	(2) 2-Year	5.00	92.97	94.13	0.85	15.06
1898	(2) 5-Year	6.32	92.97	94.22	0.92	17.91
1898	(2) 10-Year	7.24	92.97	94.27	0.97	19.89
1898	(2) 25-Year	8.38	92.97	94.34	1.03	23.23
1898	(2) 100-Year	10.81	92.97	94.45	1.15	31.03
1898	(4) 2-Year	4.78	92.97	94.10	0.85	14.01
1898	(4) 5-Year	2.33	92.97	93.84	0.69	8.53
1898	(4) 10-Year	1.78	92.97	93.72	0.72	7.06
1898	(4) 25-Year	2.60	92.97	93.89	0.68	12.52
1898	(4) 100-Year	3.29	92.97	94.07	0.62	41.05
1877	(2) 2-Year	5.00	92.93	94.11	0.82	14.86
1877	(2) 5-Year	6.32	92.93	94.20	0.89	17.68
1877	(2) 10-Year	7.24	92.93	94.25	0.94	19.63
1877	(2) 25-Year	8.38	92.93	94.32	1.00	22.95
1877	(2) 100-Year	10.81	92.93	94.43	1.12	30.70
1877	(4) 2-Year	4.78	92.93	94.08	0.81	13.82
1877	(4) 5-Year	2.33	92.93	93.82	0.66	8.43
1877	(4) 10-Year	1.78	92.93	93.70	0.69	6.99
1877	(4) 25-Year	2.60	92.93	93.87	0.65	12.41
1877	(4) 100-Year	3.29	92.93	94.06	0.58	40.88
1857	(2) 2-Year	5.00	92.89	94.09	0.79	14.66
1857	(2) 5-Year	6.32	92.89	94.18	0.87	17.44
1857	(2) 10-Year	7.24	92.89	94.24	0.92	19.37
1857	(2) 25-Year	8.38	92.89	94.30	0.98	22.66

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1857	(2) 100-Year	10.81	92.89	94.40	1.10	30.37
1857	(4) 2-Year	4.78	92.89	94.07	0.79	13.63
1857	(4) 5-Year	2.33	92.89	93.80	0.63	8.32
1857	(4) 10-Year	1.78	92.89	93.67	0.67	6.91
1857	(4) 25-Year	2.60	92.89	93.86	0.62	12.29
1857	(4) 100-Year	3.29	92.89	94.05	0.56	40.69
1837	(2) 2-Year	5.00	92.86	94.08	0.76	14.45
1837	(2) 5-Year	6.32	92.86	94.17	0.84	17.20
1837	(2) 10-Year	7.24	92.86	94.22	0.89	19.10
1837	(2) 25-Year	8.38	92.86	94.28	0.95	22.36
1837	(2) 100-Year	10.81	92.86	94.38	1.08	30.03
1837	(4) 2-Year	4.78	92.86	94.05	0.76	13.43
1837	(4) 5-Year	2.33	92.86	93.79	0.60	8.21
1837	(4) 10-Year	1.78	92.86	93.65	0.64	6.83
1837	(4) 25-Year	2.60	92.86	93.85	0.60	12.16
1837	(4) 100-Year	3.29	92.86	94.04	0.53	40.50
1817	(2) 2-Year	5.00	92.81	94.07	0.73	14.23
1817	(2) 5-Year	6.32	92.81	94.15	0.81	16.94
1817	(2) 10-Year	7.24	92.81	94.20	0.87	18.82
1817	(2) 25-Year	8.38	92.81	94.26	0.93	22.06
1817	(2) 100-Year	10.81	92.81	94.36	1.06	29.68
1817	(4) 2-Year	4.78	92.81	94.04	0.73	13.23
1817	(4) 5-Year	2.33	92.81	93.78	0.57	8.09
1817	(4) 10-Year	1.78	92.81	93.63	0.60	6.75
1817	(4) 25-Year	2.60	92.81	93.84	0.56	12.03
1817	(4) 100-Year	3.29	92.81	94.04	0.50	40.30
1797	(2) 2-Year	5.00	92.77	94.05	0.70	14.00
1797	(2) 5-Year	6.32	92.77	94.14	0.78	16.68
1797	(2) 10-Year	7.24	92.77	94.19	0.83	18.54
1797	(2) 25-Year	8.38	92.77	94.25	0.90	21.74
1797	(2) 100-Year	10.81	92.77	94.35	1.03	29.32
1797	(4) 2-Year	4.78	92.77	94.03	0.70	13.01
1797	(4) 5-Year	2.33	92.77	93.77	0.53	7.97
1797	(4) 10-Year	1.78	92.77	93.62	0.56	6.66
1797	(4) 25-Year	2.60	92.77	93.83	0.53	11.89
1797	(4) 100-Year	3.29	92.77	94.03	0.48	40.08
1777	(2) 2-Year	5.00	92.73	94.04	0.66	13.76
1777	(2) 5-Year	6.32	92.73	94.13	0.74	16.40
1777	(2) 10-Year	7.24	92.73	94.18	0.79	18.23
1777	(2) 25-Year	8.38	92.73	94.24	0.86	21.42
1777	(2) 100-Year	10.81	92.73	94.33	0.99	28.96
1777	(4) 2-Year	4.78	92.73	94.02	0.66	12.77
1777	(4) 5-Year	2.33	92.73	93.76	0.50	7.83
1777	(4) 10-Year	1.78	92.73	93.61	0.52	6.56
1777	(4) 25-Year	2.60	92.73	93.82	0.50	11.73
1777	(4) 100-Year	3.29	92.73	94.03	0.45	39.84
1757	(2) 2-Year	5.00	92.69	94.04	0.64	13.50

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1757	(2) 5-Year	6.32	92.69	94.12	0.72	16.10
1757	(2) 10-Year	7.24	92.69	94.17	0.77	17.92
1757	(2) 25-Year	8.38	92.69	94.22	0.83	21.08
1757	(2) 100-Year	10.81	92.69	94.31	0.97	28.58
1757	(4) 2-Year	4.78	92.69	94.01	0.63	12.53
1757	(4) 5-Year	2.33	92.69	93.75	0.47	7.69
1757	(4) 10-Year	1.78	92.69	93.60	0.49	6.46
1757	(4) 25-Year	2.60	92.69	93.81	0.47	11.57
1757	(4) 100-Year	3.29	92.69	94.02	0.43	39.59
1736	(2) 2-Year	5.00	92.66	94.03	0.61	13.23
1736	(2) 5-Year	6.32	92.66	94.11	0.69	15.80
1736	(2) 10-Year	7.24	92.66	94.16	0.74	17.60
1736	(2) 25-Year	8.38	92.66	94.21	0.81	20.73
1736	(2) 100-Year	10.81	92.66	94.30	0.94	28.19
1736	(4) 2-Year	4.78	92.66	94.00	0.61	12.27
1736	(4) 5-Year	2.33	92.66	93.75	0.45	7.54
1736	(4) 10-Year	1.78	92.66	93.59	0.47	6.35
1736	(4) 25-Year	2.60	92.66	93.81	0.45	11.39
1736	(4) 100-Year	3.29	92.66	94.02	0.41	39.33
1715	(2) 2-Year	5.00	92.62	94.02	0.58	12.95
1715	(2) 5-Year	6.32	92.62	94.10	0.66	15.48
1715	(2) 10-Year	7.24	92.62	94.15	0.71	17.26
1715	(2) 25-Year	8.38	92.62	94.20	0.77	20.37
1715	(2) 100-Year	10.81	92.62	94.29	0.91	27.79
1715	(4) 2-Year	4.78	92.62	93.99	0.57	12.00
1715	(4) 5-Year	2.33	92.62	93.74	0.42	7.37
1715	(4) 10-Year	1.78	92.62	93.58	0.43	6.23
1715	(4) 25-Year	2.60	92.62	93.81	0.42	11.20
1715	(4) 100-Year	3.29	92.62	94.02	0.38	39.05
1694	(2) 2-Year	5.00	92.58	94.02	0.56	12.65
1694	(2) 5-Year	6.32	92.58	94.09	0.64	15.15
1694	(2) 10-Year	7.24	92.58	94.14	0.69	16.91
1694	(2) 25-Year	8.38	92.58	94.19	0.75	19.99
1694	(2) 100-Year	10.81	92.58	94.28	0.89	27.37
1694	(4) 2-Year	4.78	92.58	93.99	0.55	11.72
1694	(4) 5-Year	2.33	92.58	93.74	0.39	7.19
1694	(4) 10-Year	1.78	92.58	93.58	0.41	6.10
1694	(4) 25-Year	2.60	92.58	93.80	0.40	10.99
1694	(4) 100-Year	3.29	92.58	94.01	0.37	38.75
1673	(2) 2-Year	5.00	92.53	94.01	0.53	12.34
1673	(2) 5-Year	6.32	92.53	94.09	0.61	14.81
1673	(2) 10-Year	7.24	92.53	94.13	0.66	16.54
1673	(2) 25-Year	8.38	92.53	94.19	0.72	19.60
1673	(2) 100-Year	10.81	92.53	94.27	0.86	26.95
1673	(4) 2-Year	4.78	92.53	93.98	0.52	11.42
1673	(4) 5-Year	2.33	92.53	93.74	0.37	6.99
1673	(4) 10-Year	1.78	92.53	93.57	0.38	5.97
1673	(4) 25-Year	2.60	92.53	93.80	0.37	10.77

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1673	(4) 100-Year	3.29	92.53	94.01	0.35	38.44
1653	(2) 2-Year	5.00	92.50	94.01	0.51	12.01
1653	(2) 5-Year	6.32	92.50	94.08	0.59	14.45
1653	(2) 10-Year	7.24	92.50	94.13	0.64	16.16
1653	(2) 25-Year	8.38	92.50	94.18	0.70	19.20
1653	(2) 100-Year	10.81	92.50	94.26	0.83	26.51
1653	(4) 2-Year	4.78	92.50	93.98	0.50	11.10
1653	(4) 5-Year	2.33	92.50	93.73	0.35	6.78
1653	(4) 10-Year	1.78	92.50	93.57	0.36	5.82
1653	(4) 25-Year	2.60	92.50	93.80	0.35	10.53
1653	(4) 100-Year	3.29	92.50	94.01	0.33	38.11
1632	(2) 2-Year	5.00	92.46	94.00	0.49	11.68
1632	(2) 5-Year	6.32	92.46	94.08	0.57	14.08
1632	(2) 10-Year	7.24	92.46	94.12	0.62	15.77
1632	(2) 25-Year	8.38	92.46	94.17	0.68	18.78
1632	(2) 100-Year	10.81	92.46	94.25	0.82	26.06
1632	(4) 2-Year	4.78	92.46	93.97	0.49	10.78
1632	(4) 5-Year	2.33	92.46	93.73	0.33	6.56
1632	(4) 10-Year	1.78	92.46	93.56	0.34	5.66
1632	(4) 25-Year	2.60	92.46	93.79	0.34	10.29
1632	(4) 100-Year	3.29	92.46	94.01	0.32	37.77
1615	(2) 2-Year	5.00	92.43	94.00	0.47	11.39
1615	(2) 5-Year	6.32	92.43	94.07	0.55	13.76
1615	(2) 10-Year	7.24	92.43	94.12	0.60	15.44
1615	(2) 25-Year	8.38	92.43	94.17	0.66	18.43
1615	(2) 100-Year	10.81	92.43	94.24	0.79	25.68
1615	(4) 2-Year	4.78	92.43	93.97	0.47	10.50
1615	(4) 5-Year	2.33	92.43	93.73	0.32	6.36
1615	(4) 10-Year	1.78	92.43	93.56	0.32	5.52
1615	(4) 25-Year	2.60	92.43	93.79	0.32	10.07
1615	(4) 100-Year	3.29	92.43	94.01	0.31	37.48
1555	(2) 2-Year	5.00	92.35	93.99	0.42	10.29
1555	(2) 5-Year	6.32	92.35	94.06	0.49	12.57
1555	(2) 10-Year	7.24	92.35	94.10	0.54	14.19
1555	(2) 25-Year	8.38	92.35	94.15	0.59	17.12
1555	(2) 100-Year	10.81	92.35	94.22	0.71	24.27
1555	(4) 2-Year	4.78	92.35	93.96	0.42	9.44
1555	(4) 5-Year	2.33	92.35	93.72	0.29	5.61
1555	(4) 10-Year	1.78	92.35	93.55	0.30	4.97
1555	(4) 25-Year	2.60	92.35	93.79	0.29	9.24
1555	(4) 100-Year	3.29	92.35	94.00	0.27	36.37
1488	(2) 2-Year	5.00	92.28	93.98	0.39	8.97
1488	(2) 5-Year	6.32	92.28	94.05	0.45	11.14
1488	(2) 10-Year	7.24	92.28	94.09	0.50	12.70
1488	(2) 25-Year	8.38	92.28	94.14	0.55	15.56
1488	(2) 100-Year	10.81	92.28	94.20	0.67	22.62
1488	(4) 2-Year	4.78	92.28	93.95	0.38	8.16

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1488	(4) 5-Year	2.33	92.28	93.72	0.26	4.66
1488	(4) 10-Year	1.78	92.28	93.55	0.26	4.26
1488	(4) 25-Year	2.60	92.28	93.78	0.26	8.20
1488	(4) 100-Year	3.29	92.28	94.00	0.25	35.03
1416	(2) 2-Year	5.00	92.20	93.98	0.36	7.64
1416	(2) 5-Year	6.32	92.20	94.04	0.43	9.72
1416	(2) 10-Year	7.24	92.20	94.08	0.47	11.22
1416	(2) 25-Year	8.38	92.20	94.13	0.52	14.02
1416	(2) 100-Year	10.81	92.20	94.18	0.64	21.00
1416	(4) 2-Year	4.78	92.20	93.95	0.35	6.88
1416	(4) 5-Year	2.33	92.20	93.72	0.23	3.69
1416	(4) 10-Year	1.78	92.20	93.55	0.22	3.49
1416	(4) 25-Year	2.60	92.20	93.78	0.23	7.15
1416	(4) 100-Year	3.29	92.20	94.00	0.23	33.68
1400	(2) 2-Year	5.00	92.17	93.97	0.35	7.11
1400	(2) 5-Year	6.32	92.17	94.04	0.41	9.15
1400	(2) 10-Year	7.24	92.17	94.08	0.46	10.63
1400	(2) 25-Year	8.38	92.17	94.12	0.51	13.41
1400	(2) 100-Year	10.81	92.17	94.18	0.62	20.36
1400	(4) 2-Year	4.78	92.17	93.95	0.34	6.36
1400	(4) 5-Year	2.33	92.17	93.71	0.22	3.28
1400	(4) 10-Year	1.78	92.17	93.54	0.21	3.17
1400	(4) 25-Year	2.60	92.17	93.78	0.22	6.71
1400	(4) 100-Year	3.29	92.17	94.00	0.22	33.13
1364	(2) 2-Year	5.00	91.63	93.97	0.24	6.23
1364	(2) 5-Year	6.32	91.63	94.04	0.28	8.22
1364	(2) 10-Year	7.24	91.63	94.08	0.32	9.67
1364	(2) 25-Year	8.38	91.63	94.12	0.36	12.41
1364	(2) 100-Year	10.81	91.63	94.17	0.45	19.32
1364	(4) 2-Year	4.78	91.63	93.94	0.23	5.50
1364	(4) 5-Year	2.33	91.63	93.71	0.13	2.60
1364	(4) 10-Year	1.78	91.63	93.54	0.12	2.60
1364	(4) 25-Year	2.60	91.63	93.78	0.14	5.98
1364	(4) 100-Year	3.29	91.63	94.00	0.15	32.24
1340	(2) 2-Year	5.79	91.60	93.97	0.27	5.60
1340	(2) 5-Year	7.32	91.60	94.04	0.33	7.56
1340	(2) 10-Year	8.33	91.60	94.08	0.37	8.99
1340	(2) 25-Year	9.65	91.60	94.12	0.41	11.71
1340	(2) 100-Year	11.62	91.60	94.17	0.48	18.58
1340	(4) 2-Year	5.26	91.60	93.94	0.25	4.88
1340	(4) 5-Year	2.44	91.60	93.71	0.14	2.09
1340	(4) 10-Year	1.86	91.60	93.54	0.12	2.18
1340	(4) 25-Year	2.71	91.60	93.78	0.15	5.44
1340	(4) 100-Year	3.43	91.60	94.00	0.16	31.59
1312	(2) 2-Year	6.08	92.47	93.95	0.71	5.07
1312	(2) 5-Year	7.69	92.47	94.00	0.85	7.00
1312	(2) 10-Year	8.76	92.47	94.03	0.95	8.41

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1312	(2) 25-Year	10.15	92.47	94.06	1.08	11.11
1312	(2) 100-Year	12.20	92.47	94.09	1.27	17.97
1312	(4) 2-Year	5.46	92.47	93.92	0.65	4.37
1312	(4) 5-Year	2.47	92.47	93.71	0.36	1.67
1312	(4) 10-Year	1.87	92.47	93.54	0.32	1.82
1312	(4) 25-Year	2.73	92.47	93.77	0.37	5.00
1312	(4) 100-Year	3.44	92.47	93.99	0.39	31.05
1302	(2) 2-Year	6.08	92.57	93.91	1.03	4.98
1302	(2) 5-Year	7.69	92.57	93.97	1.13	6.90
1302	(2) 10-Year	8.76	92.57	94.00	1.18	8.31
1302	(2) 25-Year	10.15	92.57	94.04	1.26	11.00
1302	(2) 100-Year	12.20	92.57	94.07	1.39	17.85
1302	(4) 2-Year	5.46	92.57	93.89	0.98	4.29
1302	(4) 5-Year	2.47	92.57	93.68	0.77	1.62
1302	(4) 10-Year	1.87	92.57	93.50	0.85	1.79
1302	(4) 25-Year	2.73	92.57	93.74	0.73	4.94
1302	(4) 100-Year	3.44	92.57	93.98	0.49	30.95
1268	(2) 2-Year	6.08	92.47	93.87	0.59	4.63
1268	(2) 5-Year	7.69	92.47	93.93	0.62	6.46
1268	(2) 10-Year	8.76	92.47	93.96	0.64	7.77
1268	(2) 25-Year	10.15	92.47	94.00	0.67	10.34
1268	(2) 100-Year	12.20	92.47	94.05	0.64	16.97
1268	(4) 2-Year	5.46	92.47	93.84	0.57	3.96
1268	(4) 5-Year	2.47	92.47	93.59	0.68	1.50
1268	(4) 10-Year	1.87	92.47	93.43	0.81	1.71
1268	(4) 25-Year	2.73	92.47	93.67	0.53	4.78
1268	(4) 100-Year	3.44	92.47	93.98	0.24	30.39
1212	(2) 2-Year	6.08	92.36	93.78	0.84	3.93
1212	(2) 5-Year	7.69	92.36	93.85	0.85	5.52
1212	(2) 10-Year	8.76	92.36	93.88	0.86	6.62
1212	(2) 25-Year	10.15	92.36	93.93	0.84	8.90
1212	(2) 100-Year	12.20	92.36	94.00	0.80	15.06
1212	(4) 2-Year	5.46	92.36	93.74	0.83	3.36
1212	(4) 5-Year	2.47	92.36	93.41	0.89	1.32
1212	(4) 10-Year	1.87	92.36	93.30	0.83	1.58
1212	(4) 25-Year	2.73	92.36	93.54	0.74	4.52
1212	(4) 100-Year	3.44	92.36	93.97	0.24	28.91
1169	(2) 2-Year	6.08	92.30	93.70	0.86	3.39
1169	(2) 5-Year	7.69	92.30	93.76	0.91	4.74
1169	(2) 10-Year	8.76	92.30	93.80	0.95	5.69
1169	(2) 25-Year	10.15	92.30	93.84	0.99	7.78
1169	(2) 100-Year	12.20	92.30	93.91	1.04	13.62
1169	(4) 2-Year	5.46	92.30	93.67	0.83	2.90
1169	(4) 5-Year	2.47	92.30	93.32	0.73	1.19
1169	(4) 10-Year	1.87	92.30	93.24	0.65	1.47
1169	(4) 25-Year	2.73	92.30	93.49	0.59	4.34
1169	(4) 100-Year	3.44	92.30	93.97	0.28	27.40

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [(1)]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
1091	(2) 2-Year	6.08	92.15	93.57	0.83	2.61
1091	(2) 5-Year	7.69	92.15	93.64	0.85	3.66
1091	(2) 10-Year	8.76	92.15	93.68	0.88	4.46
1091	(2) 25-Year	10.15	92.15	93.72	0.91	6.34
1091	(2) 100-Year	12.20	92.15	93.80	0.88	11.79
1091	(4) 2-Year	5.46	92.15	93.53	0.82	2.26
1091	(4) 5-Year	2.47	92.15	93.18	0.71	0.93
1091	(4) 10-Year	1.87	92.15	93.14	0.58	1.23
1091	(4) 25-Year	2.73	92.15	93.42	0.51	3.95
1091	(4) 100-Year	3.44	92.15	93.96	0.19	24.74
1002	(2) 2-Year	6.08	92.06	93.36	1.06	1.89
1002	(2) 5-Year	7.69	92.06	93.45	1.07	2.63
1002	(2) 10-Year	8.76	92.06	93.50	1.06	3.23
1002	(2) 25-Year	10.15	92.06	93.57	0.99	4.83
1002	(2) 100-Year	12.20	92.06	93.70	0.86	9.70
1002	(4) 2-Year	5.46	92.06	93.32	1.03	1.66
1002	(4) 5-Year	2.47	92.06	93.00	0.85	0.65
1002	(4) 10-Year	1.87	92.06	93.04	0.60	0.95
1002	(4) 25-Year	2.73	92.06	93.37	0.47	3.42
1002	(4) 100-Year	3.44	92.06	93.96	0.14	20.77
961	(2) 2-Year	6.08	91.96	93.25	0.88	1.61
961	(2) 5-Year	7.69	91.96	93.33	0.93	2.25
961	(2) 10-Year	8.76	91.96	93.39	0.95	2.77
961	(2) 25-Year	10.15	91.96	93.48	0.88	4.20
961	(2) 100-Year	12.20	91.96	93.67	0.55	8.56
961	(4) 2-Year	5.46	91.96	93.22	0.85	1.41
961	(4) 5-Year	2.47	91.96	92.95	0.64	0.51
961	(4) 10-Year	1.87	91.96	93.02	0.43	0.80
961	(4) 25-Year	2.73	91.96	93.35	0.32	3.09
961	(4) 100-Year	3.44	91.96	93.96	0.08	18.02
910	(2) 2-Year	6.08	91.93	93.17	0.79	0.99
910	(2) 5-Year	7.69	91.93	93.26	0.80	1.41
910	(2) 10-Year	8.76	91.93	93.32	0.77	1.75
910	(2) 25-Year	10.15	91.93	93.43	0.70	2.59
910	(2) 100-Year	12.20	91.93	93.65	0.44	5.00
910	(4) 2-Year	5.46	91.93	93.14	0.78	0.86
910	(4) 5-Year	2.47	91.93	92.89	0.67	0.31
910	(4) 10-Year	1.87	91.93	93.00	0.40	0.51
910	(4) 25-Year	2.73	91.93	93.35	0.24	2.01
910	(4) 100-Year	3.44	91.93	93.96	0.06	10.36
840	(2) 2-Year	6.08	91.86	93.10	0.50	
840	(2) 5-Year	7.69	91.86	93.21	0.48	
840	(2) 10-Year	8.76	91.86	93.28	0.46	
840	(2) 25-Year	10.15	91.86	93.41	0.41	
840	(2) 100-Year	12.20	91.86	93.64	0.34	
840	(4) 2-Year	5.46	91.86	93.06	0.51	
840	(4) 5-Year	2.47	91.86	92.80	0.52	
840	(4) 10-Year	1.87	91.86	92.97	0.23	

Table D-2: HEC-RAS Results for Van Gaal Drain Reach 2 Under Proposed Conditions (Riparian) [1]

HEC-RAS River Station	Profile	Flow (m^3/s)	Minimum Channel Elevation (m)	Water Surface Elevation (m)	Channel Velocity (m/s)	Cumulative Volume (1000 m^3)
840	(4) 25-Year	2.73	91.86	93.35	0.12	
840	(4) 100-Year	3.44	91.86	93.96	0.05	

[1] All channel infrastructure removed from the HEC-RAS model for riparian storage analysis.
For Scenario 2 (the Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River) and
Scenario 4 (the Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain).

APPENDIX D

Geomorphology

J.F. Sabourin and Associates Inc.
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS

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October 31, 2013

David Schaeffer Engineering Limited
120 Iber Road, Unit 203
Ottawa, Ontario K2S 1E9

Attention: **Kevin Murphy, P.Eng.**

Subject: **Richmond Village (South) Limited Subdivision / Continuous Erosion Analysis** *our file: 922-11*

As requested by your office, we have performed, based on the available information described below, a continuous erosion analysis for Van Gaal Drain in the City of Ottawa under existing and proposed conditions.

As per the October 2013 *Richmond Village (South) Limited Subdivision / Preliminary Stormwater Management Analysis*, the proposed Richmond Village (South) development consists of a 126.81 ha drainage area to be treated by two Stormwater Management (SWM) facilities; SWM Facility 1 (91.82 ha at 51% imperviousness) discharging to Van Gaal Drain, and SWM Facility 2 (34.99 ha at 51% imperviousness) discharging to the Jock River. It should be noted that excess major system flows from 30.79 ha and 21.75 ha of the SWM Facility 1 drainage area will discharge directly to the Van Gaal Drain and Moore Drain Tributary, respectively. Additionally, of the undeveloped lands south of the proposed subdivision, 97.50 ha will drain through SWM Facility 1, 71.8 ha will drain through SWM Facility 2, and 94.2 ha will be conveyed through the subdivision by a tributary of the Moore Drain.

Existing drainage characteristics of the subject site, and of the undeveloped lands south of the proposed subdivision, are as per the *Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond* (November 2009, JFSA). Refer to the October 2013 *Preliminary SWM Analysis* memo for existing and proposed drainage plans and further details.

Continuous SWMHYMO models of the Van Gaal Drain under existing and proposed conditions were created for the purposes of this erosion analysis based on the single-event SWMHYMO models submitted with the October 2013 *Preliminary SWM Analysis* memo. Continuous modelling parameters were set as follows for both existing and proposed conditions:

APII=[50], APIK=[0.90]/day;	used to compute the Antecedent Precipitation Index during the continuous simulation. Without model calibration these are the default values.
IaREC=[6](hrs);	the time that it takes for the Initial Abstraction over pervious areas to recover during a dry period in undeveloped areas.
SMIN=[-1], SMAX=[-1](mm);	the negative values indicate that the storage volume in the SCS procedure will vary between the "S" determined for AMC I and AMC III conditions of the entered CN value in undeveloped areas.
SK=[0.03]/(mm);	a calibration coefficient that can typically vary from 0.01 to 0.3 for undeveloped areas. The higher the value, the more runoff generated. To set the baseline for existing conditions, we decided to take a value in the low range.

InitGWResVol=[100](mm), GWResK=[0.9](mm/day/mm), VhydCond=[1](mm/hr);
parameters that are used to simulate both the groundwater storage and discharge to surface watercourses from undeveloped areas. Without adequate field measurements, these parameters were selected based on previous experience.

IaRECper=[3](hrs); the time that it takes for the Initial Abstraction over pervious areas to recover during a dry period in urban areas.

IaRECimp=[2](hrs); the time that it takes for the Initial Abstraction over impervious areas to recover during a dry period in urban areas.

InterEventTime=[12](hrs); the continuous dry time required to reset the parameters in the SCS procedure to their initial values.

Under existing and proposed conditions, by means of 36 years of continuous hydrologic simulations using hourly rainfall data from the Ottawa International Airport from 1967 to 2003 (excluding missing 2001 rainfall data), flows at the Fortune Street erosion site were computed and compared. It should be noted that restoration works are proposed for this critical erosion site and several other points along the Van Gaal Drain. The erosion thresholds at Fortune Street were set at 60 L/s, 151 L/s and 385 L/s, as provided by Coldwater Consulting Limited to correspond to their critical shear stress thresholds of 0.5 Pa, 1.0 Pa and 2.0 Pa.

Based on the 60 L/s erosion threshold, erosion occurs for 479.45 hours and 596.88 hours in an average year under existing and proposed conditions, respectively; that is, for 9.87% and 12.29% of the total simulation duration. This corresponds to a 24.5% increase in erosion under proposed conditions. Similarly, based on the 151 L/s erosion threshold, erosion occurs for 328.44 hours and 362.94 hours in an average year under existing and proposed conditions, respectively; that is, for 6.76% and 7.47% of the total simulation duration. This corresponds to a 10.5% increase in erosion under proposed conditions. Finally, based on the 385 L/s erosion threshold, erosion occurs for 203.81 hours and 201.84 hours in an average year under existing and proposed conditions, respectively; that is, for 4.20% and 4.15% of the total simulation duration. This corresponds to a 1.0% decrease in erosion under proposed conditions.

A summary of the erosion analysis results may be found in Attachment A. Digital SWMHYMO modelling input and output files are also attached.

Yours truly,
J.F. Sabourin and Associates Inc.

Laura Pipkins, P.Eng.

cc: J.F. Sabourin, M.Eng, P.Eng.
Director of Water Resources Projects

Attachment A: Simulated Annual Erosion Hours in the Van Gaal Drain at Fortune Street

ATTACHMENT

A

Simulated Annual Erosion Hours
In the Van Gaal Drain at Fortune Street

JFSA Water Resources and Environmental Consultants

SIMULATED ANNUAL EROSION HOURS IN THE VAN GAAL DRAIN AT FORTUNE STREET

Table 1A: Existing Conditions (60 L/s Erosion Threshold)

Year [(1)]	Duration (h)	Peak Flow (m^3/s)	Average Flow (m^3/s)	Erosion Hours (h)	Total Exceedance (%)
1967	2544	6.576	0.129	373.00	14.66
1968	5160	5.096	0.068	488.80	9.47
1969	5160	5.825	0.049	382.50	7.41
1970	5160	6.150	0.058	452.30	8.77
1971	5160	5.267	0.051	419.80	8.14
1972	5160	10.071	0.111	668.30	12.95
1973	5160	7.253	0.088	585.50	11.35
1974	4392	3.542	0.038	324.00	7.38
1975	3696	5.493	0.080	444.50	12.03
1976	5160	3.728	0.045	421.80	8.17
1977	5160	5.297	0.062	512.00	9.92
1978	5160	5.782	0.050	486.00	9.42
1979	5160	8.422	0.107	608.80	11.80
1980	5160	3.583	0.054	544.80	10.56
1981	5160	21.687	0.142	701.80	13.60
1982	5160	5.226	0.043	442.30	8.57
1983	5160	6.867	0.054	465.50	9.02
1984	3696	4.399	0.069	394.00	10.66
1985	5160	3.375	0.045	446.80	8.66
1986	5160	9.724	0.120	731.00	14.17
1987	5160	6.648	0.068	494.80	9.59
1988	5160	7.423	0.066	462.00	8.95
1989	5160	4.226	0.045	413.80	8.02
1990	5160	7.061	0.079	542.80	10.52
1991	5160	4.841	0.051	442.30	8.57
1992	5160	9.789	0.072	490.50	9.51
1993	5160	1.914	0.048	532.50	10.32
1994	4416	4.772	0.077	471.80	10.68
1995	2952	12.479	0.098	248.30	8.41
1996	5136	4.963	0.052	427.50	8.32
1997	5160	1.542	0.029	396.50	7.68
1998	5088	2.992	0.044	428.00	8.41
1999	4440	4.772	0.052	450.50	10.15
2000	5160	7.496	0.064	502.30	9.73
2002	5088	12.146	0.095	535.80	10.53
2003	4440	5.617	0.09	527.30	11.88
Average	4858	6.446	0.069	479.45	9.87

[(1)] Based on a simulation period from April 1st to October 31st.

SIMULATED ANNUAL EROSION HOURS IN THE VAN GAAL DRAIN AT FORTUNE STREET

Table 1B: Proposed Conditions (60 L/s Erosion Theshold)

Year [1]	Duration (h)	Peak Flow (m^3/s)	Average Flow (m^3/s)	Erosion Hours (h)	Total Exceedance (%)
1967	2544	4.540	0.110	458.80	18.03
1968	5160	3.532	0.063	615.30	11.92
1969	5160	4.144	0.046	463.00	8.97
1970	5160	4.088	0.054	567.80	11.00
1971	5160	3.474	0.048	528.30	10.24
1972	5160	7.493	0.102	867.00	16.80
1973	5160	4.845	0.081	745.80	14.45
1974	4392	2.280	0.037	387.30	8.82
1975	3696	3.628	0.073	575.50	15.57
1976	5160	2.671	0.043	513.30	9.95
1977	5160	3.518	0.059	629.80	12.21
1978	5160	3.804	0.048	589.30	11.42
1979	5160	6.585	0.099	805.30	15.61
1980	5160	2.665	0.051	640.30	12.41
1981	5160	17.112	0.128	893.00	17.31
1982	5160	3.685	0.043	534.00	10.35
1983	5160	5.072	0.051	573.80	11.12
1984	3696	3.216	0.063	472.50	12.78
1985	5160	2.345	0.044	550.50	10.67
1986	5160	7.984	0.110	938.30	18.18
1987	5160	4.851	0.064	623.30	12.08
1988	5160	4.984	0.062	582.80	11.29
1989	5160	2.795	0.044	519.30	10.06
1990	5160	5.063	0.073	687.50	13.32
1991	5160	3.393	0.048	521.00	10.10
1992	5160	6.769	0.067	612.00	11.86
1993	5160	1.350	0.048	636.30	12.33
1994	4416	3.266	0.071	605.30	13.71
1995	2952	10.216	0.084	308.50	10.45
1996	5136	3.443	0.049	536.80	10.45
1997	5160	1.037	0.029	474.00	9.19
1998	5088	1.986	0.042	519.30	10.21
1999	4440	3.255	0.051	542.00	12.21
2000	5160	5.238	0.060	622.30	12.06
2002	5088	9.318	0.09	686.30	13.49
2003	4440	4.038	0.082	662.00	14.91
Average	4858	4.658	0.064	596.88	12.29

[1] Based on a simulation period from April 1st to October 31st.

Avg. Change in Erosion Threshold Exceedance: 24.5%

SIMULATED ANNUAL EROSION HOURS IN THE VAN GAAL DRAIN AT FORTUNE STREET

Table 2A: Existing Conditions (151 L/s Erosion Threshold)

Year [1]	Duration (h)	Peak Flow (m^3/s)	Average Flow (m^3/s)	Erosion Hours (h)	Total Exceedance (%)
1967	2544	6.576	0.129	288.00	11.32
1968	5160	5.096	0.068	349.30	6.77
1969	5160	5.825	0.049	266.30	5.16
1970	5160	6.150	0.058	295.80	5.73
1971	5160	5.267	0.051	292.80	5.67
1972	5160	10.071	0.111	468.00	9.07
1973	5160	7.253	0.088	402.30	7.80
1974	4392	3.542	0.038	206.30	4.70
1975	3696	5.493	0.080	307.80	8.33
1976	5160	3.728	0.045	284.00	5.50
1977	5160	5.297	0.062	361.00	7.00
1978	5160	5.782	0.050	323.00	6.26
1979	5160	8.422	0.107	446.30	8.65
1980	5160	3.583	0.054	369.00	7.15
1981	5160	21.687	0.142	464.50	9.00
1982	5160	5.226	0.043	281.00	5.45
1983	5160	6.867	0.054	295.80	5.73
1984	3696	4.399	0.069	297.30	8.04
1985	5160	3.375	0.045	322.50	6.25
1986	5160	9.724	0.120	502.50	9.74
1987	5160	6.648	0.068	313.30	6.07
1988	5160	7.423	0.066	327.00	6.34
1989	5160	4.226	0.045	272.00	5.27
1990	5160	7.061	0.079	374.00	7.25
1991	5160	4.841	0.051	273.50	5.30
1992	5160	9.789	0.072	338.30	6.56
1993	5160	1.914	0.048	348.30	6.75
1994	4416	4.772	0.077	328.80	7.45
1995	2952	12.479	0.098	185.50	6.28
1996	5136	4.963	0.052	278.00	5.41
1997	5160	1.542	0.029	256.50	4.97
1998	5088	2.992	0.044	295.30	5.80
1999	4440	4.772	0.052	306.80	6.91
2000	5160	7.496	0.064	343.80	6.66
2002	5088	12.146	0.095	393.80	7.74
2003	4440	5.617	0.09	365.30	8.23
Average	4858	6.446	0.069	328.44	6.76

[1] Based on a simulation period from April 1st to October 31st.

SIMULATED ANNUAL EROSION HOURS IN THE VAN GAAL DRAIN AT FORTUNE STREET

Table 2B: Proposed Conditions (151 L/s Erosion Theshold)

Year [1]	Duration (h)	Peak Flow (m^3/s)	Average Flow (m^3/s)	Erosion Hours (h)	Total Exceedance (%)
1967	2544	4.540	0.110	315.50	12.40
1968	5160	3.532	0.063	388.00	7.52
1969	5160	4.144	0.046	282.00	5.47
1970	5160	4.088	0.054	329.30	6.38
1971	5160	3.474	0.048	306.50	5.94
1972	5160	7.493	0.102	559.50	10.84
1973	5160	4.845	0.081	468.30	9.08
1974	4392	2.280	0.037	199.50	4.54
1975	3696	3.628	0.073	344.30	9.32
1976	5160	2.671	0.043	294.00	5.70
1977	5160	3.518	0.059	391.00	7.58
1978	5160	3.804	0.048	350.50	6.79
1979	5160	6.585	0.099	527.50	10.22
1980	5160	2.665	0.051	408.30	7.91
1981	5160	17.112	0.128	542.50	10.51
1982	5160	3.685	0.043	295.50	5.73
1983	5160	5.072	0.051	325.80	6.31
1984	3696	3.216	0.063	325.30	8.80
1985	5160	2.345	0.044	360.30	6.98
1986	5160	7.984	0.110	567.50	11.00
1987	5160	4.851	0.064	349.00	6.76
1988	5160	4.984	0.062	365.80	7.09
1989	5160	2.795	0.044	291.50	5.65
1990	5160	5.063	0.073	418.30	8.11
1991	5160	3.393	0.048	300.50	5.82
1992	5160	6.769	0.067	377.30	7.31
1993	5160	1.350	0.048	367.30	7.12
1994	4416	3.266	0.071	364.00	8.24
1995	2952	10.216	0.084	201.80	6.84
1996	5136	3.443	0.049	297.50	5.79
1997	5160	1.037	0.029	259.00	5.02
1998	5088	1.986	0.042	321.00	6.31
1999	4440	3.255	0.051	341.30	7.69
2000	5160	5.238	0.060	378.00	7.33
2002	5088	9.318	0.09	447.00	8.79
2003	4440	4.038	0.082	405.30	9.13
Average	4858	4.658	0.064	362.94	7.47

[1] Based on a simulation period from April 1st to October 31st.

Avg. Change in Erosion Threshold Exceedance: 10.5%

SIMULATED ANNUAL EROSION HOURS IN THE VAN GAAL DRAIN AT FORTUNE STREET

Table 3A: Existing Conditions (385 L/s Erosion Threshold)

Year [(1)]	Duration (h)	Peak Flow (m^3/s)	Average Flow (m^3/s)	Erosion Hours (h)	Total Exceedance (%)
1967	2544	6.576	0.129	205.80	8.09
1968	5160	5.096	0.068	231.30	4.48
1969	5160	5.825	0.049	171.80	3.33
1970	5160	6.150	0.058	188.30	3.65
1971	5160	5.267	0.051	171.50	3.32
1972	5160	10.071	0.111	276.00	5.35
1973	5160	7.253	0.088	273.80	5.31
1974	4392	3.542	0.038	109.00	2.48
1975	3696	5.493	0.080	176.80	4.78
1976	5160	3.728	0.045	161.30	3.13
1977	5160	5.297	0.062	225.30	4.37
1978	5160	5.782	0.050	194.80	3.78
1979	5160	8.422	0.107	283.30	5.49
1980	5160	3.583	0.054	203.30	3.94
1981	5160	21.687	0.142	306.00	5.93
1982	5160	5.226	0.043	170.00	3.29
1983	5160	6.867	0.054	177.00	3.43
1984	3696	4.399	0.069	191.80	5.19
1985	5160	3.375	0.045	193.50	3.75
1986	5160	9.724	0.120	302.50	5.86
1987	5160	6.648	0.068	182.50	3.54
1988	5160	7.423	0.066	220.00	4.26
1989	5160	4.226	0.045	155.50	3.01
1990	5160	7.061	0.079	268.00	5.19
1991	5160	4.841	0.051	177.30	3.44
1992	5160	9.789	0.072	205.80	3.99
1993	5160	1.914	0.048	212.50	4.12
1994	4416	4.772	0.077	227.00	5.14
1995	2952	12.479	0.098	104.00	3.52
1996	5136	4.963	0.052	161.30	3.14
1997	5160	1.542	0.029	131.00	2.54
1998	5088	2.992	0.044	184.00	3.62
1999	4440	4.772	0.052	183.00	4.12
2000	5160	7.496	0.064	207.30	4.02
2002	5088	12.146	0.095	262.00	5.15
2003	4440	5.617	0.09	243.00	5.47
Average	4858	6.446	0.069	203.81	4.20

[(1)] Based on a simulation period from April 1st to October 31st.

SIMULATED ANNUAL EROSION HOURS IN THE VAN GAAL DRAIN AT FORTUNE STREET

Table 3B: Proposed Conditions (385 L/s Erosion Theshold)

Year [1]	Duration (h)	Peak Flow (m^3/s)	Average Flow (m^3/s)	Erosion Hours (h)	Total Exceedance (%)
1967	2544	4.540	0.110	211.30	8.31
1968	5160	3.532	0.063	228.30	4.42
1969	5160	4.144	0.046	169.80	3.29
1970	5160	4.088	0.054	175.00	3.39
1971	5160	3.474	0.048	171.30	3.32
1972	5160	7.493	0.102	295.50	5.73
1973	5160	4.845	0.081	278.00	5.39
1974	4392	2.280	0.037	105.00	2.39
1975	3696	3.628	0.073	174.80	4.73
1976	5160	2.671	0.043	153.00	2.97
1977	5160	3.518	0.059	222.30	4.31
1978	5160	3.804	0.048	183.00	3.55
1979	5160	6.585	0.099	287.00	5.56
1980	5160	2.665	0.051	185.00	3.59
1981	5160	17.112	0.128	319.80	6.20
1982	5160	3.685	0.043	158.00	3.06
1983	5160	5.072	0.051	170.30	3.30
1984	3696	3.216	0.063	191.50	5.18
1985	5160	2.345	0.044	187.00	3.62
1986	5160	7.984	0.110	316.50	6.13
1987	5160	4.851	0.064	182.50	3.54
1988	5160	4.984	0.062	221.50	4.29
1989	5160	2.795	0.044	152.00	2.95
1990	5160	5.063	0.073	277.00	5.37
1991	5160	3.393	0.048	172.30	3.34
1992	5160	6.769	0.067	207.80	4.03
1993	5160	1.350	0.048	197.80	3.83
1994	4416	3.266	0.071	233.80	5.29
1995	2952	10.216	0.084	95.80	3.25
1996	5136	3.443	0.049	154.00	3.00
1997	5160	1.037	0.029	112.80	2.19
1998	5088	1.986	0.042	179.30	3.52
1999	4440	3.255	0.051	182.50	4.11
2000	5160	5.238	0.060	208.30	4.04
2002	5088	9.318	0.09	273.30	5.37
2003	4440	4.038	0.082	233.30	5.25
Average	4858	4.658	0.064	201.84	4.15

[1] Based on a simulation period from April 1st to October 31st.

Avg. Change in Erosion Threshold Exceedance: -1.0%

Erosion Hazard Assessment: Van Gaal Drain, Richmond, ON

Submitted to: David Schaeffer Engineering Limited

Prepared by: M.H. Davies, Ph.D., P.Eng.

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Version History

Version	Date	Status	Comments	Reviewed by	Approved by
0.91	3 October 2013	For discussion with DSEL	Completed 1st draft	NJM	MHD
1.0	10 Oct 2013	For discussion with RVCA and City	Working Draft	MHD	MHD
1.1	15 Oct 2013	For discussion with RVCA and City	Working Draft	MHD	MHD
1.2	15 Oct 2013	For discussion with RVCA and City	Working Draft	MHD	MHD
1.3	1 Nov 2013	For Client Use	Final Report	MHD	MHD

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Provisos

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Submitted 1 November 2013,

M.H. Davies, Ph.D., P.Eng.
Coldwater Consulting Ltd.

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EXECUTIVE SUMMARY

An analysis has been undertaken of present erosion conditions in the van Gaal Drain in Richmond, ON. Using hydrologic analysis supplied by J.F. Sabourin & Associates, Coldwater Consulting Ltd. has assessed erosion thresholds for the length of the drain extending from Perth Street downstream to the Jock River. An existing HEC-RAS one-dimensional flow model was refined over the study area and used to compute bed shears and erosive power. Using a 36-year continuous hydrologic simulation (supplied by JFSA) and a critical bed shear stress of 0.5 Pa, it is shown that while the number of hours that erosion thresholds are exceeded will increase by 12% post-development, these increases mostly occur during low flow conditions. The effects of flood attenuation by stormwater management facilities offset this effect, resulting in a net decrease in erosional power (as quantified by the Erosion Index) by 21%.

Although conditions post-development will be an improvement over existing conditions, the drain will continue to experience erosion. Conceptual designs are presented herein for protection and restoration measures that will protect critical areas – notably in the immediate vicinity of Fortune St. and downstream of Fowler St.

1 Introduction

Coldwater Consulting Ltd., (Coldwater) has been engaged to provide the following analysis and design services to David Schaeffer Engineering Ltd (DSEL):

- Review previous studies of the Van Gaal Drain, its present condition and hydraulic conditions as provided by DSEL;
- Conduct site investigations of the drain, its bed composition, morphology and bank characteristics for the reach (VGR1) extending from Perth Street downstream to its confluence with the Jock River; and,
- Develop a preliminary erosion hazard model and present quantitative estimates for any required restoration works.

1.1 Background Information

The following documents were referenced when preparing this design brief:

- Report from JFSA "Floodplain mapping report for the van Gaal and Arbuckle municipal drains in the village of Richmond", provided by DSEL dated November 2009.
- Report by Robinson Consultants (Robinson) for the City of Ottawa on the Arbuckle Municipal Drain dated February 2010
- Report by Parish Geomorphic (Parish) and Kilgour and Associates (Kilgour) for Mattamy Homes on the Mattamy Lands natural environment and assessment on impacts from development dated February 2010
- Report from JTB Environmental Systems Inc. " Van Gaal Drain Erosion Assessment, Richmond, Ontario", provided by DSEL dated October 2012.
- Memorandum from JTB Environmental Systems Inc. "Richmond Village Development: Existing Erosion Remediation Costs", provided by DSEL dated November 2012.
- Report from JTB Environmental Systems Inc. " Van Gaal Drain Restoration Memo, Richmond, Ontario", provided by DSEL dated January 2013.
- HEC-RAS model developed and provided by JFSA, September 2013.
- Continuous time series of discharge for pre- and post-development at 4 junctions (provided by JFSA, September 2013),
- JFSA report on continuous erosion analysis and updated pre-and post development hydrology (JFSA file 922-11, dated 18 Oct, 2013),
- Stormwater Management Planning and Design Manual, (Ontario MoE, March 2003),
- Cross-sectional data (Arbuckle drain cross sections.dwg) surveyed by J.D.Barnes and provided by DSEL.

2 Background

2.1 Previous Work

Six reports dealing with Van Gaal Drain and surrounding area were reviewed in the preparation of the present report. These reports are the first six documents listed in Section 1.1.

Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond (JFSA, 2009)

The JFSA report details the flood risk mapping that was performed for the Arbuckle and Van Gaal Drains. Hydrologic analyses were performed using the SYMHYMO model and hydraulic analyses using the HEC-RAS model. Based on a review of earlier DSEL models, the drainage area was estimated at 1147 ha. The report notes that access to certain areas could be obtained and so it was necessary to assume cross-sectional profiles based on earlier data at these sections. Channel sections were modelled using a Manning's n value of 0.035 for the channels, and 0.08 for the summer floodplain and 0.05 for the spring floodplain.

Three 100-year spring and summer event discharges were studied and the maximum discharge from the Van Gaal Drain at the Jock River was found to be 16.419 m^3/s. The 2-year spring and summer event discharges varied ranged from 5.666 m^3/s to 7.883 m^3/s. Flood risk elevations were computed at various stations along the river from the maximum of three values (Van Gaal Drain spring flood, Van Gaal Drain summer flood, Jock River flood).

Engineer's Report, Arbuckle Municipal Drain Modifications and Improvements, Goulbourn Ward (Robinson, 2010)

The Robinson report notes that while the Arbuckle Award Drain has existed from the late 1800s, the Van Gaal Municipal Drain was only constructed in 1971. Based on contour mapping, the drainage area was estimated at 1095 ha. SYMHYMO modelling was also performed and 2-year return period flows at various points in the Van Gaal Drain were within the range determined be JFSA (2009); the 100-year event was not investigated. The report details recommendations for:

- works to improve drainage, including culvert replacement and re-leveling, and land clearing and excavation;
- erosion control, such as buffer strips, rock protection, rootwads and revetment, and;
- flow checks and sediment traps.

The report also contains a discussion of the apportioning of costs for construction and future maintenance. The discussion identifies six principles that should be used to determine assessment and then applies the principles and rules from the Drainage Act to determine project cost sharing.

Mattamy Richmond Lands Natural Environment and Impact Assessment Study, (Parish and Kilgour, 2010)

This report covers a broad range of environmental topics, including an erosion threshold analysis. The erosion threshold analysis was conducted at four sites; however, only one site ("VG-R2") was located on the main branch of the Van Gaal Drain and this site was upstream of Perth St, the limit of the present analysis. The analysis was based on critical shear stress and permissible velocities, and found that the calculated erosion thresholds for the four reaches were discharges well below bankfull. At the VG-R2 site, the critical discharge was calculated to be 0.33 m^3/s.

Van Gaal Drain Erosion Assessment, (JTBES, 2012a)

This report describes work that was undertaken to investigate erosion downstream of Perth Street, a reach not specifically investigated in the earlier Mattamy report (Parish and Kilgour, 2010). This study delineated the drain into three reaches: Reach 1 running between the Jock River and the Fowler Culvert; Reach 2 running between the Fowler Culvert and the Fortune Culvert, and; Reach 3 running between the Fortune Culvert and the Perth Culvert. Following on a site visit, 51 erosion assessment sites were investigated and categorized, and, based on this, four sites were chosen for erosion threshold assessment. The threshold was determined as the critical velocity for the bank material, which in this case is coarse clay. The critical velocity for coarse clay was given as 0.225 m/s, which led to critical discharges for the four sections ranging from 0.02 to 0.05 m^3/s.

Richmond Village Development: Existing Erosion Remediation Costs, (JTBES, 2012b)

The purpose of this memo was to summarize the causes of erosion along the Van Gaal Drain and to estimate costs to remediate the erosion. It was concluded that, under existing conditions, Reach 3 had the most severe erosion and that, although not all sites required remediation, repairs at selected locations could simply shift the problem to a downstream site. It was deemed preferable to remediate all sites at once. It was also noted that even if the additional stormwater flows were limited to the threshold rate, erosion of the Drain would continue to occur. Consequently, a redesign for the section south of Perth Street was recommended. The cost for all 51 sites identified previously was estimated to be $1.41 million.

Van Gaal Drain Restoration Memo, (JTBES, 2013)

The purpose of this memo was to detail remediation costs for the erosion problems on the Van Gaal Drain downstream of Perth St. The work expands on the information provided in the earlier memo (JTBES, 2012b) and identifies 32 sites for remediation (4 in Reach 1, 7 in Reach 2 and 21 in Reach 3). Descriptions of works at the sites are presented. No reassessment of the erosion threshold is attempted; however, it is noted that after the proposed remediation works were completed, the threshold discharges for the site could be increased an undefined amount.

2.2 Review

The report and memos cited in the previous section provide valuable information about the previous work performed on the Van Gaal Drain. Of paramount importance here are the four last documents, which address erosion threshold analyses and provide a basis for the design of the stormwater management system and the required treatment of the existing drain.

A problem with the approaches taken by both Parish and JTBES is that even when using reasonable critical shear stress values, calculations performed in narrow channels will predict erosive conditions for almost all flows. However, erosion is a natural process and the erosion threshold in the channel should be exceeded to maintain a healthy system. It is not the aim of the development works to eliminate erosion, but to ensure that post-development conditions do result in a substantial increase in erosion. Clearly, a more sophisticated approach that integrates the impact of all events is required. The present work will examine not just the frequency with which the erosion threshold is exceeded but also the total amount of erosion that occurs both pre- and post-project.

In common with both the Parish and JTBES approaches, the present work will require an erosion threshold for the Van Gaal Drain. The first erosion threshold analysis (Parish and Kilgour, 2010) utilized a permissible tractive force technique to establish a critical discharge. Although the resulting discharge may appear to be low, this is a valid geomorphic approach and an approach based on similar principles will be employed in the present work. Loose, clayey soils are competent below unit tractive forces, or shear stresses, ranging between 0.5 Pa and 2 Pa (Chow, 1959). This range of critical shear stresses will be used for the modelling work presented herein.

3 Field Investigation

A site visit to Van Gaal Drain was conducted on 26 August 2013 to review and characterize the site. The day was sunny with some cloudy periods with daytime high of 24°C. The last recorded precipitation was 22 August 2013. Photos and notes regarding the channel geometry were taken at numerous locations at this time. A rapid geomorphic assessment and a rapid stream assessment were also taken during the site visit.

The field investigation found several sites with significant erosion on the Van Gaal Drain. This agrees with previous studies. For most of the reach between Perth St. and Jock River, the channel is too narrow for the current hydrologic conditions. The existing drain will continue to erode and widen until it reaches equilibrium - even without the proposed storm management plan. Figure 1 through Figure 4 show examples of erosion in the Van Gaal Drain. Figure 5 shows the location of each photo.

Figure 1 Typical undercutting banks between Perth St. and Fortune St.

Figure 2 Eroding bank downstream of Fortune St.

Figure 3 Bank widening upstream of Fowler St.

Figure 4 Eroding banks downstream of Fowler St.

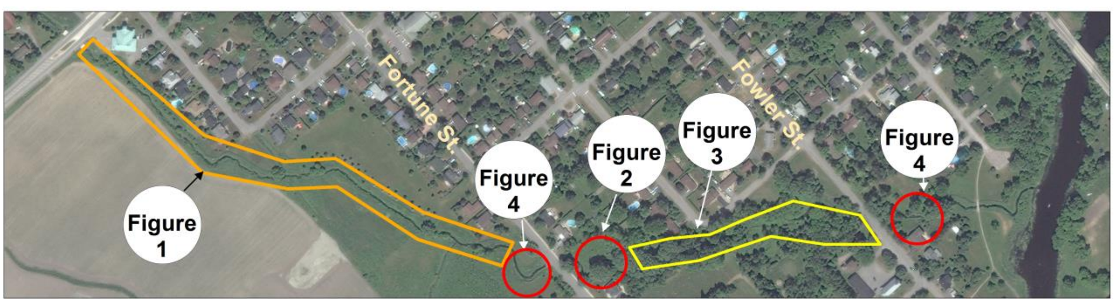

Figure 5 Locations of photographs

4 Erosion Model

Flow conditions in the Van Gaal drain were evaluated under existing conditions (pre-project) as well as under fully developed conditions (post-project) which includes the proposed storm water management pond. As noted in previous studies (JTB 2012, DSEL 2009), the erosion thresholds for this reach are very low and hence are exceeded frequently. In such situations, it is often beneficial to examine not just the frequency with which the erosion threshold is exceeded but also the total amount of erosion that occurs both pre- and post-project. By computing the amount by which the erosion threshold is exceeded, its duration, and the area of stream-bed affected, the erosional effort of 'effective work' can be computed (MOE, 2003).

This measure, in comparison to frequency of exceedance analysis, provides a more complete picture of the erosional consequences of a project.

4.1 Methodology

An erosion hazard model was developed to estimate the erosion potential for pre- and post-development on the Van Gaal Drain. A cumulative effective work approach was developed In addition to analysis of the frequency of exceedance of erosion thresholds. This model computes an erosion index (EI) based on the cumulative effective work, W_i The cumulative effective work is calculated as :

$$W_i = \sum (\tau - \tau_c) V \Delta t \qquad \text{(Eq. 1)}$$

where τ is the shear stress generated by the flow, τ_c is critical shear stress for either the bed or the bank, V is the mean channel velocity and Δt is the time step. For the present analysis, EI is multiplied by the wetted perimeter, P, to express the results as the total erosional energy across the channel width (Joules/m):

$$\mathrm{EI} = \sum (\tau - \tau_c) V P \Delta t \qquad \text{(Eq. 2)}$$

Calculating EI requires a continuous time series of discharge and a table relating discharge to shear stress, velocity and wetted perimeter. The continuous time series of discharge for pre- and post-development was provided by JFSA from their hydrologic model (JFSA, 2009). The dataset spans 36 years (April to October) between 1967 and 2003 with a time step of 15-minutes.

4.2 Critical Shear Stress

It is difficult to accurately determine the *in situ* critical shear stress for small streams. Typically, there is no single specific value that captures the range of erosion and transport processes that occur. Critical shear stress is dependent on a range of variables, include sediment size and type, weathering, vegetation, biological activity, etc. It can vary spatially for even small streams and can also be dependent upon weather conditions, freeze-thaw activities and exposure. The present modelling exercise was performed using several critical shear stress values that spanned the range of expected values. Based on the characteristics of the stream bed and banks, critical shear thresholds are estimated to be between 0.5 and 2.0 Pa.

Sensitivity tests were performed which showed that, while the magnitudes of the predicted erosion varied, the relative performance of the two scenarios tested (pre- and post-development) were unaffected by the value of critical shear stress selected.

4.3 HEC-RAS Model Refinement

The original HEC-RAS model (JFSA, 2009) covers a very large domain and was found not to have sufficient resolution in the reach downstream of Fortune St. New cross-sectional survey data was provided by DSEL and were incorporated into the HEC-RAS model by Coldwater.

Figure 6 shows the original model (with only one cross-section below Fowler St.) and Figure 7 shows the refined model (with 7 cross-sections below Fowler St.).

Figure 6 Original HEC-RAS model provided by JFSA with limited number of cross-sections d/s of Fortune St.

Figure 7 HEC-RAS model provided by JFSA with supplemental cross-sections added.

4.4 Threshold Flow Rates

Station 592, (located 592 m upstream of the Jock River) was identified as a critical erosion section. Using the refined HEC-RAS model, critical shear stresses of 0.5, 1 and 2 Pa were found to be associated with flow rates of 60, 158 and 385 L/s, respectively. These 'threshold flow rates' were transmitted to JFSA for their 'Continuous Erosion Analysis'.

4.5 Model Operation

The erosion model requires two types of input; the predicted discharge for the scenario being studied and station-specific values for shear stress, velocity and wetted perimeter as a function of discharge. These station-specific values were calculated using the refined HEC-RAS model. At each station, 22 discharges scenarios ranging between 0 m^3/s and 16.42 m^3/s were modelled to obtain these relationships (16.42m^3/s being the 1:100 year flow level). In total 726 (= 22 scenarios x 33 stations) sets of discharge, shear stress, velocity and wetted perimeter data were created to model the Van Gaal Drain between Perth St. and Jock River.

The erosion model was applied sequentially to each station. For each year, the erosion model stepped through the 15-minute time series of discharges from the JFSA hydrologic model. At each time step, the model interpolated the shear stress, velocity and wetted perimeter from the input discharge. These values were used to compute EI. The cumulative value of EI was also stored, as was the total time where the shear stress at the station was above critical.

Simulations were performed for both pre-development and post-development hydrographs. At noted in Section 4.2 above, the erosion model was run for a range of critical shear stresses. The results presented below are from the simulations with τ_c = 0.5 Pa.

5 Results

5.1 Single Event Simulation

This section shows comparisons of erosion potential for pre- and post-development on the Van Gaal Drain for a selected rainfall event, 9 April 1980 to 12 April 1980, at Station 592, using a critical shear threshold of 0.5 Pa.

Figure 8 shows the hydrograph for the event. The peak discharge decreases by 0.5 m^3/s from pre- to post-development. Pre-development discharge remains higher than post-development condition until it hits the 19.25 hour mark. The shear stress, shown in Figure 9, mimics the pattern. The shear stress is lower up until after the peak of the event. Shear stress is above critical until 31.75 hr for pre-development condition and until 40.5 hr for post-development case. Figure 10 shows the erosion index (EI) results; post-development EI remains lower than pre-development conditions until 19.25 hr. In total, there's 30.75 hours of erosion for the pre-development condition and 39.5 hours of erosion for the post-development condition. The cumulative erosion index for the event, a measure the impact of the event on the stream, is shown in Figure 11. Although the total duration of erosion for the event is longer in the post-development case, the cumulative EI is less; the cumulative EI for the pre-development case is 66.1 MJ and 50.8 MJ for the post-development case. This pattern was found to be repeated for the majority of the events at stations downstream of the retention pond (Stations 746 and lower). Stations upstream of this point showed lesser variation in the results of the two scenarios.

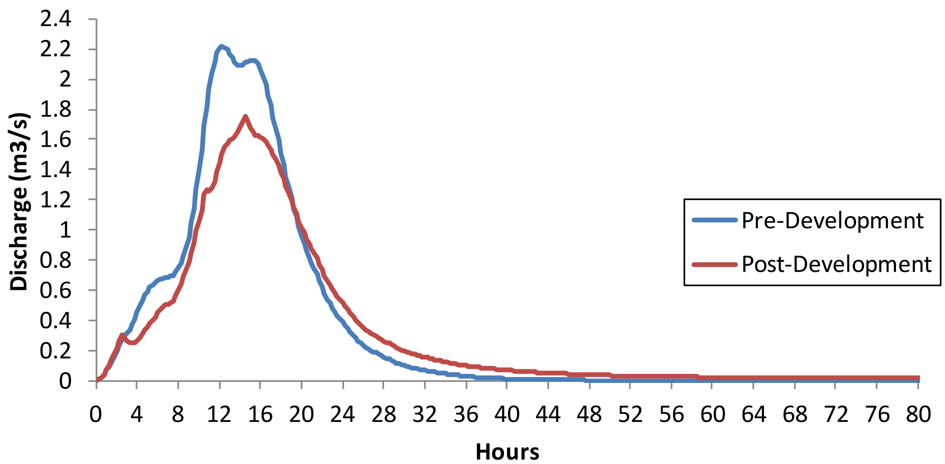

Figure 8 Continuous time series of discharge for pre- and post-development cases for the April 1980 event

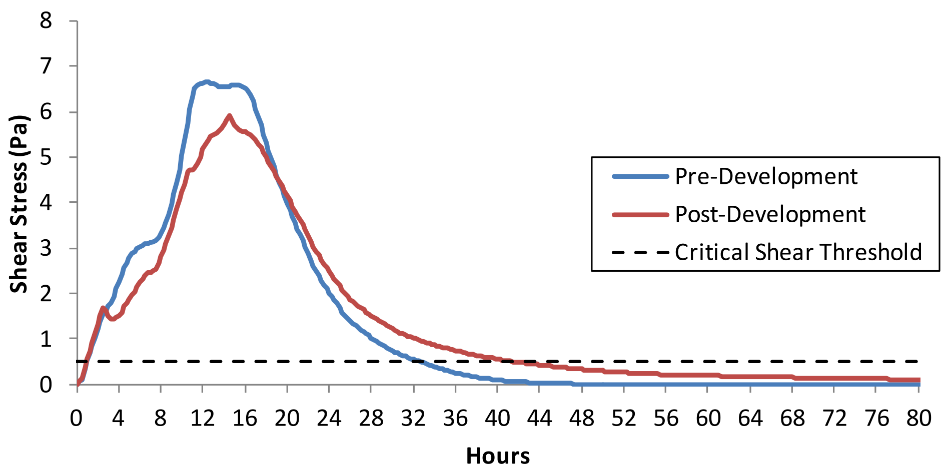

Figure 9 Continuous time series of shear stress for pre- and post-development cases for the April 1980 event

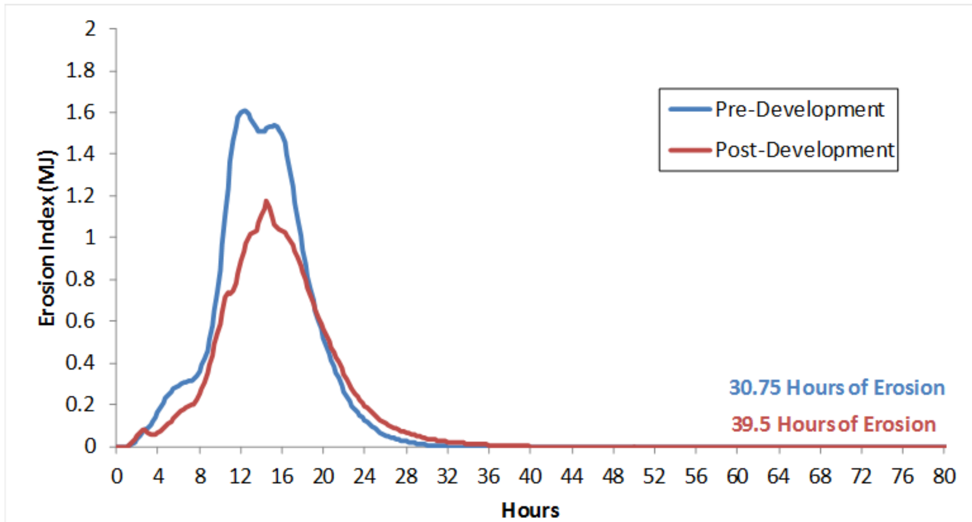

Figure 10 Continuous time series of erosion index for pre- and post-development cases for the April 1980 event

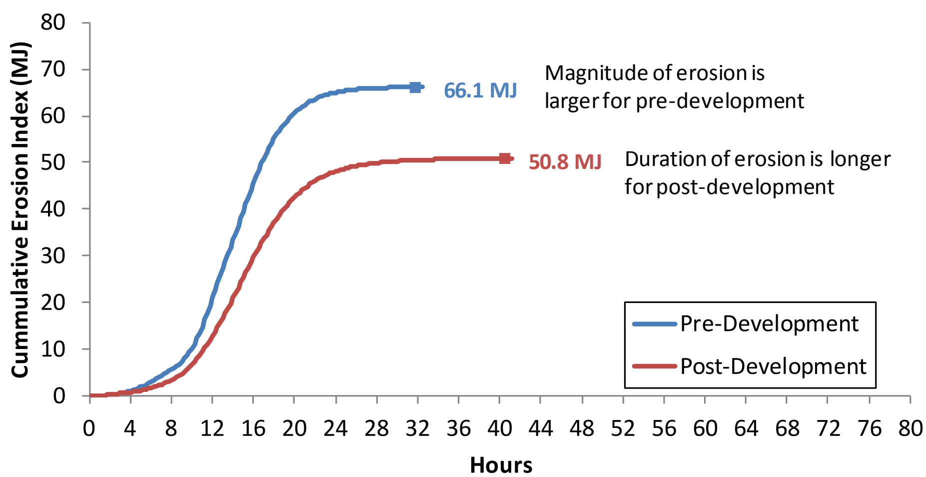

Figure 11 Cumulative erosion index for pre- and post-development cases for the April 1980 event

5.2 Long-term Simulations

The results in this section are for the model application at all stations for a 36-year simulation. Continuous time series of discharge for pre- and post-development (from SWMHYMO simulations) were provided by JFSA in September 2013 and an updated version in October 2013. The results from the extended HEC-RAS model were used to compute a 36-year analysis of flow and erosion conditions within the van Gaal drain (as per the methodology described in Section 4.4).

Figure 12 and Figure 13 show the average annual time above critical shear and the change in this measure computed as post-development minus pre-development. Upstream of Station 746 there is little change. Downstream of this point, the post-development case tends to spend more time in an erosional state. However, as was illustrated by the example in Section 5.1, this is not truly representative of the impact of the changes to the system on potential erosion of the stream. Figure 14 and Figure 15 show the annual average erosion index and change in this measure. These plots illustrate that the impact on the stream of the changes to the system lead to a reduction in erosion potential along the entire reach. This is illustrated in plan view in Figure 16.

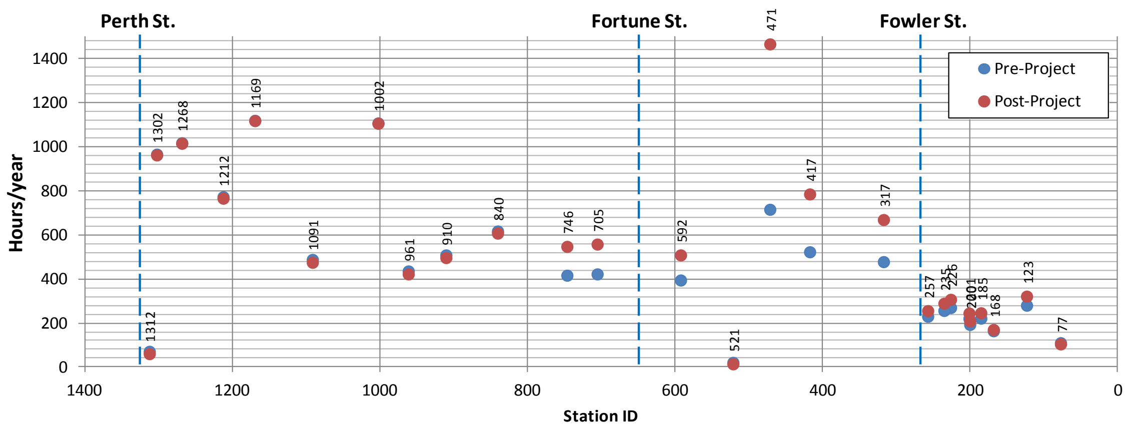

Figure 12 Average annual time above critical shear for a 36-year simulation

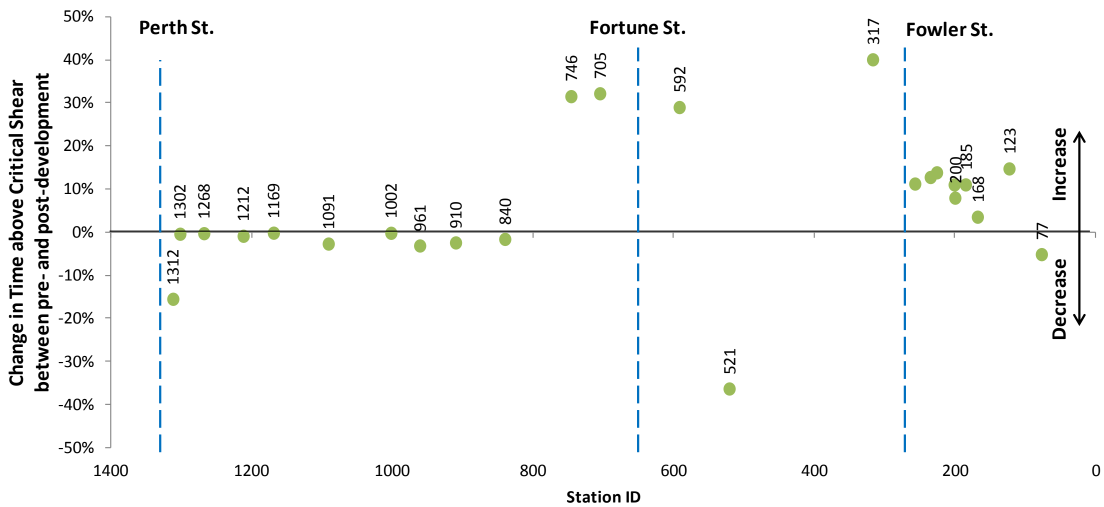

Figure 13 Change in annual time above critical shear for a 36-year simulation (post - pre)

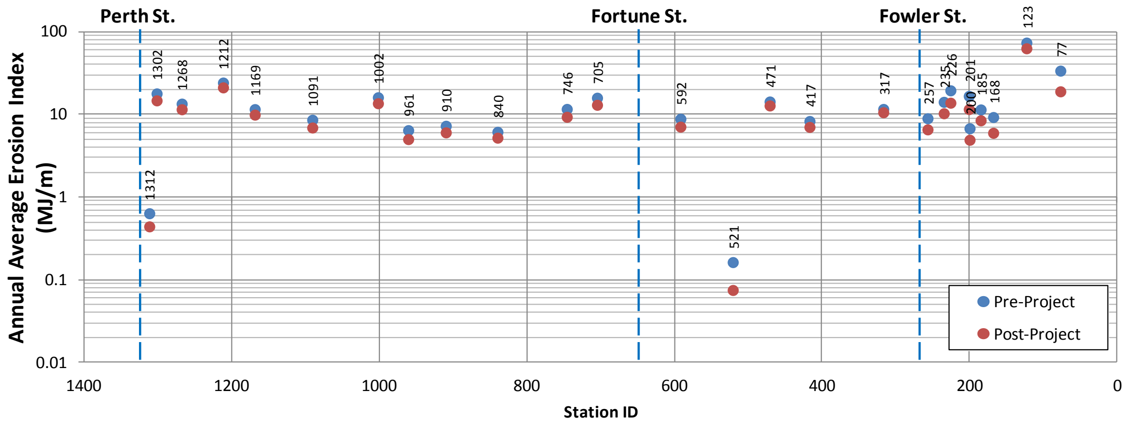

Figure 14 Annual average erosion index for a 36-year simulation

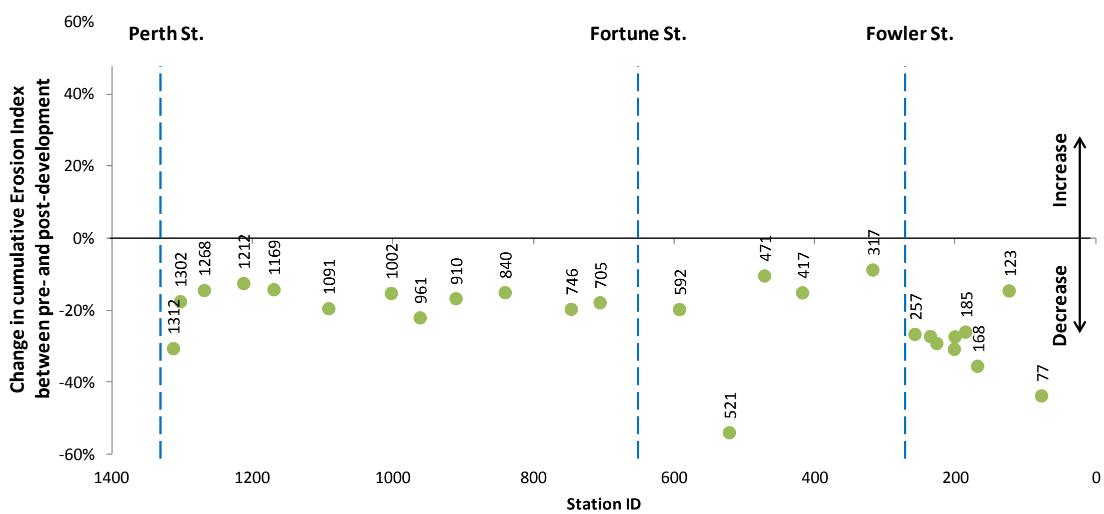

Figure 15 Change in erosion index for a 36-year simulation (post - pre)

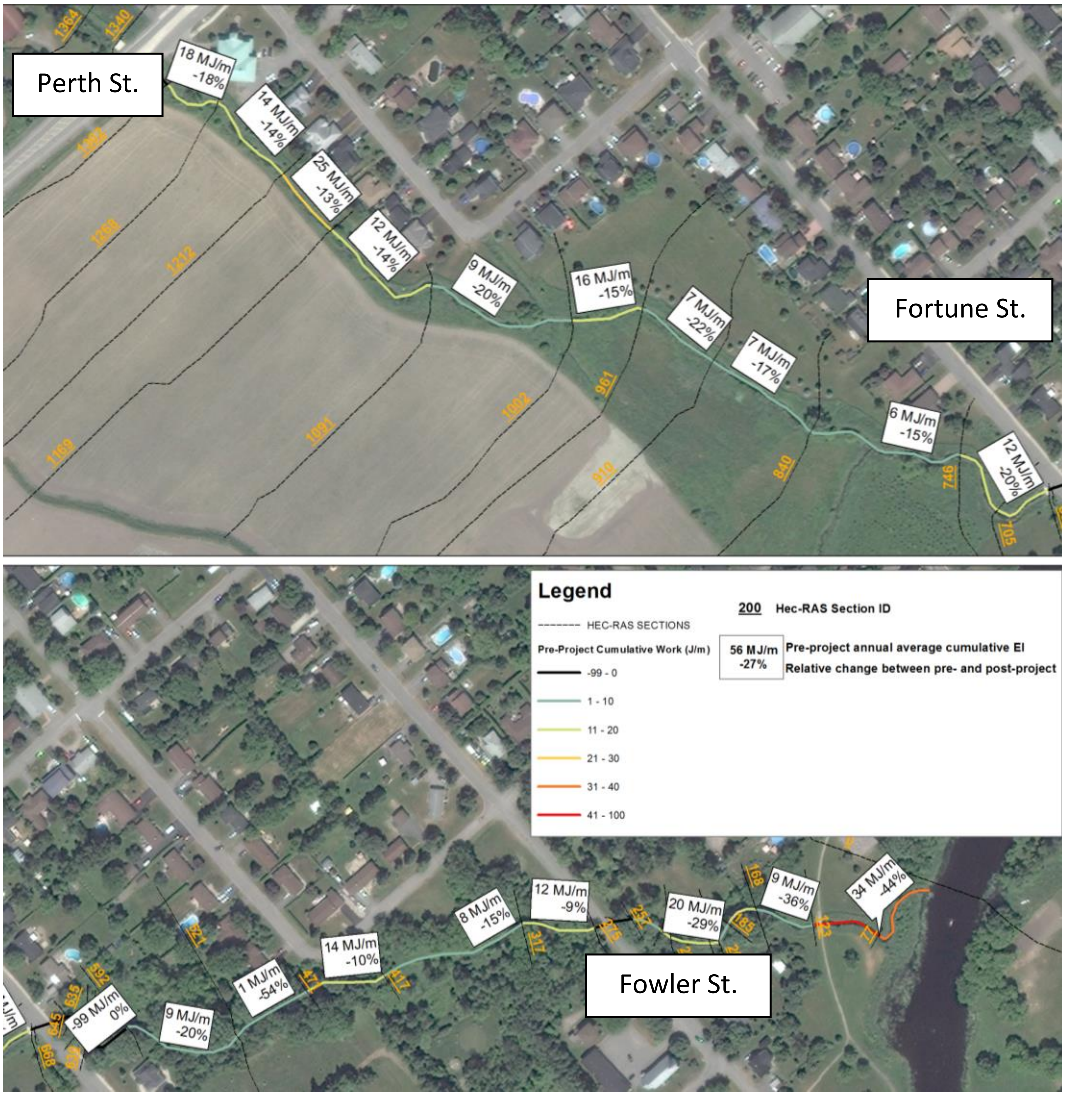

Figure 16 Annual average pre-development erosion index and change in erosion index over the 36-year simulation

The following table (Table 1) shows the annual average erosion index for existing and post-development conditions, alongside the annual hours above critical shear from the hydrologic analysis. It is important to note here that while patterns in total erosion threshold hours are the same between JFSA's 'continuous erosion analysis' and Coldwater's calculations, differences in the absolute numbers do exist. It is our understanding that the JFSA analysis was undertaken using a 1 hour timestep, while the Coldwater analysis was undertaken using a 15 minute timestep. JFSA's approach considers just one critical flow threshold, whereas the Coldwater approach looks at when a critical shear stress of 0.5 Pa occurs which varies spatially throughout the reach.

Looking at erosion simply in terms of hours above threshold gives the impression that erosion will be 12% worse under post-development conditions. This calculation reflects the fact that post-development will see a slight increase in the duration of low-flow conditions – but this calculation does not take into consideration the overall reduction in flow peaks.

The Erosion Index (indicating the erosional energy of the stream) is consistently reduced throughout the drain due to attenuation of flood peaks by implementation of the stormwater management plan. Looking at the entire study reach, Erosion Index is reduced by 21% relative to pre-project (existing) conditions.

Table 1 Average annual erosion index and average annual hours above critical shear

Station (Chainage u/s from Jock River)	Hours above 0.5 Pa threshold			Erosion Index (MJ/m)		
	Pre	Post	Δ	Pre	Post	Δ
77	108	101	-7%	34.2	18.9	-45%
123	278	312	12%	74.5	62.8	-16%
168	162	165	2%	9.4	6.0	-37%
185	220	239	9%	11.6	8.4	-27%
200	191	203	6%	6.9	4.9	-28%
201	218	238	9%	16.9	11.5	-32%
226	268	299	11%	19.8	13.8	-30%
235	255	282	11%	14.3	10.3	-28%
257	228	249	9%	9.1	6.6	-28%
317	476	628	32%	11.8	10.5	-10%
417	521	714	37%	8.4	7.0	-17%
471	714	1319	85%	14.5	12.6	-13%
521	19	12	-37%	0.2	0.1	-55%
592	393	489	24%	9.0	7.1	-21%
705	421	533	27%	16.1	13.0	-19%
746	415	524	26%	11.8	9.3	-21%
840	616	606	-2%	6.2	5.3	-15%
910	507	495	-2%	7.4	6.1	-17%
961	434	421	-3%	6.5	5.1	-22%
1002	1106	1105	0%	16.3	13.8	-15%
1091	486	473	-3%	8.7	7.0	-20%
1169	1118	1117	0%	11.7	10.0	-14%
1212	771	765	-1%	24.5	21.5	-13%
1268	1017	1014	0%	13.6	11.7	-14%
1302	965	961	0%	18.1	14.9	-18%
1312	69	58	-15%	0.6	0.4	-31%
Length-weighted annual averages:			+12.3%			-21.4%

6 Restoration and Protection Works

As described in JTB (2012), opportunities exist to implement restoration works in critical reaches in order to reduce erosion and to restore natural channel processes. Most notably these are required in the waters immediately upstream and downstream of the Fortune St. crossing as well as downstream of Fowler St.

As shown in Figure 17, conceptual restoration works have been developed for five specific sites. Bank restoration works are proposed both upstream of Fortune St. and downstream of Fowler St. This involves re-grading of the slopes, riprap bank protection and live stake plantings to re-establish vegetative cover.

The existing meander immediately downstream of Fortune St. is creating an erosional hotspot. Here, a channel re-alignment is recommended (Item C in the Figure 17) that will shift the channel away from the eroding bank. Cross-vanes will be used to develop riffle-pool structures that will stabilize the channel in its new location while also providing natural in-stream features.

The upstream wingwall for the Fowler St. crossing is presently being undercut, as identified in Item B in Figure 17, wingwall restoration works are proposed to remedy this situation.

Downstream of Fowler St., bank re-grading and revetment is required to protect the adjacent property on the west side of the stream. A small timber weir exists beneath the pedestrian bridge just upstream of this site and the remnants of a somewhat larger timber weir exist further downstream. It is quite possible that the loss of this downstream weir has significantly increased erosion upstream. We are proposing several cross-vane weir structures composed of quarrystone to replace and improve the function of these weirs. These structures will reduce channel slope in the area and help to stabilize the banks.

All of the proposed works will be undertaken within a framework of natural channel design. Even though riprap and slope re-grading will be required in several areas, measures will be incorporated in such a way that diversity and quality of aquatic habitat is enhanced through a combination of appropriate plantings and boulder features.

Preliminary cost estimates for these works are presented in Figure 18.

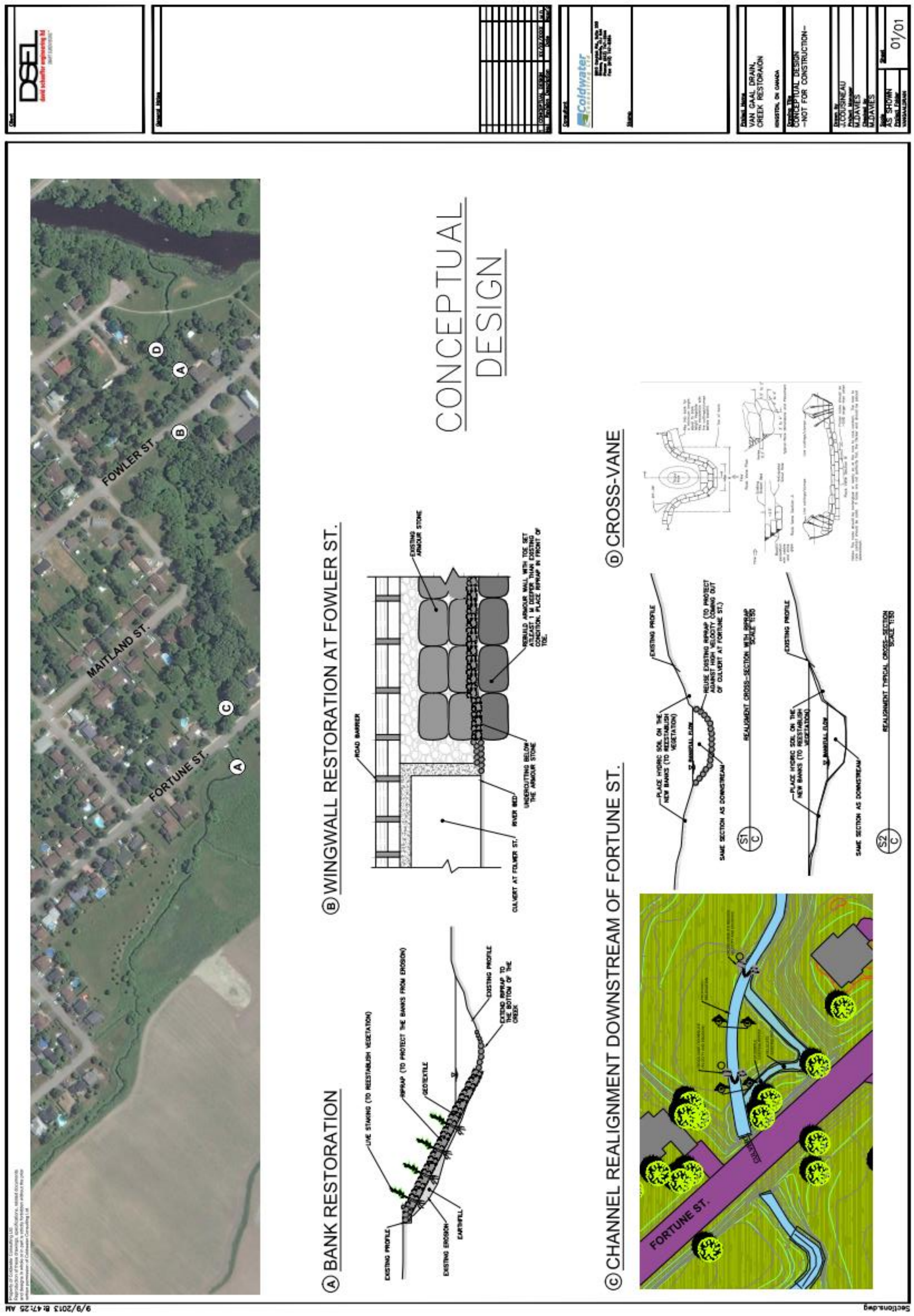

Figure 17 Restoration Conceptual Designs

Preliminary Cost Estimate - (Class D - Indicative estimate)
Project: Van Gaal Drain

Prepared by:	J. Cousineau
Checked by:	M. Davies

10 Sept 2013

Bank Restoration						
Items	***Quantity***	***Units***	***Unit Price***			***Price***
U/S of Fortune St.						
Mobilization/Demobilization	1	LS	$	5,000.00	$	5,000
Riprap	110	m^2	$	125.00	$	13,750
Non-Woven Geotextile	110	m^2	$	5.00	$	550
Backfill	18	m^3	$	45.00	$	797
Final grading of the proposed bank	110	m^2	$	10.00	$	1,100
Plantings	110	m^2	$	25.00	$	2,750
Silt Fence	54	m	$	25.00	$	1,350
Sediment trap	1	LS	$	1,000.00	$	1,000
			Cost at Fortune St. :		$	26,297
D/S of Fowler St.						
Mobilization/Demobilization	1	LS	$	5,000.00	$	5,000
Riprap	116	m^2	$	125.00	$	14,500
Non-Woven Geotextile	116	m^2	$	5.00	$	580
Backfill	19	m^3	$	45.00	$	837
Final grading of the proposed bank	116	m^2	$	10.00	$	1,160
Plantings	116	m^2	$	25.00	$	2,900
Silt Fence	136	m	$	25.00	$	3,400
Sediment trap	1	LS	$	1,000.00	$	1,000
			Cost at Fowler St. :		$	29,377
			Bank Restoration Cost:		$	55,674

Channel Realignment d/s of Fortune St.						
Items	***Quantity***	***Units***	***Unit Price***			***Price***
Mobilization/Demobilization	1	LS	$	5,000.00	$	5,000
Stockpile salvage riprap material	48	m^3	$	25.00	$	1,200
Excavation of the proposed channel	180	m^3	$	10.00	$	1,800
Final grading of the proposed channel	200	m^2	$	10.00	$	2,000
Cross-vane	2	EA	$	3,500.00	$	7,000
Place salvage riprap material	48	m^3	$	25.00	$	1,200
Hydric soil	350	m^2	$	5.00	$	1,750
Filling excavated material in the existing channel	212	m^3	$	10.00	$	2,120
Final grading of the old channel	150	m^2	$	10.00	$	1,500
Pumping of construction area	1	LS	$	750.00	$	750
Silt Fence	170	m	$	25.00	$	4,250
Sediment trap	1	LS	$	1,000.00	$	1,000
			Channel Realignment Cost:		$	29,570

Cross-vane downstream of Fowler St.						
Items	***Quantity***	***Units***	***Unit Price***			***Price***
Mobilization/Demobilization	1	LS	$	5,000.00	$	5,000
Cross-vane	1	EA	$	3,500.00	$	3,500
			Cross-Vane Cost:		$	8,500
			Total Construction Cost:		$	93,744
Additional Items						
Contingency				15%	$	14,062
Engineering Design				20%	$	18,749
Construction Monitoring				15%	$	14,062
Sub-total					$	121,868
HST				13%	$	15,843
Total					$	137,711

Figure 18 Planning level cost estimate - PRELIMINARY

7 Summary

The Van Gaal Drain is presently experiencing high levels of erosion. This erosion is expected to continue to erode until it reaches a new equilibrium, even without the proposed storm management plan.

From the erosion hazard model, the proposed storm water management plan is predicted to reduce erosion by an average of 21% - the drain will, however, continue to experience erosion.

Conceptual designs have been developed for protection and restoration measures that will protect critical areas – notably in the immediate vicinity of Fortune St. and downstream of Fowler St. Erosion sites upstream of the proposed SWM outfall could be left to naturally erode or could be improved – in large part, by excavating the drain to form a wider cross-section. Eroding sections in undeveloped reaches such as those between Fortune St. and Fowler St. are best left to re-shape naturally without the introduction of restoration works.

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1. AMENDMENT TO THE ENGINEER’S REPORT FOR THE VAN GAAL MUNICIPAL DRAIN

MODIFICATION AU RAPPORT DE L’INGÉNIEUR POUR LE DRAIN MUNICIPAL VAN GAAL

COMMITTEE RECOMMENDATION, AS AMENDED

That Council:

1. **Adopt the Engineer’s Report prepared by Robinson Consultants Inc., entitled Amendment to the Engineer’s Report for the Van Gaal Municipal Drain dated January 2019,** as amended by the following

   a. **All references to the drawing completed by Nak Design Strategies, entitled Planting Plan III, Revision 8 dated January 2015, be replaced with the drawing by Nak Design Strategies, entitled Planting Plan III, revision 9 dated May 30, 2019** (set out in supporting Document 1 below),

   b. **All references to the drawing completed by Coldwater Consulting Ltd. entitled Sections, Village of Richmond Channel Re-Alignment, Revision 5 dated June 5, 2016 be replaced with the drawing by Coldwater Consulting Ltd. entitled Sections, Village of Richmond Channel Re-Alignment, Revision 6 dated May 27, 2019** (set out in supporting Document 2 below)**,**

   c. **All references to the drawing completed by Coldwater Consulting Ltd. entitled Van Gaal Drain, Village of Richmond, Channel Re-Alignment, Revision 5, dated June 5, 2016 be replaced with the drawing by Coldwater Consulting Ltd. entitled Van Gaal Drain, Village of Richmond Re-Alignment, Revision 6 dated May 27, 2019** (set out in supporting Document 3 below)**,**

2. **Give 1st and 2nd reading to the By-law attached as Document 2 to this report in accordance with Sections 42 and 45 of the Drainage Act of Ontario.**

RECOMMANDATION DU COMITÉ, TELLES QUE MODIFIÉES

Que le Conseil

1. **Adopte le rapport d'ingénieur produit par Robinson Consultants Inc., intitulé Amendment to the Engineer's Report for the Van Gaal Municipal Drain (Modification au rapport de l'ingénieur pour le drain municipal Van Gaal), daté du mois de janvier 2019, dans sa version modifiée par ce qui suit :**

    a. **toutes les mentions de la version 8 du dessin de Nak Design Strategies intitulé Planting Plan III, Revision 8 (Plan de plantation III) et datée de janvier 2015 soient remplacés par des renvois à la version 9 du dessin, datée du 30 mai 2019** (comme l'indique le document 1 à l'appui ci-dessous)**;**

    b. **toutes les mentions de la version 5 du dessin de Coldwater Consulting Ltd. intitulé Sections, Village of Richmond Channel Re-Alignment, Revision 5 (Vue en coupe, modification du tracé des canaux de drainage du village de Richmond) et datée du 5 juin 2016 soient remplacés par des renvois à la version 6 du dessin, datée du 27 mai 2019** (comme l'indique le document 2 à l'appui ci-dessous)**;**

    c. **toutes les mentions de la version 5 du dessin de Coldwater Consulting Ltd. intitulé Van Gaal Drain, Village of Richmond, Channel Re-Alignment, Revision 5 (Installation de drainage Van Gaal, modification du tracé des canaux de drainage du village de Richmond) et datée du 5 juin 2016 soient remplacées par des renvois à la version 6 du dessin, datée du 27 mai 2019** (comme l'indique le document 3 à l'appui ci-dessous)**.**

2. **Présente en première et deuxième lectures le règlement joint au présent rapport en tant que document 2, conformément aux articles 42 et 45 de la Loi sur le drainage de l'Ontario.**

DOCUMENTATION/DOCUMENTATION

1. Document 1 - Planting Plan III, revision 9 dated May 30, 2019

   Document 1 - Plan de plantation III, version 8 datée du 30 mai 2019

2. Document 2 - Sections, Village of Richmond Channel Re-Alignment, Revision 6 dated May 27, 2019

   Document 2 - Vue en coupe, modification du tracé des canaux de drainage du village de Richmond, version 6, datée du 27 mai 2019;

3. Document 3 - Van Gaal Drain, Village of Richmond Re-Alignment, Revision 6 dated May 27, 2019

   Document 3 - Installation de drainage Van Gaal, modification du tracé des canaux de drainage du village de Richmond, version 6 datée du 5 juin 2016

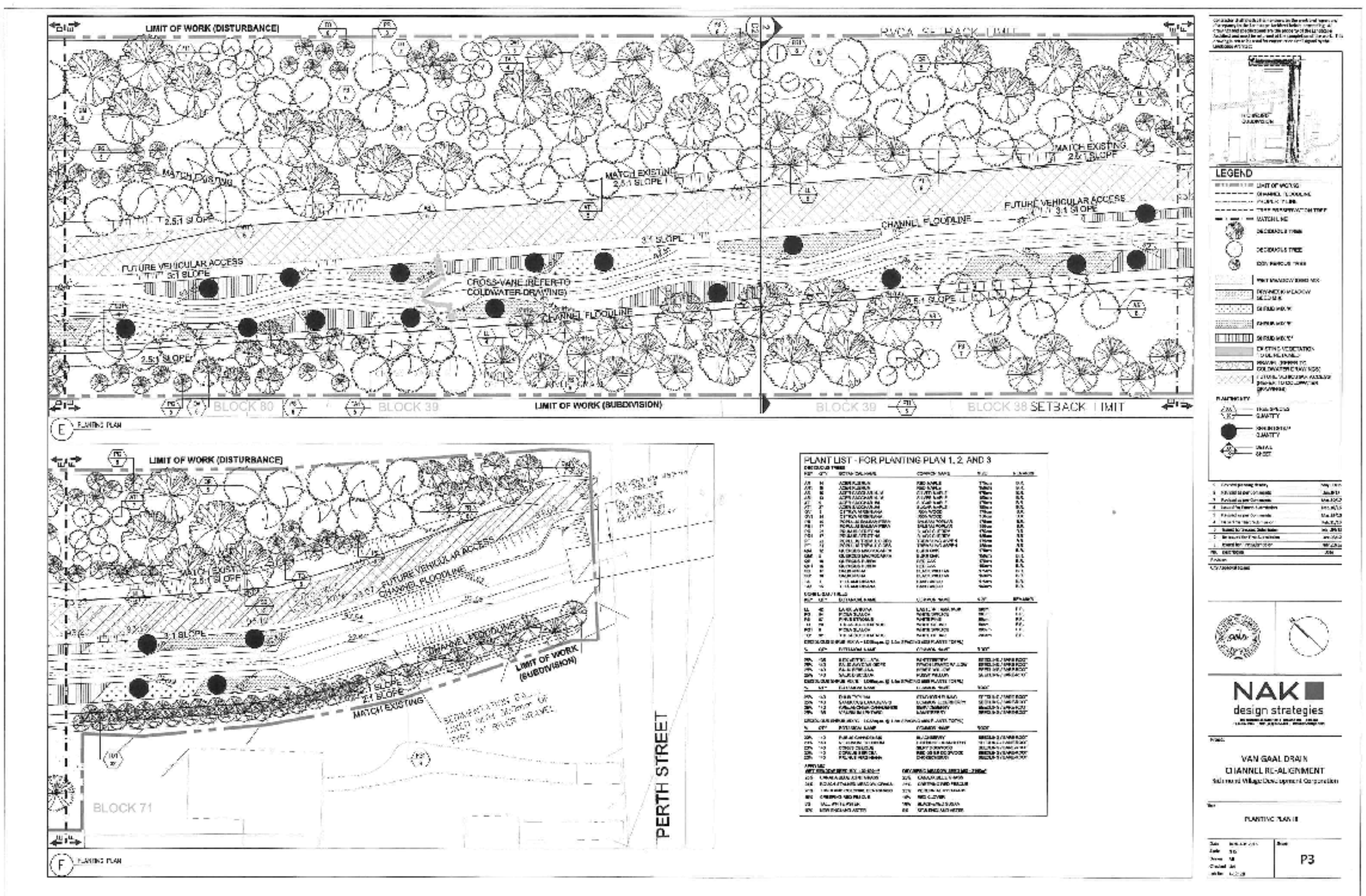
4. Director's report, Parks, Forestry and Stormwater Services, dated February 4, 2019 (ACS2019-PWE-GEN-0004)

   Rapport de la Directrice, Services des parcs, de la foresterie et des eaux pluviales, daté le 4 février 2019 (ACS2019-PWE-GEN-0004)

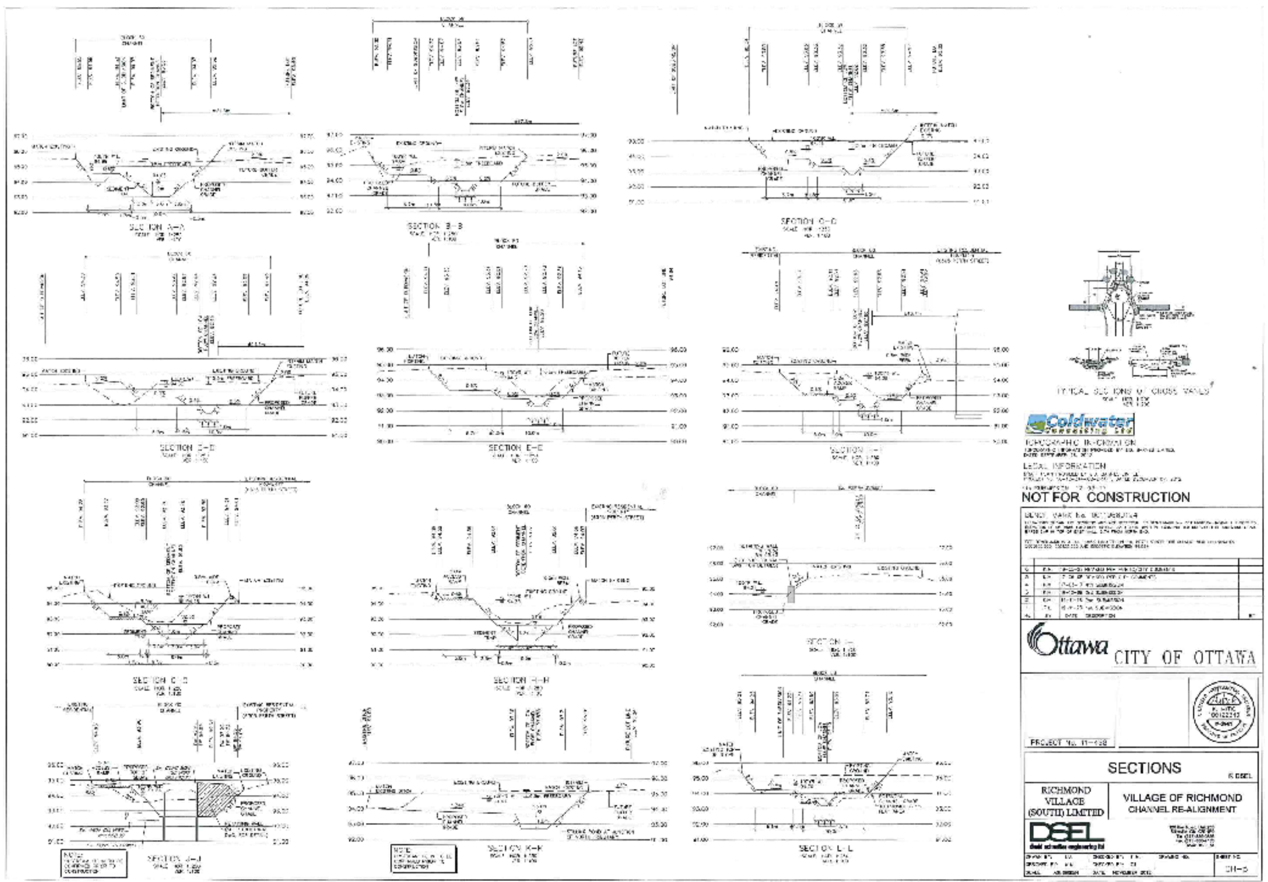
5. Extract of draft Minutes, Agriculture and Rural Affairs Committee, June 6, 2019

   Extrait de l'ébauche du procès-verbal, Comité de l'agriculture et des affaires rurales, le 6 juin 2019

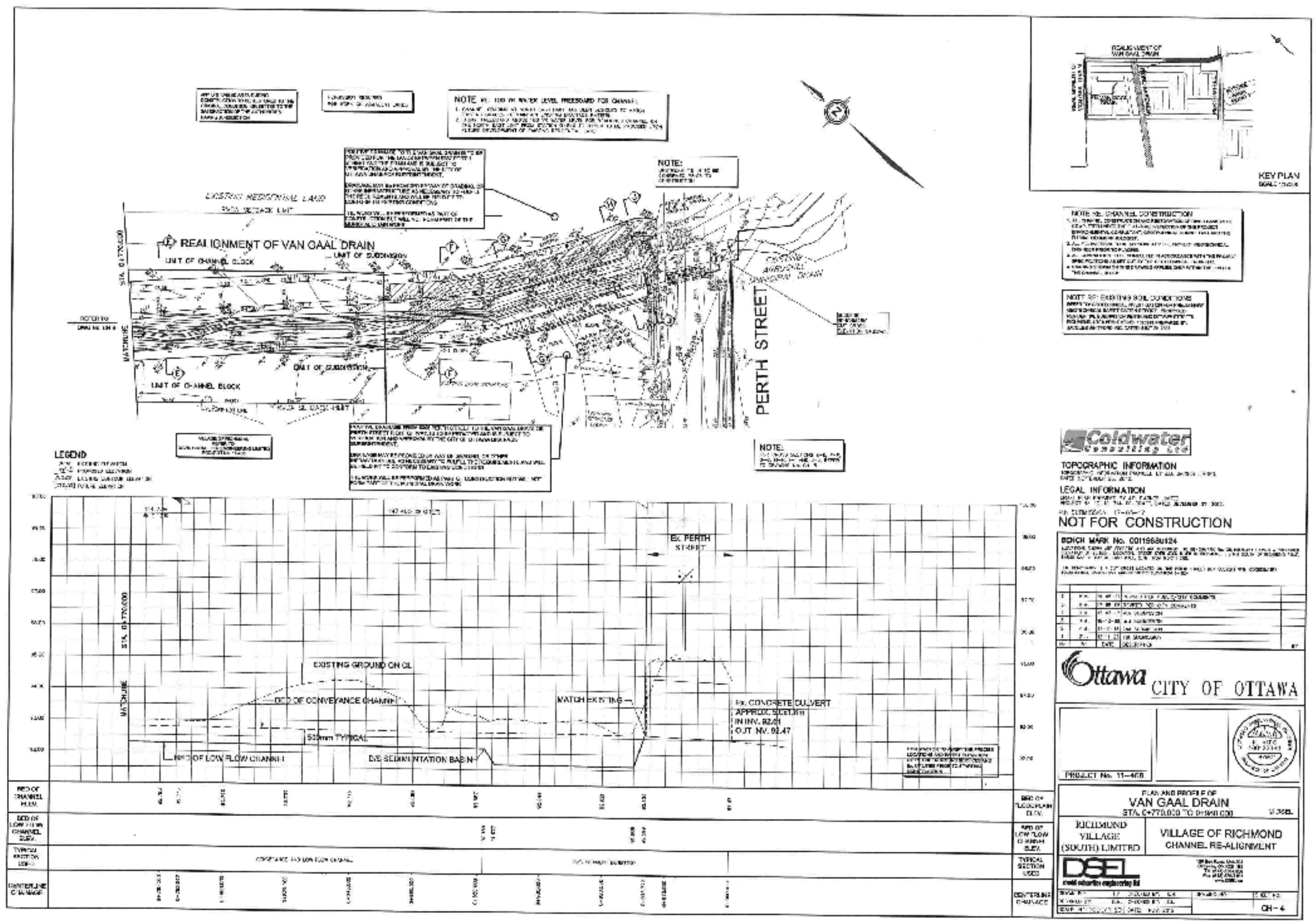
Document 1 - Planting Plan III, revision 9 dated May 30, 2019



Document 2 - Sections, Village of Richmond Channel Re-Alignment, Revision 6 dated May 27, 2019



<u>**Document 3 - Van Gaal Drain, Village of Richmond Re-Alignment, Revision 6 dated May 27, 2019**</u>



Report to
Rapport au:

Agriculture and Rural Affairs Committee
Comité de l'agriculture et des affaires rurales
6 June 2019 / 6 juin 2019

and Council
et au Conseil
12 June 2019 / 12 juin 2019

Submitted on February 4, 2019
Soumis le 4 février 2019

Submitted by
Soumis par:
Laila Gibbons, Director, Parks, Forestry & Stormwater Services / Directrice, Services des parcs, de la foresterie et des eaux pluviales

Contact Person
Personne ressource:
Dave Ryan, Drainage Superintendent
613-580-2424, x25106 David.Ryan@ottawa.ca

Ward: RIDEAU-GOULBOURN (21) **File Number**: ACS2019-PWE-GEN-0004

SUBJECT: **Amendment to the Engineer’s Report for the Van Gaal Municipal Drain**

OBJET: **Modification au rapport de l’ingénieur pour le drain municipal Van Gaal**

REPORT RECOMMENDATIONS

That the Agriculture and Rural Affairs Committee recommend that Council adopt the Engineer’s Report prepared by Robinson Consultants Inc., entitled Amendment to the Engineer’s Report for the Van Gaal Municipal Drain dated January 2019 and give 1st and 2nd reading to the By-law attached as Document 2 to this report in accordance with Sections 42 and 45 of the Drainage Act of Ontario.

RECOMMANDATIONS DU RAPPORT

Que le Comité de l’agriculture et des affaires rurales recommande au Conseil d’adopter le rapport d’ingénieur produit par Robinson Consultants Inc., intitulé Amendment to the Engineer’s Report for the Van Gaal Municipal Drain (Modification au rapport de l’ingénieur pour le drain municipal Van Gaal), daté du mois de janvier 2019, et présente en première et deuxième lectures le règlement joint au présent rapport en tant que document 2, conformément aux articles 42 et 45 de la Loi sur le drainage de l’Ontario.

BACKGROUND

On September 13, 2013 the Council of the City of Ottawa appointed Andy Robinson, P.Eng. of Robinson Consultants Inc., as the Engineer of record to prepare a report under Section 78 of the *Drainage Act* to address changes within the watershed of the Van Gaal Municipal Drain.

The purpose of this report is to accommodate the change in land use from rural/agricultural to urban development for the lands identified as Block N (N1 through N5) on Dwg. No. 13056-A4 Rideau-Goulbourn Ward, former Township of Goulbourn. The amendments in the report include modifications to portions of the main drain. This report will also include the abandonment of the West Main Drain between station 1+754 and Station 1+935. The West Main Drain will now connect to the Van Gaal Municipal Drain at Station 0+281.30.

To address the land use changes and partial abandonment of the West Main Drain, amendments are required to the existing Engineers Report, entitled Engineer’s Report Van Gaal Municipal Drain, dated July 2003 and prepared by Robinson Consultants Inc.

The required amendments are detailed in the Engineer's Report entitled Amendment to the Engineer's Report for the Van Gaal Municipal Drain dated January 2019 prepared by Robinson Consultants Inc. (the said report shall hereinafter be referred to as the "Engineer's Report dated January 2019").

Pursuant to Section 9 of the Drainage Act, the on-site meeting was held on December 4, 2013. All affected landowners were notified of the meeting.

DISCUSSION

The Van Gaal Municipal Drain was first constructed in 1972 under By-law No. 12-72 in the former Township of Goulbourn. The Engineers Report was updated in 2003 under by-law 2003-397, City of Ottawa to accommodate development within Lot 22, concession 4 Ridau-Goulbourn Ward, former Township of Goulbourn. A new Engineer's report is required to address land use changes and partial abandonment of the West Main Drain.

The Engineer's Report dated January 2019 accommodates the change in land use from rural/agricultural to urban development for the lands identified as Block N (N1 through N5) on Dwg. No. 13056-A4 Rideau-Goulbourn Ward, former Township of Goulbourn. The amendments in the report include modifications to portions of the main drain including relocating the drain, lowering the profile and increasing the cross-section of the drain to accommodate the proposed drainage and stormwater management systems for the development area. This report also includes the partial abandonment of the West Main Drain between station 1+754 and Station 1+935. The West Main Drain will now connect to the Van Gaal Municipal Drain at Station 0+281.30.

Initial costs for the amended Engineers Report have been paid for by the City of Ottawa Parks, Forestry and Stormwater Services Branch of the Public Works and Environmental Services Department from capital internal order 907486. All costs associated with this report will be recovered through assessments to the property owners of the lands in Block N (N1 and N3). Future maintenance costs for the Van Gaal Municipal Drain will be assessed as per assessment schedule "A" - summary for future maintenance of section(s) of the Van Gaal Municipal Drain in the Engineer's Report dated January 2019.

The *Drainage Act* prescribes the process and timelines that must be followed for any modification or construction of a municipal drain.

This report places the request for amendment to an existing drainage works before the Agriculture and Rural Affairs Committee and Council as required under Section 78 of the *Drainage Act*.

Should the Agricultural and Rural Affairs Committee and Council adopt the Engineer's Report dated November 2018 and give 1st and 2nd reading to the provisional By-law, the process will continue as set out by the Drainage Act R.S.O. 1990.

RURAL IMPLICATIONS

The Van Gaal Municipal Drain will continue to provide legal and sufficient outlet for some urban and rural lands and roads.

CONSULTATION

As part of the development planning process consultation between the developer, their representatives, City approvals and drainage staff, the Council-appointed Drainage Engineer and regulatory agencies is ongoing. The required on-site meeting with the affected landowners was held on December 4, 2013.

COMMENTS BY THE WARD COUNCILLOR(S)

The Councillor for Rideau-Goulbourn is aware of this report and the proposed drainage works.

LEGAL IMPLICATIONS

There are no legal impediments to adopting the recommendation outlined in this report.

RISK MANAGEMENT IMPLICATIONS

There are no risk implications associated with this report.

FINANCIAL IMPLICATIONS

There are no financial implications associated with this report. Initial costs for the amended Engineers Report have been paid for by the City of Ottawa Parks, Forestry and Stormwater Services Branch of the Public Works and Environmental Services Department from capital internal order 907486. All costs associated with this report will be recovered through assessments to the property owners of the lands in Block N (N1 and N3). Future maintenance costs for the Van Gaal Municipal Drain will be assessed as per assessment schedule "A" - summary for future maintenance of section(s) of the Van Gaal Municipal Drain in the Engineer's Report dated January 2019.

ACCESSIBILITY IMPACTS

There are no accessibility impacts associated with this report.

ENVIRONMENTAL IMPLICATIONS

The modifications to the Van Gaal Municipal Drain are associated with a development application for the area for which discussion with the various City departments and regulatory agencies are ongoing. The proposed storm water management system, including any drainage works modifications, will provide outlet for the proposed development and improve storm water management in the area while continuing to provide legal and sufficient outlet for the area lands and roads, including some agricultural lands. There are no provincially significant wetlands affected by this undertaking and the drainage works will protect and enhance existing fish habitat. The proposed works will require compliance with City, Provincial and Federal policy standards, regulations and legislation.

TERM OF COUNCIL PRIORITIES

The recommendations of this report align with the current Strategic Priority as part of the sustainable environmental services strategic priority by supporting an environmentally sustainable Ottawa.

SUPPORTING DOCUMENTATION

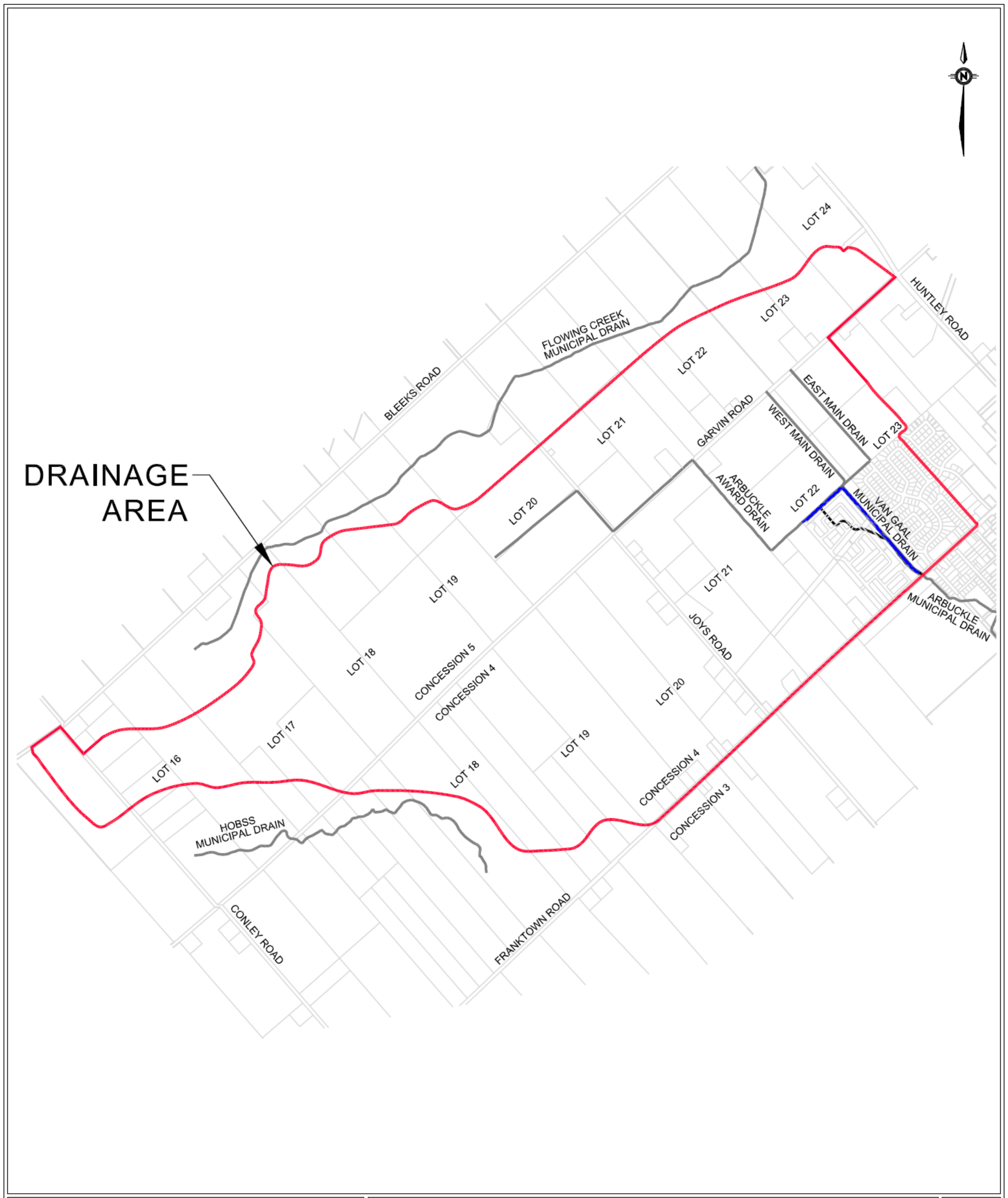
DOCUMENT 1 – Location Plan

DOCUMENT 2 – Provisional By-law (Previously distributed)

DISPOSITION

Upon approval by Council, the Office of the Drainage Superintendent will notify all affected landowners of the date of the 1st sitting of the Court of Revision as required under Section 46 of the Drainage Act R.S.O. 1990.

Document 1



Robinson Consultants	Title: LOCATION PLAN	Fig. No. 3.1
	Project: VAN GAAL MUNICIPAL DRAIN	Job No. 13056
	Scale: NTS	Date: JANUARY 2019

NATURAL CHANNEL DESIGN: VAN GAAL DRAIN, RICHMOND VILLAGE DEVELOPMENT, RICHMOND, ON

Submitted to: David Schaeffer Engineering Limited

Prepared by: M.H. Davies, Ph.D., P.Eng.
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Version: 1.21

Date: 23 February 2017

Version History

Version	Date	Status	Comments	Reviewed by	Approved by
1	24 September 2014	For discussion		NJM	MHD
1.1	18 January 2016	For review	Revised meander and pool layout	NJM	MHD
1.2	15 February 2017	For review	Revised cross-section and layout	NJM	MHD

For further information please contact:

Michael Davies (mdavies@coldwater-consulting.com) 613 747-2544

Provisos

This report was prepared by Coldwater Consulting Ltd. The recommendations and opinions contained in this report are based upon a limited dataset and a limited scope of work. The material contained herein reflects the judgement of Coldwater Consulting Ltd. in light of the information available to them at the time of preparation. The present report applies only to the project described in this document. Use of this report for purposes other than those described herein, or by person(s) other than the Richmond Village Development Corporation or their agent(s) is not authorized without review by Coldwater for the applicability of our recommendations to the altered use of the report.

Submitted 15 February 2017,

M.H. Davies, Ph.D., P.Eng.
Coldwater Consulting Ltd.

Table of Contents

1 Introduction

This design brief describes the methodology, rationale and design parameters for creation of a natural stream channel of Van Gaal Drain upstream of Perth Street. It is understood that approximately 900 m of the existing Van Gaal Drain upstream of Perth Street will be realigned to follow the boundary of the Richmond Village Development Corporation site in the Village of Richmond. While for the purposes of this project, this reach is referred to as part of Van Gaal Drain, it is commonly also referred to as the Arbuckle Drain.

A natural stream channel is one that provides a diversity of stream characteristics (pools, meanders, fast water, etc.), a diversity of bed materials (sands, gravels, rocks), and supports a variety of flora and fauna. For the present case, the emphasis on the design is to create as natural a channel as possible, which will provide a diversity of aquatic and terrestrial habitats as well as be aesthetically pleasing. The inclusion of natural channel features into a Municipal Drain creates unique challenges for maintenance and access.

1.1 Scope of Work

The present scope of work involves the design of a low-flow channel using natural channel design principles. This channel sits within a larger conveyance channel designed to pass the 100-year flood. The design of the overall geometry of the conveyance channel and associated culverts was not within the original scope of this work. This most recent work undertaken by Coldwater (Version 1.2) has included modifications to the conveyance channel to ease maintenance and detailing of the confluence with the drainage tributary at the northern corner of the project.

Coldwater Consulting Ltd., (Coldwater) has been engaged to provide the following design and analysis services to David Schaeffer Engineering Ltd. (DSEL):

- Channel design, including 'natural channel design' for the low-flow inner channel;
- Bank erosion assessment of the proposed channel & recommendations, and;
- Planting recommendations for erosion control.

1.2 Background Information

The following documents were referenced when preparing this design brief:

- JTB Environmental Systems Inc. " Van Gaal Drain Erosion Assessment, Richmond, Ontario", provided by DSEL dated October 2012;
- HEC-RAS model developed and provided by JFSA, September 2013;
- continuous time series of discharge for pre- and post-development at 4 junctions (provided by JFSA, 2014-10-Jan);
- JFSA report on continuous erosion analysis and updated pre-and post development hydrology (JFSA file 922-11, dated 2013-Oct-18);
- Updated JFSA report with model results reflecting new channel design (JFSA file 922-11, dated 2017-Jan-04).
- Stormwater Management Planning and Design Manual, (Ontario MoE, March 2003);
- cross-sectional data (Arbuckle drain cross sections.dwg) surveyed by J.D. Barnes and provided by DSEL, and;
- ACAD files: 468_channelbase.dwg, 468_Channel_Prof_rev_Section.dwg to provide base layout information for the site and proposed development (provided by DSEL, July 2014).

2 Site Description

Van Gaal Drain is located in Richmond, Ontario. Approximately 900 m of the existing Van Gaal Drain upstream of Perth Street will be realigned to follow the boundary of the Richmond Village Corporation site (see Figure 1).

The City of Ottawa and the Rideau Valley Conservative Authority (RVCA) have accepted that an engineered conveyance channel be constructed just upstream of Perth Street. As a condition of these changes to Van Gaal Drain, natural channel design features are to be incorporated into the conveyance channel.

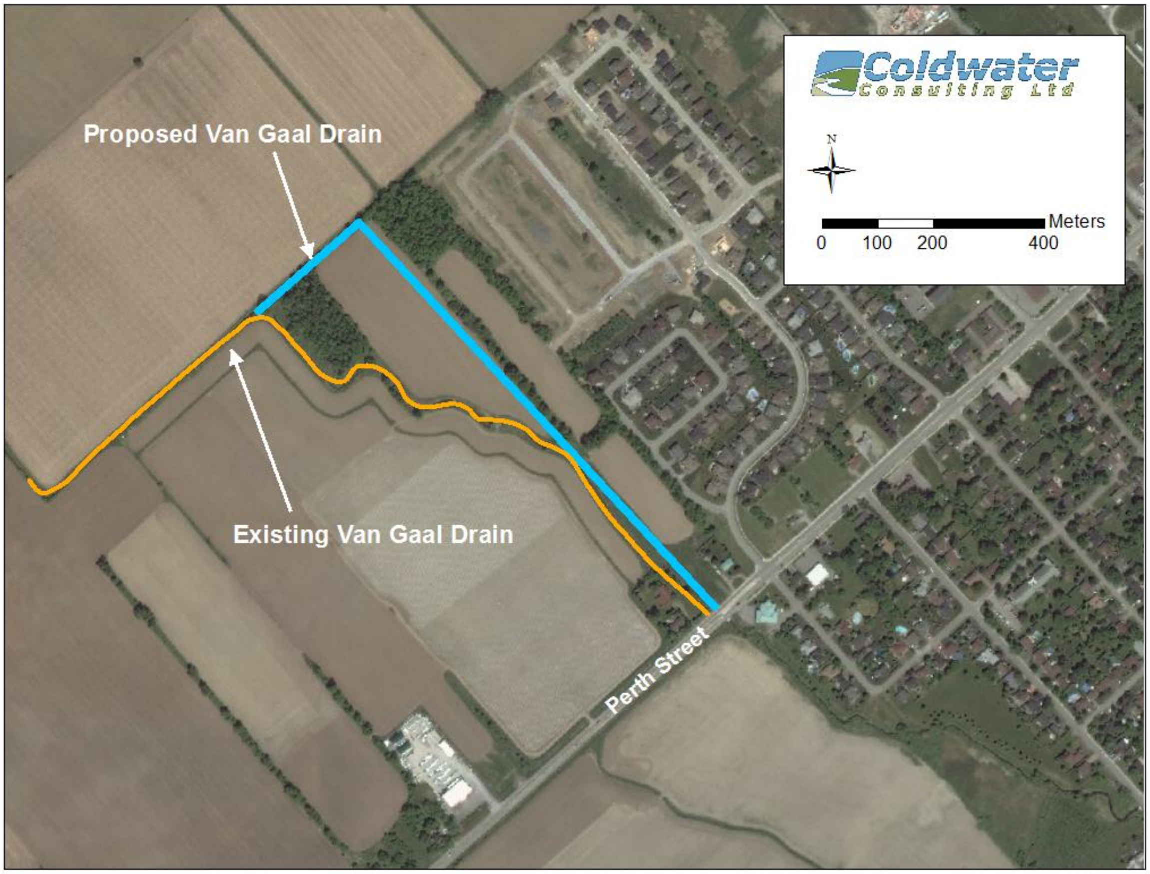

Figure 1 Site Location

3 Design

Natural channel design is being applied throughout Ontario for the restoration of degraded rivers and streams. The goal of natural channel design is to restore the hydraulic and ecological functioning of a channel through the re-creation of natural features such as banks, runs, riffles, meanders, and pools. Planting of appropriate natural vegetation is integral to the design for both its ecological value, and to aid in soil retention and erosion protection. All approaches to natural channel design typically use the geomorphic and hydraulic characteristics of stable, natural river/stream reaches from the subject watershed or from other watersheds that demonstrate similar geomorphic and hydraulic characteristics as reference conditions to guide the design. A more detailed discussion of Coldwater's approach to natural channel design is provided in *APPENDIX A - Natural Channel Design*, p. 17.

At this site, a conveyance channel with a trapezoidal form will be constructed to carry flows up to the 100-year return period flow. The task at hand is to naturalize this channel to the extent possible while maintaining flood conveyance capacity. This is mainly obtained by designing a natural channel to carry low flow conditions that fits within this larger flood channel. As described in *APPENDIX A - Natural Channel Design*, the design for low flows should aim to meet biological needs. Summer low flows are often a critical period for fish and other species and, thus, the low-flow channel is designed to provide increased depths at that time (Copeland, McComas, Thorne, Soar, & Fripp, 2001).

3.1 Design Parameters

The original conveyance channel was designed by DSEL to have a 10.0 m wide base and 2.5H:1V side slopes. The slope of the conveyance channel varies between 0.120% and 0.196% over its length. The elevation of the base of the conveyance channel was taken from the AutoCAD file (468_channelbase.dwg) provided by DSEL. The low flow channel was design to fit within the base of the conveyance channel. The most recent modifications to this channel (as shown in Figure 2, below) include widening the base of the conveyance channel to approximately 19 m to include a grassed step on the left-hand side of the channel (when viewed looking downstream). This grassed step will provide aquatic habitat during high water conditions and will also provide access for heavy equipment during maintenance of the Municipal Drain.

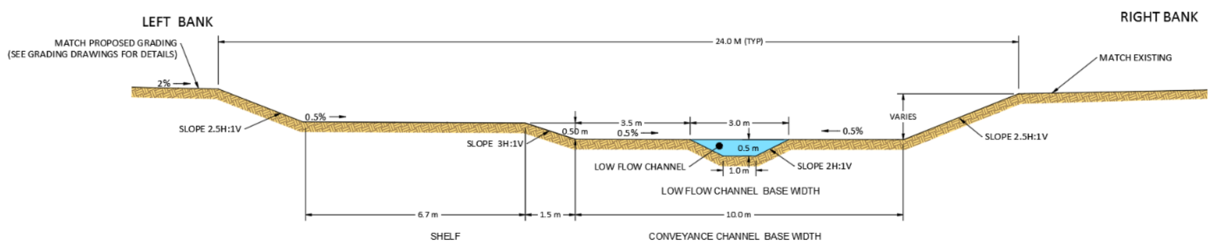

Figure 2 Typical channel cross-section

3.2 Hydrology

3.2.1 HEC-RAS

Discharges and water levels for the conveyance channel were produced by J.F. Sabourin and Associates Inc. (JFSA) and provided to Coldwater through the HEC-RAS model by DSEL. Post-development peak flows expected in the conveyance channel upstream of Perth Street are given in Table 1. Peak discharge was taken from JFSA's HEC-RAS model for Station 1340 which is located at Perth Street.

Table 1 Post-development flows at Station 1340 (from JFSA's HEC-RAS model, Jan 2017)

Event	Post-development Peak Flow (m^3/s)
2-Year	3.76
5-Year	5.64
100-Year	11.43

3.2.2 SWMHYMO

The hydrologic analysis by JFSA was performed using SWMHYMO (Van Gaal Proposed Conditions Continuous Hydrographs 20140110.xlsx), a complex hydrologic model used for the simulation and management of stormwater runoff in rural and urban areas. SWMHYMO processes rainfall records to simulate the transformation of rainfall into surface runoff. The surface runoff at Perth Street was simulated between 1967 and 2003 during the summer months (April 1^{rst} to October 31st). A total of 1,380 rainfall events, approximately 40 per year and 5 per month were calculated using JFSA's output file. A rainfall event is defined when the surface runoff starts and ends with a discharge of 0 m^3/s.

3.2.3 Low Flow Conditions

The JFSA analysis provides flow conditions corresponding to return periods of 2 years and longer, but little information on high frequency events (i.e., low flows). The low-flow channel was designed using the average monthly peak flow for the summer season. This discharge was selected in place of the 7-day annual low-flow discharge (see APPENDIX A - Natural Channel Design, Design Flow, p. 20) for two reasons:

- first, not enough is known about the base-flow to establish the 7-day annual low-flow with any accuracy, and;
- second, this discharge corresponds to a low-flow channel with dimensions similar to those of the existing channel immediately downstream of Perth St.

The surface peak runoff was calculated for each rainfall event and the 80th percentile of all the surface peak runoff (an event that only occurs once a month) was used to determine the monthly peak flow. **A discharge of 0.43 m^3/s (corresponding to the expected monthly peak flow) has been selected as the design discharge for the low flow channel.**

3.3 Hydraulics

Table 2 shows the characteristics of the conveyance channel. Table 3 shows flow depths, velocities and shear stresses in the conveyance channel under a variety of flow conditions ranging from the 100-year return period flow down to a 2-year return period event. These numbers are based on conditions from the HEC-RAS model at Reach 2, RS 1555[1] which is

[1] JFSA HEC-RAS simulation results (P922 2017-Jan-06) RS 1555.

slightly upstream of the Perth St. crossing and was chosen as a representative cross-section. A Manning's roughness coefficient of 0.08 was specified for the conveyance channel bed and banks to account for heavy vegetation. This is the same value of Manning's roughness coefficient used in the JFSA HEC-RAS model. Velocities in the conveyance channel will range from a high of 0.76 m/s for the 100-year event down to low of 0.55 m/s for the 2-yr event.

Table 2 Characteristic of the conveyance channel

Characteristic	Value
Max. stream slope	0.00196
Base (m)	10.0
Side slope 1	2.5H:1V
Side slope 2	2.5H:1V
Manning, n	0.08
River Gravel Type 'A' D50	38.1 mm

Table 3 shows the predicted mobility for the river gravel 'Type A'. Mobility (M) is the ratio of the shear stress exerted by the flow to the critical shear stress at which sediment transport is initiated; a value of $M > 1$ indicates sediment mobility. Calculations show that the river gravel 'Type A' with a D_{50} of 38.1 mm would be expected to be stable at all conditions.

Table 3 Flow conditions in mid-section of conveyance channel

Return Period	100-yr	5-yr	2-yr
Discharge, Q (m^3/s) (at Perth St.)	11.43	5.64	3.76
Discharge, Q at RS 1555 (m^3/s)	9.54	4.41	2.80
Depth, y (m)	1.81	1.66	1.57
Velocity (m/s)	0.76	0.64	0.55
Froude No.	0.18	0.16	0.14
River Gravel Type 'A'			
Shear stress (Pa)	5.82	4.20	3.19
Mobility	0.17	0.12	0.09
Mobile?	No	No	No

The river stone 'Type A' as specified in Section 3.6.1 is a well-graded sandy-gravel. The stone diameter varies between 0.5 and 150 mm. Regarding the fines in this sediment mix: Sediment mobility analysis using the hiding and exposure function (Egiazaroff, 1965) indicates that all sediments greater 1 mm are stable under the 2-yr flood event and all sediments greater than 3 mm are stable during the 100-yr flood event.

3.4 Conveyance Channel Assessment

The cross-section of the conveyance channel is sufficient to pass the design flood while also providing some storage. This section examines requirements for erosion control in the conveyance channel. The natural channel design documented herein specifies that the channel be lined with straw fibre erosion control blanket over the placed topsoil at the time of construction. The channel is to be planted with native plants and a seed mix that includes a nurse species (a quick-germinating plant such as annual rye or oats that will provide cover and erosion protection as the native plants germinate and take root). Specifications for seed mix and plants are provided in the landscape drawings.

3.4.1 Bank Erosion Assessment

The resistance of the conveyance channel to erosion was investigated using the USDOT design methodology for channels with vegetative linings (US Dept. of Transportation, Federal Highways Administration). The USDOT approach requires estimation of the properties of both the soil and the vegetation. For the present application, the soil was assumed to a clayey-sand and the vegetation was assumed to be a 'fair coverage' of mixed grass with an average stem height of 7.5 cm. The input values used in the calculation and the results for the 100-year return period event are presented in Table 4. This analysis shows that the vegetative lining for the main conveyance channel will withstand the 1:100 yr flood event (the critical shear stress for the vegetation is 88.4 Pa, which far exceeds the expected shear stresses due to flow events).

For bare soil conditions (before the vegetative cover has been established), the shear stresses imposed by the 1:100 month flood event down to the 3 month return period event would cause erosion of the bare soil. Thus, straw fibre erosion control blankets are required until the vegetation matures.

Table 4 Vegetation stability during the 100-yr return period events

Property	
Soil	
Type	clayey-sand
Plasticity index, PI	16
Voids ratio, e	0.5
Manning (soil), n_s	0.016
$\tau_{cr\ (soil)}$	3.3 Pa
Discharge	11.43 m^3/s
Velocity	1.745 m/s
τ_{bed}	11.0 Pa
Mobility	3.34
Mobile?	Yes
Threshold flow rate	1.95 m^3/s (3-month return period)
Vegetation	
Growth	Mixed
Coverage	Fair
Stem height	7.5 cm
Vegetation Roughness Coefficient, C_n	0.142
Vegetation Cover Factor, C_f	0.7
$\tau_{cr\ (\mathrm{vegetation})}$	88.4 Pa
Discharge	11.43 m^3/s
Velocity	0.76 m/s
τ_{bed}	5.8 Pa
Mobility	0.07
Mobile?	No

3.5 Low-Flow Channel Design

The geometry for the meandering channel is based on techniques developed by C. Thorne as presented in several US government reports (USDA, 2007), (US Army Corps of Engineers, 2001). Cross-vane weirs have been incorporated into the design following the work of Rosgen (2006).

3.5.1 Design Methodology

A natural stream channel is one that provides a diversity of stream characteristics (pools, meanders, fast water, etc.), a diversity of bed materials (sands, gravels, rocks), and supports a variety of flora and fauna. For the present case, the emphasis on the design is to create as natural a channel as possible, which will provide a diversity of aquatic and terrestrial habitats as well as be aesthetically pleasing.

Meanders can be seen as a natural response of the streambed to the flows that it carries. The ‘equilibrium theory’ for meanders states that meanders act to decrease the stream gradient (channel slope) until the transport capacity of the stream balances the erodibility of the streambed. Meanders are generated by the ‘channel-forming flow’, which for most natural channels is the flow with a 1- to 2-year return period. The present low-flow channel is designed to meet environmental needs and, thus, the meanders will be designed using the bank-full conditions for that channel, which is the summer season monthly return period flow. In order to ensure channel stability, the meandering low-flow channel will be built as a partially-controlled channel since it will be frequently exposed to flows greater than the bankfull condition. Coldwater's stream design philosophy is further discussed in *APPENDIX A - Natural Channel* Design, p. 17.

In order to add diversity to the design, several cross-vane weirs, constructed with small boulders and stones, are included in the design. These features will add to the diversity of aquatic habitat and will create local flow accelerations that will increase oxygenation of the water while also creating back-eddies where finer sediments can accumulate. Pools are also included in the design to further increase the diversity of aquatic habitat and to provide some holding areas that will tend to preserve cooler, deeper pockets of standing water during dry weather.

Just upstream of Perth St., an inline sediment detention pond has been incorporated into the design. The purpose of this pond is two-fold. It provides a sedimentation trap that can be readily maintained by access via the west side of the channel at Perth Street. It also provides a deep-water pool which will be used as a refuge by fish and will generally add to the diversity of aquatic habitat in the stream.

3.5.2 Flow Conditions and Bed Stability

A channel base width of 1.0 m with 2H:1V side slope was selected as a starting point for the channel design (Table 5). This channel has a bankfull flow capacity of 0.45 m^3/s which exceeds the calculated monthly flow of 0.43 m^3/s. Table 6 shows conditions in the low flow meandering channel under the monthly flow.

Table 5 Characteristic of the low flow channel

Characteristic	Value
Max. stream slope	0.00195
Base width (m)	1.0
Side slope 1	2H:1V
Side slope 2	2H:1V
Manning’s n	0.035
River Gravel Type 'A' D50	38.1 mm
Critical shear stress (Pa)	34.1

Table 6 Flow conditions in the low flow meandering channel

Condition	Monthly Flow
Discharge, Q (m^3/s)	0.430
Depth, y (m)	0.371
Channel width at surface (m)	2.982
Wetted area (m2)	0.830
Wetted perimeter (m)	3.157
Hydraulic radius (m)	0.263
Velocity (m/s)	0.518
Froude No.	0.272
Gravel Type 'A'	
Shear stress (Pa)	7.09
Mobility	0.2
Mobile?	No

Table 6 shows that 38.1 mm gravel would be well below the threshold for mobility for these conditions.

3.5.3 Meandering Channel Design

In natural channel systems, the width of the channel and its depth control the shape and size of the turbulent eddies that create meanders. Consequently, the meander length is directly related to bankfull channel width. For the range of channel slopes under consideration (less than 0.196%), selection of a narrower channel would generate a shorter meander length. In order to create meanders that fit within the 10.0 m wide base of the conveyance channel, the low-flow channel slope is varied between 0.112% and 0.195%. Channel width was selected to provide the longest practical meanders, thereby limiting the complexity and cost of the construction works.

Coldwater's in-house channel design software was used to develop a three-dimensional model of the channel including a channel cross-section that varies between trapezoidal in channel runs and triangular in meander bends (deep channel on the outside of the bend). The resulting channel has the following characteristics:

- Sinuosity, P = 1.005 to 1.054
- Meander wavelength, L_m = 33.78 m
- Radius of curvature of meanders R_c = 6.75 - 7.47 m
- Minimum bankfull channel width, W_{am}= 2.9 m
- Maximum bankfull channel width in meanders, W_{mm}= 3.2m
- Meander pool depth, y_m= 0.75 m

3.5.4 Cross-Vane Design

The conveyance channel is designed with a relatively mild slope. Although the vertical drop provided by this slope is not particularly well-suited to a riffle-pool system, cross-vane structures have been added to anchor the pools; this also adds diversity to the channel (see Figure 3). A cross-vane is a boulder structure that trains the flow toward the centre of the channel. The cross-vane design adopted herein is based on techniques developed by Rosgen (2006). The structure also improves stream habitat by creating different near-bank water levels, local flow accelerations and flow aeration.

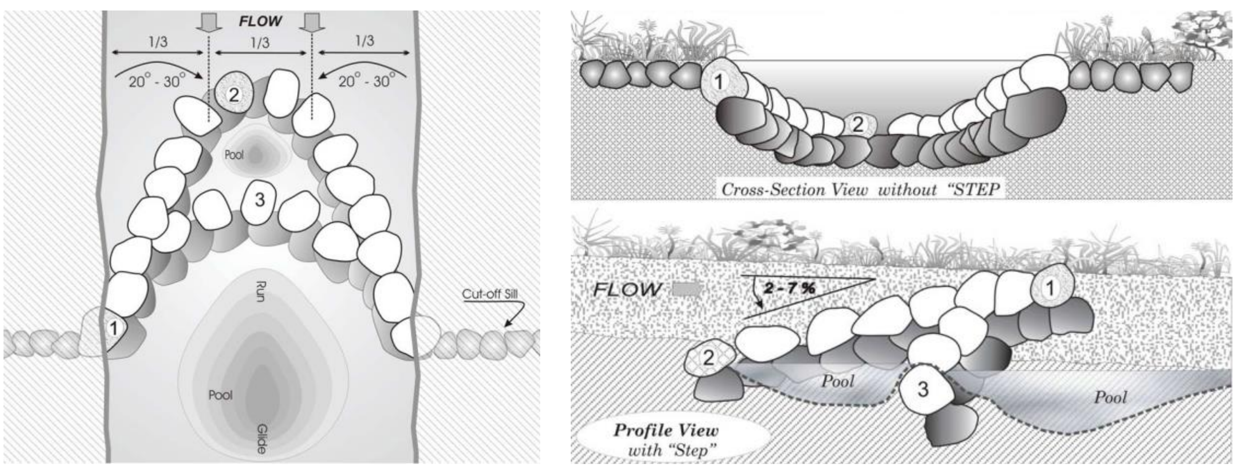

Figure 3 Cross section, profile and plan view of a cross-vane (from Rosgen 2006)

3.6 Specifications

This section describes the key features of the channel design. Note that design specifications and notes have also been added to the CAD drawings.

3.6.1 River Gravel

The river stone 'Type A' specified in the CAD drawings will be a well-graded sandy-gravel. Clean, rounded river stone is to be used for the point bars with the following characteristics:

- 75 mm < D_{90} < 100 mm
- 32 mm < D_{50} < 44 mm
- 0.75 mm < D_{10} < 4.75 mm

A gradation such as this can be obtained by mixing 25-100 mm river stone (e.g. Greely Sand and Gravel's river stone), a 9.5 to 16 mm stone (e.g. Greely 3/8 to 5/8" river stone) and a coarse washed sand such as concrete sand or MTO winter sand. This mix will allow for good particle interlocking, controlled permeability, and a broad natural gradation. The actual mix will have to be designed based on actual quarry gradations; a typical mix would consist of 50% (by mass) of the 1" to 4" stone, 25% of the 3/8" to 5/8" stone and 25% washed coarse sand. Mixing is best accomplished by layering the materials in a stockpile using layer thickness to control mix proportions (e.g. 50 cm, 25 cm and 25 cm layers). The resulting 'gravel lasagna' is mixed simply by the process of loading and unloading it into a truck for placement.

3.6.2 Boulders

Two types of boulders are required (see CAD drawings):

1. Type 'A' boulders:
    a. to be embedded in the stream bed as boulder clusters upstream of the cross-vanes
    b. maximum dimensions ranging from 0.6 to 0.9 m
    c. placed in a triangular pattern with spaces between the boulders ranging from 1 m to 2 m
2. Type 'B' boulders:
    a. to be used in the construction of the cross-vanes
    b. maximum dimensions ranging from 0.3 to 0.6 m

Boulders can be composed of granite or limestone provided that the rock is durable, clean and free of splits, joints, loose laminations or inclusions. Limestone is preferable since it tends to provide more regular slab shapes that are easier to place in the tight-fitting patterns required for the cross-vane weirs and the vegetated boulder edge treatment.

3.6.3 Straw Fibre Erosion Control Blankets

Straw fibre erosion control blankets are to be used in the main channel. These are excellent for controlling soil erosion by holding the soil in place and dissipating the force of heavy rains and run-off water, while allowing natural vegetation to become established. The erosion control blankets and their installation should have the following characteristics:

1. Soil preparation and seeding shall be completed before the installation of the erosion control blankets.
2. Erosion control blankets is to be installed as per manufacturers recommended installation.
3. Erosion control blankets shall conform to Terrafix S200 specifications or equivalent.

3.6.4 Shrubs and Seed Mix

Shrubs and seed mix are to be used to stabilize the meandering stream banks and to facilitate natural succession of vegetation soil. Shrubs are to be applied on the outside banks of the meandering stream as part of the vegetated stone bank treatment and around pools, and seeding should be applied throughout the conveyance channel. The 7 m wide access shelf along the left-hand side of the channel will (occasionally) be used to provide access for channel maintenance. No trees or shrubbery should be planted in that area. Seed mix and shrubs shall conform to the specifications specified in the landscape drawings.

4 Summary

This report describes the design of a natural channel for a portion of Van Gaal Drain in Richmond, ON. The goal of design is to ensure both the hydraulic and ecological functioning of the channel through the re-creation of various natural features. The proposed design involves a low-flow channel within a larger, conveyance channel.

The conveyance channel and the low-flow channel contained within it are to be excavated in soils that are expected to consist predominantly of Champlain Sea marine clays. The sensitive nature of these clays can result in an extremely wet and soft soil once the upper crust has been excavated and, particularly, if the freshly exposed clays are re-worked during excavation.

The design of the conveyance channel is based on available borehole data, and assumes that the soils used to construct the low-flow channel will be undisturbed and have a firm to stiff consistency. Should softer soil conditions be encountered, we request that we be notified immediately in order to permit reassessment of our recommendations.

Coldwater developed the natural channel design for the site with due consideration of the geomorphic and hydraulic characteristics of the system to ensure that stable, natural stream reaches would result. The channel is designed with a varying sinuosity along its length to ensure that setback requirements are met. The design includes cross-vane structures which, combined with the meanders, create a diversity of stream features. The design includes planting of appropriate natural vegetation to aid in soil retention and erosion protection. A detailed CAD plan of the design and its features accompanies this report (under separate cover).

5 Bibliography

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APPENDIX A - Natural Channel Design

Design Philosophy

Natural channel design is being applied throughout Ontario for the restoration of degraded rivers and streams. The Rideau Valley Conservation Authority's primary interest is described by the follow statement (RVCA 2006):

> "*…the preservation of natural channels which perform natural functions and restoration of such natural functions where degradation has occurred. Altering, straightening, changing, diverting or interfering with the channel of any natural watercourse in the Authority's area of jurisdiction must meet the following requirements:*
>
> 1. *Riverfront Erosion Protection*
> 2. *Channel Realignment, Road Crossings, Diversions, Dams*
>   a. *Hydrotechnical analyses*
>   b. *Incorporate natural channel design principles*
> 3. *Erosion and Sediment Control*
> 4. *Timing of Works*"

The goal of natural channel design is to restore the hydraulic and ecological functioning of a channel through the re-creation of natural features such as banks, runs, riffles, meanders, and pools. Planting of appropriate natural vegetation is integral to the design for both its ecological value, and to aid in soil retention and erosion protection. All approaches to natural channel design typically use the geomorphic and hydraulic characteristics of stable, natural river/stream reaches as reference conditions to guide the design. These reference reaches may be taken from the subject watershed or from other watersheds that demonstrate similar geomorphic and hydraulic characteristics.

There are two general approaches to natural channel design/restoration in the literature. The first is the 'classification-based procedure' as advocated by Rosgen (1994). In this method a geomorphically stable natural river reach is selected as a reference case and used as an analogue to guide the design of restoration works. Classification of stream reaches is essential within this process to ensure the similarity and suitability of the reference reach. The design of the restoration works then relies upon the scaling of the reference reach features based on the relative bankfull riffle width, W of the reference and subject reaches. In essence this method uses the reference reach as a scale model for the restoration project.

The second approach is a process-based method (sometimes referred to as a 'regime' or 'rational' design). In this approach, predictive relationships for sediment mobility, cross-sectional and planform geometry are used to support river observations and to develop a restoration design. The relationships used are based on a combination of analysis of natural rivers and streams, and theoretical and experimental research in the fields of fluid mechanics, sediment transport and fluvial geomorphology. This approach is best applied in conjunction with an appropriate reference reach. In which case, the design relationships can be used to scale the reference reach features for use in the study reach to allow for differences in 'boundary conditions' between the two reaches. These boundary conditions include differences in hydraulics, sediment characteristics and the sediment transport processes. In situations where no appropriate reference reach is readily available, the rational design approach can still be used to define appropriate planform and cross-sectional channel geometry.

In natural river/stream systems there can be multiple, nested flow channels depending upon flow conditions. Base flow can be carried in a low flow meandering central channel, bankfull flow carried within the main banks of the channel, and overland flow carried through the broader floodplain which might be treed or otherwise heavily vegetated.

Design Flow

Typically in natural channel design, the bankfull flow condition corresponds to the 1-year to 3-year return period flow. This has broadly been shown in the literature (Rosgen D. , 1994) to be the flow condition that typically shapes and controls a stream's morphology. For many applications, however, a low-flow channel is designed to meet biological needs; the low-flow channel is designed to provide increased depths during periods of low-flow so as to ensure that a sufficient depth of flow for aquatic species and for general biodiversity is maintained. Thus, the 7-day annual low-flow is often used for low-flow channel design (Copeland, McComas, Thorne, Soar, & Fripp, 2001). Geomorphic characteristics of the low-flow channel are derived from calculations using the bankfull conditions of the low-flow channel.

Meander Design

Meanders can be seen as a natural response of the streambed to the flows that it carries. The 'equilibrium theory' for meanders states that meanders act to decrease the stream gradient (channel slope) until the transport capacity of the stream balances the erodibility of the streambed. There are three approaches to designing a meander system:

1) FREE-FORM: Determine the appropriate stream gradient to balance sediment characteristics and ensure that sufficient sediment supply is available. Re-grade the channel as required to a slope and form close to the expected equilibrium conditions. This is approach is typically used in restoration of natural channel systems (USACE, Thorne, etc.). In this instance, native bed materials are used and the natural channel is free to re-shape itself in response to hydrodynamic forcing.

2) PARTIALLY-CONTROLLED: Layout a sinuous meandering channel in the native bed materials and then use imported gravel/cobble to build control structures such as weirs, riffles, point bars and armoured cut banks in the outer edges of meanders. This approach can be prone to failure when high flow events scour the bed and banks in an effort to adjust to a natural meander pattern. The hydrology of the Van Gaal Drain realignment is such that high flows are carried by the relatively wide and deep conveyance channel which results is relatively

low bed shears during extreme events; thus making the site well-suited to a partial-control design strategy.

3) FULLY-CONTROLLED: Develop a naturally armoured channel that will maintain the desired stream gradient (slope). This creates a natural-looking channel and uses sufficiently large sand/gravel/cobble bed materials to ensure that the channel form is stable under a wide range of flows. This is similar to the “Geomorphic Reference River Engineering” approach described in the Carp River (2004) restoration plan.

Ottawa Area Design Features

While natural channels built with meanders, riffles and pools have been commonly seen as the ‘ideal’ for natural channel design, they may not fit the hydraulics and geomorphology of all projects. The prevalence of riffle-pool meander designs in the literature might be related to the facts that some of the key natural channel designers come from Colorado (Rosgen) and B.C. (Newbury) and that trout and salmon habitat restoration is often the motivation behind stream restoration. As is often the case in low-lying streams, meander systems often exist without any riffles and their associated super-critical flow. Therefore, many projects in the Ottawa area may be more suited to designs with stable gravel bed meandering low-gradient channels.

For the van Gaal Drain realignment, a partially-controlled channel design has been adopted. This approach serves two purposes: Firstly, it ensures that the bed of the low-flow channel is predominantly clayey till overlain by loose sands and gravels – as is typical for this area. Secondly, it facilitates any future maintenance that may be required to maintain channel conditions suitable to the channel’s function as a Municipal Drain. This is also part of the rationale behind the 7m wide low-elevation grassed shelf along the left-hand side of the channel.

APPENDIX E

Existing Hydrology / Hydraulics

Adam Fobert

From: Bryan Willcott <bwillcott@jfsa.com>
Sent: March-26-10 9:58 AM
To: spichette@dsel.ca; Adam Fobert; Conway, Darlene
Cc: jfsabourin@jfsa.com
Subject: P709(02) Richmond 2,5, 10, 25 Year WSEL Results
Attachments: Spring Storm WSEL Table.pdf; Summer Storm WSEL Table.pdf; Village of Richmond (2, 5, 10, 25, 100 Yr WSEL).pdf

Good day,

Please find the attached plan showing water surface elevations for the 2, 5, 10, 25 and 100 year Spring and Summer events. WSEL tables are also attached.

The calculated flows shown on the attached tables were prepared based upon the same methodology used for the 2009 Richmond Floodplain Mapping study, taking into consideration the timing of peak flows of the Van Gaal drain and Jock River. The calculcated WSELs were determined using the 2009 Richmond Floodplain HEC-RAS spring and summer models, which do not include features including the berm that has been constructed upstream of Perth Street or any modification to Fortune Street culvert.

Best Regards,

Bryan P. Willcott, B.Eng.
Water Resources EIT

JFSA Water Resources and Environmental Consultants

J.F. Sabourin and Associates Inc.
52 Springbrook Drive, Ottawa, ON K2S 1B9
tel.: 613.836.3884 ext. 223, fax: 613.836.0332, **www.jfsa.com**

Maximum Spring Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Van Gaal Drain	Reach 3	3165	2.59	96.65
5 Year	Van Gaal Drain	Reach 3	3165	3.31	96.70
10 Year	Van Gaal Drain	Reach 3	3165	3.79	96.72
25 year	Van Gaal Drain	Reach 3	3165	4.37	96.74
100 year	Van Gaal Drain	Reach 3	3165	5.24	96.75
2 Year	Van Gaal Drain	Reach 3	3149	2.59	96.60
5 Year	Van Gaal Drain	Reach 3	3149	3.31	96.64
10 Year	Van Gaal Drain	Reach 3	3149	3.79	96.66
25 year	Van Gaal Drain	Reach 3	3149	4.37	96.68
100 year	Van Gaal Drain	Reach 3	3149	5.24	96.72
2 Year	Van Gaal Drain	Reach 3	3086	2.59	96.50
5 Year	Van Gaal Drain	Reach 3	3086	3.31	96.55
10 Year	Van Gaal Drain	Reach 3	3086	3.79	96.58
25 year	Van Gaal Drain	Reach 3	3086	4.37	96.60
100 year	Van Gaal Drain	Reach 3	3086	5.24	96.64
2 Year	Van Gaal Drain	Reach 3	3016	2.59	96.46
5 Year	Van Gaal Drain	Reach 3	3016	3.31	96.52
10 Year	Van Gaal Drain	Reach 3	3016	3.79	96.54
25 year	Van Gaal Drain	Reach 3	3016	4.37	96.56
100 year	Van Gaal Drain	Reach 3	3016	5.24	96.61
2 Year	Van Gaal Drain	Reach 3	2980	2.59	96.42
5 Year	Van Gaal Drain	Reach 3	2980	3.31	96.49
10 Year	Van Gaal Drain	Reach 3	2980	3.79	96.51
25 year	Van Gaal Drain	Reach 3	2980	4.37	96.54
100 year	Van Gaal Drain	Reach 3	2980	5.24	96.57
2 Year	Van Gaal Drain	Reach 3	2851	2.59	96.21
5 Year	Van Gaal Drain	Reach 3	2851	3.31	96.30
10 Year	Van Gaal Drain	Reach 3	2851	3.79	96.34
25 year	Van Gaal Drain	Reach 3	2851	4.37	96.38
100 year	Van Gaal Drain	Reach 3	2851	5.24	96.42
2 Year	Van Gaal Drain	Reach 3	2808	2.59	96.18
5 Year	Van Gaal Drain	Reach 3	2808	3.31	96.27
10 Year	Van Gaal Drain	Reach 3	2808	3.79	96.31
25 year	Van Gaal Drain	Reach 3	2808	4.37	96.35
100 year	Van Gaal Drain	Reach 3	2808	5.24	96.39
2 Year	Van Gaal Drain	Reach 3	2658	2.59	96.11
5 Year	Van Gaal Drain	Reach 3	2658	3.31	96.19
10 Year	Van Gaal Drain	Reach 3	2658	3.79	96.22
25 year	Van Gaal Drain	Reach 3	2658	4.37	96.25
100 year	Van Gaal Drain	Reach 3	2658	5.24	96.29

Maximum Spring Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Van Gaal Drain	Reach 2	2554	4.13	96.10
5 Year	Van Gaal Drain	Reach 2	2554	5.24	96.18
10 Year	Van Gaal Drain	Reach 2	2554	6.01	96.21
25 year	Van Gaal Drain	Reach 2	2554	6.94	96.24
100 year	Van Gaal Drain	Reach 2	2554	8.32	96.28
2 Year	Van Gaal Drain	Reach 2	2478	4.13	96.03
5 Year	Van Gaal Drain	Reach 2	2478	5.24	96.09
10 Year	Van Gaal Drain	Reach 2	2478	6.01	96.11
25 year	Van Gaal Drain	Reach 2	2478	6.94	96.13
100 year	Van Gaal Drain	Reach 2	2478	8.32	96.16
2 Year	Van Gaal Drain	Reach 2	2157	4.13	95.19
5 Year	Van Gaal Drain	Reach 2	2157	5.24	95.32
10 Year	Van Gaal Drain	Reach 2	2157	6.01	95.38
25 year	Van Gaal Drain	Reach 2	2157	6.94	95.43
100 year	Van Gaal Drain	Reach 2	2157	8.32	95.48
2 Year	Van Gaal Drain	Reach 2	2076	5.00	95.03
5 Year	Van Gaal Drain	Reach 2	2076	6.32	95.13
10 Year	Van Gaal Drain	Reach 2	2076	7.24	95.17
25 year	Van Gaal Drain	Reach 2	2076	8.38	95.21
100 year	Van Gaal Drain	Reach 2	2076	10.81	95.27
2 Year	Van Gaal Drain	Reach 2	1974	5.00	94.89
5 Year	Van Gaal Drain	Reach 2	1974	6.32	94.97
10 Year	Van Gaal Drain	Reach 2	1974	7.24	95.02
25 year	Van Gaal Drain	Reach 2	1974	8.38	95.06
100 year	Van Gaal Drain	Reach 2	1974	10.81	95.11
2 Year	Van Gaal Drain	Reach 2	1922	5.00	94.82
5 Year	Van Gaal Drain	Reach 2	1922	6.32	94.89
10 Year	Van Gaal Drain	Reach 2	1922	7.24	94.92
25 year	Van Gaal Drain	Reach 2	1922	8.38	94.95
100 year	Van Gaal Drain	Reach 2	1922	10.81	94.99
2 Year	Van Gaal Drain	Reach 2	1833	5.00	94.71
5 Year	Van Gaal Drain	Reach 2	1833	6.32	94.76
10 Year	Van Gaal Drain	Reach 2	1833	7.24	94.78
25 year	Van Gaal Drain	Reach 2	1833	8.38	94.80
100 year	Van Gaal Drain	Reach 2	1833	10.81	94.85
2 Year	Van Gaal Drain	Reach 2	1796	5.00	94.68
5 Year	Van Gaal Drain	Reach 2	1796	6.32	94.73
10 Year	Van Gaal Drain	Reach 2	1796	7.24	94.75
25 year	Van Gaal Drain	Reach 2	1796	8.38	94.77
100 year	Van Gaal Drain	Reach 2	1796	10.81	94.81

Maximum Spring Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Van Gaal Drain	Reach 2	1735	5.00	94.64
5 Year	Van Gaal Drain	Reach 2	1735	6.32	94.68
10 Year	Van Gaal Drain	Reach 2	1735	7.24	94.69
25 year	Van Gaal Drain	Reach 2	1735	8.38	94.70
100 year	Van Gaal Drain	Reach 2	1735	10.81	94.72
2 Year	Van Gaal Drain	Reach 2	1728	5.00	94.64
5 Year	Van Gaal Drain	Reach 2	1728	6.32	94.67
10 Year	Van Gaal Drain	Reach 2	1728	7.24	94.68
25 year	Van Gaal Drain	Reach 2	1728	8.38	94.68
100 year	Van Gaal Drain	Reach 2	1728	10.81	94.69
2 Year	Van Gaal Drain	Reach 2	1717	5.00	94.42
5 Year	Van Gaal Drain	Reach 2	1717	6.32	94.55
10 Year	Van Gaal Drain	Reach 2	1717	7.24	94.59
25 year	Van Gaal Drain	Reach 2	1717	8.38	94.63
100 year	Van Gaal Drain	Reach 2	1717	10.81	94.69
2 Year	Van Gaal Drain	Reach 2	1615	5.00	94.29
5 Year	Van Gaal Drain	Reach 2	1615	6.32	94.40
10 Year	Van Gaal Drain	Reach 2	1615	7.24	94.46
25 year	Van Gaal Drain	Reach 2	1615	8.38	94.52
100 year	Van Gaal Drain	Reach 2	1615	10.81	94.61
2 Year	Van Gaal Drain	Reach 2	1555	5.00	94.22
5 Year	Van Gaal Drain	Reach 2	1555	6.32	94.33
10 Year	Van Gaal Drain	Reach 2	1555	7.24	94.39
25 year	Van Gaal Drain	Reach 2	1555	8.38	94.45
100 year	Van Gaal Drain	Reach 2	1555	10.81	94.55
2 Year	Van Gaal Drain	Reach 2	1488	5.00	94.16
5 Year	Van Gaal Drain	Reach 2	1488	6.32	94.26
10 Year	Van Gaal Drain	Reach 2	1488	7.24	94.31
25 year	Van Gaal Drain	Reach 2	1488	8.38	94.36
100 year	Van Gaal Drain	Reach 2	1488	10.81	94.45
2 Year	Van Gaal Drain	Reach 2	1416	5.00	94.02
5 Year	Van Gaal Drain	Reach 2	1416	6.32	94.10
10 Year	Van Gaal Drain	Reach 2	1416	7.24	94.17
25 year	Van Gaal Drain	Reach 2	1416	8.38	94.25
100 year	Van Gaal Drain	Reach 2	1416	10.81	94.41
2 Year	Van Gaal Drain	Reach 2	1400	5.00	94.02
5 Year	Van Gaal Drain	Reach 2	1400	6.32	94.11
10 Year	Van Gaal Drain	Reach 2	1400	7.24	94.16
25 year	Van Gaal Drain	Reach 2	1400	8.38	94.23
100 year	Van Gaal Drain	Reach 2	1400	10.81	94.36

Maximum Spring Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Van Gaal Drain	Reach 2	1364	5.00	93.99
5 Year	Van Gaal Drain	Reach 2	1364	6.32	94.06
10 Year	Van Gaal Drain	Reach 2	1364	7.24	94.11
25 year	Van Gaal Drain	Reach 2	1364	8.38	94.18
100 year	Van Gaal Drain	Reach 2	1364	10.81	94.31
2 Year	Van Gaal Drain	Reach 2	1340	5.79	93.96
5 Year	Van Gaal Drain	Reach 2	1340	7.32	94.01
10 Year	Van Gaal Drain	Reach 2	1340	8.34	94.05
25 year	Van Gaal Drain	Reach 2	1340	9.65	94.10
100 year	Van Gaal Drain	Reach 2	1340	11.62	94.21
2 Year	Van Gaal Drain	Reach 2	1312	6.08	93.94
5 Year	Van Gaal Drain	Reach 2	1312	7.69	93.98
10 Year	Van Gaal Drain	Reach 2	1312	8.76	94.01
25 year	Van Gaal Drain	Reach 2	1312	10.15	94.04
100 year	Van Gaal Drain	Reach 2	1312	3.44	94.13
2 Year	Van Gaal Drain	Reach 2	1302	6.08	93.91
5 Year	Van Gaal Drain	Reach 2	1302	7.69	93.97
10 Year	Van Gaal Drain	Reach 2	1302	8.76	94.00
25 year	Van Gaal Drain	Reach 2	1302	10.15	94.04
100 year	Van Gaal Drain	Reach 2	1302	12.20	94.15
2 Year	Van Gaal Drain	Reach 2	1268	6.08	93.87
5 Year	Van Gaal Drain	Reach 2	1268	7.69	93.93
10 Year	Van Gaal Drain	Reach 2	1268	8.76	93.96
25 year	Van Gaal Drain	Reach 2	1268	10.15	94.00
100 year	Van Gaal Drain	Reach 2	1268	12.20	94.14
2 Year	Van Gaal Drain	Reach 2	1212	6.08	93.78
5 Year	Van Gaal Drain	Reach 2	1212	7.69	93.85
10 Year	Van Gaal Drain	Reach 2	1212	8.76	93.89
25 year	Van Gaal Drain	Reach 2	1212	10.15	93.94
100 year	Van Gaal Drain	Reach 2	1212	3.44	94.12
2 Year	Van Gaal Drain	Reach 2	1169	6.08	93.70
5 Year	Van Gaal Drain	Reach 2	1169	7.69	93.76
10 Year	Van Gaal Drain	Reach 2	1169	8.76	93.80
25 year	Van Gaal Drain	Reach 2	1169	10.15	93.87
100 year	Van Gaal Drain	Reach 2	1169	3.44	94.12
2 Year	Van Gaal Drain	Reach 2	1091	6.08	93.57
5 Year	Van Gaal Drain	Reach 2	1091	7.69	93.64
10 Year	Van Gaal Drain	Reach 2	1091	8.76	93.69
25 year	Van Gaal Drain	Reach 2	1091	10.15	93.78
100 year	Van Gaal Drain	Reach 2	1091	3.44	94.12

Maximum Spring Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Van Gaal Drain	Reach 2	1002	6.08	93.38
5 Year	Van Gaal Drain	Reach 2	1002	7.69	93.49
10 Year	Van Gaal Drain	Reach 2	1002	8.76	93.59
25 year	Van Gaal Drain	Reach 2	1002	10.15	93.71
100 year	Van Gaal Drain	Reach 2	1002	3.44	94.12
2 Year	Van Gaal Drain	Reach 2	961	6.08	93.28
5 Year	Van Gaal Drain	Reach 2	961	7.69	93.41
10 Year	Van Gaal Drain	Reach 2	961	8.76	93.52
25 year	Van Gaal Drain	Reach 2	961	10.15	93.69
100 year	Van Gaal Drain	Reach 2	961	3.44	94.11
2 Year	Van Gaal Drain	Reach 2	910	6.08	93.22
5 Year	Van Gaal Drain	Reach 2	910	7.69	93.38
10 Year	Van Gaal Drain	Reach 2	910	8.76	93.49
25 year	Van Gaal Drain	Reach 2	910	10.15	93.68
100 year	Van Gaal Drain	Reach 2	910	3.44	94.11
2 Year	Van Gaal Drain	Reach 2	840	6.08	93.18
5 Year	Van Gaal Drain	Reach 2	840	7.69	93.35
10 Year	Van Gaal Drain	Reach 2	840	8.76	93.48
25 year	Van Gaal Drain	Reach 2	840	10.15	93.67
100 year	Van Gaal Drain	Reach 2	840	3.44	94.11
2 Year	Van Gaal Drain	Reach 1	746	7.86	93.17
5 Year	Van Gaal Drain	Reach 1	746	9.97	93.35
10 Year	Van Gaal Drain	Reach 1	746	11.34	93.48
25 year	Van Gaal Drain	Reach 1	746	13.11	93.67
100 year	Van Gaal Drain	Reach 1	746	4.06	94.12
2 Year	Van Gaal Drain	Reach 1	705	7.86	93.14
5 Year	Van Gaal Drain	Reach 1	705	9.97	93.34
10 Year	Van Gaal Drain	Reach 1	705	11.34	93.47
25 year	Van Gaal Drain	Reach 1	705	13.11	93.66
100 year	Van Gaal Drain	Reach 1	705	4.06	94.11
2 Year	Van Gaal Drain	Reach 1	668	7.86	93.05
5 Year	Van Gaal Drain	Reach 1	668	9.97	93.28
10 Year	Van Gaal Drain	Reach 1	668	11.34	93.42
25 year	Van Gaal Drain	Reach 1	668	13.11	93.63
100 year	Van Gaal Drain	Reach 1	668	4.06	94.11
2 Year	Van Gaal Drain	Reach 1	666	7.86	92.64
5 Year	Van Gaal Drain	Reach 1	666	9.97	92.83
10 Year	Van Gaal Drain	Reach 1	666	11.34	93.01
25 year	Van Gaal Drain	Reach 1	666	3.31	93.43
100 year	Van Gaal Drain	Reach 1	666	4.06	94.10

Maximum Spring Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Moore Drain	Reach 1	298	1.07	93.79
5 Year	Moore Drain	Reach 1	298	1.36	93.81
10 Year	Moore Drain	Reach 1	298	1.55	93.82
25 year	Moore Drain	Reach 1	298	1.78	93.83
100 year	Moore Drain	Reach 1	298	0.32	94.11
2 Year	Moore Drain	Reach 1	130	1.07	93.18
5 Year	Moore Drain	Reach 1	130	1.36	93.36
10 Year	Moore Drain	Reach 1	130	1.55	93.48
25 year	Moore Drain	Reach 1	130	1.78	93.67
100 year	Moore Drain	Reach 1	130	0.32	94.11
2 Year	Joys Road Trib	Reach 1	705	1.57	97.24
5 Year	Joys Road Trib	Reach 1	705	2.00	97.39
10 Year	Joys Road Trib	Reach 1	705	2.29	97.49
25 year	Joys Road Trib	Reach 1	705	2.64	97.60
100 year	Joys Road Trib	Reach 1	705	3.17	97.79
2 Year	Joys Road Trib	Reach 1	664	1.57	97.26
5 Year	Joys Road Trib	Reach 1	664	2.00	97.40
10 Year	Joys Road Trib	Reach 1	664	2.29	97.49
25 year	Joys Road Trib	Reach 1	664	2.64	97.61
100 year	Joys Road Trib	Reach 1	664	3.17	97.79
2 Year	Joys Road Trib	Reach 1	635	1.57	97.19
5 Year	Joys Road Trib	Reach 1	635	2.00	97.31
10 Year	Joys Road Trib	Reach 1	635	2.29	97.40
25 year	Joys Road Trib	Reach 1	635	2.64	97.50
100 year	Joys Road Trib	Reach 1	635	3.17	97.67
2 Year	Joys Road Trib	Reach 1	622	1.57	97.08
5 Year	Joys Road Trib	Reach 1	622	2.00	97.14
10 Year	Joys Road Trib	Reach 1	622	2.29	97.18
25 year	Joys Road Trib	Reach 1	622	2.64	97.21
100 year	Joys Road Trib	Reach 1	622	3.17	97.26
2 Year	Joys Road Trib	Reach 1	602	1.57	97.07
5 Year	Joys Road Trib	Reach 1	602	2.00	97.14
10 Year	Joys Road Trib	Reach 1	602	2.29	97.17
25 year	Joys Road Trib	Reach 1	602	2.64	97.22
100 year	Joys Road Trib	Reach 1	602	3.17	97.27
2 Year	Joys Road Trib	Reach 1	322	1.57	96.54
5 Year	Joys Road Trib	Reach 1	322	2.00	96.58
10 Year	Joys Road Trib	Reach 1	322	2.29	96.61
25 year	Joys Road Trib	Reach 1	322	2.64	96.65
100 year	Joys Road Trib	Reach 1	322	3.17	96.71

Maximum Spring Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Joys Road Trib	Reach 1	275	1.57	96.31
5 Year	Joys Road Trib	Reach 1	275	2.00	96.39
10 Year	Joys Road Trib	Reach 1	275	2.29	96.44
25 year	Joys Road Trib	Reach 1	275	2.64	96.49
100 year	Joys Road Trib	Reach 1	275	3.17	96.56
2 Year	Joys Road Trib	Reach 1	30	1.57	96.12
5 Year	Joys Road Trib	Reach 1	30	2.00	96.19
10 Year	Joys Road Trib	Reach 1	30	2.29	96.22
25 year	Joys Road Trib	Reach 1	30	2.64	96.26
100 year	Joys Road Trib	Reach 1	30	3.17	96.29

Maximum Summer Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Van Gaal Drain	Reach 3	3165	1.33	96.50
5 Year	Van Gaal Drain	Reach 3	3165	2.15	96.61
10 Year	Van Gaal Drain	Reach 3	3165	2.74	96.67
25 year	Van Gaal Drain	Reach 3	3165	3.51	96.72
100 year	Van Gaal Drain	Reach 3	3165	4.81	96.75
2 Year	Van Gaal Drain	Reach 3	3149	1.33	96.46
5 Year	Van Gaal Drain	Reach 3	3149	2.15	96.57
10 Year	Van Gaal Drain	Reach 3	3149	2.74	96.62
25 year	Van Gaal Drain	Reach 3	3149	3.51	96.66
100 year	Van Gaal Drain	Reach 3	3149	4.81	96.72
2 Year	Van Gaal Drain	Reach 3	3086	1.33	96.35
5 Year	Van Gaal Drain	Reach 3	3086	2.15	96.47
10 Year	Van Gaal Drain	Reach 3	3086	2.74	96.53
25 year	Van Gaal Drain	Reach 3	3086	3.51	96.58
100 year	Van Gaal Drain	Reach 3	3086	4.81	96.65
2 Year	Van Gaal Drain	Reach 3	3016	1.33	96.26
5 Year	Van Gaal Drain	Reach 3	3016	2.15	96.41
10 Year	Van Gaal Drain	Reach 3	3016	2.74	96.48
25 year	Van Gaal Drain	Reach 3	3016	3.51	96.54
100 year	Van Gaal Drain	Reach 3	3016	4.81	96.61
2 Year	Van Gaal Drain	Reach 3	2980	1.33	96.21
5 Year	Van Gaal Drain	Reach 3	2980	2.15	96.36
10 Year	Van Gaal Drain	Reach 3	2980	2.74	96.44
25 year	Van Gaal Drain	Reach 3	2980	3.51	96.51
100 year	Van Gaal Drain	Reach 3	2980	4.81	96.57
2 Year	Van Gaal Drain	Reach 3	2851	1.33	95.90
5 Year	Van Gaal Drain	Reach 3	2851	2.15	96.10
10 Year	Van Gaal Drain	Reach 3	2851	2.74	96.21
25 year	Van Gaal Drain	Reach 3	2851	3.51	96.31
100 year	Van Gaal Drain	Reach 3	2851	4.81	96.41
2 Year	Van Gaal Drain	Reach 3	2808	1.33	95.86
5 Year	Van Gaal Drain	Reach 3	2808	2.15	96.07
10 Year	Van Gaal Drain	Reach 3	2808	2.74	96.18
25 year	Van Gaal Drain	Reach 3	2808	3.51	96.28
100 year	Van Gaal Drain	Reach 3	2808	4.81	96.38
2 Year	Van Gaal Drain	Reach 3	2658	1.33	95.78
5 Year	Van Gaal Drain	Reach 3	2658	2.15	95.99
10 Year	Van Gaal Drain	Reach 3	2658	2.74	96.10
25 year	Van Gaal Drain	Reach 3	2658	3.51	96.19
100 year	Van Gaal Drain	Reach 3	2658	4.81	96.28

Maximum Summer Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Van Gaal Drain	Reach 2	2554	1.95	95.77
5 Year	Van Gaal Drain	Reach 2	2554	3.20	95.98
10 Year	Van Gaal Drain	Reach 2	2554	4.11	96.09
25 year	Van Gaal Drain	Reach 2	2554	5.28	96.18
100 year	Van Gaal Drain	Reach 2	2554	7.27	96.27
2 Year	Van Gaal Drain	Reach 2	2478	1.95	95.72
5 Year	Van Gaal Drain	Reach 2	2478	3.20	95.92
10 Year	Van Gaal Drain	Reach 2	2478	4.11	96.02
25 year	Van Gaal Drain	Reach 2	2478	5.28	96.09
100 year	Van Gaal Drain	Reach 2	2478	7.27	96.16
2 Year	Van Gaal Drain	Reach 2	2157	1.95	94.93
5 Year	Van Gaal Drain	Reach 2	2157	3.20	95.12
10 Year	Van Gaal Drain	Reach 2	2157	4.11	95.25
25 year	Van Gaal Drain	Reach 2	2157	5.28	95.37
100 year	Van Gaal Drain	Reach 2	2157	7.27	65.47
2 Year	Van Gaal Drain	Reach 2	2076	2.80	94.74
5 Year	Van Gaal Drain	Reach 2	2076	4.41	94.97
10 Year	Van Gaal Drain	Reach 2	2076	5.53	95.08
25 year	Van Gaal Drain	Reach 2	2076	6.96	95.17
100 year	Van Gaal Drain	Reach 2	2076	9.54	95.26
2 Year	Van Gaal Drain	Reach 2	1974	2.80	94.61
5 Year	Van Gaal Drain	Reach 2	1974	4.41	94.84
10 Year	Van Gaal Drain	Reach 2	1974	5.53	94.93
25 year	Van Gaal Drain	Reach 2	1974	6.96	95.01
100 year	Van Gaal Drain	Reach 2	1974	9.54	95.10
2 Year	Van Gaal Drain	Reach 2	1922	2.80	94.55
5 Year	Van Gaal Drain	Reach 2	1922	4.41	94.79
10 Year	Van Gaal Drain	Reach 2	1922	5.53	94.86
25 year	Van Gaal Drain	Reach 2	1922	6.96	94.92
100 year	Van Gaal Drain	Reach 2	1922	9.54	94.99
2 Year	Van Gaal Drain	Reach 2	1833	2.80	94.47
5 Year	Van Gaal Drain	Reach 2	1833	4.41	94.69
10 Year	Van Gaal Drain	Reach 2	1833	5.53	94.74
25 year	Van Gaal Drain	Reach 2	1833	6.96	94.78
100 year	Van Gaal Drain	Reach 2	1833	9.54	94.85
2 Year	Van Gaal Drain	Reach 2	1796	2.80	94.44
5 Year	Van Gaal Drain	Reach 2	1796	4.41	94.66
10 Year	Van Gaal Drain	Reach 2	1796	5.53	94.71
25 year	Van Gaal Drain	Reach 2	1796	6.96	94.74
100 year	Van Gaal Drain	Reach 2	1796	9.54	94.80

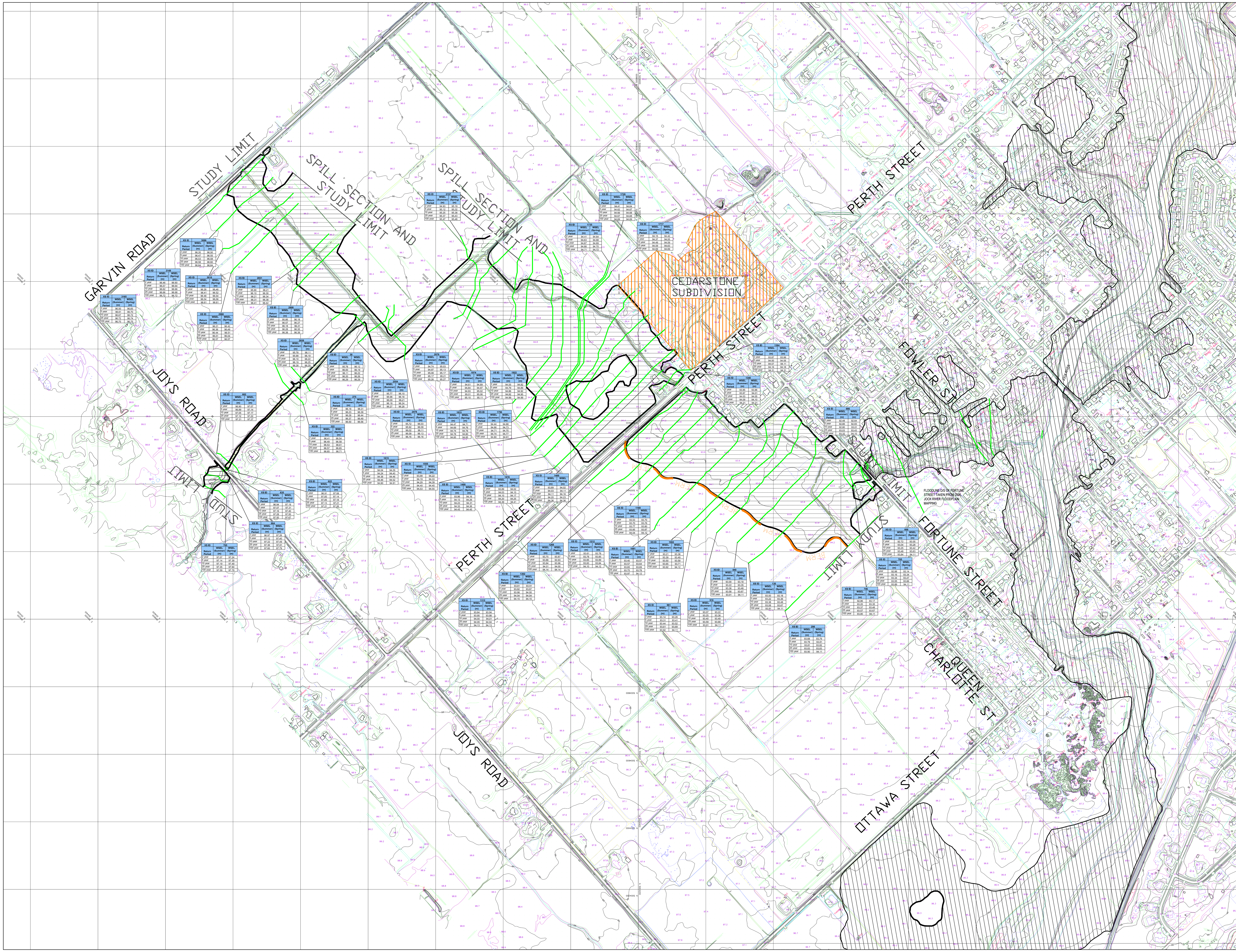
Maximum Summer Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Van Gaal Drain	Reach 2	1735	2.80	94.41
5 Year	Van Gaal Drain	Reach 2	1735	4.41	94.63
10 Year	Van Gaal Drain	Reach 2	1735	5.53	94.67
25 year	Van Gaal Drain	Reach 2	1735	6.96	94.68
100 year	Van Gaal Drain	Reach 2	1735	9.54	94.71
2 Year	Van Gaal Drain	Reach 2	1728	2.80	94.41
5 Year	Van Gaal Drain	Reach 2	1728	4.41	94.62
10 Year	Van Gaal Drain	Reach 2	1728	5.53	94.66
25 year	Van Gaal Drain	Reach 2	1728	6.96	94.67
100 year	Van Gaal Drain	Reach 2	1728	9.54	94.69
2 Year	Van Gaal Drain	Reach 2	1717	2.80	94.15
5 Year	Van Gaal Drain	Reach 2	1717	4.41	94.37
10 Year	Van Gaal Drain	Reach 2	1717	5.53	94.49
25 year	Van Gaal Drain	Reach 2	1717	6.96	94.59
100 year	Van Gaal Drain	Reach 2	1717	9.54	94.69
2 Year	Van Gaal Drain	Reach 2	1615	2.80	94.04
5 Year	Van Gaal Drain	Reach 2	1615	4.41	94.24
10 Year	Van Gaal Drain	Reach 2	1615	5.53	94.36
25 year	Van Gaal Drain	Reach 2	1615	6.96	94.46
100 year	Van Gaal Drain	Reach 2	1615	9.54	94.60
2 Year	Van Gaal Drain	Reach 2	1555	2.80	93.99
5 Year	Van Gaal Drain	Reach 2	1555	4.41	94.19
10 Year	Van Gaal Drain	Reach 2	1555	5.53	94.29
25 year	Van Gaal Drain	Reach 2	1555	6.96	94.40
100 year	Van Gaal Drain	Reach 2	1555	9.54	94.53
2 Year	Van Gaal Drain	Reach 2	1488	2.80	93.96
5 Year	Van Gaal Drain	Reach 2	1488	4.41	94.13
10 Year	Van Gaal Drain	Reach 2	1488	5.53	94.23
25 year	Van Gaal Drain	Reach 2	1488	6.96	94.33
100 year	Van Gaal Drain	Reach 2	1488	9.54	94.45
2 Year	Van Gaal Drain	Reach 2	1416	2.80	93.89
5 Year	Van Gaal Drain	Reach 2	1416	4.41	94.03
10 Year	Van Gaal Drain	Reach 2	1416	5.53	94.10
25 year	Van Gaal Drain	Reach 2	1416	6.96	94.20
100 year	Van Gaal Drain	Reach 2	1416	9.54	94.39
2 Year	Van Gaal Drain	Reach 2	1400	2.80	93.89
5 Year	Van Gaal Drain	Reach 2	1400	4.41	94.03
10 Year	Van Gaal Drain	Reach 2	1400	5.53	94.11
25 year	Van Gaal Drain	Reach 2	1400	6.96	94.20
100 year	Van Gaal Drain	Reach 2	1400	9.54	94.36

Maximum Summer Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Van Gaal Drain	Reach 2	1364	2.80	93.87
5 Year	Van Gaal Drain	Reach 2	1364	4.41	94.00
10 Year	Van Gaal Drain	Reach 2	1364	5.53	94.07
25 year	Van Gaal Drain	Reach 2	1364	6.96	94.16
100 year	Van Gaal Drain	Reach 2	1364	9.54	94.31
2 Year	Van Gaal Drain	Reach 2	1340	3.64	93.85
5 Year	Van Gaal Drain	Reach 2	1340	5.57	93.97
10 Year	Van Gaal Drain	Reach 2	1340	6.92	94.03
25 year	Van Gaal Drain	Reach 2	1340	8.58	94.09
100 year	Van Gaal Drain	Reach 2	1340	11.43	94.21
2 Year	Van Gaal Drain	Reach 2	1312	3.87	93.84
5 Year	Van Gaal Drain	Reach 2	1312	5.93	93.95
10 Year	Van Gaal Drain	Reach 2	1312	7.38	94.00
25 year	Van Gaal Drain	Reach 2	1312	9.17	94.05
100 year	Van Gaal Drain	Reach 2	1312	12.20	94.14
2 Year	Van Gaal Drain	Reach 2	1302	3.87	93.81
5 Year	Van Gaal Drain	Reach 2	1302	5.93	93.92
10 Year	Van Gaal Drain	Reach 2	1302	7.38	93.98
25 year	Van Gaal Drain	Reach 2	1302	9.17	94.04
100 year	Van Gaal Drain	Reach 2	1302	12.20	94.15
2 Year	Van Gaal Drain	Reach 2	1268	3.87	93.75
5 Year	Van Gaal Drain	Reach 2	1268	5.93	93.88
10 Year	Van Gaal Drain	Reach 2	1268	7.38	93.94
25 year	Van Gaal Drain	Reach 2	1268	9.17	94.01
100 year	Van Gaal Drain	Reach 2	1268	12.20	94.14
2 Year	Van Gaal Drain	Reach 2	1212	3.87	93.61
5 Year	Van Gaal Drain	Reach 2	1212	5.93	93.78
10 Year	Van Gaal Drain	Reach 2	1212	7.38	93.85
25 year	Van Gaal Drain	Reach 2	1212	9.17	93.93
100 year	Van Gaal Drain	Reach 2	1212	12.20	94.10
2 Year	Van Gaal Drain	Reach 2	1169	3.87	93.53
5 Year	Van Gaal Drain	Reach 2	1169	5.93	93.70
10 Year	Van Gaal Drain	Reach 2	1169	7.38	93.77
25 year	Van Gaal Drain	Reach 2	1169	9.17	93.85
100 year	Van Gaal Drain	Reach 2	1169	12.20	94.04
2 Year	Van Gaal Drain	Reach 2	1091	3.87	93.40
5 Year	Van Gaal Drain	Reach 2	1091	5.93	93.57
10 Year	Van Gaal Drain	Reach 2	1091	7.38	93.65
25 year	Van Gaal Drain	Reach 2	1091	9.17	93.75
100 year	Van Gaal Drain	Reach 2	1091	12.20	93.97

Maximum Summer Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Van Gaal Drain	Reach 2	1002	3.87	93.21
5 Year	Van Gaal Drain	Reach 2	1002	5.93	93.39
10 Year	Van Gaal Drain	Reach 2	1002	7.38	93.50
25 year	Van Gaal Drain	Reach 2	1002	9.17	93.65
100 year	Van Gaal Drain	Reach 2	1002	12.20	93.92
2 Year	Van Gaal Drain	Reach 2	961	3.87	93.14
5 Year	Van Gaal Drain	Reach 2	961	5.93	93.31
10 Year	Van Gaal Drain	Reach 2	961	7.38	93.44
25 year	Van Gaal Drain	Reach 2	961	9.17	93.61
100 year	Van Gaal Drain	Reach 2	961	12.20	93.92
2 Year	Van Gaal Drain	Reach 2	910	3.87	93.07
5 Year	Van Gaal Drain	Reach 2	910	5.93	93.25
10 Year	Van Gaal Drain	Reach 2	910	7.38	93.40
25 year	Van Gaal Drain	Reach 2	910	9.17	93.59
100 year	Van Gaal Drain	Reach 2	910	12.20	93.91
2 Year	Van Gaal Drain	Reach 2	840	3.87	93.00
5 Year	Van Gaal Drain	Reach 2	840	5.93	93.22
10 Year	Van Gaal Drain	Reach 2	840	7.38	93.38
25 year	Van Gaal Drain	Reach 2	840	9.17	93.58
100 year	Van Gaal Drain	Reach 2	840	12.20	93.91
2 Year	Van Gaal Drain	Reach 1	746	5.36	92.96
5 Year	Van Gaal Drain	Reach 1	746	8.09	93.20
10 Year	Van Gaal Drain	Reach 1	746	10.02	93.37
25 year	Van Gaal Drain	Reach 1	746	12.40	93.57
100 year	Van Gaal Drain	Reach 1	746	16.38	93.90
2 Year	Van Gaal Drain	Reach 1	705	5.36	92.88
5 Year	Van Gaal Drain	Reach 1	705	8.09	93.16
10 Year	Van Gaal Drain	Reach 1	705	10.02	93.34
25 year	Van Gaal Drain	Reach 1	705	12.40	93.55
100 year	Van Gaal Drain	Reach 1	705	16.38	93.89
2 Year	Van Gaal Drain	Reach 1	668	5.36	92.72
5 Year	Van Gaal Drain	Reach 1	668	8.09	93.04
10 Year	Van Gaal Drain	Reach 1	668	10.02	93.25
25 year	Van Gaal Drain	Reach 1	668	12.40	93.48
100 year	Van Gaal Drain	Reach 1	668	16.38	93.84
2 Year	Van Gaal Drain	Reach 1	666	5.36	92.48
5 Year	Van Gaal Drain	Reach 1	666	8.09	92.66
10 Year	Van Gaal Drain	Reach 1	666	10.02	92.80
25 year	Van Gaal Drain	Reach 1	666	12.40	93.03
100 year	Van Gaal Drain	Reach 1	666	16.38	93.32

Maximum Summer Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Moore Drain	Reach 1	298	0.67	93.68
5 Year	Moore Drain	Reach 1	298	1.06	93.78
10 Year	Moore Drain	Reach 1	298	1.32	93.81
25 year	Moore Drain	Reach 1	298	1.64	93.83
100 year	Moore Drain	Reach 1	298	2.17	93.90
2 Year	Moore Drain	Reach 1	130	0.67	93.00
5 Year	Moore Drain	Reach 1	130	1.06	93.22
10 Year	Moore Drain	Reach 1	130	1.32	93.38
25 year	Moore Drain	Reach 1	130	1.64	93.58
100 year	Moore Drain	Reach 1	130	2.17	93.91
2 Year	Joys Road Trib	Reach 1	705	0.66	97.07
5 Year	Joys Road Trib	Reach 1	705	1.11	97.14
10 Year	Joys Road Trib	Reach 1	705	1.44	97.19
25 year	Joys Road Trib	Reach 1	705	1.87	97.35
100 year	Joys Road Trib	Reach 1	705	2.62	97.59
2 Year	Joys Road Trib	Reach 1	664	0.66	96.97
5 Year	Joys Road Trib	Reach 1	664	1.11	97.12
10 Year	Joys Road Trib	Reach 1	664	1.44	97.22
25 year	Joys Road Trib	Reach 1	664	1.87	97.36
100 year	Joys Road Trib	Reach 1	664	2.62	97.60
2 Year	Joys Road Trib	Reach 1	635	0.66	96.94
5 Year	Joys Road Trib	Reach 1	635	1.11	97.07
10 Year	Joys Road Trib	Reach 1	635	1.44	97.16
25 year	Joys Road Trib	Reach 1	635	1.87	97.28
100 year	Joys Road Trib	Reach 1	635	2.62	97.50
2 Year	Joys Road Trib	Reach 1	622	0.66	96.91
5 Year	Joys Road Trib	Reach 1	622	1.11	97.00
10 Year	Joys Road Trib	Reach 1	622	1.44	97.06
25 year	Joys Road Trib	Reach 1	622	1.87	97.13
100 year	Joys Road Trib	Reach 1	622	2.62	97.21
2 Year	Joys Road Trib	Reach 1	602	0.66	96.90
5 Year	Joys Road Trib	Reach 1	602	1.11	96.99
10 Year	Joys Road Trib	Reach 1	602	1.44	97.05
25 year	Joys Road Trib	Reach 1	602	1.87	97.12
100 year	Joys Road Trib	Reach 1	602	2.62	97.21
2 Year	Joys Road Trib	Reach 1	322	0.66	96.41
5 Year	Joys Road Trib	Reach 1	322	1.11	96.49
10 Year	Joys Road Trib	Reach 1	322	1.44	96.53
25 year	Joys Road Trib	Reach 1	322	1.87	96.57
100 year	Joys Road Trib	Reach 1	322	2.62	96.65

Maximum Summer Scenario Results					
Return Period	*River*	*Reach*	*River Station*	*Q Total (m^3/s)*	*W.S. Elev (m)*
2 Year	Joys Road Trib	Reach 1	275	0.66	96.18
5 Year	Joys Road Trib	Reach 1	275	1.11	96.23
10 Year	Joys Road Trib	Reach 1	275	1.44	96.28
25 year	Joys Road Trib	Reach 1	275	1.87	96.37
100 year	Joys Road Trib	Reach 1	275	2.62	96.50
2 Year	Joys Road Trib	Reach 1	30	0.66	95.78
5 Year	Joys Road Trib	Reach 1	30	1.11	96.00
10 Year	Joys Road Trib	Reach 1	30	1.44	96.11
25 year	Joys Road Trib	Reach 1	30	1.87	96.20
100 year	Joys Road Trib	Reach 1	30	2.62	96.29



LEGEND :

100 Yr Floodlines

Cross Section Locations

Cedarstone Subdivision

Water Surface Elevation Tables

XS ID	xxx	
Return Period	WSEL (Summer) (m)	WSEL (Spring) (m)
2 year	XXX	XXX
5 year	XXX	XXX
10 year	XXX	XXX
25 year	XXX	XXX
100 year	XXX	XXX

SCALE : 1:5000

0 100 200 300 400 500 m

J.F. Sabourin & Associates Inc.
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS
OTTAWA (613) 836-3884
GATINEAU (819) 243-6858

CLIENT :

MATTAMY homes

PROJECT :

Van Gaal and Arbuckle Drain 2, 5, 10, 25, and 100 Yr WSEL

No.	BY	DATE	DESCRIPTION	BY
1	CB	03/25/2010	ISSUED FOR REVIEW	CB

WSEL for the 2, 5, 10, 25, and 100 Year Design Storms

DESIGNED:
DRAWN: CB
VERIFIED: BW
APPROVED: JFS

DRAWING REF.

DATE	PROJECT No.
Mar/10	709(02)

APPENDIX F

Hydrogeology

TECHNICAL MEMORANDUM

DATE August 11, 2011 **PROJECT No.** 08-1122-0078 (9600)

TO Ms. Susan Murphy
Mattamy Homes

FROM Dale Holtze
Brian Byerley

EMAIL Dale_Holtze@Golder.com
Brian_Byerley@Golder.com

GROUNDWATER MONITORING PROGRAM
PROPOSED MATTAMY HOMES DEVELOPMENT
RICHMOND (OTTAWA), ONTARIO

This memo presents the results of a one year groundwater monitoring program conducted by Golder Associates Ltd. (Golder) at the site of the proposed Mattamy Homes (Mattamy) development in the Village of Richmond (in the City of Ottawa), Ontario (see Key Plan: Figure 1). The results of previous hydrogeological investigation conducted at the site by Golder are discussed in the Technical Memorandum entitled: Hydrogeological Investigation Proposed Mattamy Homes Development Richmond (Ottawa), Ontario, dated July 16, 2010, which includes a summary of the drilling of eight boreholes equipped with monitoring and/or multi-level monitoring wells, description of subsurface conditions and hydraulic conductivity testing performed in all groundwater monitors.

Monitoring Program

The groundwater monitoring program included monthly groundwater level measurements from April 2010 to April 2011 at monitoring wells MW10-1, MW10-2, MW10-3, MW10-4, MW10-5, MW10-6, MW10-7 and MW10-8, located as shown on Figure 2. Groundwater monitor MW10-5 was observed to be damaged in June 2010 (MW10-5A) and July 2010 (MW10-5B); therefore groundwater levels are not available for the remainder of the monitoring program at this location.

Groundwater levels at monitor MW10-6A (bedrock) was measured continuously (two hour interval) using a transducer from March 19 to April 21, 2011 in order to assess the hydrogeological response of the shallow overburden and bedrock aquifers related to the spring melt and precipitation recharge events. Average daily climatic data was obtained from Environment Canada database at the Ottawa-Macdonald Cartier International Airport. Local rain gauge data for the period between August 1 to October 3, 2010, was also provided by the City of Ottawa. Monitor MW10-6B (overburden) was frozen during that time period and thus could not provide useful data.

Results

Monthly groundwater levels and description of the subsurface conditions at each monitoring well are presented in Table 1. Groundwater levels are subject to seasonal fluctuations ranging from 0.5 metres (MW10-4A) to 1.8 metres (MW10-6B) in overburden monitoring wells (see Figures 2 and 3) and 0.8 metres (MW10-3A) to

1.3 metres (MW10-8) in bedrock monitoring wells (see Figure 4). The groundwater levels generally vary from less than 0.1 to 2 metres below ground surface, with the exception of bedrock monitor MW10-3A where water levels were up to 0.2 metres above ground surface, indicating artesian conditions in the upper bedrock. Continuous groundwater level measurements at monitors MW10-6A (bedrock) and MW10-6B (overburden) in Spring 2011 are presented in Figure 5.

Discussion

Groundwater levels are subject to seasonal variability: minimum groundwater levels are encountered in the summer and winter months and maximum levels occur in spring and fall.

The greatest fluctuations in groundwater levels occurred at MW10-7 and MW10-6B (overburden monitors) and at MW10-6A and MW10-8 (bedrock monitors). Shallow groundwater levels are influenced significantly by infiltration, which vary according to precipitation, snowmelt and evapotranspiration.

The horizontal groundwater flow direction within the overburden is interpreted to be controlled by local surface water drainage features (i.e. Jock River, drains and ditches).

Multi-level monitors installed within the overburden and bedrock were used to assess vertical hydraulic gradients. In general, the hydraulic gradients indicated groundwater was observed to consistent upward flow from the bedrock to the overburden at MW10-3 and downward at MW10-6.

If you have any questions regarding the content of this memo, please contact the undersigned.

Yours truly,

GOLDER ASSOCIATES LTD.

Dale Holtze

Dale Holtze, B.Sc., GIT.
Environmental Consultant

for Brian Byerley, M.Sc., P.Eng.
Senior Hydrogeologist/Associate

DH/BTB/sg
n:\active\2008\1122 - environmental\08-1122-0078 mattamy richmond\phase 9600\mem 11aug11 groundwater levels.docx

Attachments: Table 1 – Groundwater Monitoring Data
Figure 1: Key Plan
Figure 2: Spring 2011 Groundwater Levels
Figure 3: Groundwater Levels in Overburden Monitoring Wells April 2010 to April 2011
Figure 4: Groundwater Levels in Bedrock Monitoring Wells April 2010 to April 2011
Figure 5: Continuous Measurements of Groundwater Levels at MW10-6 March and April 2011

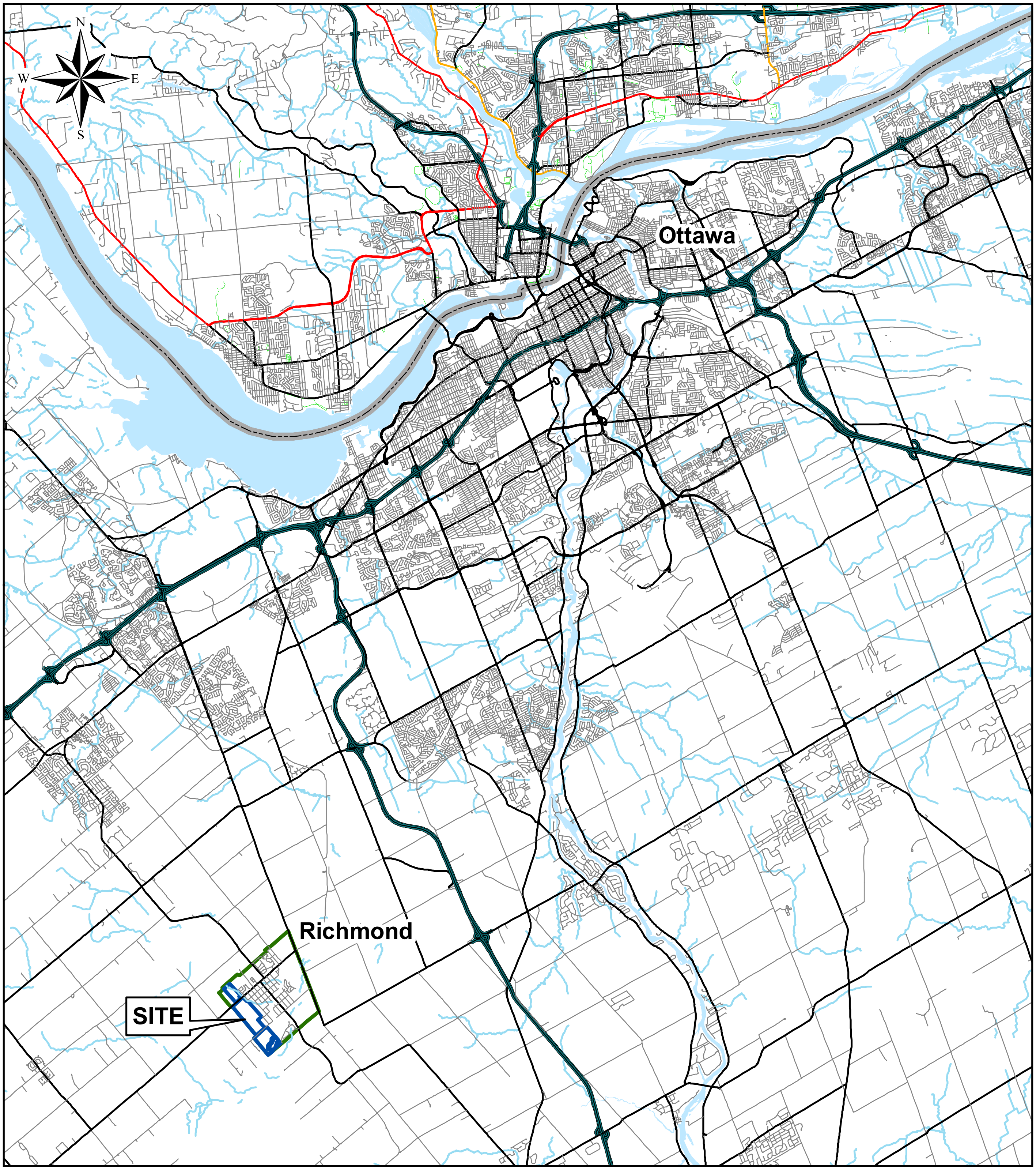
Table 1: Groundwater Monitoring Data

Well ID	Ground Surface Elevation (geodetic)	Screen depth (middle of screen) (mbgs)	Soil/rock at depth of well screen	Groundwater Level (mbgs)						
				Apr.29 & 30, 2010	May 14, 2010	Jun.16, 2010	Jul. 15, 2010	Aug. 20, 2011	Sept. 16, 2010	Oct. 1, 2010
MW10-1A	94.55	1.11	Grey silty Clay	0.73	0.78	0.80	0.81	0.78	0.81	0.61
MW10-1B	94.55	1.21	Grey brown silty Clay (weathered crust)	0.74	0.77	0.80	0.79	0.79	0.81	0.62
MW10-2	94.90	2.12	Grey brown silty find Sand	0.73	0.67	0.86	0.66	0.96	0.94	0.17
MW10-3A	94.0	4.55	Fresh grey Dolomite	0.22	0.26	0.58	0.28	0.23	0.25	-0.09[1]
MW10-3B	94.0	2.12	Grey brown silty Clay (weathered crust)/grey brown fine sandy Silt	0.82	0.81	0.87	0.79	0.87	0.85	0.44
MW10-4A	94.34	3.03	Grey brown fine sandy Silt	0.48	0.47	0.56	0.49	0.64	0.62	0.11
MW10-4B	94.34	1.21	Grey brown silty Clay (weathered crust)	0.47	0.49	0.56	0.49	0.64	0.62	0.08
MW10-5A	95.65	3.03	Glacial Till	0.82	0.79	--[2]	--[2]	--[2]	--[2]	--[2]
MW10-5B	95.65	1.21	Grey brown silty find Sand	0.89	0.88	1.33	--[2]	--[2]	--[2]	--[2]
MW10-6A	95.67	4.24	Fresh grey Dolomite	1.38	1.38	1.98	1.34	1.31	1.52	0.66
MW10-6B	95.67	1.52	Grey brown silty Sand trace Clay	1.29	1.28	1.84	1.59	1.12	1.55	0.31
MW10-7	95.36	2.42	Grey brown silty fine Sand	0.51	0.49	1.09	0.98	0.38	0.47	0.03
MW10-8	93.32	2.42	Weathered to fresh grey Dolomite	1.02	1.15	1.52	1.39	1.24	1.29	0.23

Golder Associates

Well ID	Ground Surface Elevation (geodetic)	Screen depth (middle of screen) (mbgs)	Soil/rock at depth of well screen	Groundwater Level (mbgs)						
				Oct 18, 2010	Nov. 19, 2010	Dec. 15, 2010	Jan. 18, 2011	Feb. 14, 2011	Mar. 15, 2011	Apr. 15, 2011
MW10-1A	94.55	1.11	Grey silty Clay	0.77	0.72	0.78	1.00	1.21	0.89	0.64
MW10-1B	94.55	1.21	Grey brown silty Clay (weathered crust)	0.75	0.72	0.78	0.97	1.17	0.90	0.66
MW10-2	94.90	2.12	Grey brown silty find Sand	0.59	0.34	0.55	0.78	0.89	0.56	0.13
MW10-3A	94.0	4.55	Fresh grey Dolomite	0.08	-0.06[1]	--[3]	--[3]	--[3]	--[3]	-0.21[1]
MW10-3B	94.0	2.12	Grey brown silty Clay (weathered crust)/grey brown fine sandy Silt	0.72	0.56	0.73	0.90	0.77	0.69	0.29
MW10-4A	94.34	3.03	Grey brown fine sandy Silt	0.47	0.27	0.44	0.53	0.64	0.41	0.21
MW10-4B	94.34	1.21	Grey brown silty Clay (weathered crust)	0.46	0.25	0.44	0.56	0.65	--[3]	0.26
MW10-5A	95.65	3.03	Glacial Till	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
MW10-5B	95.65	1.21	Grey brown silty find Sand	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
MW10-6A	95.67	4.24	Fresh grey Dolomite	0.84	0.67	0.68	1.22	1.44	0.56	0.46
MW10-6B	95.67	1.52	Grey brown silty Sand trace Clay	0.62	0.26	0.50	1.16	1.42	--[3]	0.05
MW10-7	95.36	2.42	Grey brown silty fine Sand	0.06	0.04	0.03	--[3]	--[3]	--[3]	0.02
MW10-8	93.32	2.42	Weathered to fresh grey Dolomite	0.31	0.26	0.27	0.80	0.81	--[3]	0.19

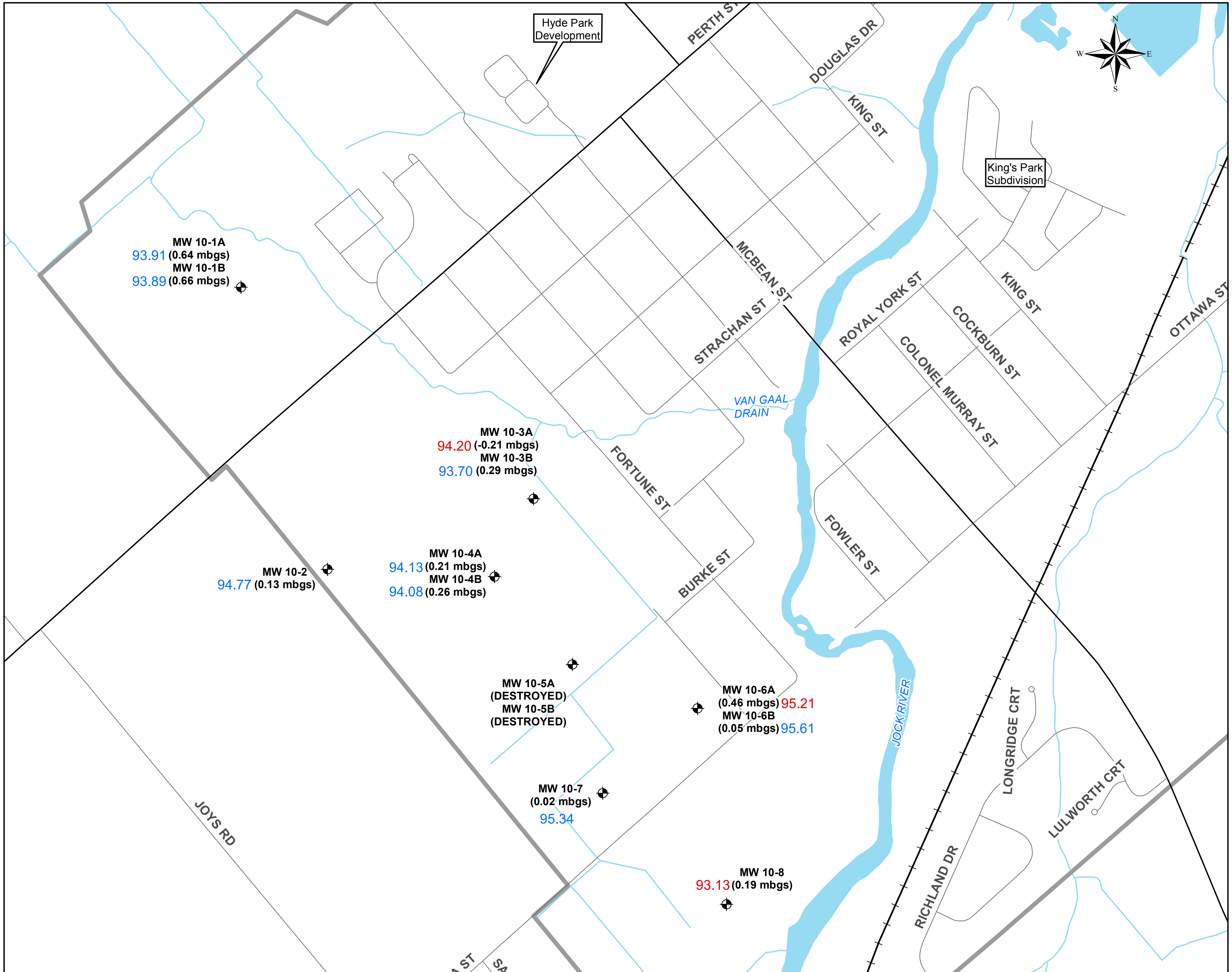
Notes: [1] Artesian conditions exist. Groundwater level above ground surface.
[2] Monitoring well MW 10-5 A and B vandalized and groundwater levels not available after May 14, 2010.
[3] Groundwater in monitoring well frozen. Depth to groundwater level could not be measured.



REFERENCE

Digital base map data supplied by DMTI Spatial Inc. CANMAP, 2005
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 18

Golder Associates, Ottawa, Ontario	DATE 10 Aug 2011	TITLE	
	DESIGN JPAO	**KEY PLAN**	
	GIS ABD		
PROJECT No. 08-1122-0078	CHECK DH	PROJECT MATTAMY HOMES VILLAGE OF RICHMOND	**FIGURE: 1**
SCALE AS SHOWN REV. 0	REVIEW BTB		



LEGEND

- MONITORING WELL (CURRENT INVESTIGATION) (0.64 mbgs) - SPRING 2011 GROUNDWATER LEVEL, metres below ground surface
- MAJOR ROAD
- LOCAL ROAD
- RAILWAY
- RICHMOND VILLAGE BOUNDARY
- WATERCOURSE
- SURFACE WATER
- 95.34 SPRING 2011 GROUNDWATER ELEVATION IN OVERBURDEN
- 95.34 SPRING 2011 GROUNDWATER ELEVATION IN BEDROCK

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. TECHNICAL MEMO NO. 08-1122-0078 PHASE 9600

REFERENCE

DIGITAL DATA PROVIDED BY ONTARIO MINISTRY OF NATURAL RESOURCES, USED UNDER LICENSE © QUEEN'S PRINTER FOR ONTARIO, 2008.
WATER WELLS PROVIDED BY ONTARIO MINISTRY OF ENVIRONMENT, 2006.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 18

250 0 250

SCALE 1:10,000 METRES

PROJECT
MATTAMY HOMES
VILLAGE OF RICHMOND

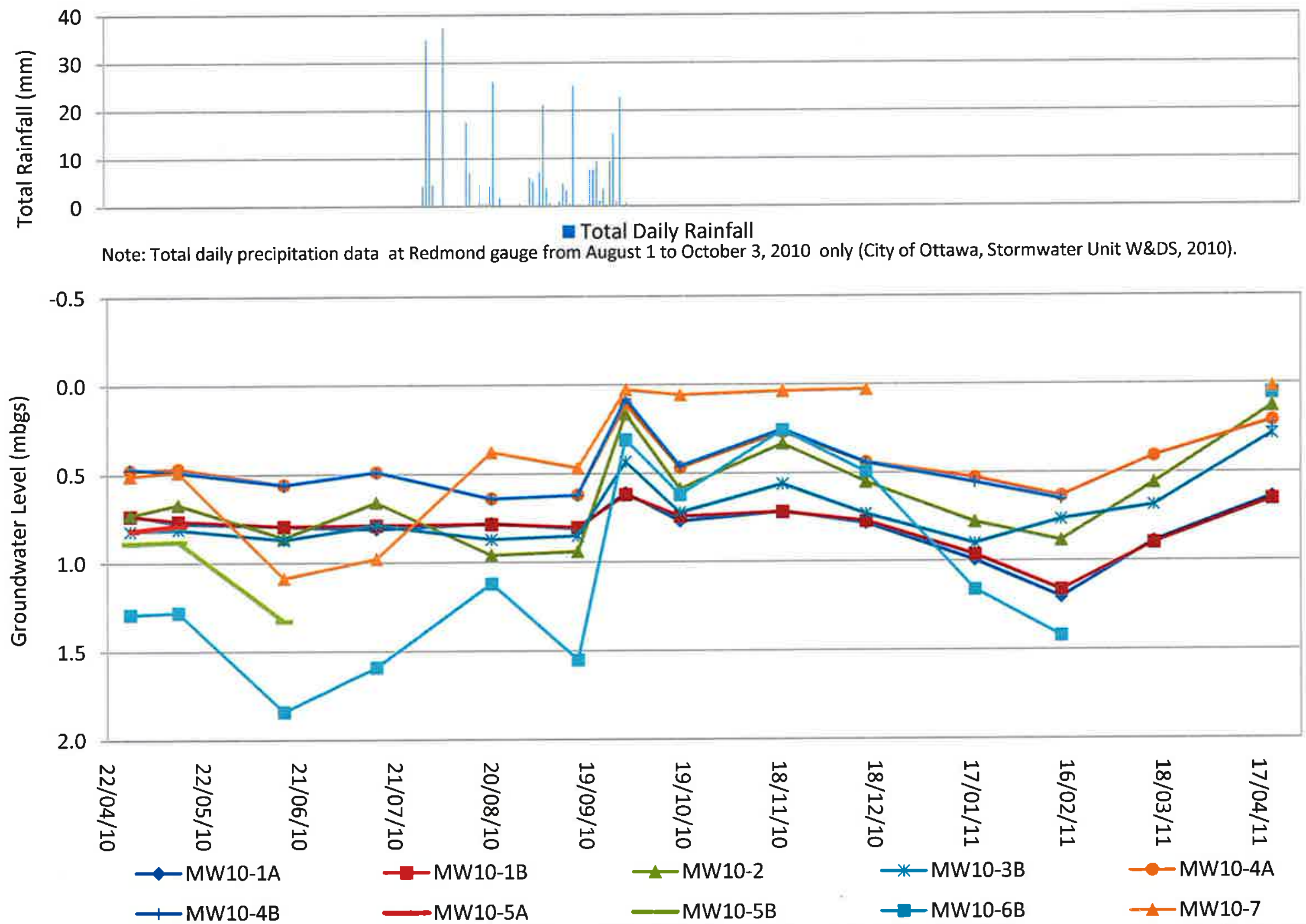
TITLE
SPRING 2011 GROUNDWATER LEVELS

Golder Associates
Ottawa, Ontario

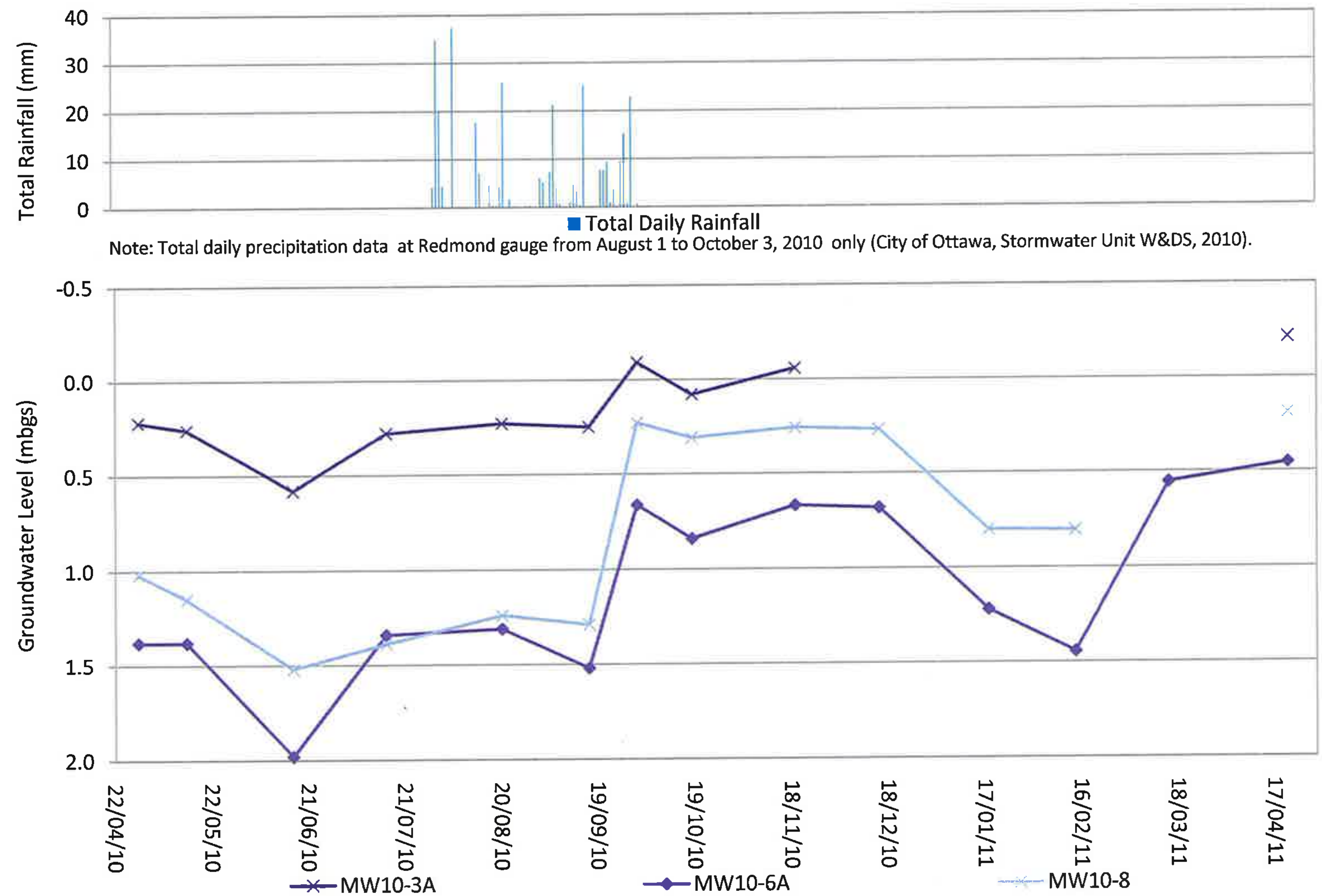
PROJECT No. 08-1122-0078			SCALE AS SHOWN	REV. 0
DESIGN	DH	10 Aug. 2011		
GIS	BR	10 Aug. 2011		
CHECK	DH	10 Aug. 2011		
REVIEW	JPAO	11 Aug. 2011		

FIGURE 2

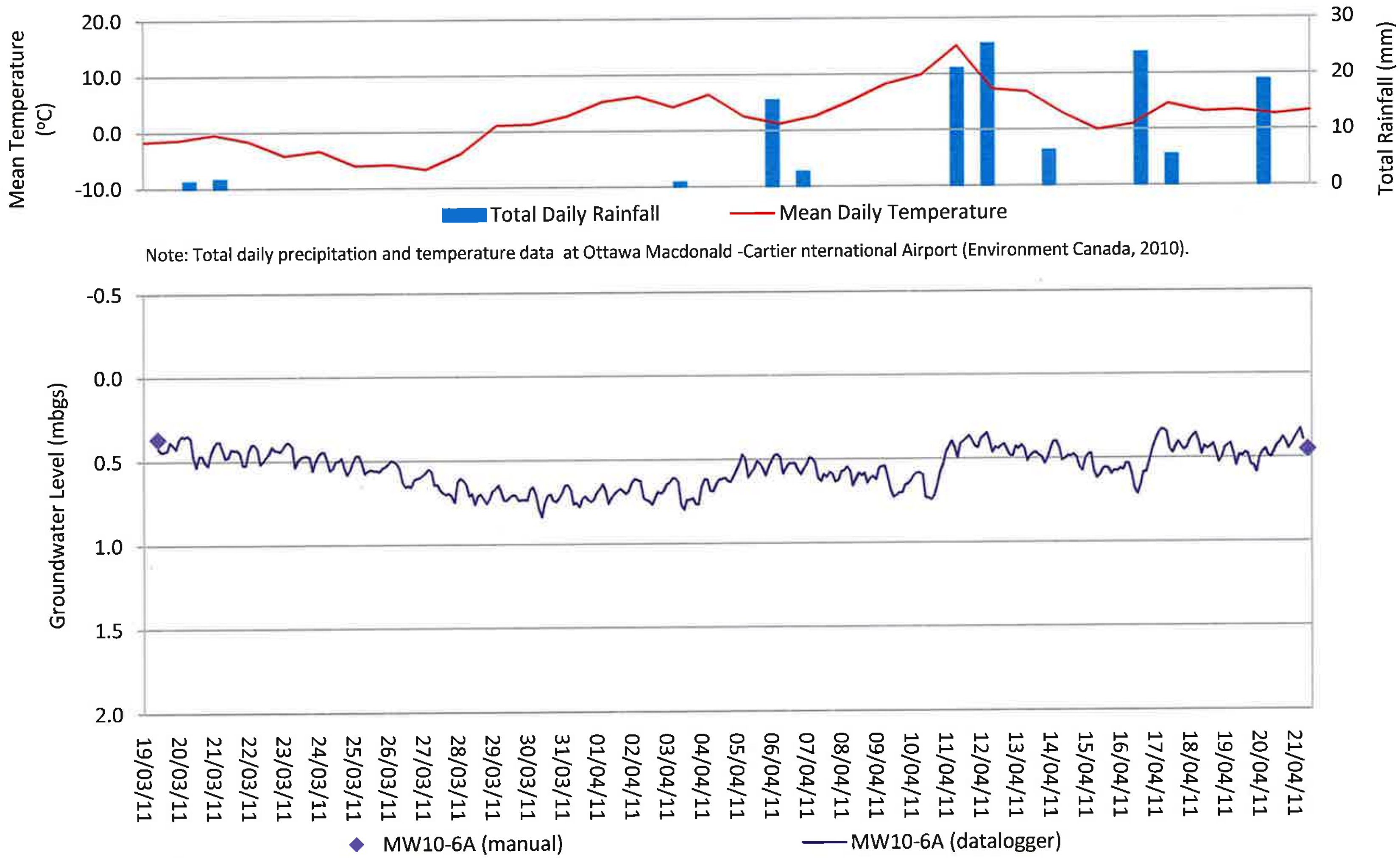
Path: N:\Active\2008\1122 - Environmental\08-1122-0078 Mattamy Richmond\GIS\mxd\Phase 9600\081122078-9600-02.mxd



Golder Associates	Date: August 2011 Project: 08-1122-0078 (9600)	Drawn: DH Checked: BTB	Groundwater Levels in Overburden Monitoring Wells April 2010 to April 2011	Figure 3



Golder Associates	Date: August 2011 Project: 08-1122-0078 (9600)	Drawn: DH Checked: BTB	Groundwater Levels in Bedrock Monitoring Wells April 2010 to April 2011	Figure 4



Notes: MW10-6A is situated in the upper bedrock .

Golder Associates	Date: August 2011 Project: 08-1122-0078 (9600)	Drawn: DH Checked: BTB	Continuous Measurements of Groundwater Levels at MW10-6 During March and April 2011	Figure 5

TECHNICAL MEMORANDUM

DATE July 9, 2019 **Project No.** 1522173

TO Andrew Finnson
Caivan Communities

CC Jocelyn Chandler, J.F. Sabourin and Associates Inc.; Kevin Murphy, DSEL

FROM Caitlin Cooke **EMAIL** ccooke@golder.com

GROUNDWATER MONITORING RESULTS
RICHMOND VILLAGE PHASE I DEVELOPMENT (FOX RUN)
RICHMOND (OTTAWA), ONTARIO

This memo provides the most recent results of the groundwater monitoring program for Caivan Communities Richmond Phase I development (Fox Run) in Ottawa, Ottawa. The groundwater monitoring program was developed to comply with Condition 11 of the Draft Conditions of Approval for Richmond Village Phase I. Condition 11 includes the following description of the required groundwater monitoring program:

> *Following the issuance of building permits, for the first phase of the first subdivision, the owner shall install monitoring wells at locations satisfactory to the City in order to verify that the sustained ground water level is at or lower than the location of the underside of footings. Reports on the levels in the monitoring wells shall be to the satisfaction of the General Manager, Planning and Growth Management.*
>
> *If required, based upon the monitored results, the Owner's professional engineers shall provide recommendations to the Owner and the City for any revisions to the approved Master Drainage Plan and any required reports.*

The intent of the groundwater monitoring is to collect post-development groundwater elevations across the site and to compare to the residence under-side of footing (USF) elevations , to determine if the design of the sub-surface drainage is functioning as intended.

Site Servicing Timeline

The installation of watermains and sewers along Noriker Court, Meynell Road, Pelham Crescent and Cantle Crescent occurred between April and July 2018. The installation of watermains and sewers along Equitation Circle occurred in September and October 2018. Excavation of the stormwater management pond commenced at the end of May 2018.

Groundwater Monitoring Program

The groundwater monitoring program is being conducted at 6 groundwater monitoring locations indicated on Figure 1. The borehole logs and well installation details for each of the monitors are attached. The monitoring well screen for 16-22 was installed into the silt underlying the silty clay deposit (weathered crust). The screens for monitoring wells 18-01, 18-02, 18-03, 18-04 and 18-05 were installed across the bottom of the silty clay deposit and into the underlying clayey silt and sandy silt/silty sand deposits; monitoring well 18-01 also encountered the glacial till deposit.

The results of hydraulic conductivity testing of the groundwater monitoring wells found that the range in hydraulic conductivity of the screened deposits is approximately 3×10^{-8} to 2×10^{-6} m/s, with a geometric mean of approximately 2×10^{-7} m/s.

A pressure transducer was installed in monitoring well 16-22 on April 24, 2018. Pressure transducers were installed in monitoring wells 18-01, 18-02, 18-03, 18-04 and 18-05 on November 23, 2018. The pressure transducers were programed to measure and record water pressure at one hour intervals. A barometric transducer is also located on-site, and records barometric pressure at one hour intervals.

Manual groundwater level measurements were obtained at all six monitoring wells on a monthly basis between October 2018 and May 2019. Transducer data was also downloaded on the dates of the manual measurements. Note that a manual groundwater level measurement was not obtained at 16-22 on February 27, 2019 since the lock of the protective casing had seized.

The attached Figures 2 to 7 provide the currently available groundwater elevation monitoring data. On each plot the USF elevation for the closest residential lot to each monitoring well, and the elevation of the springline of the storm sewer installed in the adjacent roadway are indicated. Daily precipitation, as recorded by Environment Canada at the Ottawa International Airport, is included on Figures 2 to 7.

Results

Figure 2 for monitoring well 16-22 shows that the highest groundwater elevations were recorded during the spring freshet in April 2018. Groundwater elevations had a declining trend through the summer of 2018 and were influenced by precipitation events. An increasing trend was noted from September to December 2018. In early 2019, groundwater elevations dropped to about 92.2 metres and remained stable, showing little influence from precipitation events while the ground was frozen. At the beginning of the melt period in mid-March 2019, groundwater elevations again rose through the spring freshet until the latter part of April 2019 but did not reach the highest recorded value from April 2018. A decline in groundwater elevations was again noted following the spring freshet. The maximum groundwater elevation recorded during the 2019 spring freshet was 93.37 metres, only 0.01 metres above the USF of the nearest lot (93.36 metres), for a period of 11 hours. This monitoring well was located within the basement footprint of a house, and was abandoned, in accordance with Ontario Regulation 903, on May 28, 2019 prior to construction of the house foundation starting.

Similar trends in groundwater elevations were noted at monitoring wells 18-02, 18-03 and 18-05 (Figures 4, 5 and 7, respectively). The groundwater elevations at all three of these monitors were above the USF of their nearest residential lots by 0.22, 0.06 and 0.03 metres, respectively, for periods ranging from a few hours up to 3 days during the peak of the 2019 spring freshet. The groundwater elevation at 18-04 (Figure 6) has had similar trends to the other monitoring wells at the site but remained below the USF for the duration of the monitoring period.

The trends in groundwater elevations at 18-01 (Figure 3) differ from the other monitoring wells on site. Groundwater elevations have largely remained above the USF elevation of the nearest residential lot, only dropping below the USF during the winter. This monitoring well is located at the property boundary and is located farther from the closest storm sewer trench than the other monitoring wells. There are no storm sewers installed along the westernmost segment of Equitation Circle, along the property boundary, so any site-wide drainage effects along the storm sewer bedding could be limited in this area. Additionally, there is a nearby ditch running along the south side of Perth Street, and a ditch running along the boundary of the agricultural property to the west. The elevation of the invert of the Perth Street ditch is about 94.5 metres near 18-01. The groundwater elevation could potentially be affected by the proximity of the well to the drainage ditches.

Inspection of the data presented on Figures 2 to 7 reveals that precipitation events influence the shallow groundwater levels at the site.

Conclusions and Recommendations

The results of groundwater elevation monitoring at monitoring wells 16-22, 18-02, 18-03, 18-04 and 18-05 indicate that groundwater elevations in Phase 1 of the Fox Run development have largely been below the USF during the 2019 spring freshet, excepting for periods ranging from a few hours up to 3 days during the peak of the freshet. It is anticipated that groundwater elevation drawdown along the storm pipe bedding will continue to develop with time, and that the construction of the remainder of the stormwater pond and improvements to surface drainage that will occur as the site is developed will continue to reduce groundwater elevations across the site.

The trend in groundwater elevations at monitoring well 18-01 does not reflect the trend across the rest of Phase 1 of the development. This well is located farther from the storm sewer trenches than are monitoring wells 16-22, 18-02, 18-03, 18-04 and 18-05, and may be influenced by off-site drainage ditches. While monitoring well 18-01 may not be responding as desired, it is not located on or adjacent to a residential lot, and it is possible that groundwater elevations within the nearby residential lots may be influenced by sub-surface drainage, such that they are below the USFs.

Due to the uncertainty regarding lowering of groundwater elevations at residential lots in the area of monitoring well 18-01, it is recommended that a new monitoring well be constructed on the closest residential lot (Lot 36), so that the trend in groundwater elevations at the residential lots can be measured. The new well should be equipped with a pressure transducer and groundwater elevation at the new well should be recorded for a period of one month to determine if the groundwater elevation in the residential lots behaves similarly to the majority of the other monitors at the site. Following the one month period, a revised memorandum should be issued containing a discussion of the results of this additional monitoring and recommendations for further groundwater monitoring, if necessary.

Limitations

This memorandum was prepared for the exclusive use of Caivan Communities. The memorandum, which specifically includes all tables, figures and attachments, is based on data and information provided to Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this memorandum.

Golder Associates Ltd. has relied in good faith on all information provided and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the memorandum as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation.

The services performed, as described in this memorandum, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this memorandum, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this memorandum.

The findings and conclusions of this memorandum are valid only as of the date of this memorandum. If new information is discovered in future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this memorandum, and to provide amendments as required.

Closure

We trust that this memo provides sufficient information for your present requirements. If you have any questions concerning this memo, please don't hesitate to contact the undersigned.

Yours truly,

Golder Associates Ltd.

PROFESSIONAL GEOSCIENTIST
CAITLIN A. MARTIN COOKE
PRACTISING MEMBER
1481
July 10/19
ONTARIO

Caitlin Cooke, M.Sc., P.Geo.
Hydrogeologist

Brian Byerley, M.Sc., P.Eng.
Senior Hydrogeologist/Principal

CAMC/BTB/sg

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Attachments: Important Information and Limitations of this Report
Figure 1: Site Plan
Figures 2-7: Groundwater Elevation and Precipitation
Record of Borehole Logs
Slug Test Analyses

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client, Caivan Communities. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then the client may authorize the use of this report for such purpose by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process, provided this report is not noted to be a draft or preliminary report, and is specifically relevant to the project for which the application is being made. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT (cont'd)

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

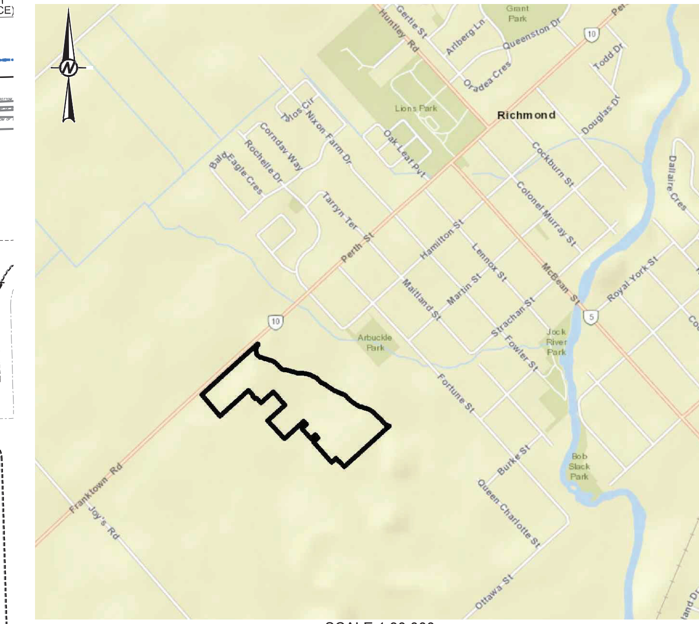
Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

KEY MAP



LEGEND

PHASE 1 RESIDENTIAL DEVELOPMENT

APPROXIMATE BOREHOLE LOCATION

REFERENCE

1. BASE PLAN SUPPLIED IN ELECTRONIC FORMAT BY CAIVAN LIMITED
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83, COORDINATE SYSTEM: MTM ZONE 9

0 50 100

1:2,500 METRES

CLIENT
CAIVAN COMMUNITIES

PROJECT
GROUNDWATER ELEVATION MONITORING, PHASE 1 FOX RUN RESIDENTIAL DEVELOPMENT, OTTAWA, ONTARIO

TITLE
SITE PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	2019-06-14
PREPARED	JM/JEM
DESIGN	----
REVIEW	CAMC
APPROVED	BTB

PROJECT No.	PHASE	Rev.	FIGURE
1522173	4000	0	1

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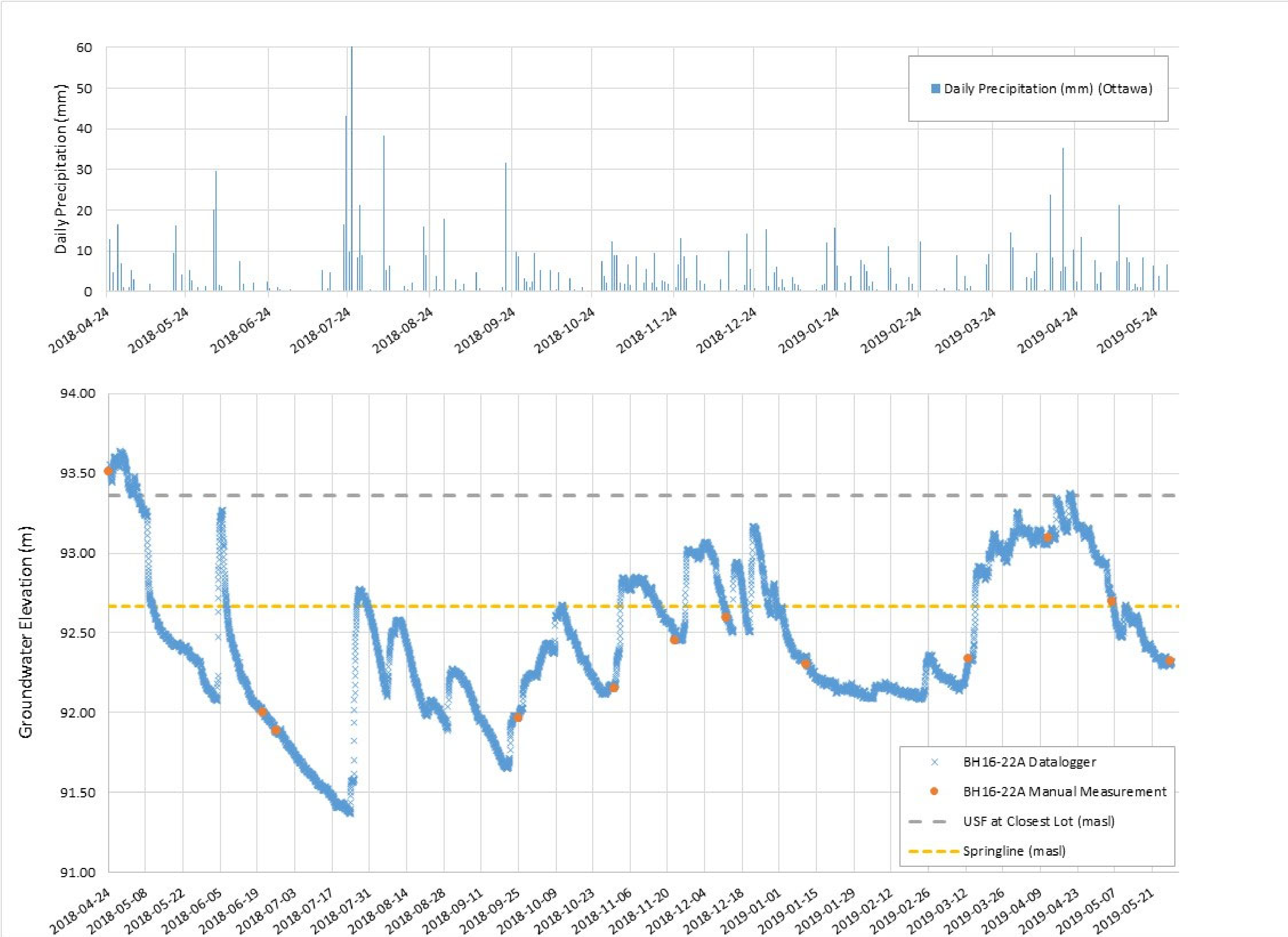


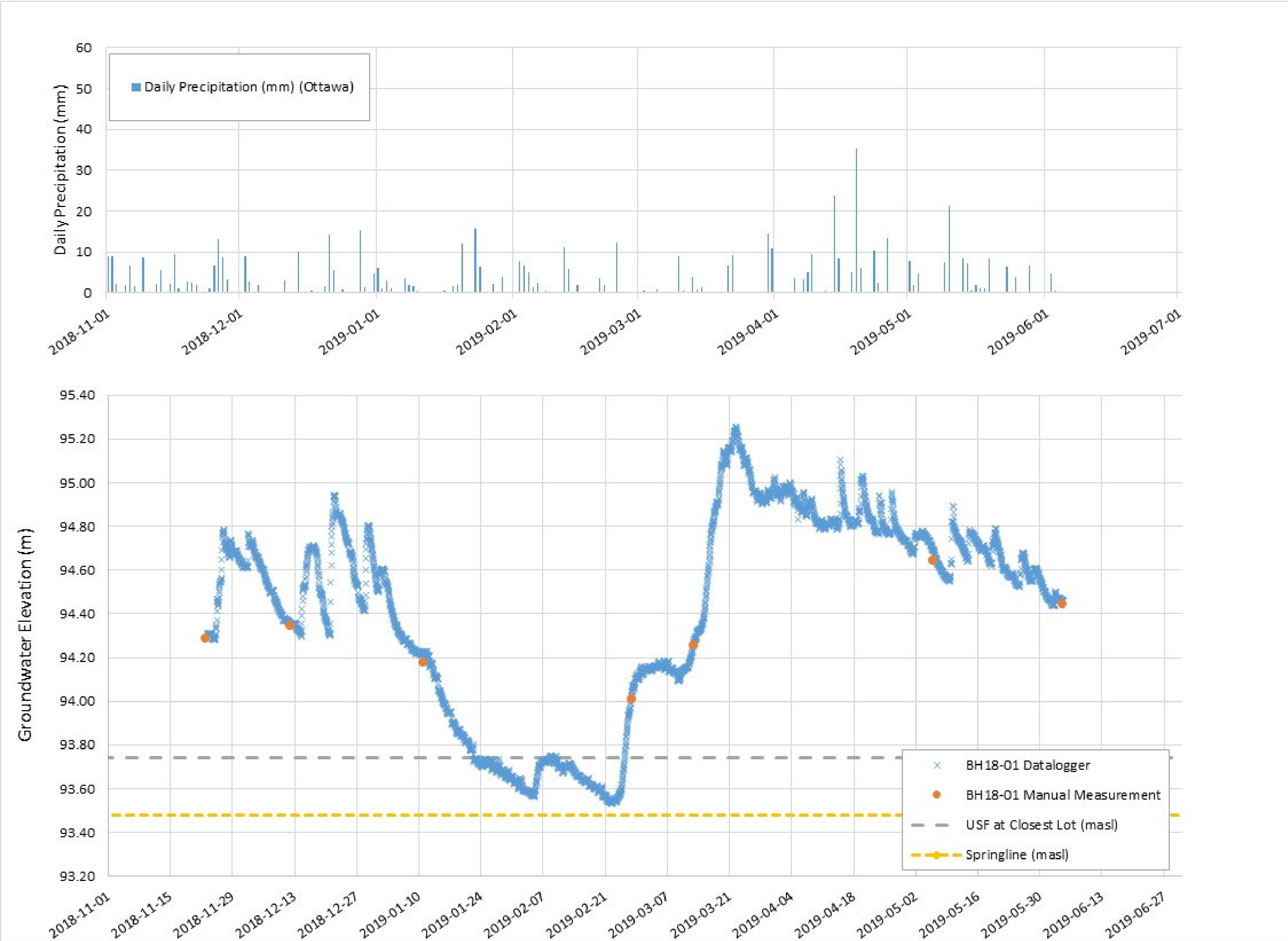
GOLDER

Date: June 2019 Drawn: CAMC

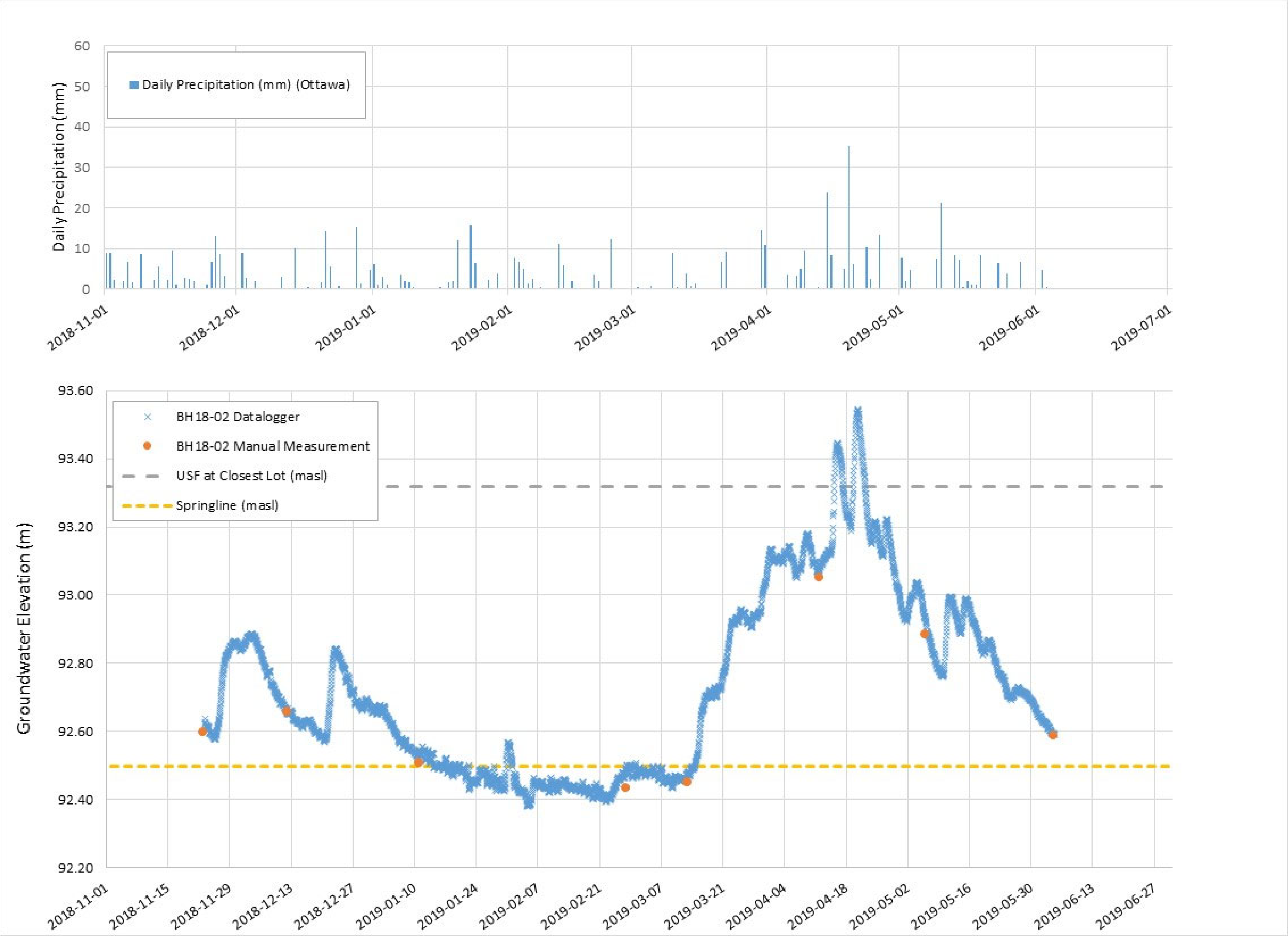
Project: 1522173(4000) Chkd: BTB

GROUNDWATER ELEVATIONS AT MONITORING WELL 16-22A

FIGURE 2



GOLDER	Date: June 2019 Drawn: CAMC Project: 1522173(4000) Chkd: BTB	**GROUNDWATER ELEVATIONS AT MONITORING WELL 18-01**	FIGURE 3



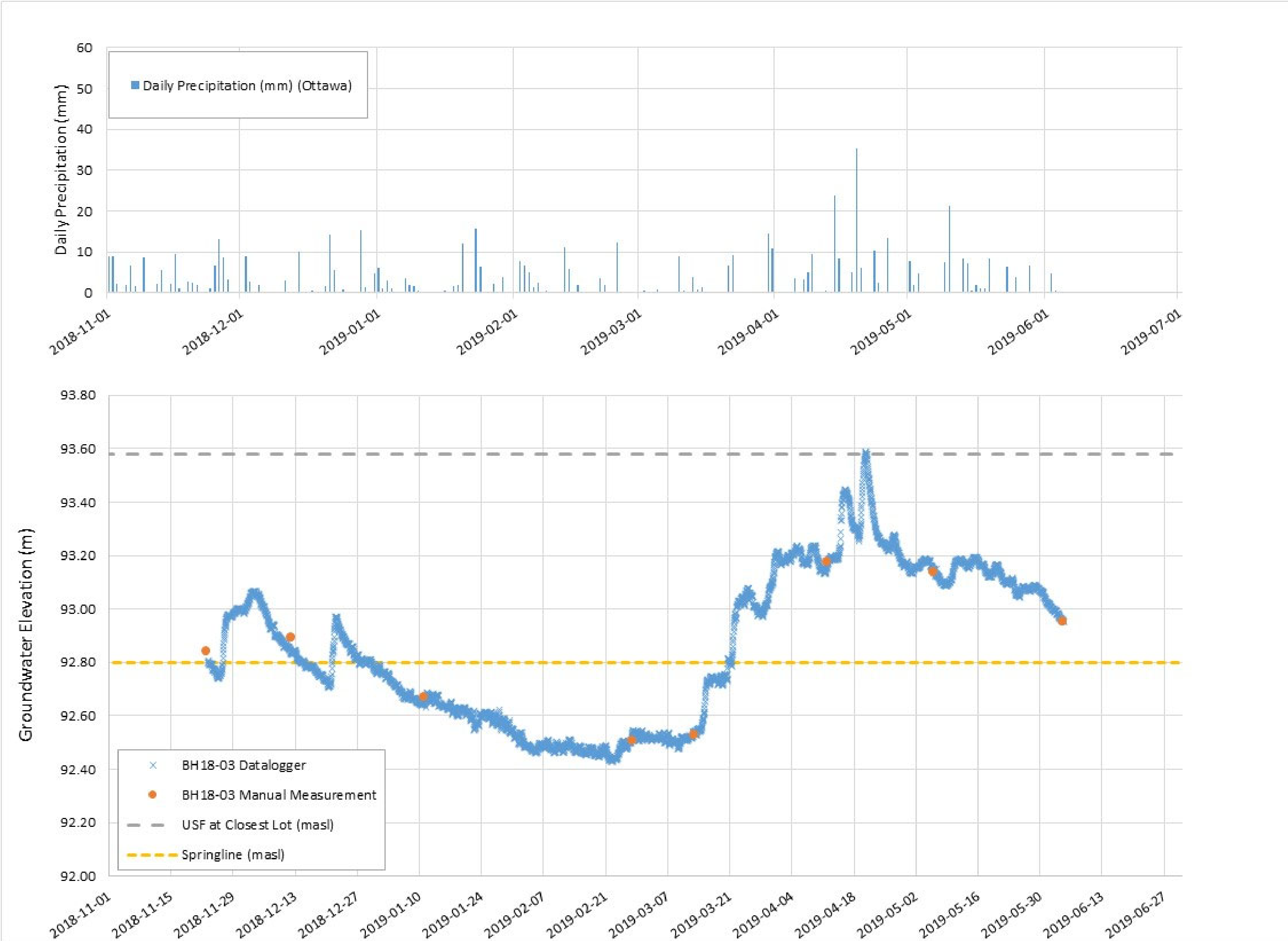
GOLDER

Date: June 2019 Drawn: CAMC

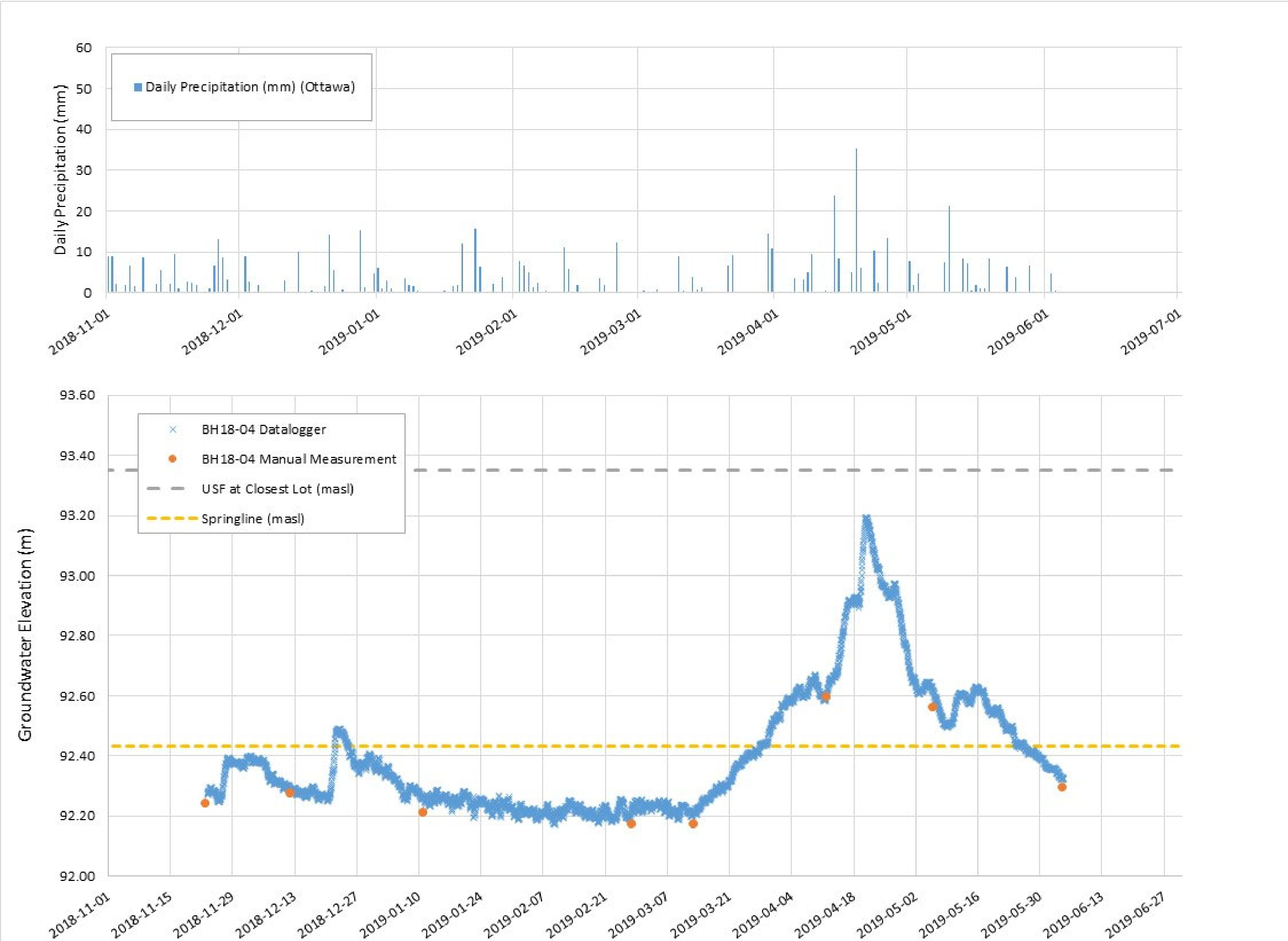
Project: 1522173(4000) Chkd: BTB

GROUNDWATER ELEVATIONS AT MONITORING WELL 18-02

FIGURE 4



GOLDER	Date: June 2019 Drawn: CAMC Project: 1522173(4000) Chkd: BTB	**GROUNDWATER ELEVATIONS AT MONITORING WELL 18-03**	FIGURE 5



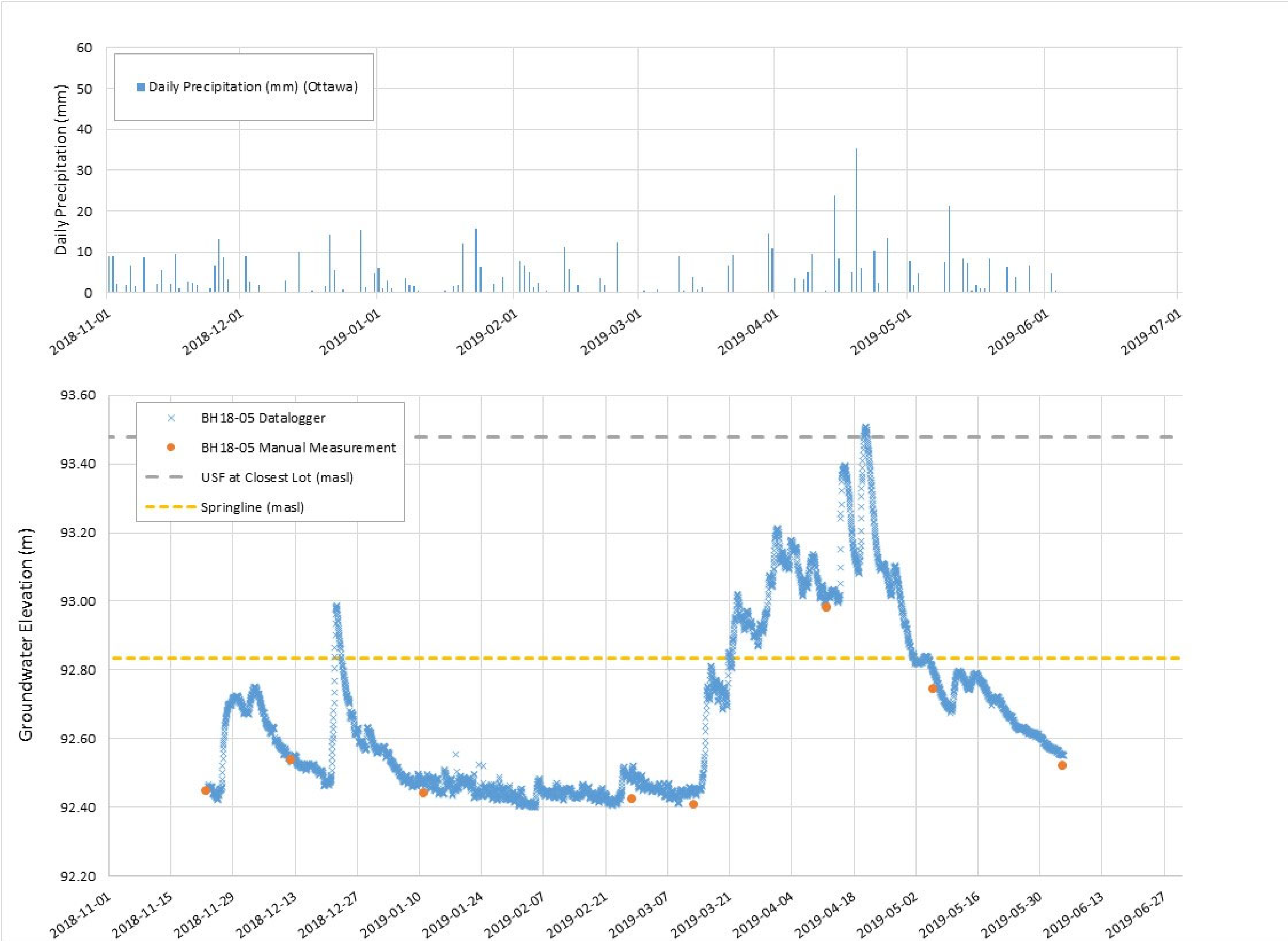
GOLDER

Date: June 2019 Drawn: CAMC

Project: 1522173(4000) Chkd: BTB

GROUNDWATER ELEVATIONS AT MONITORING WELL 18-04

FIGURE 6



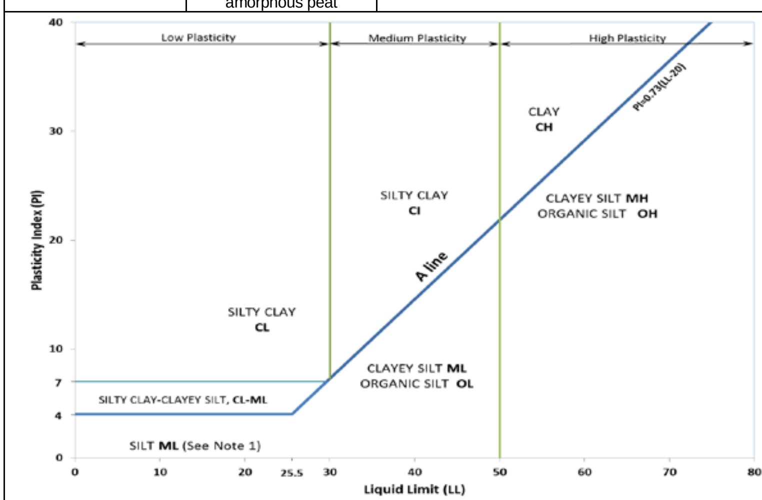
GOLDER	Date: June 2019 Drawn: CAMC Project: 1522173(4000) Chkd: BTB	**GROUNDWATER ELEVATIONS AT MONITORING WELL 18-05**	FIGURE 7

Record of Borehole Logs

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10} x D_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content ≤30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with ≤12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	≤30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators: Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)	Organic Content	USCS Group Symbol	Primary Name
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% **(see Note 2)**	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.
Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.
For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.
For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.
A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to indicate a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.,* SAND and GRAVEL)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)
An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.
2. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1,2] (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$ - u)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c′	effective cohesion
c_u, s_u	undrained shear strength (ϕ = 0 analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan \phi'$
2 shear strength = (compressive strength)/2

PROJECT: 1522173-3000

RECORD OF BOREHOLE: 16-22A

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: March 17, 2016

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Boring method: Power Auger, 200 mm Diam. (Hollow Stem)

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.30m	SHEAR STRENGTH Cu, kPa	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE	94.09						
0	TOPSOIL - (CL) SILTY CLAY, trace to some sand, trace gravel; dark brown to black, contains organic matter and rootlets; cohesive, w>PL	0.00						
	(CI/CH) SILTY CLAY to CLAY, trace sand; brown to grey brown, highly fissured (WEATHERED CRUST); cohesive, w>PL, very stiff	93.76 / 0.33						Native Backfill
1			1	SS	4		MH	
2			2	SS	2		MH	Bentonite Seal
						>96 +		Silica Sand
						>96 +		
3	(ML) SILT, some sand; brown to grey; non-cohesive, wet, compact to loose	91.04 / 3.05	3	SS	13			32 mm Diam. PVC #10 Slot Screen
4			4	SS	6			
	End of Borehole Auger Refusal	89.72 / 4.37						WL in Screen at Elev. 93.27 m on April 21, 2016

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ ; 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ├──○W──┤ Wl ; 20 40 60 80

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: KSL

PROJECT: 1522173

RECORD OF BOREHOLE: 18-01

SHEET 1 OF 1

LOCATION: N 5005331.5 ;E 355759.5

BORING DATE: October 18, 2018

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp ├──○W──┤ Wl (20, 40, 60, 80) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. / DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	95.50				
0	Power Auger 200 mm Diam. (Hollow Stem)	FILL - (SW/GW) SAND and GRAVEL, some silt; brown; non-cohesive, moist, loose	0.00				Bentonite Seal
		TOPSOIL - (SM-ML) SILTY SAND to sandy SILT; dark brown, contains organic matter	95.12 0.38				
1		(CL/CI) SILTY CLAY; grey brown, fissured, contains clayey silt and silty fine sand seams (WEATHERED CRUST); cohesive, w~PL, very stiff	94.89 0.61	1	SS	8	Native Backfill
				2	SS	6	Bentonite Seal
2							Silica Sand
		(ML-CL) CLAYEY SILT; grey brown; wet, very loose	92.91 2.59	3	SS	2	
3		(ML) sandy SILT; brown; wet, compact	92.53 2.97				38 mm Diam. PVC #10 Slot Screen
		(ML) sandy SILT, some gravel; brown (GLACIAL TILL); wet, compact	92.22 3.28	4	SS	23	
4		End of Borehole	91.69 3.81				WL in screen at Elev. 94.25 m on Oct. 31, 2018
5							
6							
7							
8							
9							
10							

DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: CAMC

RECORD OF BOREHOLE: 18-02

PROJECT: 1522173

SHEET 1 OF 1

LOCATION: N 5005423.9 ;E 356058.1

BORING DATE: October 18, 2018

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.30m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	94.70				
0	Power Auger 200 mm Diam. (Hollow Stem)	FILL - (ML-CL) SILTY CLAY and CLAYEY SILT, trace gravel, angular; brown; cohesive, moist, loose	0.00				Bentonite Seal
1		(CI/CH) SILTY CLAY; grey brown, fissured (WEATHERED CRUST); cohesive, w~>PL, very stiff	93.79 / 0.91	1	SS	6	Native Backfill
2				2	SS	11	Bentonite Seal; Silica Sand
3				3	SS	5	38 mm Diam. PVC #10 Slot Screen
				4	SS	3	
		(ML-CL,ML) CLAYEY SILT to sandy SILT; grey brown; wet, loose	91.26 / 3.44				
4		End of Borehole	90.74 / 3.96				WL in screen at Elev. 92.30 m on Oct. 31, 2018

Column headings also include: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●; rem V. ⊕ U - ○) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT (Wp ⊢—○W—⊣ Wl) (20, 40, 60, 80); STRATA PLOT; ADDITIONAL LAB. TESTING.

Depth scale: 0 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE
1 : 50

GOLDER

LOGGED: PAH
CHECKED: CAMC

MIS-BHS 001 1522173.GPJ GAL-MIS.GDT 13/11/18 SGL/JM

PROJECT: 1522173

RECORD OF BOREHOLE: 18-03

SHEET 1 OF 1

LOCATION: N 5005228.4 ;E 356158.4

BORING DATE: October 18, 2018

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Boring method: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.30m	PIEZOMETER OR STANDPIPE INSTALLATION
GROUND SURFACE	95.26				
FILL - (ML-CL) CLAYEY SILT, trace to some gravel; brown	0.00				Bentonite Seal; Native Backfill
(CL/CI) SILTY CLAY; grey brown, fissured, contains silty fine sand seams (WEATHERED CRUST); cohesive, w~PL, very stiff	94.25 / 1.01	1	SS	11	Bentonite Seal
		2	SS	6	
(ML-CL) CLAYEY SILT; grey brown; wet; loose	93.13 / 2.13				Silica Sand
(ML) sandy SILT, some clayey silt/silty clay layers; brown; non-cohesive, wet, compact	92.75 / 2.51	3	SS	12	38 mm Diam. PVC #10 Slot Screen
(SM) SILTY SAND, fine; brown; non-cohesive, wet, compact	92.06 / 3.20	4	SS	16	
End of Borehole	91.45 / 3.81				WL in screen at Elev. 92.47 m on Oct. 31, 2018

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE 1 : 50

GOLDER

LOGGED: PAH

CHECKED: CAMC

RECORD OF BOREHOLE: 18-04

PROJECT: 1522173
SHEET 1 OF 1

LOCATION: N 5005272.2 ;E 356366.2
BORING DATE: October 19, 2018
DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Boring method: Power Auger, 200 mm Diam. (Hollow Stem)

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.30m	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE	94.46				
0	FILL - (ML-CL) CLAYEY SILT	0.00	1	GRAB	-	Bentonite Seal
	(CL/CI) SILTY CLAY; grey brown, fissured, contains silty fine sand and clayey silt seams (WEATHERED CRUST); cohesive, w~PL to w>PL, very stiff	93.73 0.73	2	SS	11	Native Backfill
			3	SS	3	Bentonite Seal Silica Sand
	(CL-ML, ML) CLAYEY SILT and sandy SILT; grey brown, laminated; non-cohesive, wet, loose	91.87 2.59	4	SS	1	38 mm Diam. PVC #10 Slot Screen
	(SM) SILTY SAND, fine brown; non-cohesive, wet, compact	91.11 3.35	5	SS	13	
	End of Borehole	90.65 3.81				WL in screen at Elev. 91.87 m on Oct. 31, 2018

Other column headings: STRATA PLOT; DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa — nat V. + Q - ●, rem V. ⊕ U - ○ (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (20, 40, 60, 80); ADDITIONAL LAB. TESTING

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DEPTH SCALE
1 : 50

GOLDER

LOGGED: PAH
CHECKED: CAMC

RECORD OF BOREHOLE: 18-05

PROJECT: 1522173

SHEET 1 OF 1

LOCATION: N 5005065.5 ;E 356310.2

BORING DATE: October 19, 2018

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		95.28							
0	Power Auger 200 mm Diam. (Hollow Stem)	FILL - (ML-CL) CLAYEY SILT, some gravel; brown		0.00	1	GRAB	-				Bentonite Seal
		TOPSOIL - (ML-CL) CLAYEY SILT; dark brown, contains organic matter		94.52 / 0.76							Native Backfill
1		(CL/CI, ML_CL) SILTY CLAY and CLAYEY SILT; grey brown, fissured, contains silty fine sand seams (WEATHERED CRUST); cohesive, w~>PL, very stiff		0.85	2	SS	13				
					3	SS	5				Bentonite Seal
2											Silica Sand
		(ML-CL, ML) CLAYEY SILT and sandy SILT; grey brown, layered, contains low plasticity fines; non-cohesive, wet, compact		92.99 / 2.29	4	SS	17				
3		(SM) SILTY SAND, fine; brown; non-cohesive, wet, compact		92.38 / 2.90	5	SS	19				38 mm Diam. PVC #10 Slot Screen
											Cave
4		End of Borehole		91.47 / 3.81							WL in screen at Elev. 92.33 m on Oct. 31, 2018
5											
6											
7											
8											
9											
10											

MIS-BHS 001 1522173.GPJ GAL-MIS.GDT 13/11/18 SGL/JM

DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: CAMC

Slug Test Analyses

HVORSLEV SLUG TEST ANALYSIS
FALLING HEAD TEST 16-22

INTERVAL (metres below ground surface)

Top of Interval = **2.84**
Bottom of Interval = **4.37**

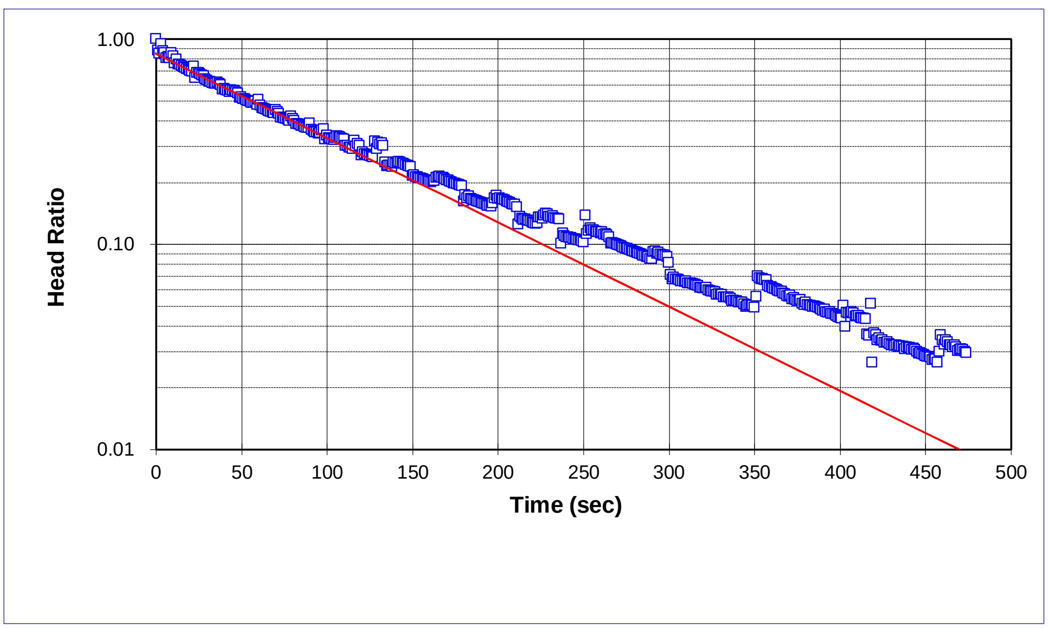
$$K = \frac{r_c^2}{2L_e} ln\left[\frac{L_e}{2R_e} + \sqrt{1 + \left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

where: r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS	
r_c =	1.6E-02
R_e =	1.0E-01
L_e =	1.5
t_1 =	0
t_2 =	100
h_1/h_0 =	0.85
h_2/h_0 =	0.33

RESULTS

K=	2E-06	m/sec
K=	2E-04	cm/sec



Project Name: Caivan Richmond
Project No.: 1522173
Test Date: 4/21/2016

Analysis By: CAMC
Checked By: BTB
Analysis Date: 4/22/2016

Golder Associates Ltd.

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST 18-01

INTERVAL (metres below ground surface)

Top of Interval = 2.29
Bottom of Interval = 3.81

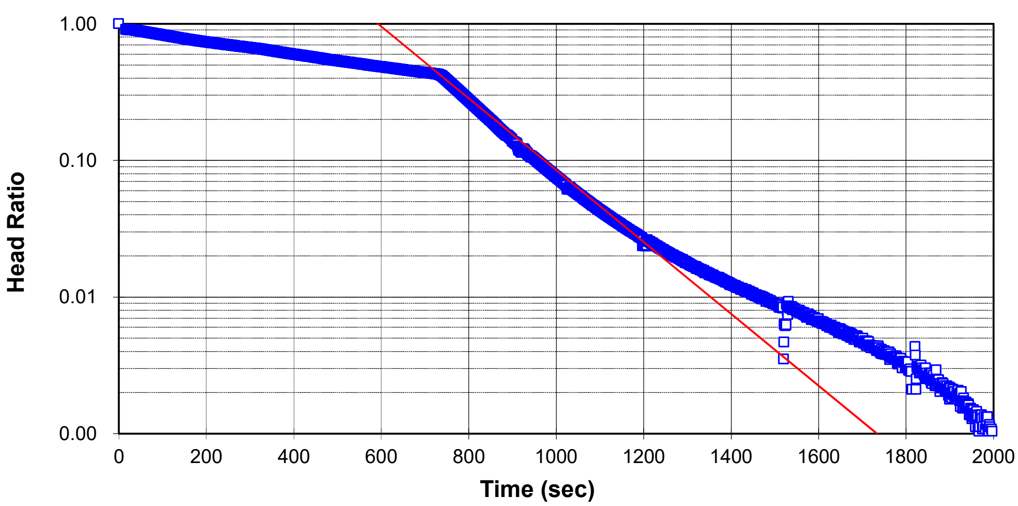
$$K = \frac{r_c^2}{2L_e} \ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS	
r_c =	1.9E-02
R_e =	1.0E-01
L_e =	1.5
t_1 =	757
t_2 =	1156
h_1/h_0 =	0.37
h_2/h_0 =	0.03

RESULTS

K=	2E-06	m/sec
K=	2E-04	cm/sec



Project Name: Caivan/Western Development Lands Richmon
Project No.: 1522173
Test Date: 2018-10-31

Analysis By: SPS
Checked By: BTB
Analysis Date: 2018-11-01

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 18-02

INTERVAL (metres below ground surface)

Top of Interval = 2.44
Bottom of Interval = 3.96

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

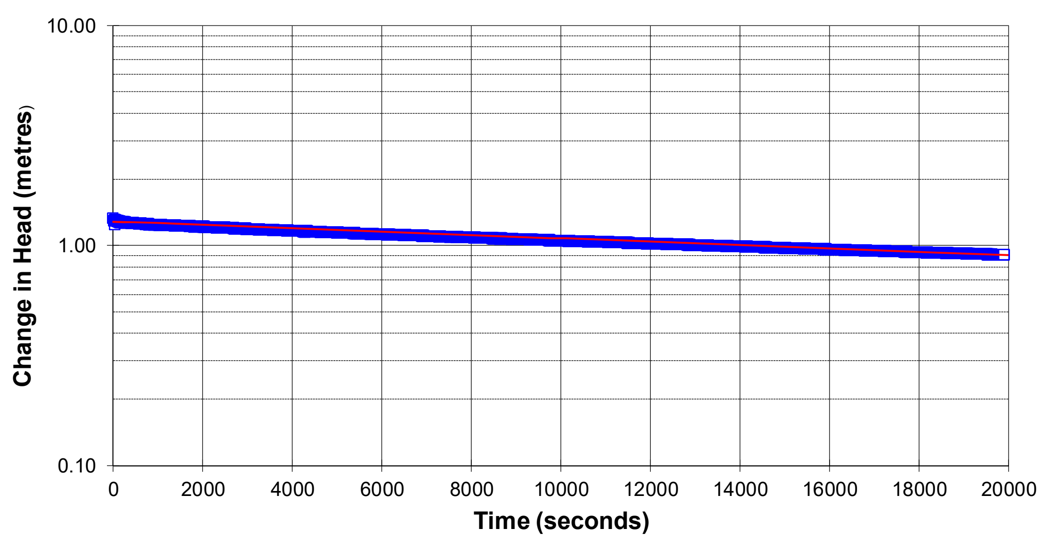
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.06
r_w =	0.10
L_e =	1.52
$ln(R_e/r_w)$	1.62
y_0 =	1.28
y_t =	0.91
t =	19438.0

RESULTS

K=	3E-08	m/sec
K=	3E-06	cm/sec



Project Name: Caivan/Western Development Lands Richmon(
Project No.: 1522173
Test Date: 11-01-18
Analysis By: SPS
Checked By: BTB
Analysis Date: 2018-11-01

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 18-03

INTERVAL (metres below ground surface)

Top of Interval =	**2.29**
Bottom of Interval =	**3.81**

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

r_c = casing radius (metres);

R_e = effective radius (metres);

L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)

y_0 = initial drawdown (metres)

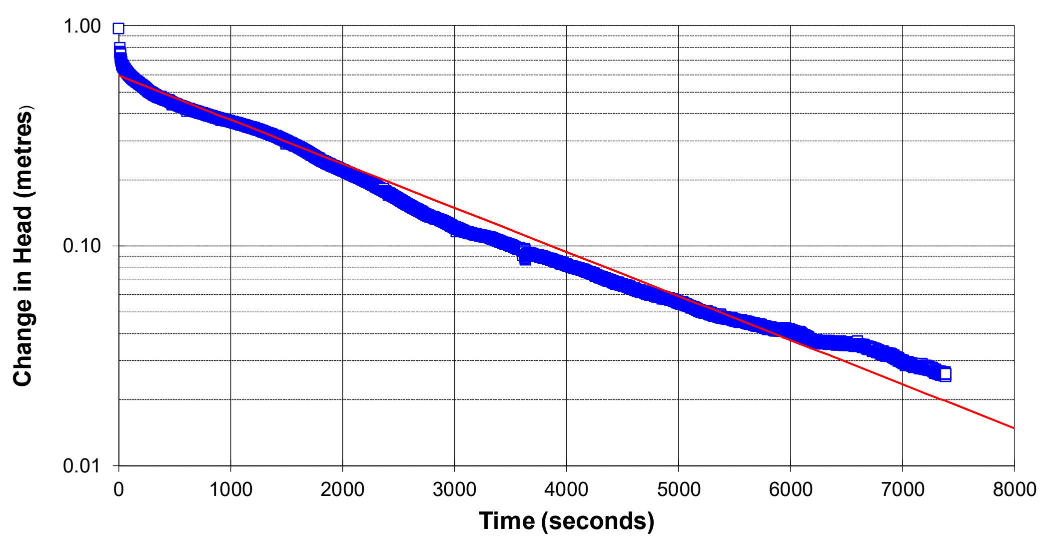
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	**0.02**
r_w =	**0.06**
L_e =	**1.02**
$ln(R_e/r_w)$	**1.76**
y_0 =	**0.55**
y_t =	**0.04**
t =	**5683.0**

RESULTS

K=	**1E-07**	**m/sec**
K=	**1E-05**	**cm/sec**



Project Name: Caivan/Western Development Lands Richmon
Project No.: 1522173
Test Date: 10-31-18

Analysis By: SPS
Checked By: BTB
Analysis Date: 2018-11-01

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 18-04

INTERVAL (metres below ground surface)

Top of Interval = **2.20**
Bottom of Interval = **3.72**

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

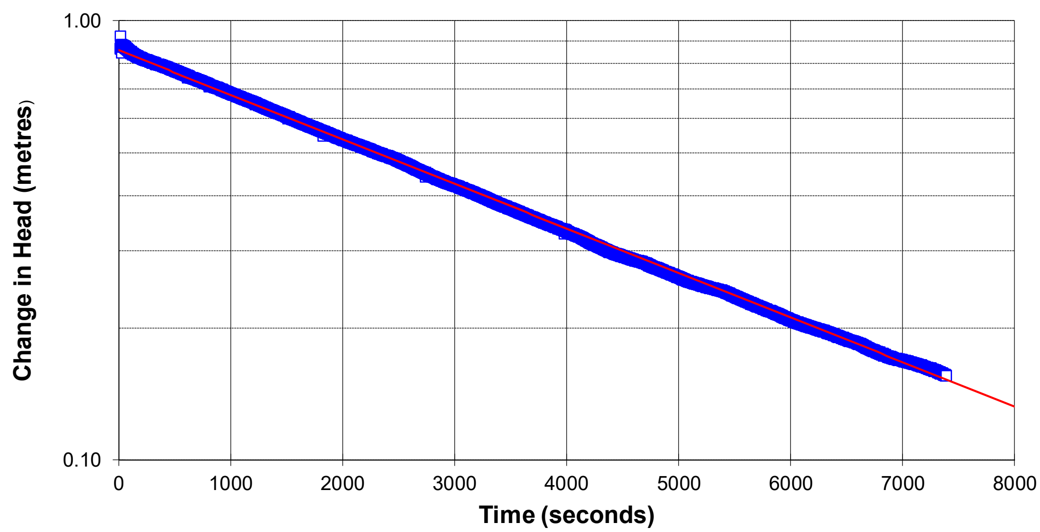
where:

r_c = casing radius (metres);
r_w = radial distance to undisturbed aquifer (metres)
R_e = effective radius (metres);
y_0 = initial drawdown (metres)
L_e = length of screened interval (metres);
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_c =	0.02
r_w =	0.06
L_e =	1.13
$ln(R_e/r_w)$	1.86
y_0 =	0.82
y_t =	0.21
t =	5835.0

RESULTS

K=	7E-08	m/sec
K=	7E-06	cm/sec



Project Name: Caivan/Western Development Lands Richmon
Project No.: 1522173
Test Date: 10-31-18

Analysis By: SPS
Checked By: BTB
Analysis Date: 2018-11-01

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 18-05

INTERVAL (metres below ground surface)

Top of Interval = 2.29
Bottom of Interval = 3.81

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

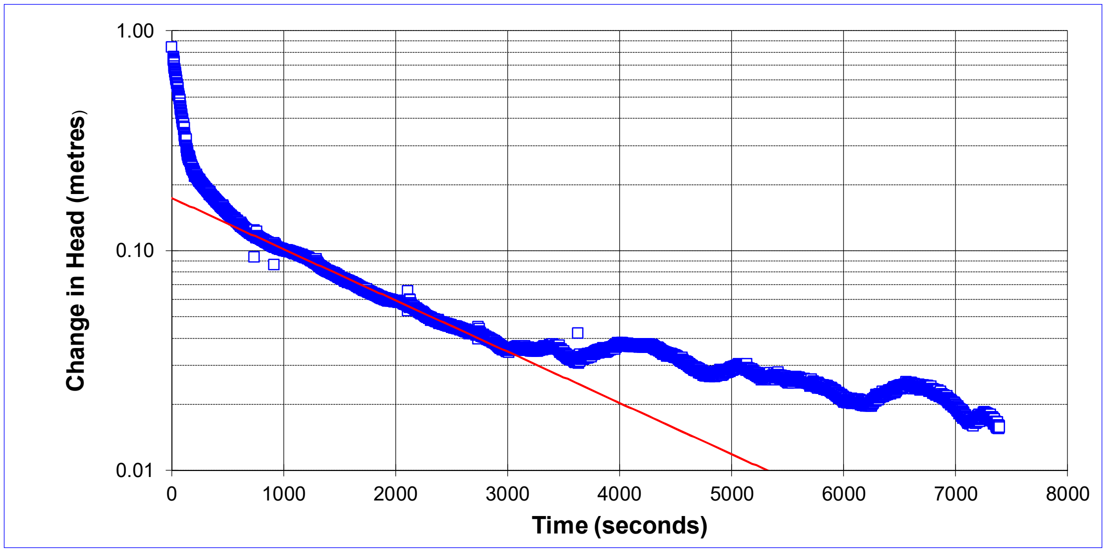
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.02
r_w =	0.06
L_e =	0.86
$ln(R_e/r_w)$	1.60
y_0 =	0.11
y_t =	0.04
t =	1885.0

RESULTS

K=	2E-07	m/sec
K=	2E-05	cm/sec



Project Name: Caivan/Western Development Lands Richmon(
Project No.: 1522173
Test Date: 10-31-18

Analysis By: SPS
Checked By: BTB
Analysis Date: 2018-11-01

Golder Associates Ltd.

TECHNICAL MEMORANDUM

DATE November 4, 2013 **PROJECT No.** 12-1127-0062 (8000)

TO Frank Cairo
Richmond Village (South) Limited

CC Mike Green
Mattamy (Jock River) Limited

FROM Brian Byerley, M.Sc., P.Eng. **EMAIL** bbyerley@golder.com

BASEMENT DEPTHS, PROPOSED DEVELOPMENT
RICHMOND VILLAGE WESTERN DEVELOPMENT LANDS
OTTAWA, ONTARIO

1.0 INTRODUCTION

This memo provides an assessment regarding proposed basement depths for the Richmond Village (South) and Mattamy (Jock River) developments in the Richmond Village Western Development Lands, in the southwest part of the City of Ottawa.

This issue has been the subject of extensive study and several memos/reports over the past several years. The intent of this current memo is to:

- Compile the applicable information from these previous reports; and,
- Provide a comprehensive recommendation regarding basement depths and, in particular, to document why the proposed founding levels, and the use of sump pumps, are feasible from an engineering/technical perspective.

2.0 BACKGROUND

The proposed development site is approximately 132 hectares (325 acres) in size and is located along the western edge of the Village of Richmond (see Figure 1). The site is legally described as Lot 22, Concessions II, III and IV, Geographic Township of Goulbourn (Village of Richmond). The site boundary is shown on Figure 2.

For the purposes of this memo, and for simplicity of description, the site is described as extending along a north-south axis, with the south limit being adjacent to the Jock River.

The northern part of the site (about two thirds of the area) is actively farmed (corn, wheat and beans) while the southern portion currently consists of fallow fields.

The site is presently zoned for future residential development.

The surrounding lands to the north and west of the site are beyond the Village boundary and are primarily used for agricultural purposes. The lands to the east of the site are within the Village boundary and consist of existing low density residential developments. The Jock River forms the south boundary of the site.

The site is crossed by two existing roadways (Perth Street and Ottawa Street) which approximately divide the site into one-third parcels (north, central, and south).

The ground surface topography across the site is gently sloping, with ground elevations varying from approximately 98 to 94 metres above sea level (masl). The lowest portion of the site is located in the area of Perth Street (between the north and central parcels). To the north of Perth Street, the site is very nearly flat (i.e., just a slight increase in elevation to the north). To the south, the site rises up to Ottawa Street and then to the height-of-land which exists between Ottawa Street and the Jock River.

Berms currently exist along the eastern site boundary, in the vicinity of the Van Gaal Drain, which prevent proper surface water drainage in wet times of the year.

Based on published geological mapping, the subsurface conditions at the site, in a simplified form, can be summarized as follows:

- Overburden soils (see also Figure 3):
  - North half of site (i.e., north parcel and north half of central parcel): marine clay (i.e., Champlain Sea clay);
  - South half of central parcel: fine grained sandy soil (likely existing as a 'cap' over the clay underlying layer); and,
  - South parcel: shallow bedrock.
- Bedrock:
  - Dolomite bedrock of the Oxford Formation; and,
  - Bedrock surface outcropping in the south part of the site, near the Jock River, but sloping down to the north and reaching depths of up to 15 metres beneath the north parcel.

Jacques Whitford Limited conducted a preliminary geotechnical investigation on this site, the results of which were produced in a report dated June 22, 2007. Due to the presence of compressible clay soils beneath portions of the site, the geotechnical report recommended grade raise restrictions which generally vary between 1.0 and 2.0 metres (except for the south part of the site, where clay is absent, and a maximum permissible grade raise of 4.0 metres was specified). For the clay areas, the maximum permissible grade raise relates to the capacity of the clay soil to support the weight of grade raise fill without undergoing significant consolidation/compression, which would lead to the settlement of structures, services, and roadways built on the site.

3.0 PURPOSE OF CURRENT ASSESSMENT

From a site development perspective, it is understood that there are several interrelated and opposing challenges associated with the grading design for this site:

- In accordance with the aforementioned geotechnical report, the site grade raise needs to be limited. This type of geotechnical restriction is a common challenge for site development in the Ottawa area, due to the extensive presence of the sensitive and compressible Champlain Sea clay (i.e., Leda clay) deposit. Where the geotechnical permissible grade raises cannot be accommodated, very costly measures can be required, such as the use of expanded polystyrene (EPS) Geofoam lightweight fill blocks for filling around the houses.
- Conversely, if the grading is kept too low, then the footings would be deeper (for conventional houses with basements), below the groundwater level and on soft wet clay (typically grey in colour), which has very little

capacity to support the footings. House footings are ideally constructed in the shallower clay, which is above the ‘normal’ water level and is therefore generally drier and stiff, since it has been ‘weathered’ by drying and exposure to air, to form a brown ‘crust’ (which is about 2 to 3 metres thick on this site). A minimum level of filling, of generally at least 0.5 to 1.0 metres, is therefore commonly needed if the footings will be constructed in the drier upper portions of the brown clay crust (since a standard-depth basement is about 2.4 metres deep relative to the finished grade around the house).

- From the perspective of the economics of developing the site, it is important to approximately achieve a ‘cut-fill’ balance. That is, the volume of soil excavated to make the excavations down to footing level should ideally equal the soil volume needed on each lot, around the house, to fill to the design finished grade level. If the footing levels are established too shallow, then fill material needs to be imported to the site at significant expense. It is understood that, given the development density, size, and location of this site, any grade raise in excess of 1.3 metres (which corresponds to a footing depth of about 1 metre below existing grade) will result in incremental imported fill costs that can greatly impact the feasibility of the development.

Given the above competing constraints, it is understood that the ‘ideal’ footing depth (i.e., feasible maximum basement depth) for this site is about 1.0 to 1.3 metres below existing grade elevations.

There is, however, an additional challenge related to the site grading, which is the focus of this memo. Because of the stormwater drainage outlet for this site (to the proposed stormwater management ponds which will ultimately discharge to the Jock River via creeks and existing drainage ditches), it is not feasible to construct house basements at 1.0 to 1.3 metres depth and also provide gravity drainage of the foundation drains (i.e., weeping tile) to the storm sewer system during storm events. Due to the elevations of the storm sewer outlets, the storm sewers will need to be installed at a relatively shallow level, with the obverts and hydraulic grade line (HGL) being above the footing level (although the *invert* levels of the storm sewers will still be below the footing levels).

It is therefore proposed to provide these houses with sump pumps. The sump pumps and weeping tile system will collect groundwater inflows during those times of the year when the groundwater level rises above the footing level and will pump to the storm sewer system. A sketch of the proposed arrangement is provided in Appendix A.

This proposed design, with the use of sump pumps, is similar to what is used for rural housing/developments and what is also understood to currently be used by all/most of the existing houses in Richmond Village. In particular, this system is consistent with what is used in the adjacent existing Richmond Oaks development, which directly abuts the east side of the site. It is understood that the use of similar sump pump systems is also common for urban developments in other municipalities of Ontario.

The City of Ottawa does not currently have clear guidelines on the use of sump pumps for *urban* house construction. In the absence of such guidelines, the acceptability of the proposed footing levels has been evaluated based on geotechnical and hydrogeological assessments, as discussed further in following sections of this memo.

It is understood that, for this site, the City of Ottawa is looking for justification to support the desire to establish footing levels at the 1.0 to 1.3 metre depths which have been proposed (and which are needed to make this development feasible). As discussed above, a *shallower* footing arrangement is not feasible for this site due to the geotechnical restrictions on the permissible grade raise and the large cost/quantity of fill material that would need to be imported to the site (since the site would not have a cut-fill ‘balance’). Therefore, it is necessary to document why the proposed founding levels (with the use of sump pumps) are indeed feasible from an engineering/technical perspective.

In the absence of detailed City of Ottawa guidelines, the acceptable founding depths for the use of sump pumps have been evaluated by means of four separate assessments:

1) By the undertaking of technical studies (i.e., groundwater modelling) focused on the expected operating conditions that will apply to the sump pumps;

2) By comparison of the design to the City of Ottawa's practices that are currently applied to individual rural residences, including examination of test pits excavated across the site to directly observe the soil and groundwater conditions;

3) By comparison of the proposed design to other developments with consistent conditions; and,

4) By comparison to the City of Ottawa Sewer Design Guidelines (October 2012).

In the absence of any specified performance objectives by the City of Ottawa, the design team has proposed the following design criteria:

- The footing/basement depths should be selected such that the sump pumps would not operate continuously, but rather, would only need to operate during limited time periods, such as during wet seasons (e.g., spring and fall) or during significant rain events; and,
- When the sump pump is required to operate, the groundwater inflow rate to the foundation drains and the corresponding necessary pumping rate should be well within the capacity of a typical sump pump.

The ultimate objective of these design criteria is to avoid basement flooding, either during power failures or due to overwhelming of the pumping system. It is considered that, provided the above criteria are met, the risk of basement flooding is reasonably small, such as would be accepted by homeowners, insurers, etc., and would be consistent with normal sump pump usage in Ontario.

An added consideration in this assessment is the effect that developing the site will have on the long-term groundwater levels. Much of eastern Ontario is underlain by Champlain Sea clay, which is a soil with a low hydraulic conductivity. As a result, and due to the relatively flat topography prevalent in the area, the natural groundwater levels in Eastern Ontario tend to be relatively shallow. This is also the case for this site, where the shallow groundwater levels reflect the current agricultural land uses and poorly drained conditions which have been created (due to the aforementioned berms which currently prevent the free-drainage of surface water).

However, urban and suburban development is well known to create conditions which lead to long term groundwater level *lowering*. The installation of sewer pipes within a 'surround' of granular material (as needed to support and install the pipes) creates an inherent subsurface drainage system. In addition, natural infiltration is reduced by development, since much of the post-development surface area is relatively impermeable (e.g., roofs, asphalt roadways, etc.) and rainwater is conveyed rapidly to the storm sewer system. This resulting combined effect of subsurface drainage and reduced infiltration causing groundwater level lowering is well known to local geotechnical engineers and, in fact, measures are sometimes implemented to prevent the groundwater level lowering from being excessive (because, in some cases, the lowering can lead to ground settlement). In the case of this site, the use of a sump pump drainage system is made even more feasible when viewed in the context that the post-development groundwater levels will end up lower than the pre-development levels. Considering the rather shallow footing levels that are proposed (at only about 1.0 to 1.3 metres depth), there is little likelihood of groundwater levels persisting above that level after full build-out of the development.

The following sections provide further detail on each of the four assessments, as described above, of the conditions on this site, in terms of using sump pumps.

It should be noted that the assessments discussed in this memo are focused on the north and central portions of the site, which are those parts underlain by clay and the surficial sandy deposit. For the south portion of the site, which is adjacent to the Jock River and where bedrock is near surface, it is proposed to set the footing levels such that the footings and foundation drains should not be below the 100-year flood level in the Jock River.

4.0 TECHNICAL STUDY

Golder Associates Ltd. (Golder Associates) has undertaken a multi-staged numerical modelling program to simulate the hydrogeologic conditions at this site, with the objective of quantitatively evaluating the future groundwater levels and potential inflows to a sump pump system, based on the proposed conceptual design.

4.1 Hydrogeologic Subsurface Investigation

For this assessment to be meaningful, it was necessary to first carry out a supplementary subsurface investigation and monitoring plan to:

- Better evaluate the subsurface stratigraphy on the site;
- Evaluate the hydraulic conductivity of the various strata (e.g., of the clay, sand, and bedrock); and,
- Evaluate the groundwater levels and, if possible, the range of groundwater level variations.

The subsurface investigation was carried out by Golder Associates in April 2010 and included the drilling of eight boreholes across the site, as shown on Figure 3. The boreholes were advanced to depths varying from about 4 to 6 metres below present ground surface. Some of the boreholes were also advanced/cored into the shallower bedrock that exists on the south part of the site. Monitoring wells were installed in the boreholes, including wells at multiple depths in some of the boreholes.

'Rising head' testing was carried out in the monitoring wells to evaluate the hydraulic conductivity of the soil and bedrock strata. This testing involved rapidly pumping down the water level in the well (or conversely *raising* the water level in the well) and then monitoring the rate at which the water level recovered.

The investigation program also included monitoring the groundwater levels in the monitoring wells over a 13 month time period, between April 2010 and April 2011, plus two follow-up monitoring sessions in May 2012 and July 2013 (see Table 1).

In summary, the results of the subsurface investigation, hydrogeologic testing, and groundwater level monitoring indicated/confirmed the following:

- The hydraulic conductivities of the key strata are as follows:
  - Surficial weathered brown silty clay crust: $4x10^{-6}$ to $1x10^{-5}$ m/s;
  - Underlying unweathered grey silty clay: $5x10^{-6}$ m/s;
  - Surficial sand and silt (central portion of site): $1x10^{-6}$ to $7x10^{-6}$ m/s;
  - Glacial till: $5x10^{-6}$ m/s; and,
  - Dolomite bedrock: $5x10^{-6}$ to $1x10^{-4}$ m/s.

- The groundwater levels varied as follows:
  - From near ground surface to 1.3 metres below ground surface in the spring and fall (average 0.5 metres below ground surface); and,
  - From 0.3 to 1.8 metres below ground surface in the summer and winter (average 0.9 metres below ground surface).

4.2 Numerical Model Construction

Two separate numerical groundwater flow models were developed (using the MODFLOW commercial software). The two models were as follows:

- The first model is referred to as the "Long Term Drainage Model". It was made to be representative of a large portion of the proposed development area and was used to predict the long term (i.e., steady state) groundwater levels that will ultimately be created at the site, for the post-development condition; and,
- The second model is referred to as the "100-year Storm Event Model". It was made to be representative of a single lot and was used to evaluate the short-term sump pump response to the 100-year storm and the spring freshet (i.e., during periods of high rain water infiltration and groundwater levels).

The details and findings of these two models are discussed separately below.

4.3 Long Term Drainage Model

The details regarding the construction of the Long Term Drainage Model are summarized as follows:

- This model was used to predict the long term groundwater levels that that will exist over a representative large section of the proposed development, for the post-development condition, and the model therefore covers an area of approximately 700 by 900 metres in size.
- The model topography and size was selected to be representative of the conditions within the central portion of the proposed development, and to represent the conditions for the construction of the first houses (approximately 150 houses in total).
- The hydraulic conductivity values (for horizontal flow) were selected based on the aforementioned testing results, as follows:
  - Overburden: 5×10^{-6} m/s (for all soil types);
  - Upper weathered bedrock (2 metre thick layer): 5×10^{-5} m/s; and,
  - Deeper bedrock: 5×10^{-7} m/s.

These values are representative of the average measured values from the subsurface investigation.

- The natural (pre-development) groundwater flow was modelled to be to the north-east, towards an existing drainage ditch (un-named tributary).
- The model boundary conditions and parameters were calibrated such that the initial groundwater levels corresponded to the highest recorded groundwater levels from the aforementioned monitoring (which were the water levels recorded in the spring of 2011).

- The effects of developing the site were simulated as follows:
  - The model simulated the installation of higher hydraulic conductivity (i.e., 'free draining') granular material as the granular 'surround' of the storm sewers, based on the alignments and invert depths of the storm sewer system as designed by DSEL, which range from about 2.0 to 2.5 metres below the future roadway surface. [*Note: It is understood that the extent of any higher conductivity pipe surround material would be subject to City approval.*]
  - The proposed 'Pond 1' storm water management pond (SWMP) was included in the model, since it will form a groundwater discharge point. The pond water level in the model was set to the 'normal operating level' of the pond (92.35 masl).
  - Infiltration to the water table from surface (recharge) was set to be consistent with current conditions (i.e., with the existing soil and vegetation cover). This represents a 'conservative' condition, since, as discussed previously, infiltration will actually be reduced due to the impermeable surfaces present in the developed condition (e.g., roofs, pavement, etc.).

The results of the modelling are summarized as follows:

- The long term (i.e., steady-state) water table within the proposed development would be at greater than approximately 1.9 metres depth (relative to the roadway level), which is below the proposed footing and foundation drain level.
- These conditions would be achieved after complete build-out of the storm sewer network. However, the effect of dewatering during construction (i.e., pumping from the trenches while the sewers are installed) and the reduced infiltration that will exist after development would decrease the time required to achieve steady-state conditions.

These results are considered to be applicable to all those portions of the site underlain by silt and clay, which includes essentially the north half of the site.

4.4 100-Year Storm Event Model

The details regarding the construction of the 100-year Storm Event Model are summarized as follows:

- This model focused on making a prediction of the sump pump response of a single house to transient/high groundwater levels, such as would occur during the 100-year storm and during the spring freshet (i.e., thaw). The model was therefore constructed to focus on 'smaller scale' conditions analogous to the development of a single lot/house, and covers an area measuring 10 metres by 14 metres (which allowed more detailed refinement of the model structure around the foundation drains).
- The model ground level and boundaries were selected to correspond to an area that is close to, and therefore hydraulically connected to, the Pond 1 SWMP, such that the groundwater levels could be evaluated during filling of the pond up to the 100-year storm event level.
- The hydraulic conductivities of the strata were consistent with the Long Term Drainage Model, as discussed previously.
- The foundation drain elevation was set at 2.4 metres depth below the finished grade around the house (which is about 2.1 metres below the roadway surface), consistent with conventional basement construction and slightly deeper than currently proposed.

- The conditions during a 100-year storm event were simulated by raising the groundwater level in the storm sewer trench backfill, up to the design storm level in the pond. To further simulate the additional impact of the 100-year storm occurring concurrently with the spring freshet, the recharge was set at 2000 millimetres per year during the same 24 hour period. Two additional simulations were completed in which the recharge was increased to 4000 millimetres per year and 8000 millimetres per year to further evaluate the sensitivity of the model to this parameter. The latter two values are well in excess of the possible actual level of infiltration, even during the spring thaw.

The results of the modelling are summarized as follows:

- The calculated groundwater inflow to the foundation drain is shown on Figure 4.
- The peak anticipated inflow to the foundation drain during the 100-year storm event ranged from 1.4 to 2.0 m^3/day for the range of recharge values simulated (2000 to 8000 millimetres per year). These flows represent the maximum expected sump pump pumping rate due to groundwater inflow.
- Following the storm event, flow to the foundation drains ended within 12 hours (as also shown on Figure 4).

Included in Appendix B is a data sheet for a typical sump pump, such as would be installed in these houses. The capacity of the sump pump, as noted in the Performance Data plot on the second sheet in the attachment, is about 100 Litres per minute for the total 'head' that this pump will need to overcome. This pumping rate is equivalent to more than 140 m^3/day, and therefore is well above the anticipated maximum required pumping rate determined from the modelling.

In the event of power outages, the proposed back-up power for the sump pump configuration will provide an additional level of protection. An assessment of the back-up pump endurance is provided in the DSEL memo provided in Appendix C.

4.5 Modelling Conclusions

The results of this modelling exercise, even if considered to provide a conceptual/qualitative rather than precise quantitative findings, provide the following three key conclusions:

- Consistent with local experience and common knowledge of geotechnical engineers and hydrogeologists, developing this site with an urban residential subdivision will result in a lowering of the groundwater level, and the resulting water table will be below the planned depth of the footings and foundation drains. As a result, sump pumps for this development would not be expected to operate continuously.
- The time required for the groundwater levels to be lowered will not be long, on the order of one year after build-out of the storm sewer network. The time would in fact likely be less, since the modelling did not consider the dewatering that would be carried out during installation of the sewer systems (i.e., the pumping from the trenches during installation of the site services).
- Even during periods of high infiltration, high groundwater levels, and high water levels in the on-site SWMPs, the rate of inflow to the foundation drains would be modest and well below the pumping capacity of a normal sump pump.

5.0 COMPARISON TO CURRENT CITY RURAL PRACTICE USING TEST PIT OBSERVATIONS

Although the City of Ottawa does not have detailed guidelines regarding the use of sump pumps for urban developments (and the corresponding founding levels and site grading design), there is understood to be an ‘unwritten’ protocol for establishing the suitable grading for individual rural houses. It is our understanding that the protocol for rural houses is as follows:

- The homeowner’s septic system contractor has a test pit excavated at the site.
- A representative of the Ottawa Septic Office (which is managed by the local Conservation Authority) inspects the test pit and establishes where the groundwater level is located. This level is established either by observed seepage or by the colour change in the soil, with the soil being browner above the water table and greyer below. The absorption trenches of the septic system then need to be constructed 0.9 metres above that level.
- The City of Ottawa’s building inspector uses that groundwater level to set the deepest allowable footing level for the house.

This protocol appears to operate from the practical perspective that the basement should be located above the groundwater level that is established based on observations made in an actual excavation at the site just prior to issuance of the building permit.

A series of test pits was thus excavated across this site in late July 2013 under observation by Golder Associates. In total, 19 test pits were excavated across the site, and were extended to depths ranging from 1.4 to 2.2 metres. City of Ottawa staff were present for excavation of several of the test pits.

The test pits were spread across the site, including the clay (north), sandy (south-central), and shallow bedrock (south) parts of the site.

The conditions observed in the test pits are summarized as follows:

- In general, groundwater seepage was observed to be at about 1.0 to 1.3 metres depth.
- A locally deeper groundwater level was observed in one test pit excavated in the sandy portion of the site, at 1.8 metres depth.
- In both the clay and sandy portions of the site, the rate of groundwater inflow to the test pits was similar and very modest. From a practical perspective, there was no noticeable difference in the rate of inflow between the clay and the sand. The sandy deposit was observed to be very fine grained (i.e., to be very ‘silty’) while the clay has very fine fissures. The result is that the conditions in the two deposits are similar (similar hydraulic conductivity), resulting in minor groundwater inflow.
- From a geotechnical/constructability perspective, it was also observed that the clay deposit at 1 metre depth was sufficiently dry and stiff to form a suitable subgrade for footing construction; i.e., the clay soil at this depth was dry to touch (did not wet the hand) and dry enough to stand on without the clay being slippery.

Based on these conditions, it is considered that a founding level at about 1 metre depth would be entirely acceptable from both a geotechnical and hydrogeological perspective. It would not be expected that, with basements constructed to this depth, the sump pumps would be required to operate other than during the spring/fall or during rain events. In addition to providing a very direct and practical assessment of the appropriate founding depth (i.e., for which sump pumps would have to work only intermittently), this exercise also emulated what is understood to be the City of Ottawa's practice for establishing the lowest founding depth for rural houses.

In regards to this assessment, the following two additional points should be noted:

- These test pits were excavated during a period of raining weather; and,
- The surface water drainage on the lower-lying portions of the site, near Perth Street, has been intentionally blocked by the construction of berms. That condition, which impedes the free runoff of rainwater to the ditches and adjacent municipal drains, has likely created a condition of increased recharge and of groundwater levels that are elevated and unrepresentative of the levels that would otherwise exist.

Figures 5a through 5g present plots of groundwater elevations at the monitoring wells, the proposed USF and storm sewer invert elevations in the vicinity of the monitoring wells, and schematics showing a foundation wall and footing drain. Only at MW10-4 and MW10-7 are the groundwater levels consistently above the proposed USF elevations. However, at these locations the storm sewer invert will be below the proposed USF elevations (as shown on Figures 5a through 5g). Therefore, because the granular material surrounding the storm sewers will control the groundwater levels (i.e. will lower the water table), the normal water table elevation will be below the USFs and will rise above the USFs only during spring/fall and rain events. [*Note: it is our understanding that groundwater level monitoring will be undertaken during site development, to monitor the effects of site grading and the installation of sewer infrastructure. DSEL will review and possibly increase USF elevations in the vicinity of MW10-4 and MW10-7 at the detailed grading design stage, based on the groundwater level monitoring results.*]

In summary, it is concluded that, based on the conditions directly observed in actual test pits at the site, a founding depth of up to 1 metre is entirely feasible and appropriate from the perspective of the operation of sump pumps (i.e., having only intermittent/seasonal flow that is well within the pump's capacity). This assessment is based on:

- The depths at which water seepage was observed in the test pits, which was at or below that level;
- The observed modest rates of groundwater inflow, even for the test pits excavated in the sandy soil; and,
- What the acceptable founding levels would be if this work had been carried out for setting the founding level of a rural house, based on our understanding of the City of Ottawa's current protocol.

6.0 COMPARISON TO OTHER DEVELOPMENTS

The proposed founding depth of 1 metre is very common and consistent with other developments in the Ottawa area, both for those equipped with sump pumps as well as those with gravity controlled foundation drainage systems. In fact, for the latter case, houses are frequently founded at greater depth in the clay, because a deeper founding level is required when the permissible grade raise is low, as established by the geotechnical conditions (i.e., based on the capacity of the clay to support the weight of the grading fill). To our knowledge, we are unaware of any difficulties in the City of Ottawa with basements that are installed to their full 2.4 metre depth in these clay deposits, even when located below the groundwater level. Although drainage systems may initially convey a continuous flow of groundwater, the flow is not sustained because the groundwater level is ultimately lowered to at/below footing level, such that the foundation drains only operate during wet seasons. These conditions are considered representative of the performance expected at this site. That is, there should be little to no actual day-to-day sustained flow into the foundation drains. The sump pumps will only be required to operate intermittently, during storms and wet seasons.

There is an existing development which is located immediately adjacent to the east side of this site which is useful for comparison purposes. The following details are understood about that development, which is known as Richmond Oaks:

- The ground conditions are understood to be similar (largely consisting of clay and a shallow water table);
- Based upon plans available, the founding depths of the houses appear to range from 0.8 to 1.1 metres below original ground surface, and the site grade raise is approximately 1.2 metres, which is consistent with what is proposed for this site. The houses are serviced with sump pumps which discharge to storm sewers; and,
- The footing level is below the storm sewer HGL.

We are not aware of any issues regarding basement flooding or the performance of the foundation drainage system and sump pumps in this development. Considering the similarity between the two developments, it would not be unreasonable to permit the use of sump pumps on the currently proposed site.

More generally, it is understood that essentially all of the houses in the entire Village of Richmond use foundation drainage systems with sump pumps. It is understood that DSEL contacted the insurance industry to obtain data on the history of claims related to basement flooding and that inquiry revealed no history of such claims. By extension, there would therefore appear to be no technical reason, from a hydrogeologic perspective, to not similarly permit the use of sump pumps for this site.

Thus, there appears to be no history of basement flooding problems in Richmond that would indicate issues with sump pump operations.

7.0 CITY OF OTTAWA SEWER DESIGN GUIDELINES

The October 2012 City of Ottawa Sewer Design Guidelines make reference to sump pumps in Section 5.7.1 (Connections General), which states, “Three types of systems are available…(2) Sump pit and pump discharging to a ditch.” Although the proposal is to discharge to a storm sewer, as the development will not be serviced with ditches, the guideline allows for the use of sump pumps. Section 6.4.3 (Water Table Considerations) states, “All development shall ensure that each foundation footing is above the average water table elevation.” As discussed in Sections 4.0, 5.0 and 6.0 of this memorandum, developing this site with an urban residential subdivision will result in a lowering of the groundwater level, as is common for developments on clay in the City of Ottawa, such that foundation footings will be above the average water table elevation.

8.0 SUMMARY AND CONCLUSIONS

This memo has summarized the results of four separate assessments regarding the basement/founding levels and the use of sump pumps in this development. It is our opinion, based on these three assessments, that the conditions on this site are suitable to have the footings and foundation drains constructed at up to 1 metre depth. More specifically, it has been shown that the following design/performance criteria would be met:

- The sump pumps would not operate continuously; and,
- When required to operate, the pumping rate would be well within the capacity of the pumps.

These conclusions have been based upon the following:

- Hydrogeologic analyses have shown that, within about a year of the site being developed (and probably sooner), the steady-state groundwater level would be lowered to below the footing level;

- Hydrogeologic analyses have also shown that, during periods of high precipitation/infiltration, when groundwater levels and surface water levels would be high (such that the sump pumps would be required to operate), the rates of inflow to the foundation drains would be well below the capacity of a normal sump pump;
- Test pits excavated across the site have shown that groundwater inflow was only observed below about 1.0 to 1.3 metres depth, the clay above that level is rather dry, and the actual rates of groundwater inflow to the test pits were modest. Furthermore, this assessment methodology was consistent with the practice which has been successfully used for setting the basement levels of individual rural houses;
- The adjacent development has similarly been constructed with sump pumps, with the basements at similar depths, and there are no known troubles or history of basement flooding;
- The entire Village of Richmond is understood to be serviced with sump pumps, and insurance records show no history of basement flooding; and,
- The proposed use of sump pits and pumps is consistent with the current City of Ottawa Sewer Use Guidelines.

At a very simple and conceptual level, it must be recognized that the proposed 1 metre founding depth is very shallow. It is also well known to local geotechnical engineers and hydrogeologists that development of sites with clay or low permeability soils results in groundwater level lowering in the long term. Therefore, given the low hydraulic conductivity of the soils and the shallow founding depths proposed on this site, there is no reason to believe that basement flooding due to groundwater inflow should be of concern.

9.0 CLOSURE

We trust that this memo is adequate for your current needs. Please contact the undersigned if you have any questions.

Yours truly,

GOLDER ASSOCIATES LTD.

for Mike Cunningham, P.Eng.
Associate, Geotechnical Engineer

Brian Byerley, M.Sc., P.Eng.
Principal, Senior Hydrogeologist

LICENSED PROFESSIONAL ENGINEER
B. T. BYERLEY
Nov 4/13
PROVINCE OF ONTARIO

MIC/BTB/sg
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Attachments:

Important Information and Limitations of this Memorandum
Table 1 – Groundwater Monitoring Data
Figure 1 – Key Plan
Figure 2 – Site Plan
Figure 3 – Surficial Geology
Figure 4 – Simulated Flows to Foundation Drain (100-Year Storm Model)
Figures 5a through 5g – Groundwater vs Proposed USF
Appendix A – Sump Pump Detail
Appendix B – Sump Pump Data Sheet
Appendix C – DSEL memorandum dated October 30, 2013

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client, Richmond Village (South) Limited and Mattamy (Jock River) Limited. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder cannot be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then the client may authorize the use of this report for such purpose by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process, provided this report is not noted to be a draft or preliminary report, and is specifically relevant to the project for which the application is being made. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client cannot rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder cannot be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT (cont'd)

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

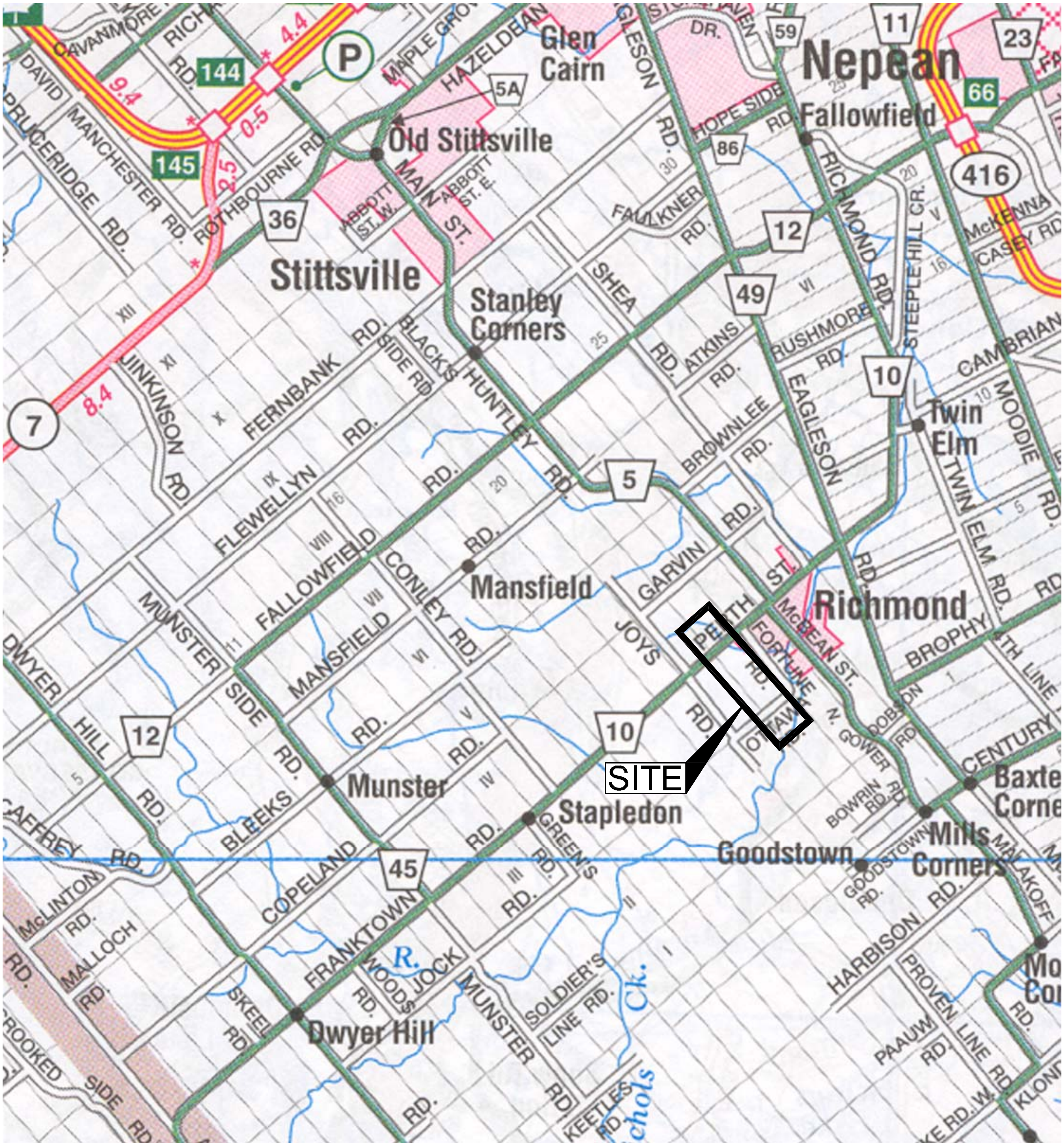
Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

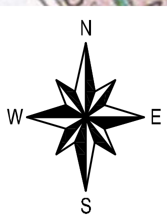
Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

Table 1: Groundwater Monitoring Data

Well ID	Ground Surface Elevation (geodetic)[1]	Screen depth (middle of screen) (mbgs)	Soil/rock at depth of well screen	Groundwater Depths (mbgs)															
				Apr.29 & 30, 2010	May 14, 2010	Jun.16, 2010	Jul. 15, 2010	Aug. 20, 2010	Sept. 16, 2010	Oct. 1, 2010	Oct 18, 2010	Nov. 19, 2010	Dec. 15, 2010	Jan. 18, 2011	Feb. 14, 2011	Mar. 15, 2011	Apr. 21, 2011	May 1, 2012	July 31, 2013
MW10-1A	94.55	3.15	Grey silty Clay	0.67	0.72	0.74	0.75	0.72	0.75	0.55	0.71	0.66	0.73	0.94	1.15	0.83	0.58	0.77	0.92
MW10-1B	94.55	1.21	Grey brown silty Clay (weathered crust)	0.66	0.69	0.72	0.72	0.71	0.73	0.55	0.67	0.65	0.70	0.89	1.09	0.83	0.58	0.75	1.23
MW10-2	94.90	2.12	Grey brown silty fine Sand	0.70	0.64	0.83	0.63	0.93	0.91	0.14	0.56	0.31	0.53	0.75	0.86	0.53	0.10	--[5]	0.82
MW10-3A	93.99	4.55	Fresh grey Dolomite	0.18	0.22	0.54	0.24	0.19	0.21	-0.13[2]	0.04	-0.09[2]	--[4]	--[4]	--[4]	--[4]	-0.25[2]	-0.09	0.08
MW10-3B	93.99	2.12	Grey brown silty Clay (weathered crust) / grey brown fine sandy Silt	0.81	0.80	0.86	0.78	0.86	0.84	0.42	0.71	0.55	0.72	0.89	0.75	0.67	0.27	0.61	0.68
MW10-4A	94.34	3.03	Grey brown fine sandy Silt	0.41	0.40	0.49	0.42	0.57	0.55	0.04	0.40	0.19	0.37	0.46	0.56	0.34	0.14	--[5]	0.46
MW10-4B	94.34	1.21	Grey brown silty Clay (weathered crust)	0.40	0.42	0.49	0.42	0.57	0.55	0.01	0.39	0.18	0.37	0.48	0.58	--[4]	0.18	0.46	0.61
MW10-5A	94.82	3.03	Glacial Till	0.81	0.78	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]
MW10-5B	94.82	1.21	Grey brown silty fine Sand	0.85	0.84	1.29	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]	--[3]
MW10-6A	95.67	4.24	Fresh grey Dolomite	1.36	1.36	1.96	1.32	1.29	1.50	0.64	0.82	0.65	0.66	1.20	1.42	0.53	0.43	0.94	1.16
MW10-6B	95.67	1.52	Grey brown silty Sand trace Clay	1.27	1.26	1.82	1.57	1.10	1.53	0.29	0.60	0.23	0.47	1.14	1.40	--[4]	0.03	0.85	1.15
MW10-7	95.36	2.42	Grey brown silty fine Sand	0.46	0.44	1.04	0.93	0.33	0.42	-0.02[2]	0.01	-0.01[2]	-0.02[2]	--[4]	--[4]	--[4]	-0.03[2]	--[5]	0.44
MW10-8	96.32	2.42	Weathered to fresh grey Dolomite	0.98	1.11	1.48	1.35	1.20	1.25	0.19	0.27	0.22	0.23	0.76	0.77	--[4]	0.15	0.40	0.77

Notes:
Groundwater depth measurements revised in September 2013 to reflect surveyed top of casing and ground surface elevations (From May 14, 2010). Previously presented data reflected manually measured height of casing at time of well construction.
Ground surface elevations at MW10-8 and MW10-5 revised in September 2013 as per surveyed elevations
1: Survey completed on May 14, 2010 by J.D. Barnes Limited (Ottawa).
2: Artesian conditions exist. Groundwater level above ground surface.
3: Monitoring well MW 10-5 A and B vandalized and groundwater levels not available.
4: Groundwater in monitoring well frozen. Depth to groundwater level could not be measured.
5: Only select wells were monitored in May 2012 as a component of a hydraulic response testing program.





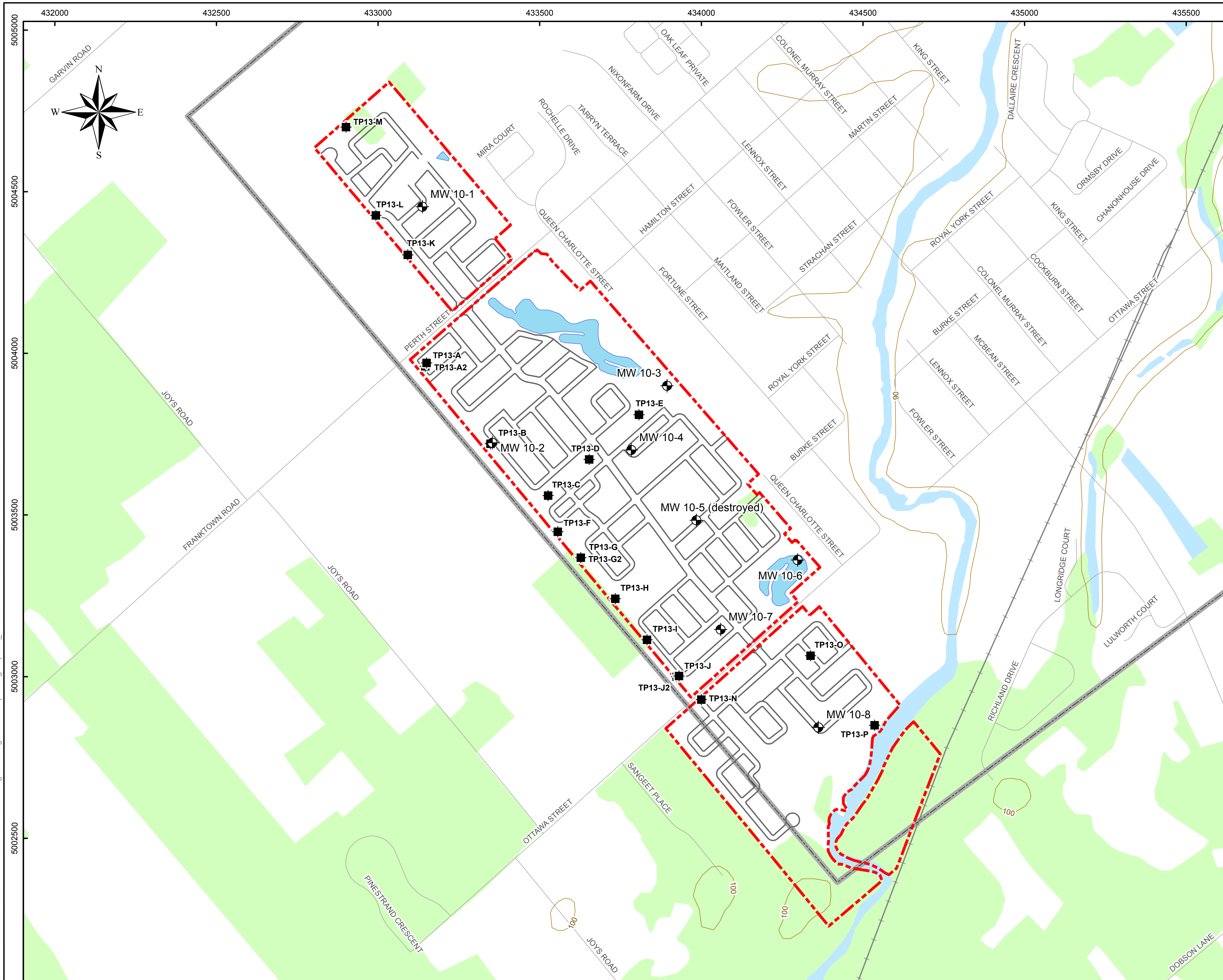
NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. TECHNICAL MEMORANDUM No. 12-1127-0062-8000

Golder Associates
Ottawa, Ontario, Canada

SCALE	1:100,000	TITLE	KEY PLAN
DATE	2013-10-16		
DESIGN			
CAD	JM		
FILE No. 1211270062-8000-01.dwg	CHECK MIC	RICHMOND VILLAGE ASSESSMENT OF SUBSURFACE DRAINAGE	FIGURE 1
PROJECT No. 12-1127-0062 REV.	REVIEW BTB		

PLOT DATE: October 16, 2013
FILENAME: N:\Active\2012\1127 - Geosciences\12-1127-0062 Richmond Village Drainage and Sump Design\Spatial_IM\CAD\Phase 8000\1211270062-8000-01.dwg



LEGEND

- MONITORING WELL LOCATION
- TEST PIT LOCATION (JULY 2013)
- RAILWAY
- PROPOSED ROADS
- ROAD
- TOPOGRAPHIC CONTOUR (m)
- PROPOSED STORMWATER MANAGEMENT POND
- RICHMOND VILLAGE BOUNDARY
- WATERBODY
- VEGETATION
- SITE BOUNDARY

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES TECHNICAL MEMORANDUM No. 12-1127-0062-8000

REFERENCE

BASE DATA - CANVEC PROVIDED BY HER MAJESTY THE QUEEN IN RIGHT OF CANADA, DEPARTMENT OF NATURAL RESOURCES
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 18

350 175 0 350 Meters

1:12,000

PROJECT

RICHMOND VILLAGE
ASSESSMENT OF SUBSURFACE DRAINAGE

TITLE

SITE PLAN

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1127-0062		
DESIGN	NB	2012-05
GIS	JEM/BR	2013-09
CHECK	MIC	2013-10-16
REVIEW	BTB	2013-10-16

SCALE AS SHOWN REV. 0.0

FIGURE 2

N:\Active\2012\1127 - Geosciences\12-1127-0062 Richmond Village Drainage and Sump Design\Spatial_IM\GIS\MXD\Phase 8000\1211270062-8000-02.mxd

LEGEND

- MONITORING WELL LOCATION
- WATERCOURSE
- RAILWAY
- ROADWAY
- PROPOSED DEVELOPMENT LANDS
- RICHMOND VILLAGE BOUNDARY

SURFICIAL GEOLOGY

- 7 Organic Deposits: Muck & Peat
- 6a Alluvial Deposits: Silty Sand, Silt, Sand & Clay
- 5a Nearshore Sediments: Gravel, Sand & Boulders
- 5b Nearshore Sediments: Fine To Medium Grained Sand
- 3 Offshore Marine Deposits: Clay, Silty Clay & Silt
- 1a Till, Plain With Local Relief <5m
- 3a Offshore Marine Deposits: Clay, Silt Underlying Erosional Terraces
- 1c Till, Hummocky To Rolling With Local Relief 5 To 10m
- r2 Bedrock: Limestone, Dolomite, Sandstone & Local Shale
- zz Water

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES TECHNICAL MEMORANDUM. 12-1127-0062-8000

REFERENCE

BASE DATA - CANVEC PROVIDED BY HER MAJESTY THE QUEEN IN RIGHT OF CANADA, DEPARTMENT OF NATURAL RESOURCES
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 18

475 237.5 0 475
Meters
1:12,000

PROJECT

RICHMOND VILLAGE
ASSESSMENT OF SUBSURFACE DRAINAGE

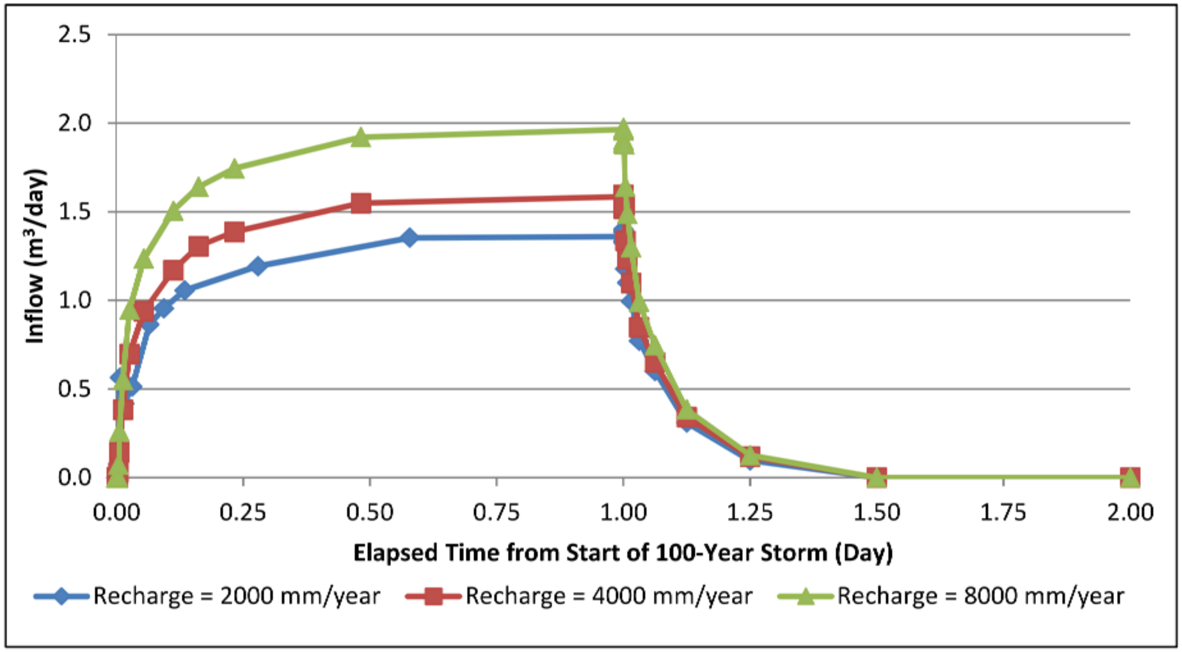
TITLE

SURFICIAL GEOLOGY

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1127-0062			SCALE AS SHOWN	REV. 0.0
DESIGN	NB	2012-05	FIGURE 3	
GIS	ABD	2012-07		
CHECK	MIC	2013-10-16		
REVIEW	BTB	2013-10-16		

N:\Active\2012\1127 - Geosciences\12-1127-0062 Richmond Village Drainage and Sump Design\Spatial_IM\GIS\MXD\Phase 8000\1211270062-8000-03.mxd



NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. TECHNICAL MEMORANDUM No. 12-1127-0062-8000

Golder Associates
Ottawa, Ontario, Canada

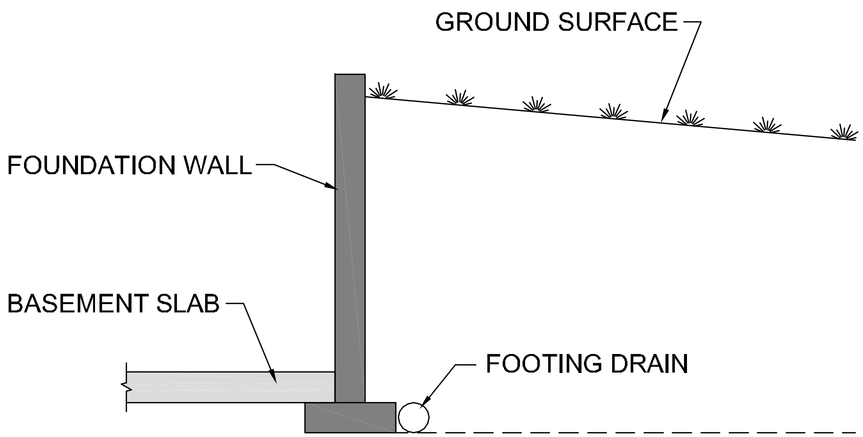
RICHMOND VILLAGE
ASSESSMENT OF SUBSURFACE DRAINAGE

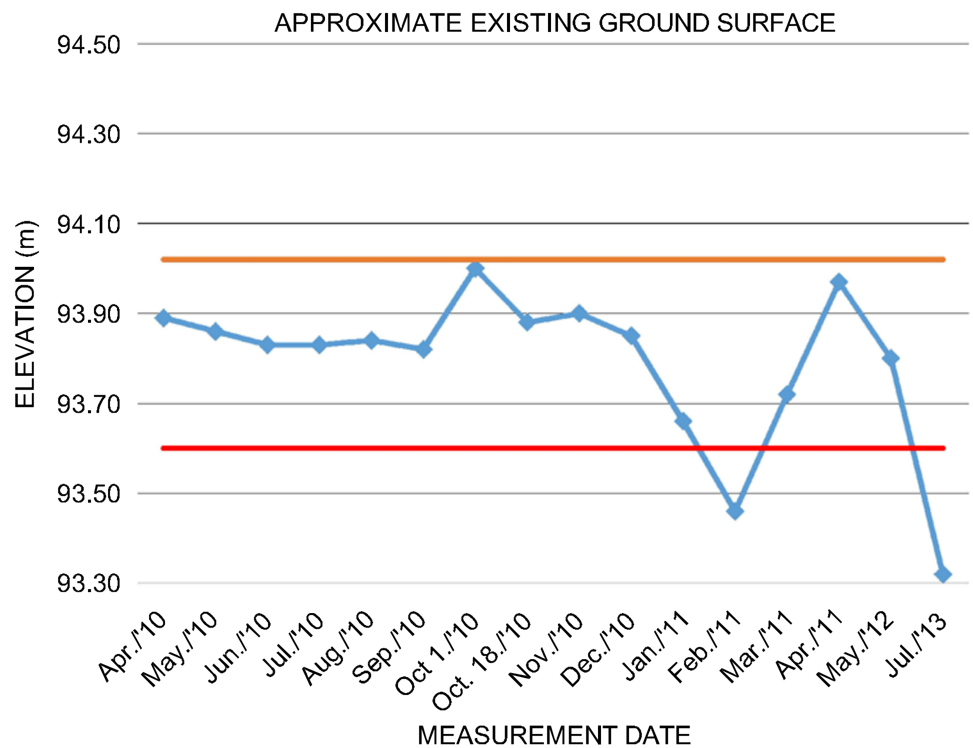
SIMULATED FLOWS TO FOUNDATION DRAIN (100-YEAR STORM MODEL)

FIGURE 4

PROJECT No. 12-1127-0062 DATE 2013-10-16 CAD JM

PLOT DATE: November 1, 2013
FILENAME: N:\Active\2012\1127 – Geosciences\12-1127-0062 Richmond Village Drainage and Sump Design\Spatial_IM\CAD\Phase 8000\1211270062-8000-05.dwg





LEGEND

MW10-1

ESTIMATED USF @ MW10-1

STORM SEWER INVERT

NOTE

1. CONCEPTUAL USF ELEVATIONS PROVIDED BY DSEL

2. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 12-1127-0062-8000

Golder Associates
Ottawa, Ontario, Canada

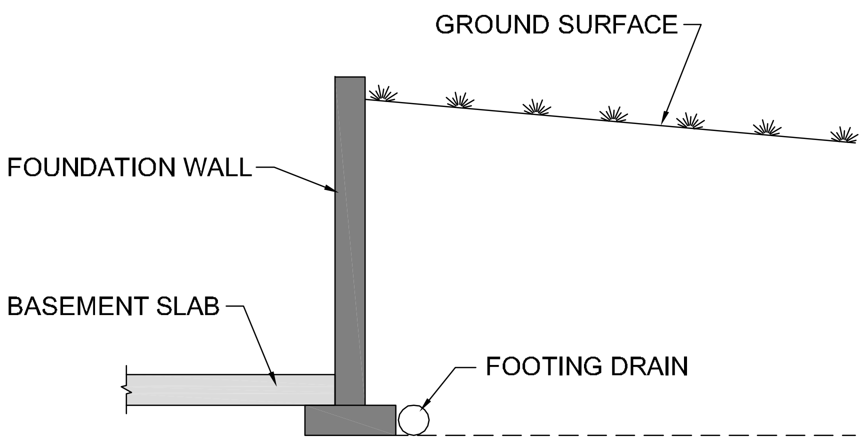
RICHMOND VILLAGE
ASSESSMENT OF SUBSURFACE DRAINAGE

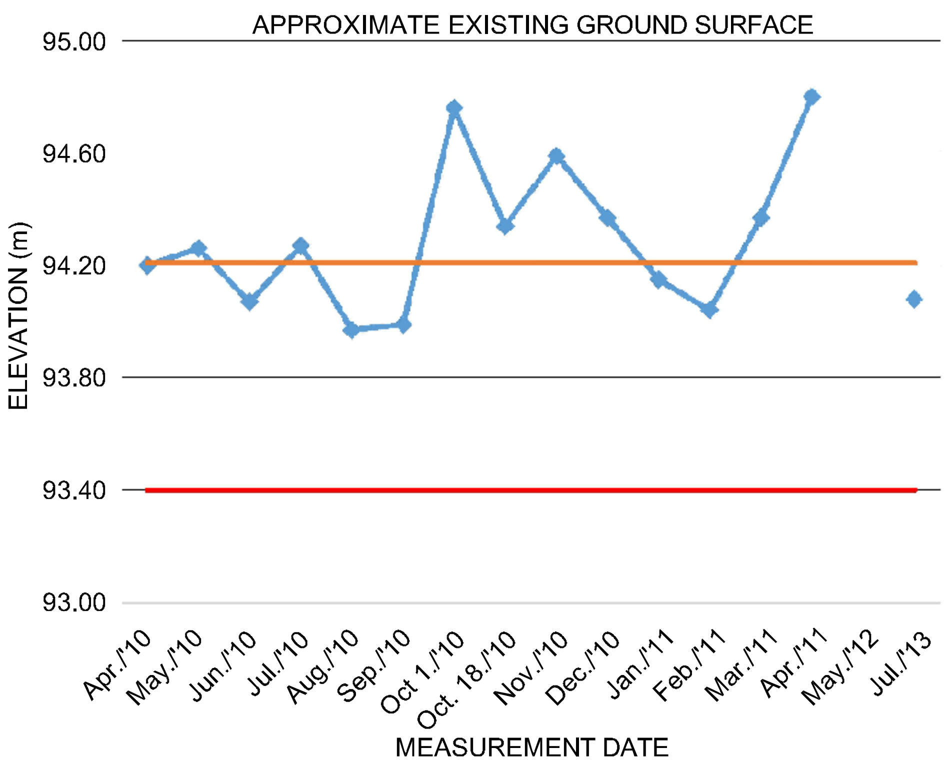
GROUNDWATER VS. PROPOSED USF IN THE VICINITY OF MONITROING WELL MW10-1

FIGURE 5A

PROJECT No. 12-1127-0062 DATE 2013-10-16 CAD JM

PLOT DATE: November 1, 2013
FILENAME: N:\Active\2012\1127 – Geosciences\12-1127-0062 Richmond Village Drainage and Sump Design\Spatial_IM\CAD\Phase 8000\1211270062-8000-05.dwg





LEGEND

- MW10-2
- ESTIMATED USF @ MW10-2
- STORM SEWER INVERT

NOTE

1. CONCEPTUAL USF ELEVATIONS PROVIDED BY DSEL
2. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 12-1127-0062-8000

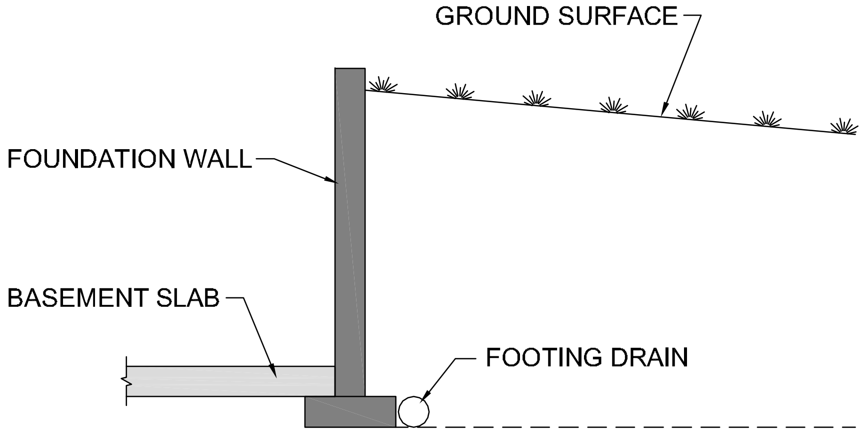
Golder Associates
Ottawa, Ontario, Canada

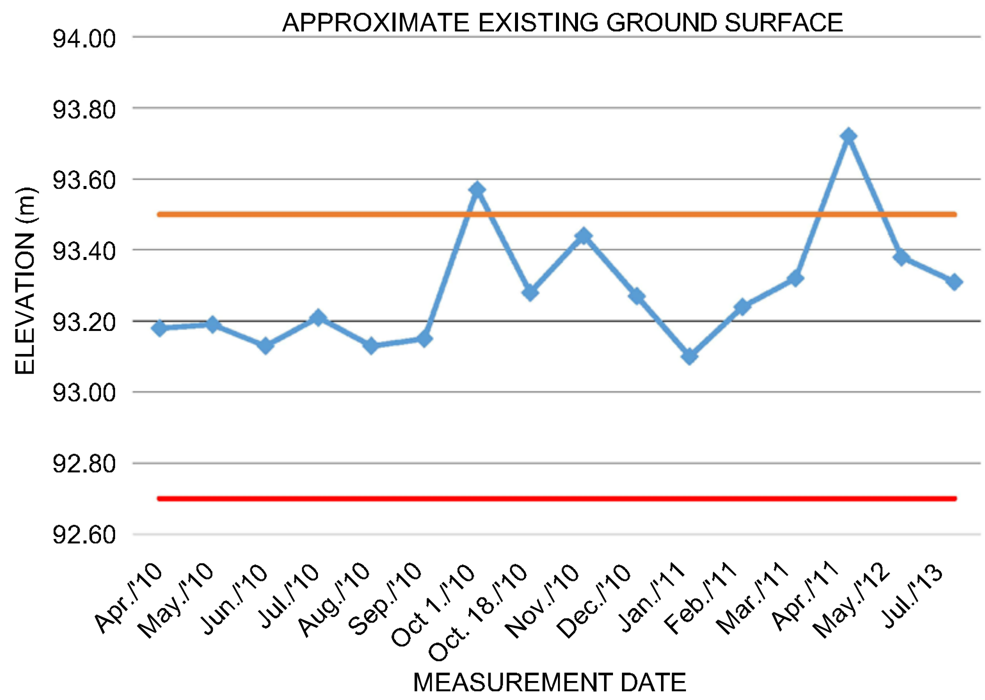
RICHMOND VILLAGE
ASSESSMENT OF SUBSURFACE DRAINAGE

GROUNDWATER VS. PROPOSED USF IN THE VICINITY OF MONITROING WELL MW10-2

FIGURE 5B

PROJECT No. 12-1127-0062 DATE 2013-10-16 CAD JM





LEGEND

- MW10-3
- ESTIMATED USF @ MW10-3
- STORM SEWER INVERT

NOTE

1. CONCEPTUAL USF ELEVATIONS PROVIDED BY DSEL
2. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 12-1127-0062-8000

Golder Associates
Ottawa, Ontario, Canada

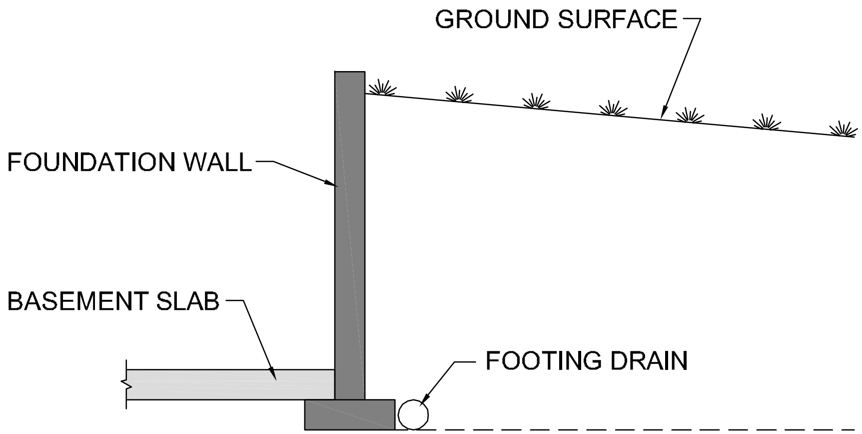
RICHMOND VILLAGE
ASSESSMENT OF SUBSURFACE DRAINAGE

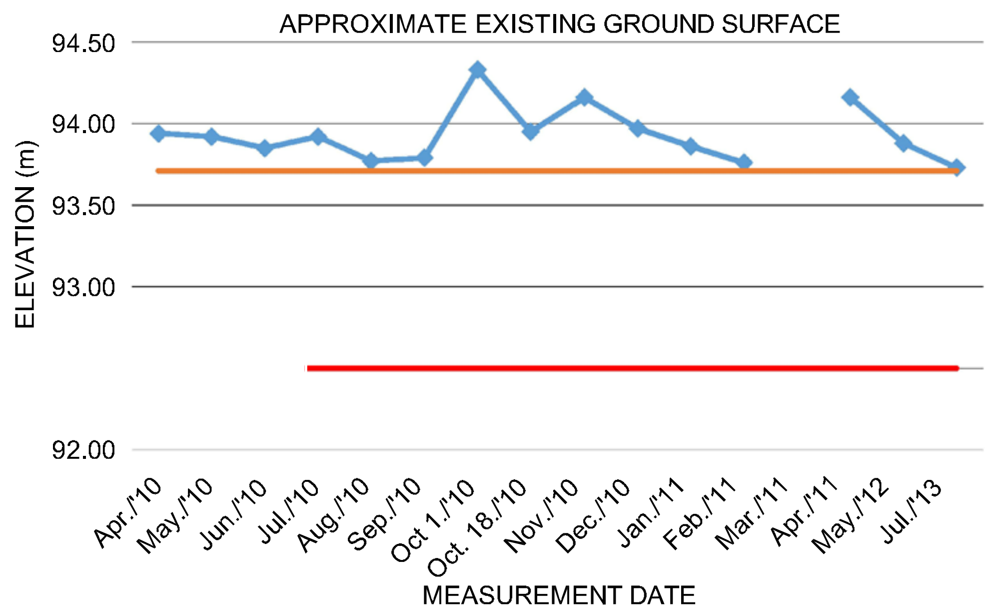
GROUNDWATER VS. PROPOSED USF IN THE VICINITY OF MONITROING WELL MW10-3

FIGURE 5C

PROJECT No. 12-1127-0062 DATE 2013-10-16 CAD JM

PLOT DATE: November 1, 2013
FILENAME: N:\Active\2012\1127 – Geosciences\12-1127-0062 Richmond Village Drainage and Sump Design\Spatial_IM\CAD\Phase 8000\1211270062-8000-05.dwg





LEGEND

- MW10-4
- ESTIMATED USF @ MW10-4
- STORM SEWER INVERT

NOTE

1. CONCEPTUAL USF ELEVATIONS PROVIDED BY DSEL
2. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 12-1127-0062-8000
3. IT IS RECOMMENDED THAT AREA SPECIFIC USF RAISES IN EXCESS OF THE GENERIC USF ELEVATION SHOWN BE REVIEWED AT THE DETAILED DESIGN STAGE TO BRING USF ELEVATIONS IN LINE WITH ANY FUTURE MONITORED GROUNDWATER ELEVATIONS.

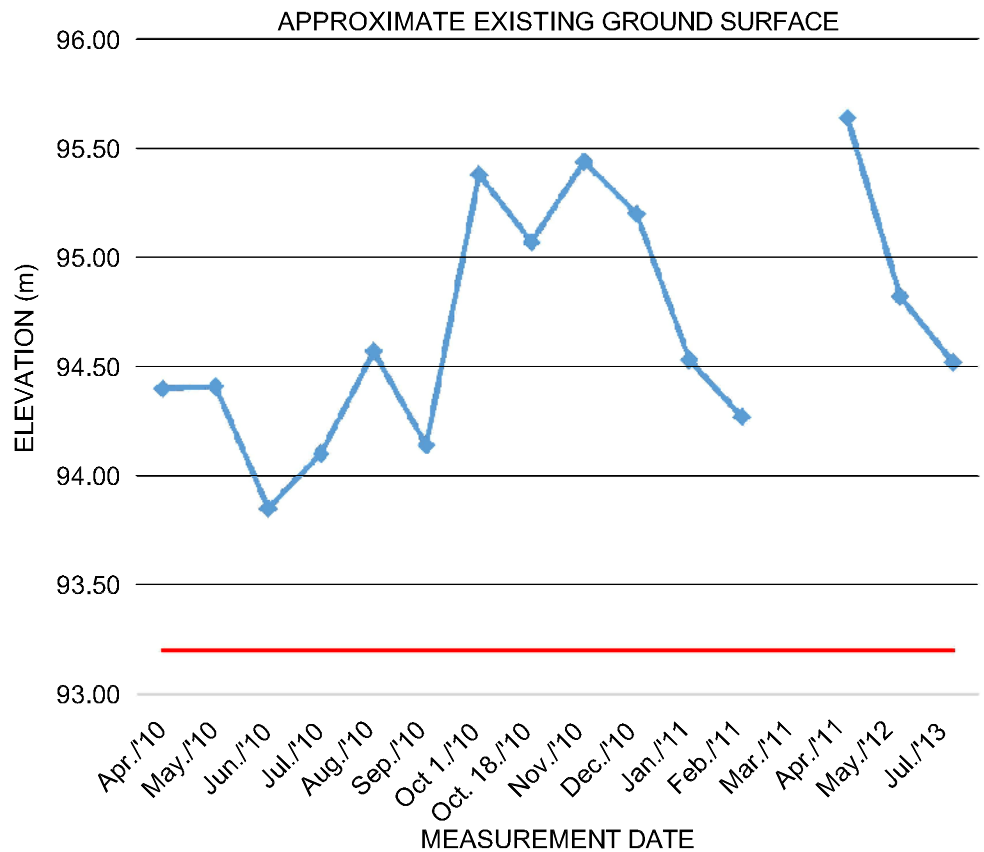
Golder Associates
Ottawa, Ontario, Canada

RICHMOND VILLAGE
ASSESSMENT OF SUBSURFACE DRAINAGE

GROUNDWATER VS. PROPOSED USF IN THE VICINITY OF MONITROING WELL MW10-4

FIGURE 5D

PROJECT No. 12-1127-0062 DATE 2013-10-16 CAD JM



LEGEND

- MW10-6
- POND 2 PERMANENT POOL

NOTE

1. CONCEPTUAL USF ELEVATIONS PROVIDED BY DSEL
2. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 12-1127-0062-8000

Golder Associates
Ottawa, Ontario, Canada

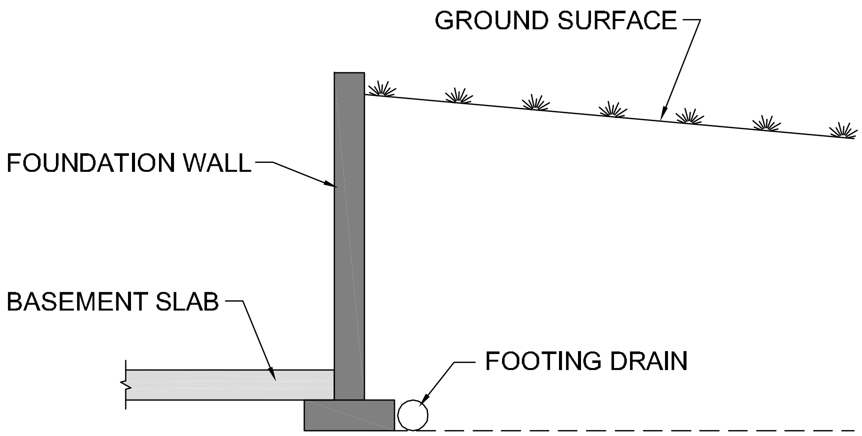
RICHMOND VILLAGE
ASSESSMENT OF SUBSURFACE DRAINAGE

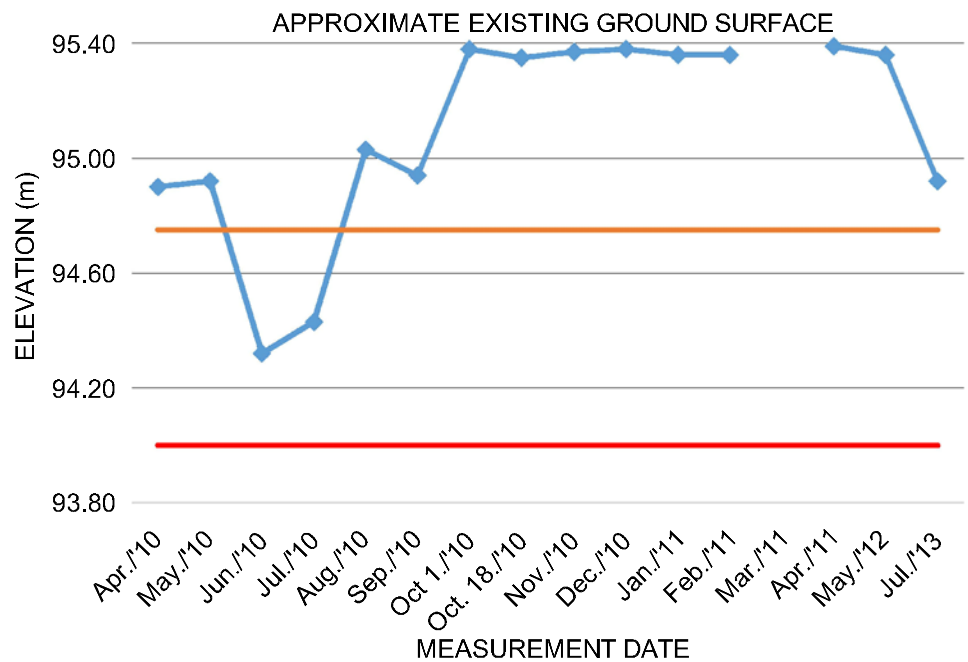
GROUNDWATER VS. PROPOSED USF IN THE VICINITY OF MONITROING WELL MW10-6

FIGURE 5E

PROJECT No. 12-1127-0062 DATE 2013-10-16 CAD JM

PLOT DATE: November 1, 2013
FILENAME: N:\Active\2012\1127 – Geosciences\12-1127-0062 Richmond Village Drainage and Sump Design\Spatial_IM\CAD\Phase 8000\1211270062-8000-05.dwg





LEGEND

- MW10-7
- ESTIMATED USF @ MW10-7
- STORM SEWER INVERT

NOTE

1. CONCEPTUAL USF ELEVATIONS PROVIDED BY DSEL
2. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 12-1127-0062-8000
3. IT IS RECOMMENDED THAT AREA SPECIFIC USF RAISES IN EXCESS OF THE GENERIC USF ELEVATION SHOWN BE REVIEWED AT THE DETAILED DESIGN STAGE TO BRING USF ELEVATIONS IN LINE WITH ANY FUTURE MONITORED GROUNDWATER ELEVATIONS.

Golder Associates
Ottawa, Ontario, Canada

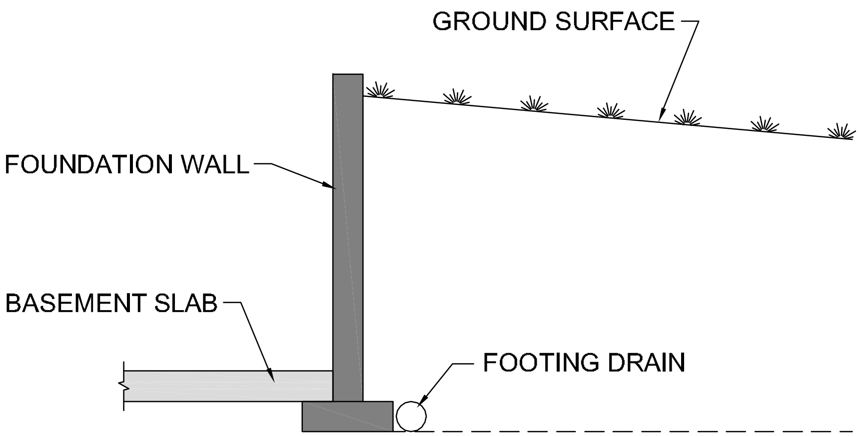
RICHMOND VILLAGE
ASSESSMENT OF SUBSURFACE DRAINAGE

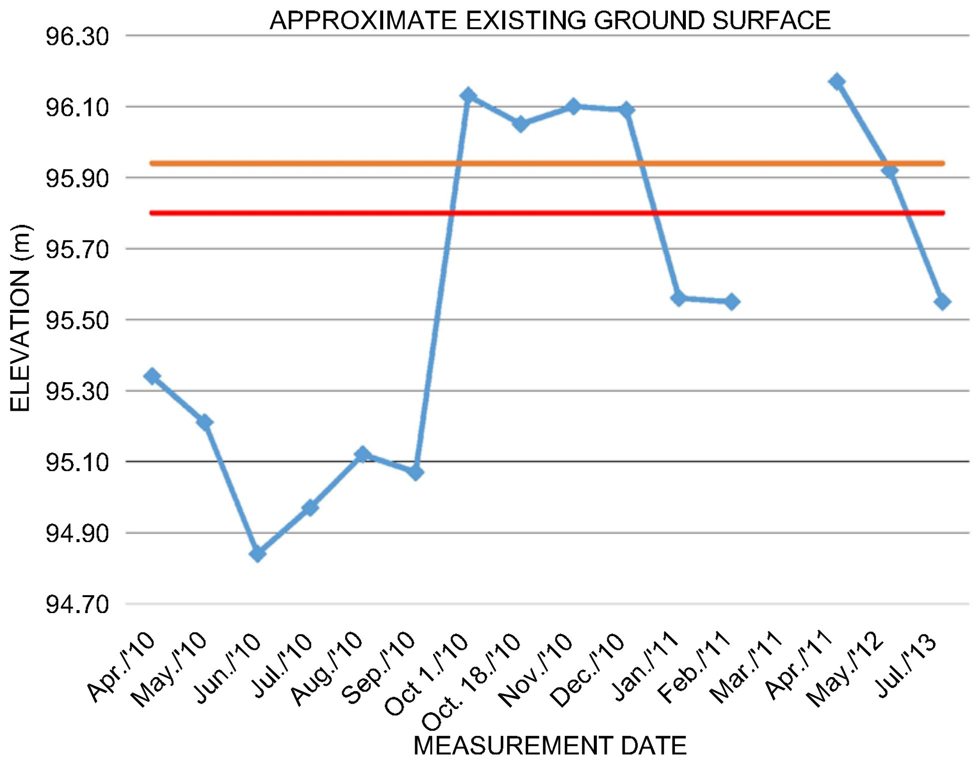
GROUNDWATER VS. PROPOSED USF IN THE VICINITY OF MONITROING WELL MW10-7

FIGURE 5F

PROJECT No. 12-1127-0062 DATE 2013-10-16 CAD JM

PLOT DATE: November 1, 2013
FILENAME: N:\Active\2012\1127 – Geosciences\12-1127-0062 Richmond Village Drainage and Sump Design\Spatial_IM\CAD\Phase 8000\1211270062-8000-05.dwg





LEGEND

- MW10-8
- ESTIMATED USF @ MW10-8
- STORM SEWER INVERT

NOTE

1. THESE GROUNDWATER LEVELS ARE IN BEDROCK
2. NO OVERBURDEN GROUNDWATER LEVELS WERE MEASURED
3. CONCEPTUAL USF ELEVATIONS PROVIDED BY DSEL
4. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 12-1127-0062-8000

Golder Associates
Ottawa, Ontario, Canada

RICHMOND VILLAGE
ASSESSMENT OF SUBSURFACE DRAINAGE

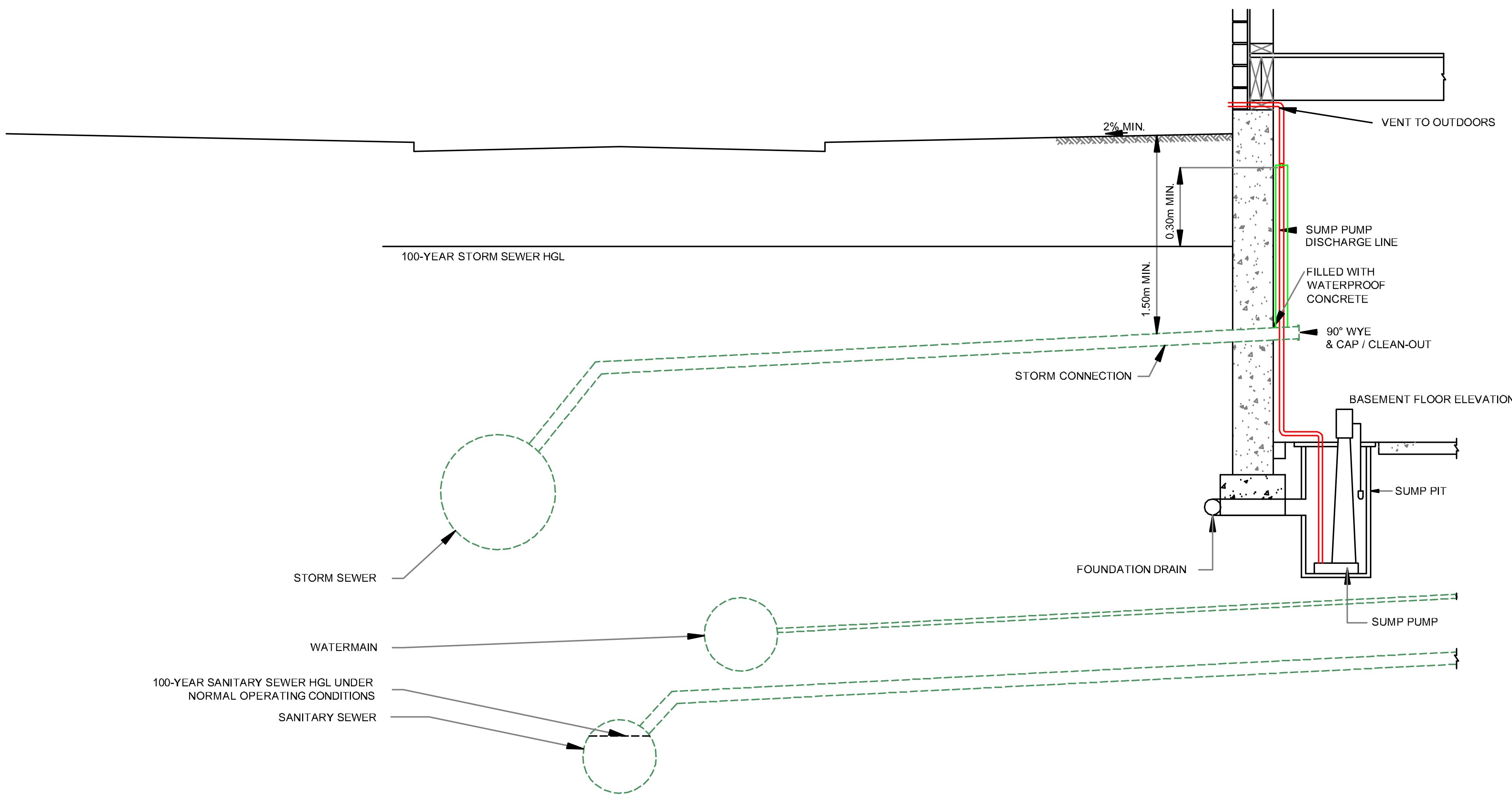
GROUNDWATER VS. PROPOSED USF IN THE VICINITY OF MONITROING WELL MW10-8

FIGURE 5G

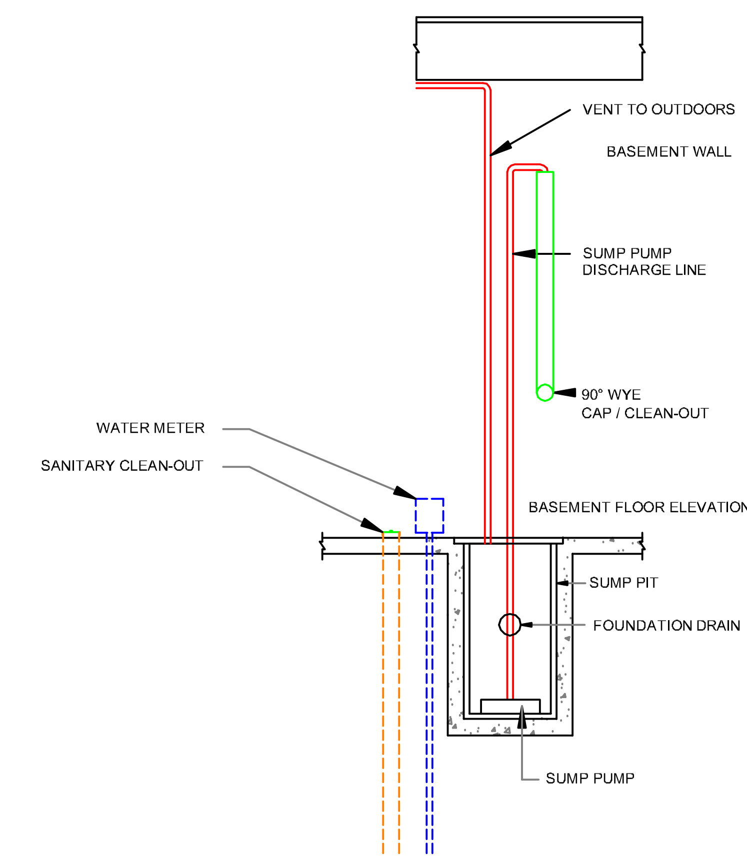
PROJECT No. 12-1127-0062 DATE 2013-10-16 CAD JM

APPENDIX A

Sump Pump Detail



SECTION VIEW



FRONT VIEW

DSEL
david schaeffer engineering ltd

120 Iber Road, Unit 203
Stittsville, Ontario, K2S 1E9
Tel. (613) 836-0856
Fax. (613) 836-7183
www.DSEL.ca

MATTAMY - VILLAGE OF RICHMOND
WESTERN DEVELOPMENT LANDS

SUMP PUMP DETAIL

CITY OF OTTAWA

PROJECT No.: 13-654
DATE: MARCH 2013
DRAWN BY: KM / ADF
SCALE: N.T.S.
FIGURE: 6

APPENDIX B

Sump Pump Data Sheet

HYDROMATIC®

FG-100A BATTERY BACK-UP SUMP PUMP

Protects Home
If AC-powered pump fails

Backs Up Residential Sump Pump
Automatically during power outage or pump failure (primary pump and piping not included)

Reliable Operation
Self-Charging System
Continuous

Solid-State Controller
Monitors battery charge and pump operation

Audible Alarm
Sounds when standby pump activates

Controller
Includes connectors for pump, charger, float switch and battery*

Area Light
Illuminates dark, powerless work area

Works with Flooded and Sealed AGM Deep Cycle Lead-Acid Battery
Can use two batteries for extended protection

Resettable Circuit Breaker
Eliminates the need for a fuse

2A 5-Stage Charger
Maintains 90% charge

* Deep cycle marine-type battery (Group 24) recommended – not included with FG-100 system

Catalog Number	Volts	Hz	Cord Length	Aprox. Wt. Lbs.
FG-100A	12	60	8'	14.75

System includes: *Pump, dual check valves, 1-1/4 x 1-1/2 inch adapter tee, battery box and control panel (battery not included).*

Pentair Water™

HYDROMATIC SUPPORTS THE PROFESSIONAL

FG-100A BATTERY BACK-UP SUMP PUMP

Features

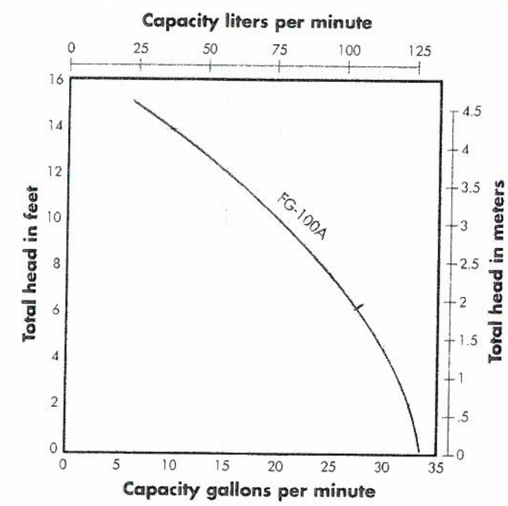
The Hydromatic® FG-100A battery operated back-up sump pump is designed to back up primary residential sump pumps in case of pump or power failure. A must for those installations where an inoperative sump pump cannot be tolerated. Separate float switch and built-in alarm automatically start back-up system and activates warning buzzer to protect against high water damage and warn of primary pump failure.

Details

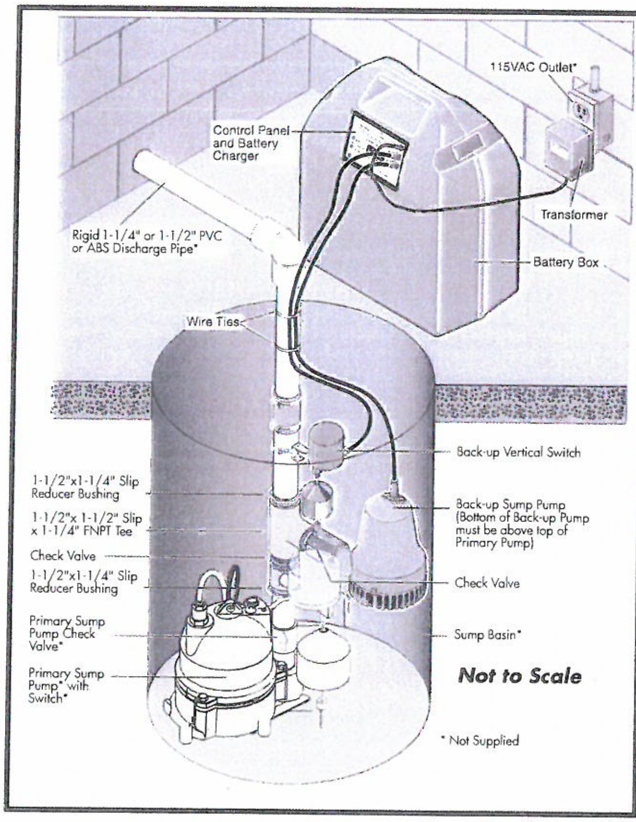
Specifications

- Housing – Thermoplastic
- Intermittent Liquid Temperature – Up to 77°F (25°C)
- Pump Down Range – Variable with float setting
- Pump Discharge – 1.25" NPT (31.75 mm)
- Motor – 12V, DC, 9A at 10 ft. (3M) lift
- Impeller – Thermoplastic
- Power Cord – 8 ft. SJT, 16/2 GA
- Capacities – Up to 30 GPM (114 LPM)
- Heads – To 16 ft. (4.88 m)
- Battery Charger – Input 120V, 60 Hz; Output 12V, 2A; Plug-in type wall-mounted transformer
- Check Valve – Dual check valves
- Battery Requirement* – 12V, deep cycle, marine type (Group 24), minimum 75–120 AH

Performance Data



Typical Installation



* Deep cycle marine-type battery (Group 24) recommended – not included with FG-100 system

HYDROMATIC®
Pentair Water

– Your Authorized Local Distributor –

USA
740 East 9th Street, Ashland, Ohio 44805
Tel: 1-888-957-8677 Fax: 419-281-4087

www.hydromatic.com

CANADA
269 Trillium Drive, Kitchener, Ontario, Canada N2G 4W5
Tel: 519-896-2163 Fax: 519-896-6337

Item #: W-02-7740 7/08

APPENDIX C

DSEL Memorandum Dated October 30, 2013

DSEL
david schaeffer engineering ltd
SMART SUBDIVISIONS™

120 Iber Road
Unit 203
Stittsville, Ontario K2S 1E9
Tel (613) 836-0856
Fax (613) 836-7183
www.DSEL.ca

October 30, 2013
DSEL File: 10-468

Attention: **Note to File**

Re: Richmond Village – Western Development Lands – Sump Pump Back-Up Evaluation

Through review of development options in the Western Development Lands, in the Village of Richmond, it has been concluded that the provision of sump pumps will be required. The sump pumps and weeping tile system will collect groundwater inflows during those times of the year when the groundwater level rises above the footing level and pump to the storm sewer system. Additional rationale is provided in Golder Associates' ***Technical Memorandum 12-1127-0062(8000).*** The proposed use of sump pumps is similar to the majority of the existing homes in Richmond.

In addition to the typical sump pump configuration, a back-up sump pump option (with standby power) is also proposed. In the event of power outages, the back-up configuration will provide an additional level of protection. After review of various guidelines it is appears that this is not a mandatory requirement of the City of Ottawa.

With the chosen back-up pump model (Hydromatic FG-100A or equivalent), the manufacturer recommends a marine-type battery with a minimum of 75 "amp-hours (AH)" of service. The AH rating is based upon testing over a standard 20 hour period to establish how long it takes the battery to drain. A 75AH battery indicates that a 3.75A load was applied over 20 hours to drain the battery (i.e. 3.75A x 20hr = 75AH). Note: Higher amp loading than the 3.75A tested will equate to less amperage hours available[1]. Assumed to be 10% efficiency loss in this case (i.e. lowers to 90% of original rating).

For a battery with 75AH of service, the pump (9 amp for this model) would have the ability to provide pumping for 7.5 hours (75AH/9A x 0.90 = 7.5 hours). At the pump rating of 100 L/min this would be equivalent to 100 L/min x 7.5hr x 60min = 45,000 L (45 m^3) of outflow. If predicted inflows to the weeping tile system (per the Golder technical memo) are in the order of 2.0m^3/day this equates to approximately 22 days of backup pumping. The back-up power would provide sufficient pumping even in extended periods of power outages.

David Schaeffer Engineering Ltd.

Per: Kevin L. Murphy, P.Eng.

[1] Peukert's law expresses the **capacity** of a **lead–acid battery** in terms of the rate at which it is discharged. As the rate increases, the battery's available capacity decreases.

Golder Associates

TECHNICAL MEMORANDUM

DATE October 23, 2013 **PROJECT No.** 12-1127-0062

TO Frank Cairo
Richmond Village (South) Limited

CC Mike Green - Mattamy (Jock River) Limited

FROM Brian Byerley, P. Eng. **EMAIL** Brian_Byerley@golder.com

STORM WATER MANAGEMENT POND 2 DESIGN RECOMMENDATIONS, WESTERN DEVELOPMENT LANDS, VILLAGE OF RICHMOND DEVELOPMENT, OTTAWA, ONTARIO

Richmond Village (South) Limited (RVSL) has requested Golder Associates Ltd. (Golder) to provide preliminary design recommendations concerning the proposed depth of Storm Water Management (SWM) Pond 2 in the Western Development Lands (the site). The current preliminary design of SWM Pond 2 (a shallow wetland pond) has been developed by David Schaeffer Engineering Ltd. (DSEL), based on the required function of the pond and the proposed lay-out of the site infrastructure.

Subsurface conditions in the vicinity of SWM Pond 2 were previously investigated by Golder in 2010 by completion of borehole BH10-06. The subsurface conditions at BH10-6 consist of 0.25 metres of topsoil, over approximately 1.58 metres of sandy silt to silty sand, over approximately 1.24 of glacial till. Dolostone bedrock was encountered directly beneath the glacial till, at approximately 3.07 metres below ground surface (mbgs). Two monitoring wells were installed in BH10-6: MW10-6A (in bedrock) and MW10-6B (in overburden). See the attached borehole record for details regarding subsurface conditions and monitoring well construction.

Groundwater level monitoring between 2010 and 2013 has indicated that the groundwater levels at MW10-6A (in bedrock) ranged from 0.43 mbgs (in spring) to 1.96 mbgs (in summer). Slug testing at MW10-6A determined that the horizontal hydraulic conductivity of the shallow bedrock to be approximately 5x10-6 m/s.

Based on the available information, Golder recommends that SWM Pond 2 be designed to be as shallow as possible, with no or minimal excavation into rock for the following reasons:

- The hydraulic head in the bedrock would prevent the construction of a pond liner, if required;
- Although the bedrock horizontal hydraulic conductivity measured at MW10-6A is similar to the hydraulic conductivity of the overlying silty sand and silty clay deposits, higher hydraulic conductivity has been measured in the bedrock elsewhere on-site. Therefore, the design of the pond should consider the possibility that vertical fractures in the shallow bedrock might permit increased groundwater flow through the bottom of the pond, which could be problematic in terms of the constructability of the pond. The outlet sewer would also need to accommodate additional flow;

- If SWM Pond 2 was excavated into bedrock, possible high rates of groundwater flow into the pond could prevent draining of the pond for regular maintenance; and,
- Lots adjacent to the development lands are serviced by individual water supply wells (typically 30 metres deep), which obtain water from the bedrock. Minimising the amount of rock excavation will also minimise the possibility of impacts to those wells.

We trust that this memorandum is sufficient for your current needs. Please contact the undersigned if you have any questions.

Yours Truly

GOLDER ASSOCIATES LTD.

LICENSED PROFESSIONAL ENGINEER
B. T. BYERLEY
23/10/13
PROVINCE OF ONTARIO

Mike Cunningham, P.Eng.
Senior Geotechnical Engineer/Associate

Brian Byerley, M.Sc., P.Eng.
Senior Hydrogeologist/Principal

MIC/BTB/

Attachments: Important Information and Limitations of this Report
Borehole Record for BH10-6

n:\active\2012\1127 - geosciences\12-1127-0062 richmond village drainage and sump design\reporting\1211270062 - tech memo - swmp 2 - 22oct2013.docx

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client, Richmond Village (South) Limited and Mattamy (Jock River) Limited. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder cannot be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then the client may authorize the use of this report for such purpose by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process, provided this report is not noted to be a draft or preliminary report, and is specifically relevant to the project for which the application is being made. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client cannot rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder cannot be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT (cont'd)

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

RECORD OF BOREHOLE: 10-6

PROJECT: 08-1122-0078

LOCATION: See Site Plan

BORING DATE: Apr. 30, 2010

SHEET 1 OF 2

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - O (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		95.67							
0	Power Auger, 200mm Diam (Hollow Stem)	TOPSOIL		0.00							Bentonite Seal
		Loose to compact grey brown SANDY SILT to SILTY SAND, trace clay		95.42 / 0.25							Silica Sand
1					1	50 DO	6				32mm Diam. PVC #10 Slot Screen 'B'
					2	50 DO	27				
2		Dense to very dense grey brown SANDY SILT, some gravel, cobbles and boulders (GLACIAL TILL)		93.84 / 1.83							Silica Sand
					3	50 DO	68				Bentonite Seal
3					4	50 DO	>100				
	Rotary Drill, NQ Core	Thinly to medium bedded light grey intebedded SANDSTONE and DOLOSTONE BEDROCK		92.60 / 3.07							Silica Sand
4					C1	NQ RC	DD				32mm Diam. PVC #10 Slot Screen 'A'
5					C2	NQ RC	DD				
		End of Borehole		90.49 / 5.18							W.L. in screen 'A' at Elev. 94.29m on Apr. 30, 2010
6											W.L. in screen 'B' at Elev. 93.38m on Apr. 30, 2010
7											
8											
9											
10											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: J.D.

CHECKED: [signature]

MIS-BHS 001 0811220078-9500.GPJ GAL-MIS.GDT 6/3/10 JM

PROJECT: 08-1122-0078

LOCATION: See Site Plan

INCLINATION: -90° AZIMUTH: ---

RECORD OF DRILLHOLE: 10-6

DRILLING DATE: Apr. 30, 2010

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

SHEET 2 OF 2

DATUM:

FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE
CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH. BREAK
SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING
VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	NOTES WATER LEVELS INSTRUMENTATION
		BEDROCK SURFACE	92.60		
	Rotary Drill NQ Core	Thinly to medium bedded light grey intebedded SANDSTONE and DOLOSTONE BEDROCK	3.07	1	Bentonite Seal; Silica Sand; 32mm Diam. PVC #10 Slot Screen 'A'
4					
5			90.49		
		End of Borehole	5.18		W.L. in screen 'A' at Elev. 94.29m on Apr. 30, 2010
6					W.L. in screen 'B' at Elev. 93.38m on Apr. 30, 2010
7					
8					
9					
10					
11					
12					
13					

Other column headings: SYMBOLIC LOG; PENETRATION RATE (m/min); COLOUR % RETURN; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER 0.3; DISCONTINUITY DATA (DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION); HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3}); DIAMETRAL POINT LOAD INDEX (MPa)

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: J.D.

CHECKED:

HYDROMATIC®

FG-100A BATTERY BACK-UP SUMP PUMP

Protects Home
If AC-powered pump fails

Backs Up Residential Sump Pump
Automatically during power outage or pump failure (primary pump and piping not included)

Reliable Operation

Self-Charging System
Continuous

Solid-State Controller
Monitors battery charge and pump operation

Audible Alarm
Sounds when standby pump activates

Controller
Includes connectors for pump, charger, float switch and battery*

Area Light
Illuminates dark, powerless work area

Works with Flooded and Sealed AGM Deep Cycle Lead-Acid Battery
Can use two batteries for extended protection

Resettable Circuit Breaker
Eliminates the need for a fuse

2A 5-Stage Charger
Maintains 90% charge

* Deep cycle marine-type battery (Group 24) recommended – not included with FG-100 system

Catalog Number	Volts	Hz	Cord Length	Aprox. Wt. Lbs.
FG-100A	12	60	8'	14.75

System includes: *Pump, dual check valves, 1-1/4 x 1-1/2 inch adapter tee, battery box and control panel (battery not included).*

Pentair Water™

HYDROMATIC SUPPORTS THE PROFESSIONAL

FG-100A BATTERY BACK-UP SUMP PUMP

Features

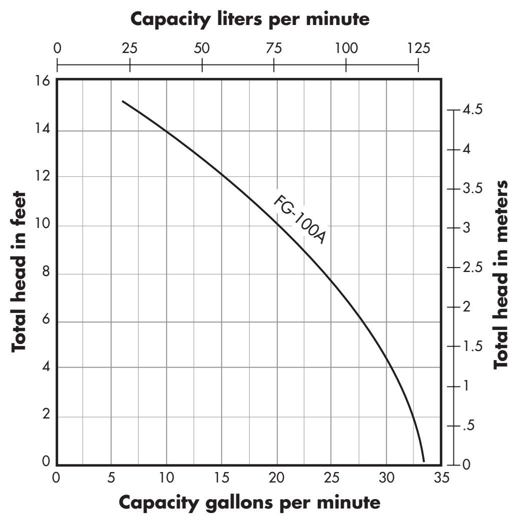
The Hydromatic® FG-100A battery operated back-up sump pump is designed to back up primary residential sump pumps in case of pump or power failure. A must for those installations where an inoperative sump pump cannot be tolerated. Separate float switch and built-in alarm automatically start back-up system and activates warning buzzer to protect against high water damage and warn of primary pump failure.

Details

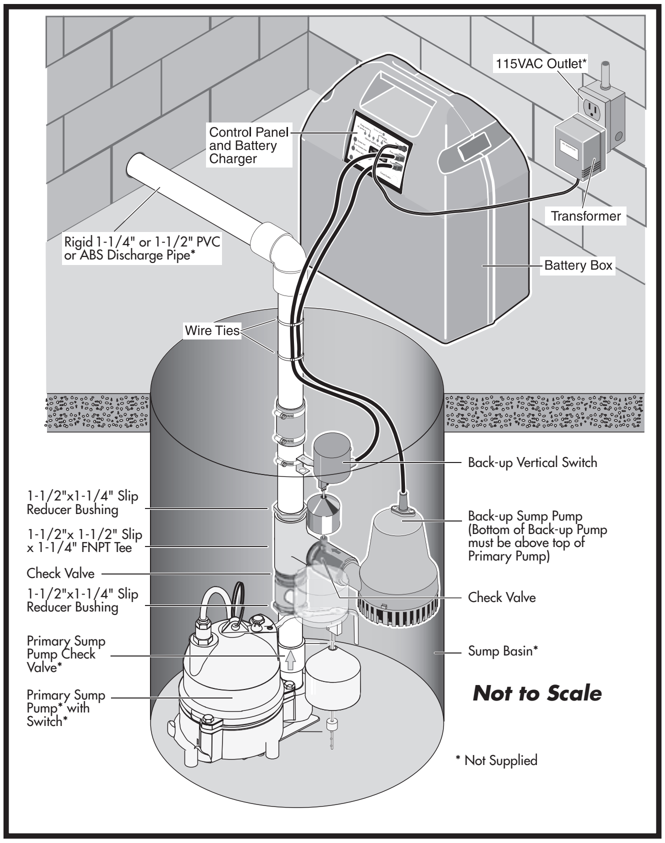
Specifications

- Housing – Thermoplastic
- Intermittent Liquid Temperature – Up to 77°F (25°C)
- Pump Down Range – Variable with float setting
- Pump Discharge – 1.25" NPT (31.75 mm)
- Motor – 12V, DC, 9A at 10 ft. (3M) lift
- Impeller – Thermoplastic
- Power Cord – 8 ft. SJT, 16/2 GA
- Capacities – Up to 30 GPM (114 LPM)
- Heads – To 16 ft. (4.88 m)
- Battery Charger – Input 120V, 60 Hz; Output 12V, 2A; Plug-in type wall-mounted transformer
- Check Valve – Dual check valves
- Battery Requirement* – 12V, deep cycle, marine type (Group 24), minimum 75–120 AH

Performance Data



Typical Installation



* Deep cycle marine-type battery (Group 24) recommended – not included with FG-100 system

– Your Authorized Local Distributor –

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Pentair Water

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269 Trillium Drive, Kitchener, Ontario, Canada N2G 4W5
Tel: 519-896-2163 Fax: 519-896-6337

Item #: W-02-7740 7/08

HYDROMATIC® CSS-3D AND CSS-3V
SUMP BASIN PACKAGE

Preplumbed Sump Basin Package

- Basement sumps, dewatering, new or existing installations
- Fully Assembled Check valve included.
- Injection-Molded Structural Foam Provides the highest quality construction for uniform wall thickness and strength.
- Proprietary "Flush Mount" Design for easy shipping and storage. Allows for pallet stacking.

The Hydromatic Preplumbed Sump Basin Package is a rugged, high quality product consisting of our D-A1 or V-A1 .3 HP Cast Iron sump pump, ideal for drain water removal. The 18" x 22" basin is constructed of the highest quality structural foam and has a 20 gallon capacity. The package comes with a single-piece structural foam lid, proprietary "Flush Mount" design for easy shipment and storage. The unit comes field-ready with 1-1/2" NPT threaded discharge flange and a 2" NPT vent flange (adaptable to 3") and includes a 1-1/2" sump check valve.

PENTAIR

WWW.HYDROMATIC.COM

HYDROMATIC® CSS-3D AND CSS-3V
SUMP BASIN PACKAGE

Specifications

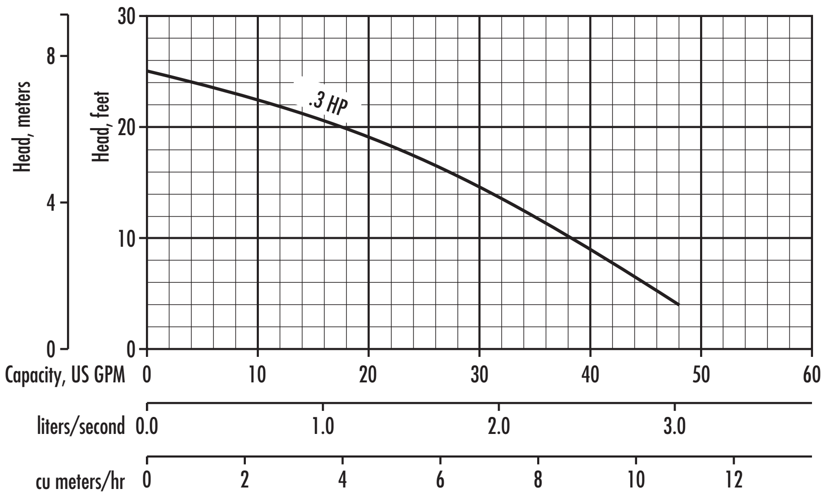
Pump (D-A1 or V-A1)

- Housing – Cast iron.
- Motor – .3 HP, 115 volt, single phase, shaded pole motor, built-in overload protection.
- Maximum Limits – Liquid temperature: 120°F (49°C).

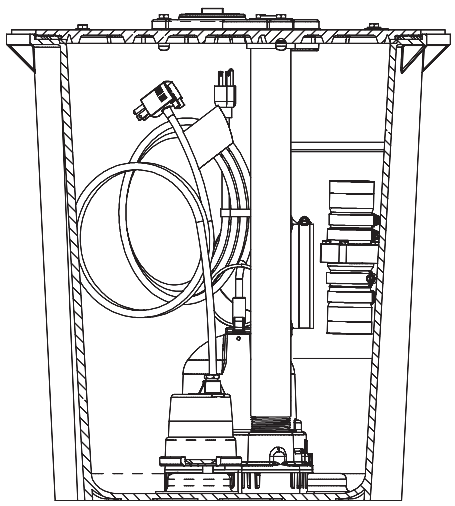
Basin, Lid, and Accessories

- Radon Proof – Radon approved basin and cover for radon prevention.
- Basin – Injection-molded structural foam (polyethylene). 20-gallon capacity. Standard 18" x 22" basin.
- Lid – Injection-molded structural foam (polyethylene). Gas-tight single-piece design with seal.
- Hub Adapter – 4" Snap-in type with stainless steel clamp. Fits 4" DWV SCH. 40 plastic pipe.
- Flanges – 1-1/2" NPT threaded discharge and 2" NPT vent flange (easily converts to 3"). Comes with gas-tight cord grommet.
- Check Valve – Sump pump check valve fits 1-1/2" black, galvanized, and DWV SCH. 40 pipe.

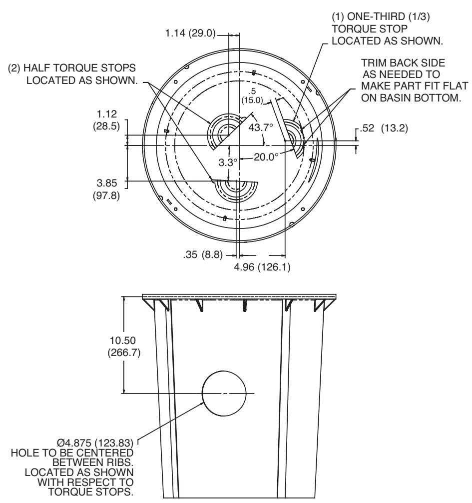
Performance Curve



Sectional View



Outline Dimensions



Ordering Information

Catalog Number	HP	Package Type	Full Load Amps	Cord Length	Mechanical Switch Type	Basin Size
CSS-3D	.3	Preassembled	12	10'	Diaphragm	18" x 22"
CSS-3V	.3	Preassembled	12	10'	Vertical	18" x 22"

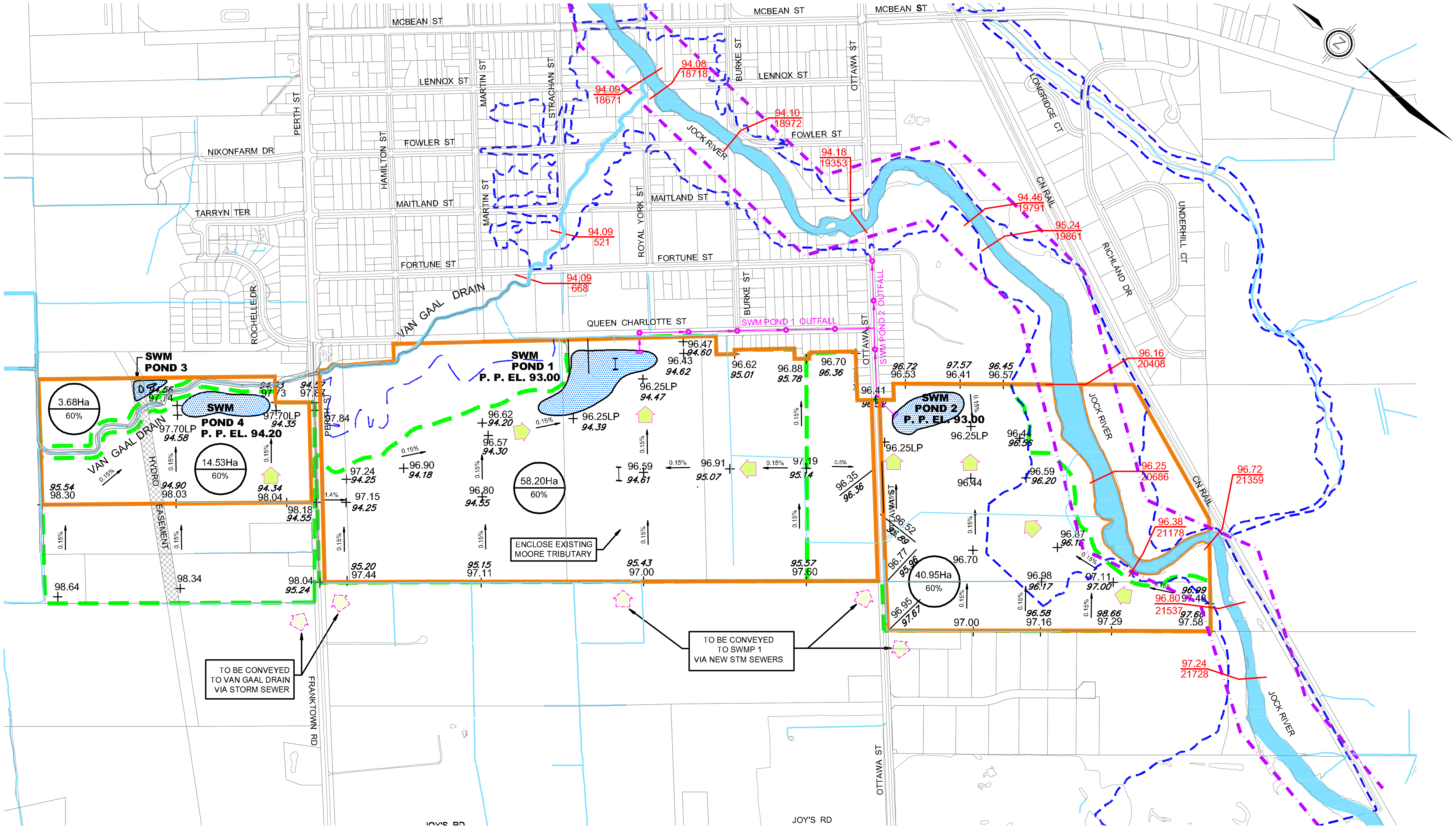
PENTAIR

USA
293 WRIGHT STREET, DELAVAN, WI 53115 WWW.HYDROMATIC.COM
PH: 888-957-8677 ORDERS FAX: 800-426-9446

CANADA
269 TRILLIUM DRIVE, KITCHENER, ONTARIO, CANADA N2G 4W5
PH: 519-896-2163 ORDERS FAX: 519-896-6337

APPENDIX G

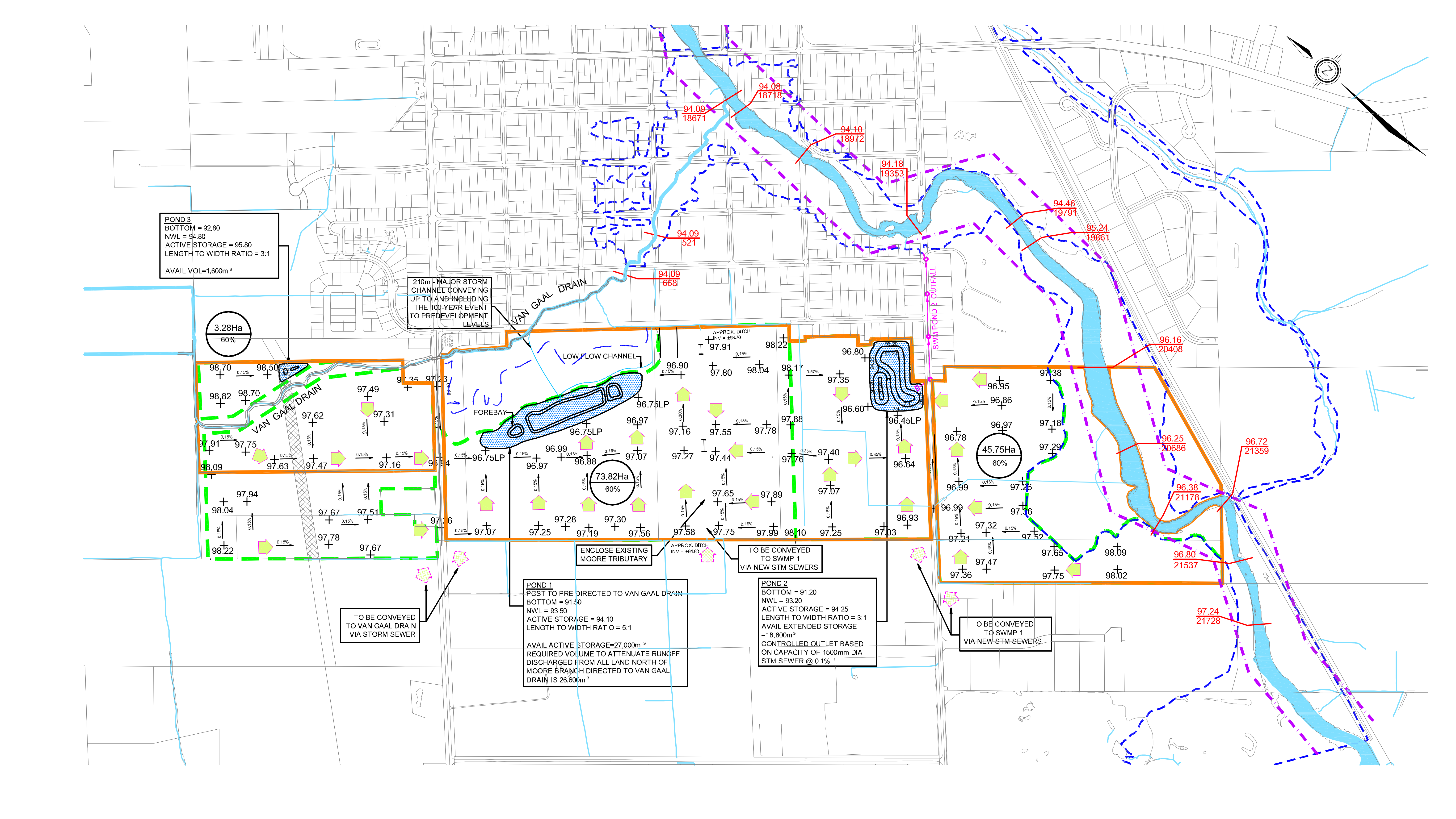
Evaluation of Alternatives



DSEL david schaeffer engineering ltd 120 Iber Road, Unit 203 Stittsville, Ontario, K2S 1E9 Tel. (613) 836-0856 Fax. (613) 836-7183 www.DSEL.ca	VILLAGE OF RICHMOND CONCEPTUAL SWM PLAN OPTION 1 CITY OF OTTAWA	PROJECT No.: 11-468 DATE: NOVEMBER 2012 DRAWN BY: KM / ADF SCALE: 1:10,000 FIGURE: 7

LEGEND

- STUDY LIMIT
- MEANDER BELT
- REGULATORY FLOOD LINE
- STORM DRAINAGE AREA
- STORM OUTFALL
- OVERLAND FLOW DIRECTION
- EXTERNAL OVERLAND FLOW DIRECTION
- EXISTING ELEVATION CONTOUR
- 96.80 FLOOD LINE ELEVATION
- 21537 FLOOD LINE SECTION
- EXISTING DITCH
- 96.84 PROPOSED ELEVATION
- 94.61 EXISTING ELEVATION
- 73.82Ha DRAINAGE AREA
- 60% IMPERVIOUSNESS



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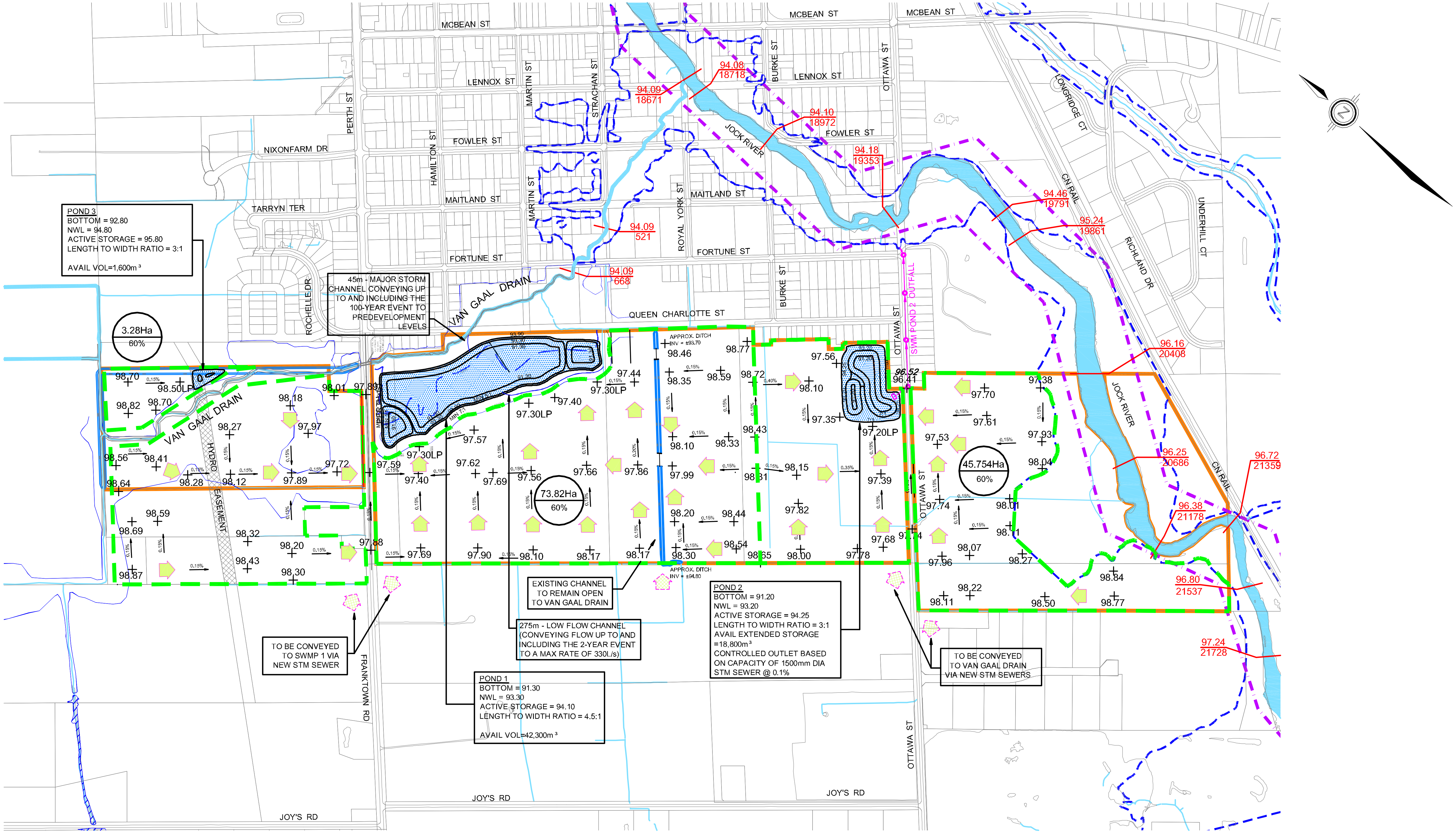
VILLAGE OF RICHMOND
CONCEPTUAL SWM PLAN
OPTION 2
CITY OF OTTAWA

LEGEND

STUDY LIMIT	96.80 FLOOD LINE ELEVATION
MEANDER BELT	21537 FLOOD LINE SECTION
REGULATORY FLOOD LINE	EXISTING DITCH
STORM DRAINAGE AREA	96.84 PROPOSED ELEVATION
STORM OUTFALL	94.61 EXISTING ELEVATION
OVERLAND FLOW DIRECTION	73.82Ha DRAINAGE AREA
EXTERNAL OVERLAND FLOW DIRECTION	60% IMPERVIOUSNESS
95.00 EXISTING ELEVATION CONTOUR	

PROJECT No.: 11-468	
DATE: NOVEMBER 2012	
DRAWN BY: KM / ADF	
SCALE:	1:10,000
FIGURE:	8



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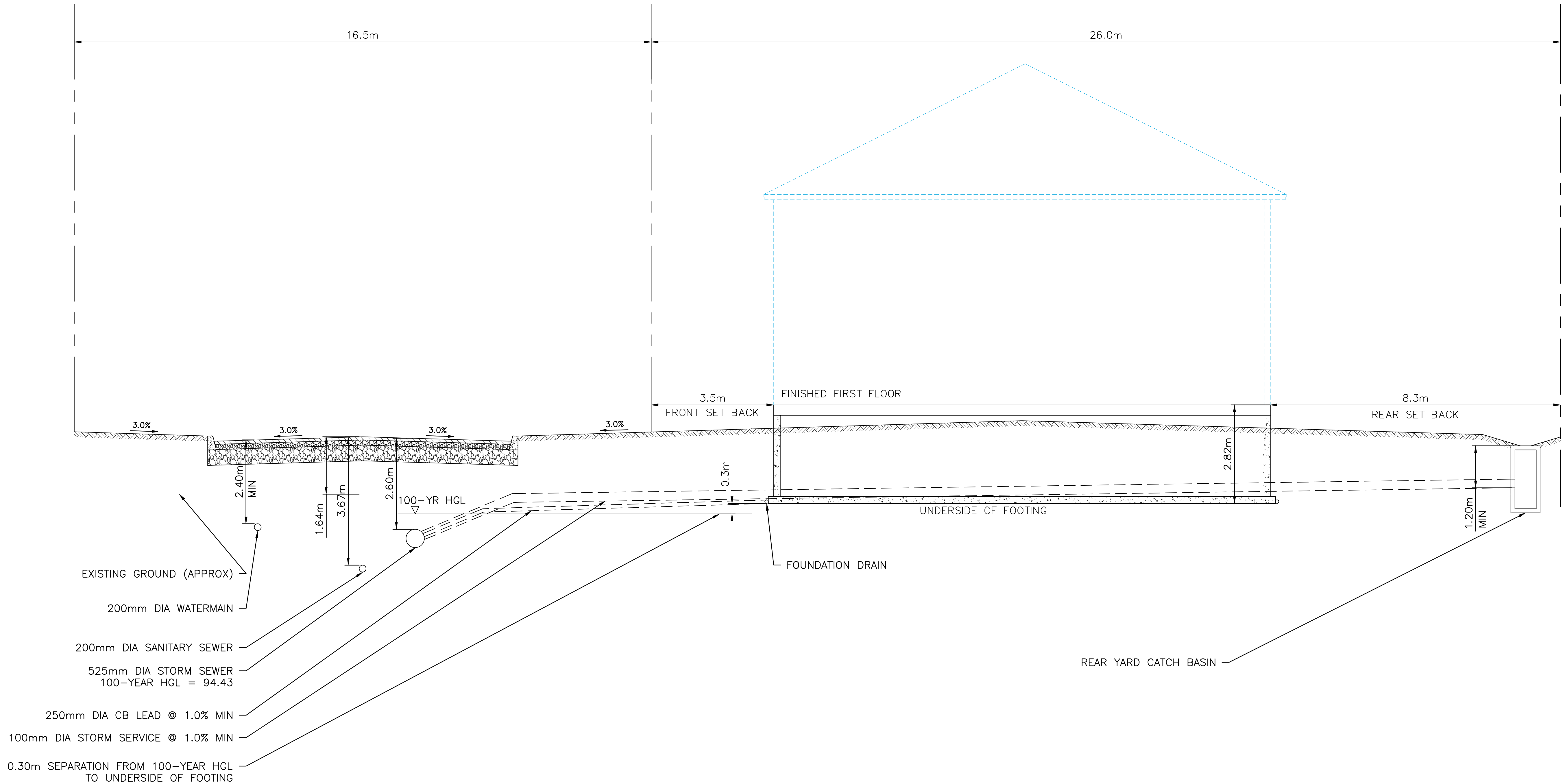
VILLAGE OF RICHMOND
CONCEPTUAL SWM PLAN
OPTION 3
CITY OF OTTAWA

LEGEND

STUDY LIMIT	96.80 FLOOD LINE ELEVATION
MEANDER BELT	21537 FLOOD LINE SECTION
REGULATORY FLOOD LINE	EXISTING DITCH
STORM DRAINAGE AREA	96.84 PROPOSED ELEVATION
STORM OUTFALL	94.61 EXISTING ELEVATION
OVERLAND FLOW DIRECTION	73.82Ha DRAINAGE AREA
EXTERNAL OVERLAND FLOW DIRECTION	60% IMPERVIOUSNESS
EXISTING ELEVATION CONTOUR	

PROJECT No.:	11-468
DATE:	NOVEMBER 2012
DRAWN BY:	KM / ADF
SCALE:	1:10,000
FIGURE:	9



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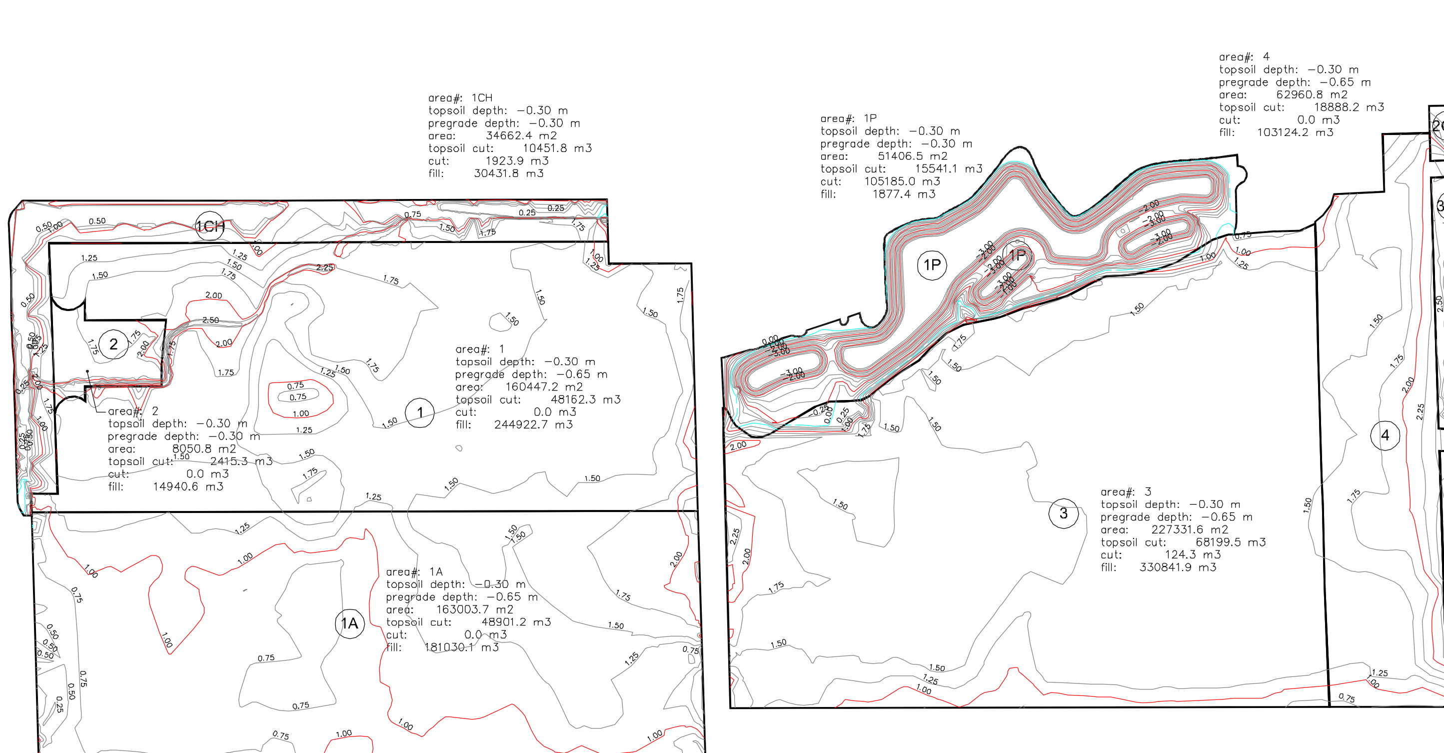
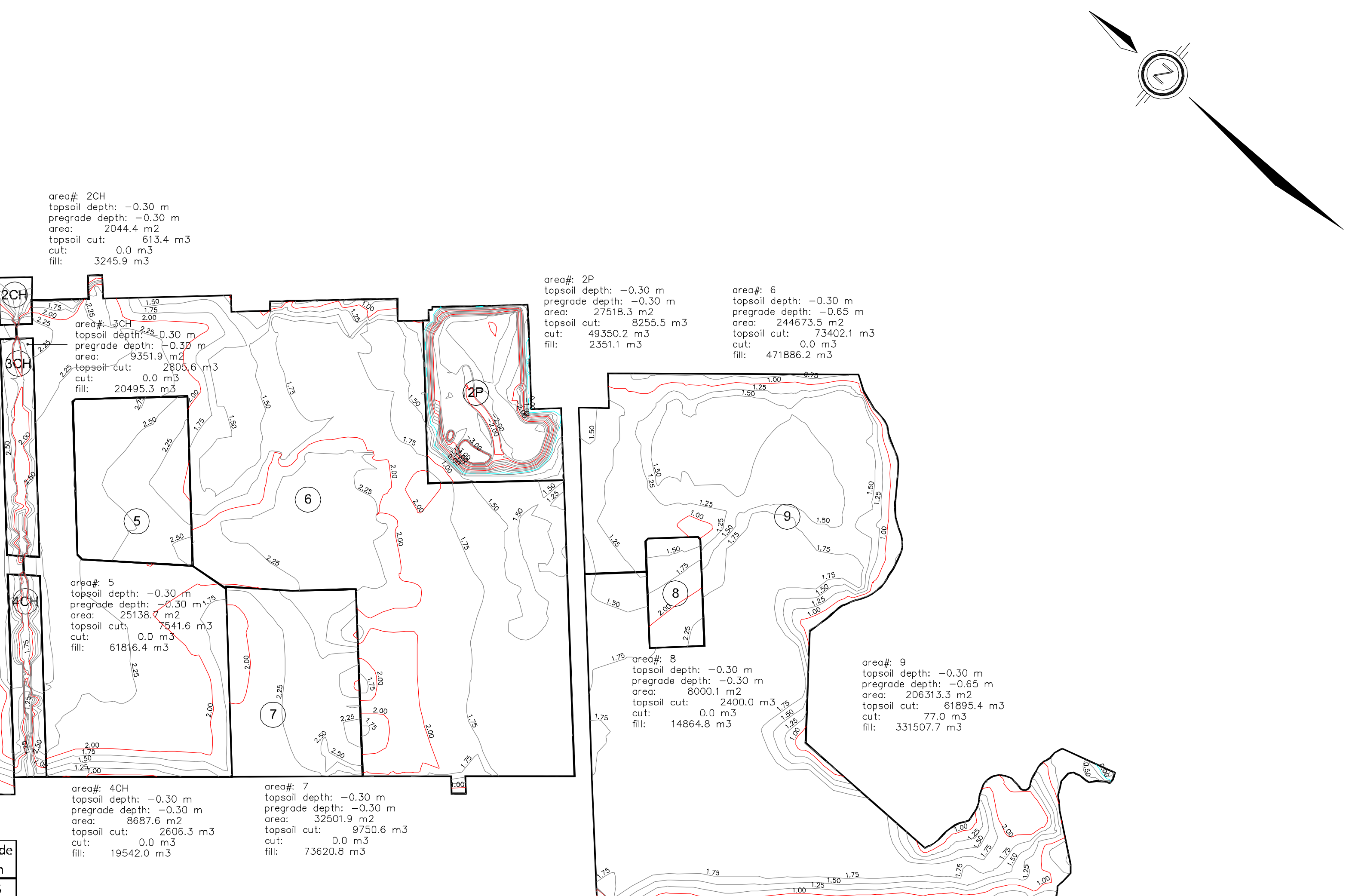
FOUNDATION SERVICE TO STREET STORM SEWER

DATE: APRIL 2012
SCALE: 1:125
PROJECT No.: 11-467
FIGURE 11





Area# ID	cut_area m2	fill_Area m2	tot_Area m2	topsoil m3	cut m3	fill m3	net m3	strip depth	pregrade depth
1	0.0	160447.2	160447.2	48162.3	0.0	244922.7	-244922.7	-0.30	-0.65
1A	1.5	163002.0	163003.7	48901.2	0.0	181030.1	-181030.1	-0.30	-0.65
2	0.0	8050.8	8050.8	2415.3	0.0	14940.6	-14940.6	-0.30	-0.30
1CH	5990.4	28672.0	34662.4	10451.8	1923.9	30431.8	-28507.9	-0.30	-0.30
3	680.7	226649.8	227331.6	68199.5	124.3	330841.9	-330717.6	-0.30	-0.65
4	0.0	62960.8	62960.8	18888.2	0.0	103124.2	-103124.2	-0.30	-0.65
2CH	0.0	2044.4	2044.4	613.4	0.0	3245.9	-3245.9	-0.30	-0.30
3CH	0.0	9351.9	9351.9	2805.6	0.0	20495.3	-20495.3	-0.30	-0.30
4CH	0.0	8687.6	8687.6	2606.3	0.0	19542.0	-19542.0	-0.30	-0.30
5	0.0	25138.7	25138.7	7541.6	0.0	61816.4	-61816.4	-0.30	-0.30
6	0.0	244673.5	244673.5	73402.1	0.0	471886.2	-471886.2	-0.30	-0.65
7	0.0	32501.9	32501.9	9750.6	0.0	73620.8	-73620.8	-0.30	-0.30
8	0.0	8000.1	8000.1	2400.0	0.0	14864.8	-14864.8	-0.30	-0.30
9	194.3	206119.0	206313.3	61895.4	77.0	331507.7	-331430.7	-0.30	-0.65
1P	46516.6	4865.0	51406.5	15541.1	105185.0	1877.4	103307.6	-0.30	-0.30
2P	23348.7	4125.0	27518.3	8255.5	49350.2	2351.1	46999.1	-0.30	-0.30
totals:			**1,272,093**	**381,830**	**156,660**	**1,906,499**	**-1,749,839**		

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VILLAGE OF RICHMOND

CUT & FILL OPTION 1

FOUNDATION SERVICE TO STORM SEWER

CITY OF OTTAWA

LEGEND

CUT/FILL CONTOUR

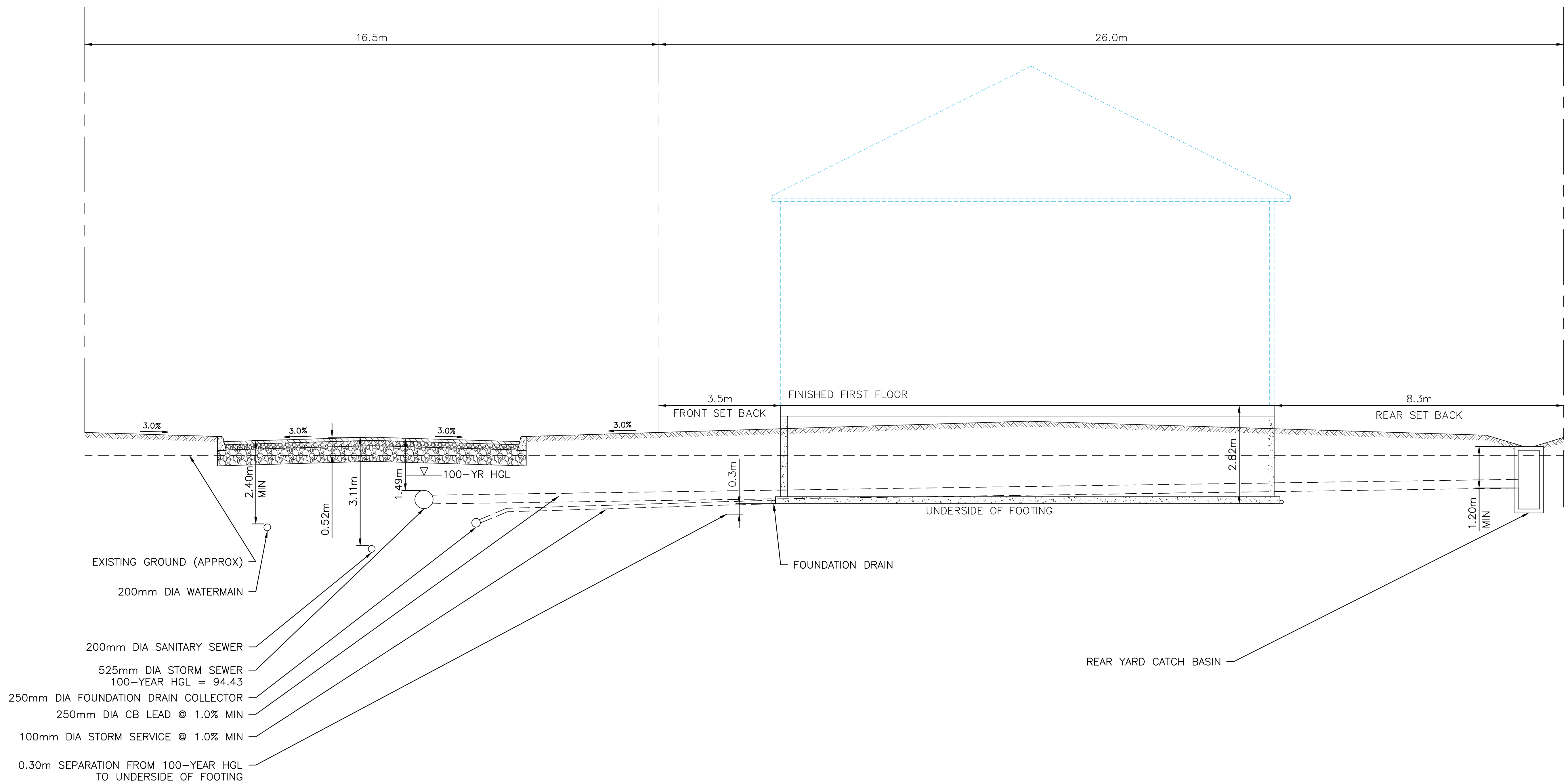
PROJECT No.: 11-468

DATE: NOVEMBER 2013

DRAWN BY: KM / ADF

SCALE: 1:7,500

FIGURE: 12



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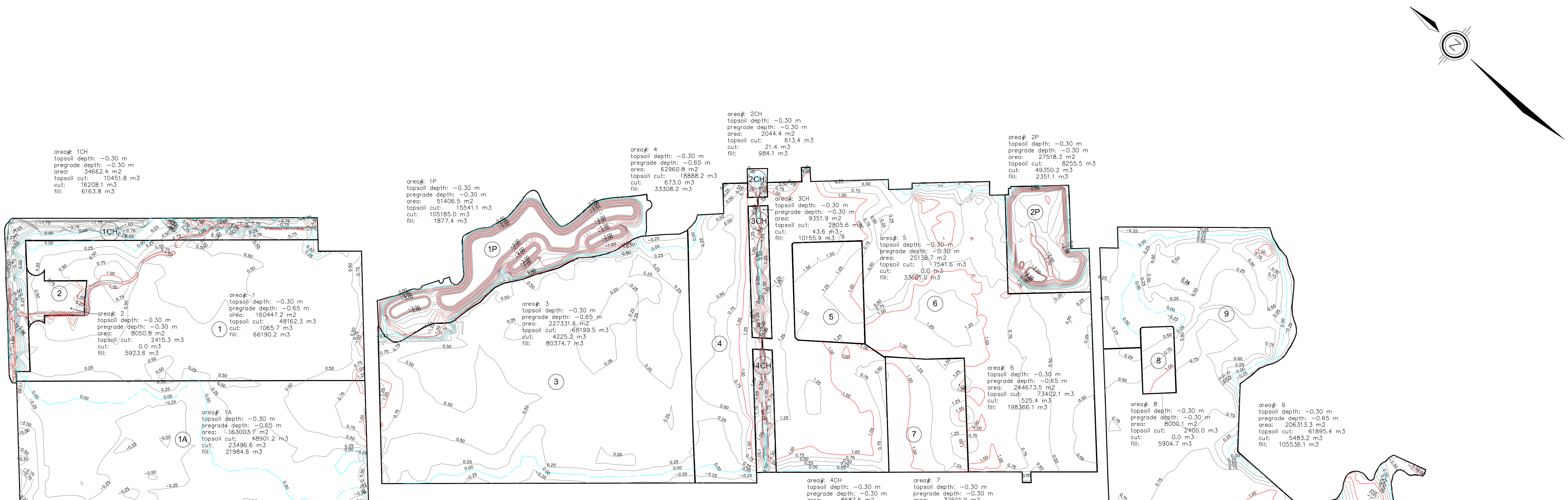
FOUNDATION SERVICE TO FOUNDATION COLLECTOR

DATE:	APRIL 2012
SCALE:	1:125
PROJECT No.:	11-467
FIGURE	13



Area# ID	cut_area m2	fill_Area m2	tot_Area m2	topsoil m3	cut m3	fill m3	net m3	strip depth	pregrade depth
1	6,016	154,430	160,447	48,162	1,066	66,190	-65,125	-0.30	-0.65
1A	92,930	70,072	163,004	48,901	23,497	21,985	1,512	-0.30	-0.65
2	0	8,051	8,051	2,415	0	5,924	-5,924	-0.30	-0.30
1CH	20,007	14,655	34,662	10,452	16,208	6,164	10,044	-0.30	-0.30
3	15,296	212,029	227,332	68,200	4,225	80,375	-76,150	-0.30	-0.65
4	3,509	59,452	62,961	18,888	673	33,308	-32,635	-0.30	-0.65
2CH	387	1,657	2,044	613	21	984	-963	-0.30	-0.30
3CH	397	8,955	9,352	2,806	44	10,156	-10,112	-0.30	-0.30
4CH	261	8,427	8,688	2,606	28	9,858	-9,830	-0.30	-0.30
5	0	25,139	25,139	7,542	0	33,661	-33,661	-0.30	-0.30
6	2,740	241,933	244,674	73,402	525	198,366	-197,841	-0.30	-0.65
7	0	32,502	32,502	9,751	0	37,219	-37,219	-0.30	-0.30
8	0	8,000	8,000	2,400	0	5,905	-5,905	-0.30	-0.30
9	25,035	181,279	206,313	61,895	5,483	105,536	-100,053	-0.30	-0.65
1P	46,517	4,865	51,407	15,541	105,185	1,877	103,308	-0.30	-0.30
2P	23,349	4,125	27,518	8,256	49,350	2,351	46,999	-0.30	-0.30
totals:			**1,272,093**	**381,830**	**206,305**	**619,858**	**-413,553**		

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VILLAGE OF RICHMOND

CUT & FILL OPTION 2

FOUNDATION SERVICE TO FOUNDATION COLLECTOR

CITY OF OTTAWA

LEGEND

2.25
2.00
CUT/FILL CONTOUR

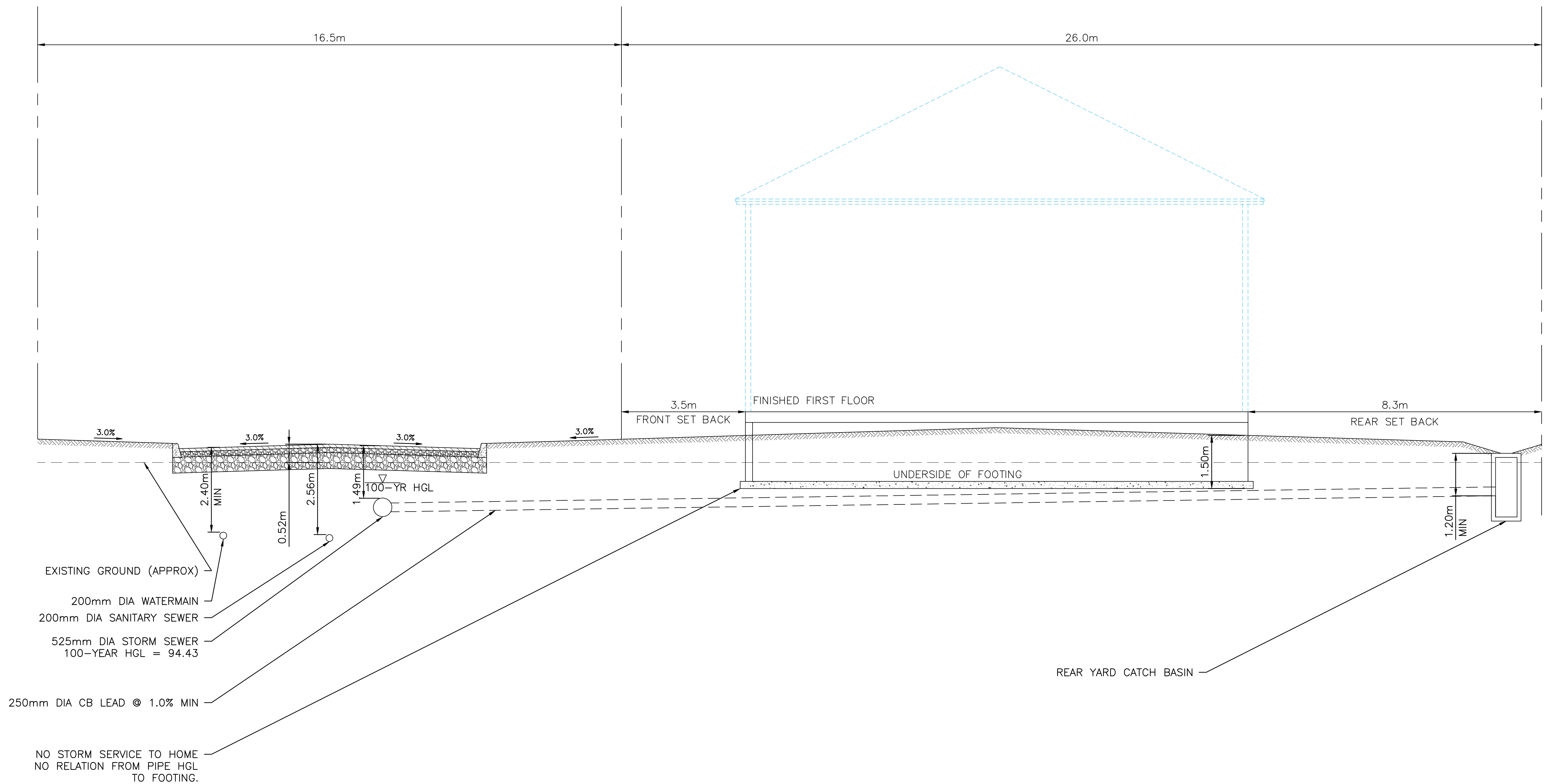
PROJECT No.: 11-468

DATE: NOVEMBER 2013

DRAWN BY: KM / ADF

SCALE: 1:7,500

FIGURE: 14



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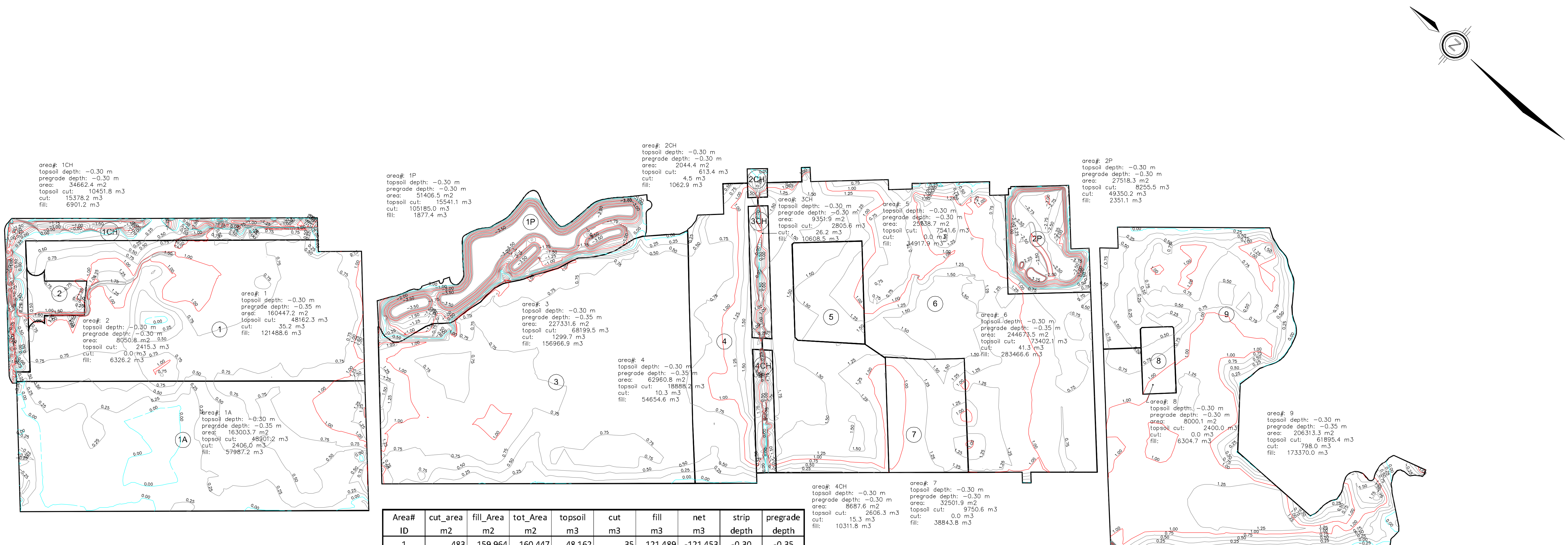
NO FOUNDATION SERVICE - SLAB ON GRADE UNITS

DATE: APRIL 2012
SCALE: 1:125
PROJECT No.: 11-467
FIGURE 15

z:\projects\11-468 caivan - richmond\b_design\b2_drawings\b2-2_main (dsel)\2013-11-04_swm_rpt_figures\11f-13f-15f-17f_swm_alternatives.dwg



Area# ID	cut_area m2	fill_Area m2	tot_Area m2	topsoil m3	cut m3	fill m3	net m3	strip depth	pregrade depth
1	483	159,964	160,447	48,162	35	121,489	-121,453	-0.30	-0.35
1A	22,050	140,947	163,004	48,901	2,406	57,987	-55,581	-0.30	-0.35
2	0	8,051	8,051	2,415	0	6,326	-6,326	-0.30	-0.30
1CH	19,228	15,434	34,662	10,452	15,378	6,901	8,477	-0.30	-0.30
1P	46,517	4,865	51,407	15,541	105,185	1,877	103,308	-0.30	-0.30
3	2,734	224,593	227,332	68,200	1,300	156,967	-155,667	-0.30	-0.35
4	176	62,785	62,961	18,888	10	54,655	-54,644	-0.30	-0.35
2CH	215	1,830	2,044	613	5	1,063	-1,058	-0.30	-0.30
3CH	265	9,087	9,352	2,806	26	10,609	-10,582	-0.30	-0.30
4CH	203	8,485	8,688	2,606	15	10,312	-10,297	-0.30	-0.30
5	0	25,139	25,139	7,542	0	34,918	-34,918	-0.30	-0.30
6	369	244,305	244,674	73,402	41	283,467	-283,425	-0.30	-0.35
7	0	32,502	32,502	9,751	0	38,844	-38,844	-0.30	-0.30
2P	23,349	4,125	27,518	8,256	49,350	2,351	46,999	-0.30	-0.30
8	0	8,000	8,000	2,400	0	6,305	-6,305	-0.30	-0.30
9	3,775	202,536	206,313	61,895	798	173,370	-172,572	-0.30	-0.35
totals:			**1,272,093**	**381,830**	**174,550**	**967,439**	**-792,890**		

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VILLAGE OF RICHMOND
CUT & FILL OPTION 3
SLAB ON GRADE UNITS
CITY OF OTTAWA

LEGEND

2.25 / 2.00 CUT/FILL CONTOUR

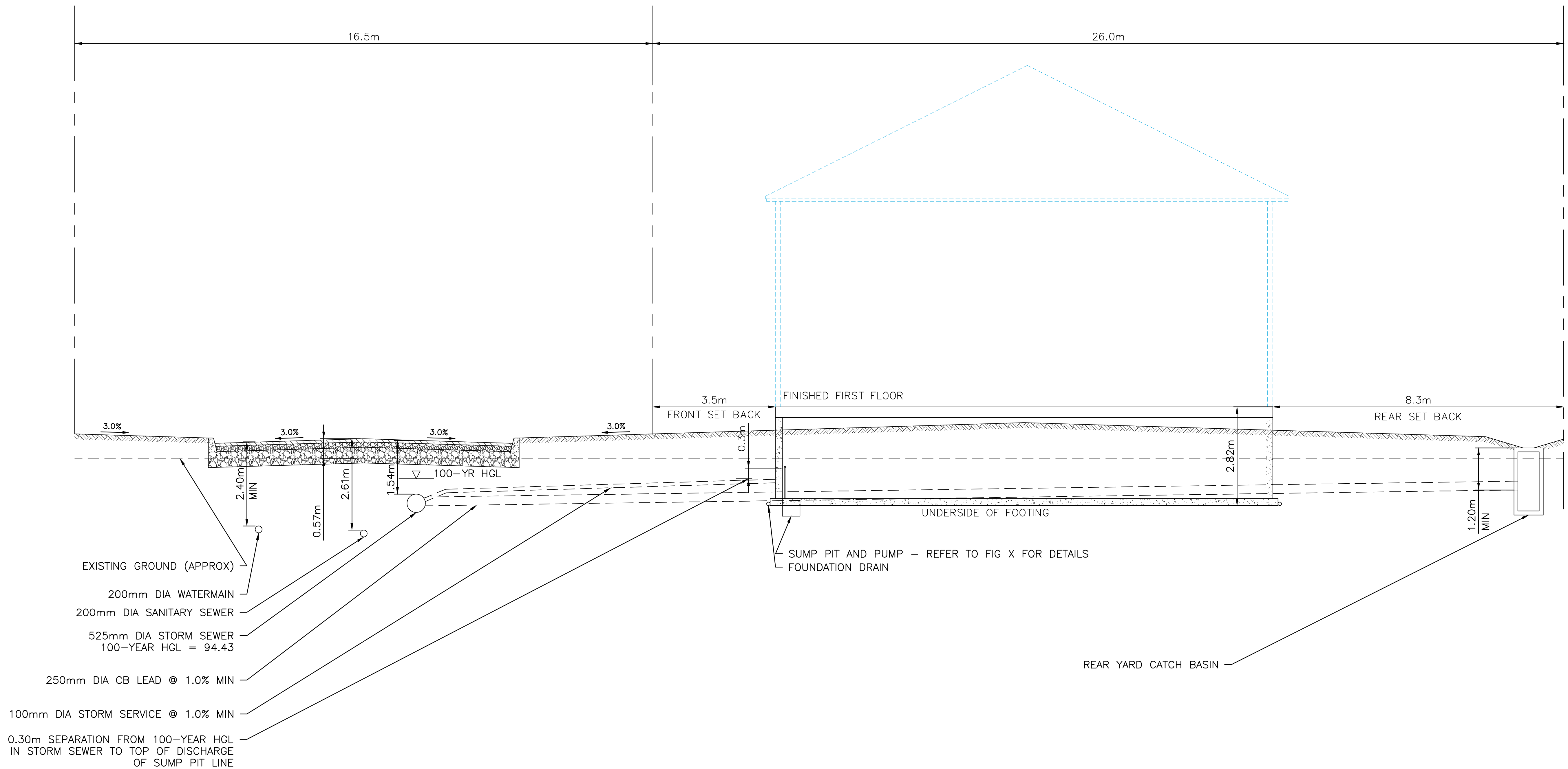
PROJECT No.: 11-468

DATE: NOVEMBER 2013

DRAWN BY: KM / ADF

SCALE: 1:7,500

FIGURE: 16



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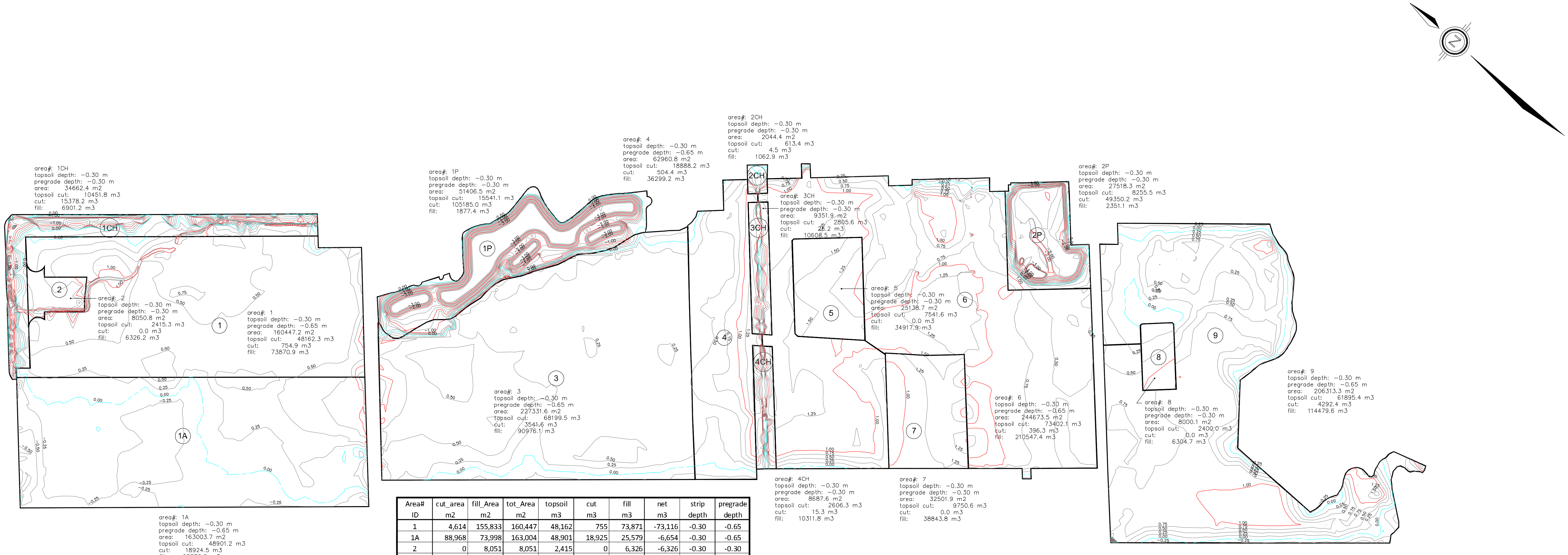
FOUNDATION SERVICE TO STORM SEWER - SUMP PUMP

DATE: APRIL 2012
SCALE: 1:125
PROJECT No.: 11-467
FIGURE 17



Area# ID	cut_area m2	fill_Area m2	tot_Area m2	topsoil m3	cut m3	fill m3	net m3	strip depth	pregrade depth
1	4,614	155,833	160,447	48,162	755	73,871	-73,116	-0.30	-0.65
1A	88,968	73,998	163,004	48,901	18,925	25,579	-6,654	-0.30	-0.65
2	0	8,051	8,051	2,415	0	6,326	-6,326	-0.30	-0.30
1CH	19,228	15,434	34,662	10,452	15,378	6,901	8,477	-0.30	-0.30
1P	46,517	4,865	51,407	15,541	105,185	1,877	103,308	-0.30	-0.30
3	12,908	214,417	227,332	68,200	3,542	90,976	-87,435	-0.30	-0.65
4	2,923	60,038	62,961	18,888	504	36,299	-35,795	-0.30	-0.65
2CH	215	1,830	2,044	613	5	1,063	-1,058	-0.30	-0.30
3CH	265	9,087	9,352	2,806	26	10,609	-10,582	-0.30	-0.30
4CH	203	8,485	8,688	2,606	15	10,312	-10,297	-0.30	-0.30
5	0	25,139	25,139	7,542	0	34,918	-34,918	-0.30	-0.30
6	2,137	242,526	244,674	73,402	396	210,547	-210,151	-0.30	-0.65
7	0	32,502	32,502	9,751	0	38,844	-38,844	-0.30	-0.30
2P	23,349	4,125	27,518	8,256	49,350	2,351	46,999	-0.30	-0.30
8	0	8,000	8,000	2,400	0	6,305	-6,305	-0.30	-0.30
9	21,481	184,793	206,313	61,895	4,292	114,480	-110,187	-0.30	-0.65
totals:			**1,272,093**	**381,830**	**198,374**	**671,257**	**-472,884**		

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VILLAGE OF RICHMOND
CUT & FILL OPTION 4
FOUNDATION DRAINAGE - SUMP PUMPS
CITY OF OTTAWA

LEGEND

2.25 / 2.00 CUT/FILL CONTOUR

PROJECT No.: 11-468
DATE: NOVEMBER 2013
DRAWN BY: KM / ADF
SCALE: 1:7,500
FIGURE: 19

Richmond Village (South) Limited
Option 1

Stage 1 Estimate
Cost Summary

			Unit	Approx. Qty.	Unit Rate	Estimated Value
A	**Site Preparation**					
	A.1	Strip and Stockpile Top Soil	m^3	381,830	$ 6.00	$ 2,291,000.00
	A.2	Site Grading - Cut to Fill	m^3	156,660	$ 6.00	$ 940,000.00
	A.3	Import Fill	m^3	1,390,491	$ 18.00	$ 25,029,000.00
	A.4	Re-use top soil as fill	m^3	229,098	$ 6.00	$ 1,375,000.00
	A.5	Engineered fill required	m^3	286,910	$ 25.00	$ 7,173,000.00
	A.6	Estimated Total Surcharge Fill	m^3	720,000	$ 18.00	$ 12,960,000.00
	A.7	Move surcharge fill	m^3	1,080,000	$ 6.00	$ 6,480,000.00
	A.8	Export Surcharge Material	m^3	540,000	$ 12.00	$ 6,480,000.00
					Sub-Total Subsection A	$ 62,728,000.00
B	**Stormwater Conveyance**					
	B.1	Local Storm Sewer	m	8,890.0	$ 445.00	$ 3,956,000.00
	B.2	Trunk Storm Sewers	m	9,225.0	$ 900.00	$ 8,303,000.00
					Sub-Total Subsection B	$ 12,259,000.00
					Estimated Capital Cost	**$ 74,987,000.00**
C	**Estimated Annual Maintenance Cost**					
	C.1	Local Storm Sewer - Flushing	m	8,890.0	$ 5.00	$ 44,000.00
	C.2	Trunk Storm Sewer - Flushing	m	9,225.0	$ 6.00	$ 55,000.00
					Estimated Life Cycle Cost	**$ 99,000.00**

Notes:
1) Import Fill required is net fill required less re-use top soil as fill.
2) Re-use top soil as fill assumes 60% of stripped and stock piled top soil is available for fill material.

Richmond Village (South) Limited
Option 2

Stage 1 Estimate
Cost Summary

			Unit	Approx. Qty.		Unit Rate		Estimated Value
A	**Site Preparation**							
	A.1	Strip and Stockpile Top Soil	m^3	381,830	$	6.00	$	2,291,000.00
	A.2	Site Grading - Cut to Fill	m^3	206,305	$	3.00	$	619,000.00
	A.3	Import Fill	m^3	184,455	$	18.00	$	3,320,000.00
	A.4	Re-use top soil as fill	m^3	229,098	$	6.00	$	1,375,000.00
	A.5	Engineered fill required	m^3		$	25.00	$	-
	A.6	Estimated Total Surcharge Fill	m^3		$	24.00	$	-
	A.7	Export Surcharge Material	m^3		$	12.00	$	-
						Sub-Total Subsection A	$	7,605,000.00
B	**Stormwater Conveyance**							
	B.1	Local Storm Sewer	m	8,890.0	$	445.00	$	3,956,000.00
	B.2	Trunk Storm Sewers	m	9,225.0	$	900.00	$	8,303,000.00
	B.3	Foundation Collector	m	17,850.0	$	300.00	$	5,355,000.00
	B.4	Lift Station	ea	1.0	$	5,000,000.00	$	5,000,000.00
						Sub-Total Subsection B	$	22,614,000.00
						Estimated Capital Cost	**$**	**30,219,000.00**
C	**Estimated Annual Maintenance Cost**							
	C.1	Local Storm Sewer - Flushing	m	8,890.0	$	5.00	$	44,000.00
	C.2	Trunk Storm Sewer - Flushing	m	9,225.0	$	6.00	$	55,000.00
	C.3	Foundation Collector - Flushing	m	17,850.0	$	5.00	$	89,000.00
	C.4	Lift Station Operation and Maintenance	m	1.0	$	100,000.00	$	100,000.00
						Estimated Life Cycle Cost	**$**	**288,000.00**

Notes:
1) Import Fill required is net fill required less re-use top soil as fill.
2) Re-use top soil as fill assumes 60% of stripped and stock piled top soil is available for fill material.

Richmond Village (South) Limited
Option 3

Stage 1 Estimate
Cost Summary

			Unit	Approx. Qty.	Unit Rate	Estimated Value
A	**Site Preparation**					
	A.1	Strip and Stockpile Top Soil	m^3	381,830	$ 6.00	$ 2,291,000.00
	A.2	Site Grading - Cut to Fill	m^3	175,550	$ 3.00	$ 527,000.00
	A.3	Import Fill	m^3	145,395	$ 18.00	$ 2,617,000.00
	A.4	Re-use top soil as fill	m^3	229,098	$ 6.00	$ 1,375,000.00
	A.5	Engineered fill required	m^3	418,398	$ 25.00	$ 10,460,000.00
	A.6	Estimated Total Surcharge Fill	m^3	-	$ 24.00	$ -
	A.7	Export Surcharge Material	m^3	-	$ 12.00	$ -
					Sub-Total Subsection A	$ 17,270,000.00
B	**Stormwater Conveyance**					
	B.1	Local Storm Sewer	m	8,890.0	$ 445.00	$ 3,956,000.00
	B.2	Trunk Storm Sewers	m	9,225.0	$ 900.00	$ 8,303,000.00
					Sub-Total Subsection B	$ 12,259,000.00
					Estimated Capital Cost	**$ 29,529,000.00**
C	**Estimated Annual Maintenance Cost**					
	C.1	Local Storm Sewer - Flushing	m	8,890.0	$ 5.00	$ 44,000.00
	C.2	Trunk Storm Sewer - Flushing	m	9,225.0	$ 6.00	$ 55,000.00
					Estimated Life Cycle Cost	**$ 99,000.00**

Notes:
1) Import Fill required is net fill required less re-use top soil as fill.
2) Re-use top soil as fill assumes 60% of stripped and stock piled top soil is available for fill material.
3) Slab on grade units require engineered fill (Granular materials) when FFE is above existing grade. IE where pregrade is 1.0m
4) Approximately 186m3 of fill required for units with USF's above existing grade

Richmond Village (South) Limited
Option 4

Stage 1 Estimate
Cost Summary

			Unit	Approx. Qty.		Unit Rate		Estimated Value
A	**Site Preparation**							
	A.1	Strip and Stockpile Top Soil	m^3	381,830	$	6.00	$	2,291,000.00
	A.2	Site Grading - Cut to Fill	m^3	198,374	$	3.00	$	595,000.00
	A.3	Import Fill	m^3	442,159	$	18.00	$	7,959,000.00
	A.4	Re-use top soil as fill	m^3	229,098	$	6.00	$	1,375,000.00
	A.5	Engineered fill required	m^3		$	25.00	$	-
	A.6	Estimated Total Surcharge Fill	m^3		$	24.00	$	-
	A.7	Export Surcharge Material	m^3		$	12.00	$	-
					Sub-Total Subsection A		$	12,220,000.00
B	**Stormwater Conveyance**							
	B.1	Local Storm Sewer	m	8,890.0	$	445.00	$	3,956,000.00
	B.2	Trunk Storm Sewers	m	9,225.0	$	900.00	$	8,303,000.00
	B.3	Sump pump assembly	ea	2,300.0	$	916.00	$	2,107,000.00
					Sub-Total Subsection B		$	14,366,000.00
					Estimated Capital Cost		**$**	**26,586,000.00**
C	**Estimated Annual Maintenance Cost**							
	C.1	Local Storm Sewer - Flushing	m	8,890.0	$	5.00	$	44,000.00
	C.2	Trunk Storm Sewer - Flushing	m	9,225.0	$	6.00	$	55,000.00
					Estimated Life Cycle Cost		**$**	**99,000.00**

Notes:
1) Import Fill required is net fill required less re-use top soil as fill.
2) Re-use top soil as fill assumes 60% of stripped and stock piled top soil is available for fill material.
3) Sump pump assembly per list price for the following:
   $436 - Hydromatic CSS-3D Sump basin package
   $360 - Hydromatic G-100A Battery backup sump pump
   $120 - Deep cycle marine-type battery (Group 24)

APPENDIX H

Rational Method Calculation Sheet

STORM SEWER CALCULATION SHEET (RATIONAL METHOD)

Local Roads Return Frequency = 2 years
Collector Roads Return Frequency = 5 years
Arterial Roads Return Frequency = 10 years

Manning 0.013

Ottawa

LOCATION: Location	From Node	To Node	AREA (Ha) 2 YEAR: AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	5 YEAR: AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	10 YEAR: AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	100 YEAR: AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	FLOW: Time of Conc. (min)	Intensity 2 Year (mm/h)	Intensity 5 Year (mm/h)	Intensity 10 Year (mm/h)	Intensity 100 Year (mm/h)	Peak Flow Q (l/s)	SEWER DATA: DIA. (mm) (actual)	DIA. (mm) (nominal)	TYPE	SLOPE (%)	LENGTH (m)	CAPACITY (l/s)	VELOCITY (m/s)	TIME OF FLOW (min)	RATIO Q/Q full
TRUNK 02																																	
	204	205	1.04	0.70	2.02	2.02			0.00	0.00			0.00	0.00			0.00	0.00	10.00	76.81	104.19	122.14	178.56	155	600	600	CONC	0.14	111.0	229.7421	0.8125	2.2768	0.677
	205	207	0.44	0.70	0.86	2.88			0.00	0.00			0.00	0.00			0.00	0.00	12.28	69.04	93.53	109.59	160.12	199	675	675	CONC	0.12	65.0	291.1883	0.8137	1.3313	0.683
	207	209	0.32	0.70	0.62	3.50			0.00	0.00			0.00	0.00			0.00	0.00	13.61	65.26	88.34	103.48	151.15	229	750	750	CONC	0.11	41.5	369.2322	0.8358	0.8276	0.619
			0.21	0.70	0.41	3.91			0.00	0.00			0.00	0.00			0.00	0.00															
	209	211	0.41	0.70	0.80	4.71			0.00	0.00			0.00	0.00			0.00	0.00	14.44	63.13	85.43	100.05	146.12	297	825	825	CONC	0.10	78.0	453.9246	0.8492	1.5309	0.655
					0.00	4.71	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	15.95														
	211	219	2.63	0.70	5.12	9.83			0.00	0.00			0.00	0.00			0.00	0.00	15.97	59.58	80.56	94.33	137.72	585	1050	1050	CONC	0.10	70.0	863.5311	0.9973	1.1699	0.678
					0.00	9.83	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	16.45														
	219	222	3.36	0.70	6.54	16.37			0.00	0.00			0.00	0.00			0.00	0.00	17.14	57.15	77.23	90.42	131.99	935	1200	1200	CONC	0.10	66.0	1232.8868	1.0901	1.0091	0.759
					0.00	16.37	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	12.72														
			0.54	0.70	1.05	17.42			0.00	0.00			0.00	0.00			0.00	0.00															
	222	224	1.52	0.70	2.96	20.37			0.00	0.00			0.00	0.00			0.00	0.00	18.15	55.22	74.60	87.32	127.45	1125	1200	1200	CONC	0.15	78.0	1509.9717	1.3351	0.9737	0.745
	224	225			0.00	20.37			0.00	0.00			0.00	0.00			0.00	0.00	19.12	53.49	72.25	84.55	123.39	1090	1200	1200	CONC	0.14	37.5	1458.7713	1.2898	0.4846	0.747
	225	HW			0.00	20.37			0.00	0.00			0.00	0.00			0.00	0.00	19.60	52.68	71.13	83.25	121.47	1073	1200	1200	CONC	0.14	17.5	1458.7713	1.2898	0.2261	0.736
TRUNK 03																																	
					0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00						900									
					0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00						1253									
	301	302			0.00	0.00	0.41	0.70	0.80	0.80			0.00	0.00			0.00	0.00	10.00	76.81	104.19	122.14	178.56	2236	1500	1500	CONC	0.18	119.0	2999.0668	1.6971	1.1686	0.746
	302	303			0.00	0.00	0.49	0.70	0.95	1.75			0.00	0.00			0.00	0.00	11.17	72.59	98.40	115.32	168.54	2325	1500	1500	CONC	0.20	96.5	3161.2940	1.7889	0.8990	0.736
	303	304			0.00	0.00	0.51	0.70	0.99	2.74			0.00	0.00			0.00	0.00	12.07	69.68	94.41	110.62	161.64	2412	1500	1500	CONC	0.21	96.5	3239.3624	1.8331	0.8774	0.745
	304	307			0.00	0.00	0.45	0.70	0.88	3.62			0.00	0.00			0.00	0.00	12.95	67.09	90.84	106.42	155.48	2482	1500	1500	CONC	0.22	96.5	3315.5931	1.8762	0.8572	0.749
					0.00	0.00	0.00	0.00	0.00	3.62			0.00	0.00			0.00	0.00	13.01														
	307	308			0.00	0.00	1.13	0.70	2.20	5.82			0.00	0.00			0.00	0.00	13.80	64.75	87.64	102.65	149.94	2663	1650	1650	CONC	0.16	70.0	3645.7793	1.7050	0.6842	0.730
	308	311	0.39	0.70	0.76	0.76			0.00	5.82			0.00	0.00			0.00	0.00	14.49	63.01	85.25	99.85	145.82	2697	1800	1800	CONC	0.10	74.5	3634.9621	1.4284	0.8692	0.742
	311	312	0.40	0.70	0.78	1.54			0.00	5.82			0.00	0.00			0.00	0.00	15.36	60.94	82.43	96.52	140.94	2726	1800	1800	CONC	0.10	70.0	3634.9621	1.4284	0.8167	0.750
	312	314	0.14	0.70	0.27	1.81			0.00	5.82			0.00	0.00			0.00	0.00	16.17	59.13	79.95	93.61	136.67	2725	1800	1800	CONC	0.10	38.5	3634.9621	1.4284	0.4492	0.750
	314	HW (Pond2)	0.35	0.70	0.68	2.49			0.00	5.82			0.00	0.00			0.00	0.00	16.62	58.19	78.66	92.09	134.44	2756	1800	1800	CONC	0.11	32.5	3812.3804	1.4982	0.3616	0.723
TRUNK 04																																	
	401	402	0.83	0.70	1.62	1.62			0.00	0.00			0.00	0.00			0.00	0.00	10.00	76.81	104.19	122.14	178.56	124	600	600	CONC	0.14	90.5	229.7421	0.8125	1.8563	0.540
	402	403	0.56	0.70	1.09	2.70			0.00	0.00			0.00	0.00			0.00	0.00	11.86	70.34	95.31	111.69	163.20	190	675	675	CONC	0.12	88.5	291.1883	0.8137	1.8127	0.653
	403	404	0.49	0.70	0.95	3.66			0.00	0.00			0.00	0.00			0.00	0.00	13.67	65.10	88.12	103.22	150.77	238	675	675	CONC	0.15	78.5	325.5584	0.9098	1.4381	0.732
	404	405	0.13	0.70	0.25	3.91			0.00	0.00			0.00	0.00			0.00	0.00	15.11	61.52	83.21	97.45	142.30	241	750	750	CONC	0.11	44.5	369.2322	0.8358	0.8874	0.652
	405	406	0.32	0.70	0.62	4.53			0.00	0.00			0.00	0.00			0.00	0.00	15.99	59.52	80.48	94.23	137.58	270	825	825	CONC	0.10	51.0	453.9246	0.8492	1.0010	0.594
	406	407	0.89	0.70	1.73	6.27			0.00	0.00			0.00	0.00			0.00	0.00	17.00	57.43	77.62	90.87	132.65	360	900	900	CONC	0.10	127.5	572.4707	0.8999	2.3615	0.629
	407	411	0.53	0.70	1.03	7.30			0.00	0.00			0.00	0.00			0.00	0.00	19.36	53.09	71.69	83.91	122.44	387	975	975	CONC	0.10	83.5	708.6833	0.9492	1.4662	0.547
					0.00	7.30	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	16.11														
	411	414	2.70	0.70	5.25	12.55			0.00	0.00			0.00	0.00			0.00	0.00	20.82	50.74	68.49	80.15	116.93	637	1050	1050	CONC	0.10	72.0	863.5311	0.9973	1.2033	0.738
					0.00	12.55	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	13.11														
	414	417	1.48	0.70	2.88	15.43			0.00	0.00			0.00	0.00			0.00	0.00	22.03	48.98	66.10	77.33	112.79	756	1200	1200	CONC	0.10	68.0	1232.8868	1.0901	1.0396	0.613
					0.00	15.43	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	13.22														
	417	420	1.34	0.70	2.61	18.04			0.00	0.00			0.00	0.00			0.00	0.00	23.07	47.57	64.17	75.07	109.48	858	1200	1200	CONC	0.10	72.0	1232.8868	1.0901	1.1008	0.696
					0.00	18.04	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	13.30														
	420	431	1.43	0.70	2.78	20.82			0.00	0.00			0.00	0.00			0.00	0.00	24.17	46.17	62.26	72.82	106.19	961	1350	1350	CONC	0.10	73.0	1687.8347	1.1792	1.0318	0.570
					0.00	20.82	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	19.10														
					0.00	20.82	0.41	0.40	0.46	0.46			0.00	0.00			0.00	0.00															
	431	432	3.80	0.70	7.39	28.22			0.00	0.46			0.00	0.00			0.00	0.00	25.20	44.94	60.58	70.85	103.30	1296	1350	1350	CONC	0.11	79.0	1770.2160	1.2367	1.0647	0.732
	432	444	0.74	0.70	1.44	29.66			0.00	0.46			0.00	0.00			0.00	0.00	26.26	43.74	58.95	68.94	100.50	1324	1350	1350	CONC	0.11	87.5	1770.2160	1.2367	1.1792	0.748
					0.00	29.66	0.00	0.00	0.00	0.46			0.00	0.00			0.00	0.00	16.36														
	444	445	3.74	0.70	7.28	36.94			0.00	0.46			0.00	0.00	0.96	0.70	1.87	1.87	27.44	42.49	57.26	66.95	97.59	1778	1500	1500	CONC	0.10	64.5	2235.3724	1.2650	0.8498	0.795
	445	446			0.00	36.94			0.00	0.46			0.00	0.00			0.00	1.87	28.29	41.64	56.10	65.60	95.60	1742	1500	1500	CONC	0.10	23.5	2235.3724	1.2650	0.3096	0.779
	446	447			0.00	36.94	0.96	0.70	1.87	2.32			0.00	0.00			0.00	1.87	28.60	41.34	55.69	65.12	94.90	1834	1500	1500	CONC	0.11	38.0	2344.4784	1.3267	0.4774	0.782
	447	448			0.00	36.94			0.00	2.32			0.00	0.00			0.00	1.87	29.08	40.89	55.08	64.39	93.84	1814	1500	1500	CONC	0.11	44.5	2344.4784	1.3267	0.5590	0.774
	448	449			0.00	36.94			0.00	2.32			0.00	0.00			0.00	1.87	29.64	40.37	54.37	63.57	92.63	1790	1500	1500	CONC	0.11	18.0	2344.4784	1.3267	0.2261	0.764
	449	HW (Pond2)			0.00	36.94			0.00	2.32			0.00	0.00			0.00	1.87	29.86	40.17	54.09	63.24	92.15	1781	1500	1500	CONC	0.11	15.5	2344.4784	1.3267	0.1947	0.760

Definitions:
Q = 2.78 AIR, where
Q = Peak Flow in Litres per second (L/s)
A = Areas in hectares (ha)
I = Rainfall Intensity (mm/h)
R = Runoff Coefficient

Notes:
1) Ottawa Rainfall-Intensity Curve
2) Min. Velocity = 0.80 m/s

LICENSED PROFESSIONAL ENGINEER
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100167932
01/10/20
PROVINCE OF ONTARIO

Designed: AK	PROJECT: WESTERN DEVELOPMENT LANDS		
Checked: WL	LOCATION: City of Ottawa		
Dwg. Reference: Dwg 3	File Ref: 17-977	Date: Oct 2019	Sheet No. SHEET 1 OF 4

977_STM.xlsx

STORM SEWER CALCULATION SHEET (RATIONAL METHOD)

Local Roads Return Frequency = 2 years
Collector Roads Return Frequency = 5 years
Arterial Roads Return Frequency = 10 years

Manning 0.013

Ottawa

LOCATION			AREA (Ha) 2 YEAR				5 YEAR				10 YEAR				100 YEAR				FLOW						SEWER DATA								
Location	From Node	To Node	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	Time of Conc. (min)	Intensity 2 Year (mm/h)	Intensity 5 Year (mm/h)	Intensity 10 Year (mm/h)	Intensity 100 Year (mm/h)	Peak Flow Q (l/s)	DIA. (mm) (actual)	DIA. (mm) (nominal)	TYPE	SLOPE (%)	LENGTH (m)	CAPACITY (l/s)	VELOCITY (m/s)	TIME OF FLOW (min)	RATIO Q/Q full
POND 2 OUTLET																																	
	1000	1001																						2094	1500	1500	CONC	0.10	53.5	2235.3724	1.2650	0.7049	0.937
	1001	1002																						2094	1500	1500	CONC	0.14	119.0	2644.9283	1.4967	1.3251	0.792
	1002	1003																						2094	1500	1500	CONC	0.10	118.0	2235.3724	1.2650	1.5547	0.937
	1003	1004																						2094	1500	1500	CONC	0.10	113.5	2235.3724	1.2650	1.4954	0.937
	1004	HW																						2094	1500	1500	CONC	0.10	30.5	2235.3724	1.2650	0.4019	0.937
TRUNK 01																																	
			0.14	0.70	0.27	0.27			0.00	0.00			0.00	0.00			0.00	0.00															
	101	102	0.58	0.75	1.21	1.48			0.00	0.00			0.00	0.00			0.00	0.00	10.00	76.81	104.19	122.14	178.56	114	600	600	CONC	0.14	95.5	229.7421	0.8125	1.9589	0.495
			0.19	0.70	0.37	1.85			0.00	0.00			0.00	0.00			0.00	0.00															
	102	103	0.48	0.75	1.00	2.85			0.00	0.00			0.00	0.00			0.00	0.00	11.96	70.02	94.87	111.17	162.44	200	675	675	CONC	0.12	83.5	291.1883	0.8137	1.7102	0.686
	103	106	0.28	0.75	0.58	3.44			0.00	0.00			0.00	0.00			0.00	0.00	13.67	65.10	88.12	103.22	150.77	224	750	750	CONC	0.11	40.0	369.2322	0.8358	0.7977	0.606
					0.00	3.44	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	13.29														
	106	109	0.91	0.75	1.90	5.33			0.00	0.00			0.00	0.00			0.00	0.00	14.47	63.06	85.32	99.93	145.94	336	825	825	CONC	0.10	45.0	453.9246	0.8492	0.8832	0.741
					0.00	5.33	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	12.62														
	109	111	0.57	0.75	1.19	6.52			0.00	0.00			0.00	0.00			0.00	0.00	15.35	60.95	82.44	96.54	140.97	398	900	900	CONC	0.10	78.0	572.4707	0.8999	1.4447	0.694
					0.00	6.52	0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00	11.37														
	111	112			0.00	6.52	1.07	0.70	2.08	2.08			0.00	0.00			0.00	0.00	16.79	57.83	78.17	91.52	133.61	540	1050	1050	CONC	0.10	98.5	863.5311	0.9973	1.6462	0.625
					0.00	6.52	0.61	0.70	1.19	3.27			0.00	0.00			0.00	0.00															
	112	113			0.00	6.52	3.59	0.40	3.99	7.26			0.00	0.00			0.00	0.00	18.44	54.68	73.87	86.46	126.19	893	1200	1200	CONC	0.10	129.0	1232.8868	1.0901	1.9723	0.724
	113	114			0.00	6.52	0.31	0.70	0.60	7.86			0.00	0.00			0.00	0.00	20.41	51.38	69.36	81.16	118.41	881	1200	1200	CONC	0.10	78.5	1232.8868	1.0901	1.2002	0.714
					0.00	6.52	0.33	0.70	0.64	8.51			0.00	0.00			0.00	0.00															
	114	122			0.00	6.52	2.63	0.75	5.48	13.99			0.00	0.00			0.00	0.00	21.61	49.57	66.90	78.27	114.18	1259	1350	1350	CONC	0.10	80.0	1687.8347	1.1792	1.1307	0.746
					0.00	6.52	0.00	0.00	0.00	13.99			0.00	0.00			0.00	0.00	21.78														
					0.00	6.52	0.24	0.70	0.47	14.46			0.00	0.00			0.00	0.00															
	122	126			0.00	6.52	3.91	0.70	7.61	22.07			0.00	0.00			0.00	0.00	22.74	48.00	64.75	75.75	110.48	1742	1350	1350	CONC	0.17	122.0	2200.6672	1.5374	1.3225	0.792
					0.00	6.52	0.00	0.00	0.00	22.07			0.00	0.00			0.00	0.00	14.61														
	126	127	2.09	0.70	4.07	10.59			0.00	22.07			0.00	0.00			0.00	0.00	24.07	46.29	62.43	73.02	106.48	1868	1500	1500	CONC	0.11	91.5	2344.4784	1.3267	1.1495	0.797
	127	130	0.65	0.70	1.26	11.85			0.00	22.07			0.00	0.00			0.00	0.00	25.22	44.92	60.55	70.82	103.26	1869	1500	1500	CONC	0.11	91.5	2344.4784	1.3267	1.1495	0.797
					0.00	11.85	0.00	0.00	0.00	22.07			0.00	0.00			0.00	0.00	13.65														
	130	138	1.46	0.70	2.84	14.70			0.00	22.07			0.00	0.00			0.00	0.00	26.37	43.63	58.80	68.76	100.24	1939	1650	1650	CONC	0.10	64.5	2882.2416	1.3479	0.7975	0.673
					0.00	14.70	0.00	0.00	0.00	22.07			0.00	0.00			0.00	0.00	19.32														
	138	139	2.77	0.70	5.39	20.09			0.00	22.07			0.00	0.00			0.00	0.00	27.16	42.78	57.65	67.41	98.26	2131	1650	1650	CONC	0.10	50.0	2882.2416	1.3479	0.6182	0.739
	139	Plug			0.00	20.09			0.00	22.07			0.00	0.00			0.00	0.00	27.78	42.15	56.79	66.40	96.79	2100	1650	1650	CONC	0.10	14.0	2882.2416	1.3479	0.1731	0.728
	Plug	140			0.00	20.09			0.00	22.07			0.00	0.00			0.00	0.00	27.95	41.98	56.55	66.13	96.38	2091	1650	1650	CONC	0.11	43.5	3022.9205	1.4137	0.5128	0.692
	140	141			0.00	20.09			0.00	22.07			0.00	0.00			0.00	0.00	28.47	41.47	55.87	65.32	95.20	2066	1650	1650	CONC	0.11	41.5	3022.9205	1.4137	0.4892	0.683
	141	HW (Pond1)			0.00	20.09			0.00	22.07			0.00	0.00			0.00	0.00	28.96	41.00	55.23	64.58	94.11	2042	1650	1650	CONC	0.19	38.0	3972.8959	1.8580	0.3409	0.514
TRUNK 101																																	
			0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00			0.00	0.00	11.15														
	307	308	0.59	0.65	1.07	1.07			0.00	0.00			0.00	0.00			0.00	0.00	11.15	72.67	98.51	115.45	168.73	77	450	450	CONC	0.20	13.0	127.5033	0.8017	0.2703	0.608
	308	311	0.43	0.65	0.78	1.84			0.00	0.00			0.00	0.00			0.00	0.00	11.42	71.77	97.27	113.98	166.58	132	600	600	CONC	0.15	65.0	237.8056	0.8411	1.2880	0.556
			0.00	0.00	0.00	1.84			0.00	0.00			0.00	0.00			0.00	0.00	11.60														
	311	312	0.80	0.65	1.45	3.29			0.00	0.00			0.00	0.00			0.00	0.00	12.70	67.78	91.79	107.54	157.12	223	675	675	CONC	0.15	71.0	325.5584	0.9098	1.3007	0.685
			0.35	0.65	0.63	3.92			0.00	0.00			0.00	0.00			0.00	0.00															
	312	315	0.52	0.65	0.94	4.86			0.00	0.00			0.00	0.00			0.00	0.00	14.00	64.22	86.92	101.81	148.70	312	675	675	CONC	0.25	102.0	420.2941	1.1745	1.4474	0.743
	315	318	1.31	0.65	2.37	7.23			0.00	0.00			0.00	0.00			0.00	0.00	15.45	60.72	82.13	96.17	140.42	439	750	750	CONC	0.25	81.0	556.6385	1.2600	1.0715	0.788
			0.00	0.00	0.00	7.23			0.00	0.00			0.00	0.00			0.00	0.00	13.55														
	318	270	1.25	0.65	2.26	9.49			0.00	0.00			0.00	0.00			0.00	0.00	16.52	58.39	78.94	92.42	134.92	554	825	825	CONC	0.25	58.5	717.7178	1.3426	0.7262	0.772
	270	271	0.50	0.65	0.90	10.39			0.00	0.00			0.00	0.00			0.00	0.00	17.25	56.92	76.93	90.06	131.46	591	900	900	CONC	0.20	81.5	809.5958	1.2726	1.0674	0.731
	271	273	0.25	0.65	0.45	10.84			0.00	0.00			0.00	0.00			0.00	0.00	18.32	54.91	74.18	86.82	126.71	595	900	900	CONC	0.30	75.5	991.5483	1.5586	0.8073	0.600
			0.00	0.00	0.00	10.84			0.00	0.00			0.00	0.00			0.00	0.00	11.11														
	273	275	0.58	0.65	1.05	11.89			0.00	0.00			0.00	0.00			0.00	0.00	19.12	53.48	72.23	84.54	123.37	636	900	900	CONC	0.20	33.0	809.5958	1.2726	0.4322	0.785
	275	276			0.00	11.89			0.00	0.00			0.00	0.00			0.00	0.00	19.56	52.76	71.24	83.37	121.65	627	900	900	CONC	0.20	29.5	809.5958	1.2726	0.3863	0.775
	276	277			0.00	11.89			0.00	0.00			0.00	0.00			0.00	0.00	19.94	52.12	70.38	82.36	120.17	620	900	900	CONC	0.20	15.5	809.5958	1.2726	0.2030	0.766
	277	278			0.00	11.89			0.00	0.00	0.87	0.65	1.57	1.57			0.00	0.00	20.15	51.80	69.93	81.84	119.40	745	975	975	CONC	0.20	112.5	1002.2295	1.3424	1.3968	0.743
	278	279			0.00	11.89			0.00	0.00			0.00	1.57			0.00	0.00	21.54	49.68	67.04	78.44	114.42	714	975	975	CONC	0.20	3.5	1002.2295	1.3424	0.0435	0.712
	279	HW (Pond 1)			0.00	11.89			0.00	0.00			0.00	1.57			0.00	0.00	21.59	49.61	66.95	78.33	114.27	713	975	975	CONC	0.20	32.5	1002.2295	1.3424	0.4035	0.711

LICENSED PROFESSIONAL ENGINEER
W. LIU
100167932
PROVINCE OF ONTARIO

Definitions:
Q = 2.78 AIR, where
Q = Peak Flow in Litres per second (L/s)
A = Areas in hectares (ha)
I = Rainfall Intensity (mm/h)
R = Runoff Coefficient

Notes:
1) Ottawa Rainfall-Intensity Curve
2) Min. Velocity = 0.80 m/s

Designed: AK	PROJECT:	WESTERN DEVELOPMENT LANDS	
Checked: WL	LOCATION:	City of Ottawa	
Dwg. Reference: Dwg 3	File Ref: 17-977	Date: Oct 2019	Sheet No. SHEET 2 OF 4

977_STM.xlsx

STORM SEWER CALCULATION SHEET (RATIONAL METHOD)

Local Roads Return Frequency = 2 years
Collector Roads Return Frequency = 5 years
Arterial Roads Return Frequency = 10 years

Manning 0.013

Ottawa

LOCATION			AREA (Ha) 2 YEAR				5 YEAR				10 YEAR				100 YEAR				FLOW						SEWER DATA								
Location	From Node	To Node	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	Time of Conc. (min)	Intensity 2 Year (mm/h)	Intensity 5 Year (mm/h)	Intensity 10 Year (mm/h)	Intensity 100 Year (mm/h)	Peak Flow Q (l/s)	DIA. (mm) (actual)	DIA. (mm) (nominal)	TYPE	SLOPE (%)	LENGTH (m)	CAPACITY (l/s)	VELOCITY (m/s)	TIME OF FLOW (min)	RATIO Q/Q full
TRUNK 104																																	
	261	262	1.06	0.65	1.92	1.92			0.00	0.00			0.00	0.00			0.00	0.00	10.00	76.81	104.19	122.14	178.56	147	675	675	CONC	0.15	97.5	325.5584	0.9098	1.7862	0.452
	262	263	0.99	0.65	1.79	3.70			0.00	0.00			0.00	0.00			0.00	0.00	11.79	70.57	95.62	112.04	163.73	261	825	825	CONC	0.10	119.0	453.9246	0.8492	2.3357	0.576
	263	264	0.68	0.65	1.23	4.93			0.00	0.00			0.00	0.00			0.00	0.00	14.12	63.92	86.51	101.32	147.98	315	900	900	CONC	0.10	107.0	572.4707	0.8999	1.9818	0.551
	264	265	0.60	0.65	1.08	6.02			0.00	0.00			0.00	0.00			0.00	0.00	16.10	59.28	80.15	93.85	137.02	357	900	900	CONC	0.10	40.5	572.4707	0.8999	0.7501	0.623
	265	266	1.81	0.65	3.27	9.29			0.00	0.00			0.00	0.00			0.00	0.00	16.85	57.71	78.01	91.33	133.32	536	1050	1050	CONC	0.10	30.0	863.5311	0.9973	0.5014	0.621
	266	267	2.68	0.65	4.84	14.13			0.00	0.00			0.00	0.00			0.00	0.00	17.36	56.72	76.65	89.73	130.97	801	1200	1200	CONC	0.10	99.0	1232.8868	1.0901	1.5136	0.650
	267	268	2.62	0.65	4.73	18.87			0.00	0.00			0.00	0.00			0.00	0.00	18.87	53.93	72.84	85.25	124.40	1017	1800x1200	1800x1200	CONC	0.10	45.5	2658.9616	1.2310	0.6160	0.383
	268	263			0.00	18.87			0.00	0.00			0.00	0.00			0.00	0.00	19.48	52.88	71.40	83.56	121.93	997	1800x1200	1800x1200	CONC	0.10	40.5	2658.9616	1.2310	0.5483	0.375
To TRUNK 102, Pipe 263 - 264						18.87				0.00				0.00				0.00	20.03														
TRUNK 109																																	
			0.00	0.00	0.00	0.00			0.00	0.00			0.00	0.00			0.00	0.00	12.54														
	301	321	1.91	0.65	3.45	3.45			0.00	0.00			0.00	0.00			0.00	0.00	12.54	68.26	92.45	108.32	158.25	236	675	675	CONC	0.15	88.0	325.5584	0.9098	1.6121	0.724
			0.00	0.00	0.00	3.45			0.00	0.00			0.00	0.00			0.00	0.00	11.11														
	321	322	0.85	0.65	1.54	4.99			0.00	0.00			0.00	0.00			0.00	0.00	14.15	63.84	86.40	101.20	147.80	318	825	825	CONC	0.10	68.0	453.9246	0.8492	1.3347	0.701
To TRUNK 102, Pipe 322 - 323						4.99				0.00				0.00				0.00	15.49														
TRUNK 110																																	
	251	252	0.86	0.65	1.55	1.55			0.00	0.00			0.00	0.00			0.00	0.00	10.00	76.81	104.19	122.14	178.56	119	675	675	CONC	0.15	70.5	325.5584	0.9098	1.2915	0.367
	252	253	0.42	0.65	0.76	2.31			0.00	0.00			0.00	0.00			0.00	0.00	11.29	72.18	97.83	114.65	167.56	167	750	750	CONC	0.15	70.5	431.1703	0.9760	1.2039	0.387
	253	320	2.80	0.65	5.06	7.37			0.00	0.00			0.00	0.00			0.00	0.00	12.50	68.39	92.63	108.53	158.57	504	1050	1050	CONC	0.10	76.5	863.5311	0.9973	1.2785	0.584
To TRUNK 102, Pipe 320 - 322						7.37				0.00				0.00				0.00	13.77														
TRUNK 102																																	
					0.00	0.00	1.14	0.65	2.06	2.06			0.00	0.00			0.00	0.00	10.00														
Contribution From TRUNK 110, Pipe 253 - 320						7.37				0.00				0.00				0.00	13.77														
	320	322			0.00	7.37	0.42	0.65	0.76	2.82			0.00	0.00			0.00	0.00	13.77	64.82	87.74	102.77	150.11	725	1050	1050	CONC	0.25	102.5	1365.3626	1.5768	1.0834	0.531
Contribution From TRUNK 109, Pipe 321 - 322						4.99				0.00				0.00				0.00	15.49														
	322	323			0.00	12.36	0.85	0.65	1.54	4.35			0.00	0.00			0.00	0.00	15.49	60.64	82.02	96.04	140.24	1107	1050	1050	CONC	0.30	32.0	1495.6798	1.7273	0.3088	0.740
	323	324			0.00	12.36	0.03	0.65	0.05	4.41			0.00	0.00			0.00	0.00	15.80	59.95	81.07	94.93	138.61	1098	1050	1050	CONC	0.30	10.5	1495.6798	1.7273	0.1013	0.734
	324	325			0.00	12.36	0.30	0.65	0.54	4.95			0.00	0.00			0.00	0.00	15.90	59.73	80.77	94.57	138.08	1138	1200	1200	CONC	0.15	37.5	1509.9717	1.3351	0.4681	0.754
	325	326			0.00	12.36	0.61	0.65	1.10	6.05			0.00	0.00			0.00	0.00	16.37	58.72	79.39	92.95	135.71	1206	1200	1200	CONC	0.20	11.5	1743.5652	1.5417	0.1243	0.692
	326	328			0.00	12.36			0.00	6.05			0.00	0.00			0.00	0.00	16.49	58.46	79.03	92.53	135.09	1201	1350	1350	CONC	0.10	72.0	1687.8347	1.1792	1.0177	0.712
					0.00	12.36	0.00	0.00	0.00	6.05			0.00	0.00			0.00	0.00	11.38														
	328	263			0.00	12.36	0.45	0.65	0.81	6.87			0.00	0.00			0.00	0.00	17.51	56.42	76.24	89.25	130.28	1221	1350	1350	CONC	0.10	65.5	1687.8347	1.1792	0.9258	0.723
Contribution From TRUNK 104, Pipe 2680 - 26300						18.87				0.00				0.00				0.00	20.03														
					0.00	31.22	0.00	0.00	0.00	6.87			0.00	0.00			0.00	0.00	13.52														
					0.00	31.22	0.28	0.65	0.51	7.37			0.00	0.00			0.00	0.00															
	263	264	0.46	0.65	0.83	32.06			0.00	7.37			0.00	0.00			0.00	0.00	20.03	51.98	70.18	82.13	119.83	2184	1500	1500	CONC	0.15	75.0	2737.7609	1.5493	0.8068	0.798
	264	265			0.00	32.06	0.87	0.65	1.57	8.94			0.00	0.00			0.00	0.00	20.84	50.72	68.46	80.11	116.87	2238	1500	1500	CONC	0.15	75.0	2737.7609	1.5493	0.8068	0.818
					0.00	32.06	0.00	0.00	0.00	8.94			0.00	0.00			0.00	0.00															
					0.00	32.06	0.23	0.65	0.42	9.36			0.00	0.00			0.00	0.00															
	265	266	2.95	0.65	5.33	37.39			0.00	9.36			0.00	0.00			0.00	0.00	21.65	49.52	66.83	78.19	114.06	2477	1500	1500	CONC	0.20	73.0	3161.2940	1.7889	0.6801	0.784
	266	267TEE			0.00	37.39			0.00	9.36	0.22	0.65	0.40	0.40			0.00	0.00	22.33	48.57	65.53	76.66	111.81	2460	1500	1500	CONC	0.20	69.5	3161.2940	1.7889	0.6475	0.778
	267TEE	HW (Pond1)			0.00	37.39			0.00	9.36			0.00	0.40			0.00	0.00	22.97	47.69	64.33	75.26	109.76	2415	1500	1500	CONC	0.20	39.5	3161.2940	1.7889	0.3680	0.764
TRUNK 103																																	
																								3186									
	2800	280			0.00	0.00			0.00	0.00	0.88	0.65	1.59	1.59			0.00	0.00	10.00	76.81	104.19	122.14	178.56	3380	1650	1650	CONC	0.15	112.0	3530.0106	1.6509	1.1307	0.903
	280	281TEE			0.00	0.00			0.00	0.00			0.00	1.59			0.00	0.00	11.13	72.72	98.58	115.53	168.84	3370	1650	1650	CONC	0.15	112.0	3530.0106	1.6509	1.1307	0.955
	281TEE	HW (Pond1)			0.00	0.00			0.00	0.00			0.00	1.59			0.00	0.00	12.26	69.09	93.59	109.66	160.23	3360	1650	1650	CONC	0.15	38.0	3530.0106	1.6509	0.3836	0.952
TRUNK 105																																	
	6	7	1.65	0.65	2.98	2.98			0.00	0.00			0.00	0.00			0.00	0.00	10.00	76.81	104.19	122.14	178.56	229	675	675	CONC	0.15	107.5	325.5584	0.9098	1.9694	0.703
	7	8	0.72	0.65	1.30	4.28			0.00	0.00			0.00	0.00			0.00	0.00	11.97	69.99	94.83	111.11	162.36	300	750	750	CONC	0.11	66.0	369.2322	0.8358	1.3162	0.812
			0.96	0.65	1.73	6.02			0.00	0.00			0.00	0.00			0.00	0.00															
	8	11			0.00	6.02			0.00	0.00			0.00	0.00			0.00	0.00	13.29	66.13	89.54	104.89	153.22	398	900	900	CONC	0.11	73.5	600.4123	0.9438	1.2980	0.663
	11	12			0.00	6.02	1.39	0.65	2.51	2.51			0.00	0.00			0.00	0.00	14.58	62.77	84.93	99.46	145.26	591	975	975	CONC	0.11	64.0	743.2733	0.9955	1.0715	0.795
	12	15	0.48	0.65	0.87	6.88			0.00	2.51			0.00	0.00			0.00	0.00	15.65	60.26	81.50	95.43	139.34	620	975	975	CONC	0.11	80.0	743.2733	0.9955	1.3393	0.834
To TRUNK 106, Pipe 15 - 104						6.88				2.51				0.00				0.00	16.99														

Definitions:
Q = 2.78 AIR, where
Q = Peak Flow in Litres per second (L/s)
A = Areas in hectares (ha)
I = Rainfall Intensity (mm/h)
R = Runoff Coefficient

Notes:
1) Ottawa Rainfall-Intensity Curve
2) Min. Velocity = 0.80 m/s

LICENSED PROFESSIONAL ENGINEER
W. LIU
100167932
Oct 10, 2019
PROVINCE OF ONTARIO

Designed: AK	PROJECT:	WESTERN DEVELOPMENT LANDS	
Checked: WL	LOCATION:	City of Ottawa	
Dwg. Reference: Dwg 3	File Ref: 17-977	Date: Oct 2019	Sheet No. SHEET 3 OF 4

STM.xlsx

STORM SEWER CALCULATION SHEET (RATIONAL METHOD)

Ottawa

Manning 0.013

Local Roads Return Frequency = 2 years
Collector Roads Return Frequency = 5 years
Arterial Roads Return Frequency = 10 years

LOCATION			AREA (Ha) 2 YEAR				5 YEAR				10 YEAR				100 YEAR				FLOW						SEWER DATA								
Location	From Node	To Node	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	AREA (Ha)	R	Indiv. 2.78 AC	Accum. 2.78 AC	Time of Conc. (min)	Intensity 2 Year (mm/h)	Intensity 5 Year (mm/h)	Intensity 10 Year (mm/h)	Intensity 100 Year (mm/h)	Peak Flow Q (l/s)	DIA. (mm) (actual)	DIA. (mm) (nominal)	TYPE	SLOPE (%)	LENGTH (m)	CAPACITY (l/s)	VELOCITY (m/s)	TIME OF FLOW (min)	RATIO Q/Q full
TRUNK 106																																	
	203	204	0.30	0.65	0.54	0.54			0.00	0.00			0.00	0.00			0.00	0.00	10.00	76.81	104.19	122.14	178.56	42	450	450	CONC	0.20	92.5	127.5033	0.8017	1.9230	0.327
	204	13	1.11	0.65	2.01	2.55			0.00	0.00			0.00	0.00			0.00	0.00	11.92	70.13	95.03	111.35	162.70	179	600	600	CONC	0.22	100.5	287.9969	1.0186	1.6444	0.620
	13	14	1.06	0.65	1.92	4.46			0.00	0.00			0.00	0.00			0.00	0.00	13.57	65.37	88.49	103.66	151.41	292	825	825	CONC	0.11	102.5	476.0801	0.8906	1.9182	0.613
	14	15			0.00	4.46			0.00	0.00			0.00	0.00			0.00	0.00	15.49	60.64	82.02	96.04	140.24	271	825	825	CONC	0.11	15.5	476.0801	0.8906	0.2901	0.569
Contribution From TRUNK 105, Pipe 12 - 15						6.88				2.51				0.00				0.00	16.99														
	15	104			0.00	11.35			0.00	2.51			0.00	0.00			0.00	0.00	16.99	57.43	77.62	90.87	132.66	847	1200	1200	CONC	0.11	13.5	1293.0625	1.1433	0.1968	0.655
	104	HW (Pond1)			0.00	11.35			0.00	2.51			0.00	0.00			0.00	0.00	17.19	57.04	77.09	90.24	131.73	841	1200	1200	CONC	0.11	55.5	1293.0625	1.1433	0.8090	0.650
TRUNK 107																																	
	205	210	0.48	0.65	0.87	0.87			0.00	0.00			0.00	0.00			0.00	0.00	10.00	76.81	104.19	122.14	178.56	67	450	450	CONC	0.20	75.0	127.5033	0.8017	1.5592	0.522
	210	211			0.00	0.87			0.00	0.00			0.00	0.00			0.00	0.00	11.56	71.30	96.62	113.22	165.46	62	450	450	CONC	0.20	11.5	127.5033	0.8017	0.2391	0.485
	211	209	0.40	0.65	0.72	1.59			0.00	0.00			0.00	0.00			0.00	0.00	11.80	70.53	95.57	111.98	163.64	112	525	525	CONC	0.20	66.5	192.3297	0.8885	1.2475	0.583
			0.00	0.00	0.00	1.59			0.00	0.00			0.00	0.00			0.00	0.00	10.97														
	209	212	0.55	0.65	0.99	2.58			0.00	0.00			0.00	0.00			0.00	0.00	13.05	66.80	90.45	105.96	154.80	173	600	600	CONC	0.15	56.5	237.8056	0.8411	1.1196	0.726
	212	20	0.59	0.65	1.07	3.65			0.00	0.00			0.00	0.00			0.00	0.00	14.17	63.81	86.35	101.14	147.72	233	675	675	CONC	0.15	69.5	325.5584	0.9098	1.2732	0.715
	20	21			0.00	3.65			0.00	0.00			0.00	0.00			0.00	0.00	15.44	60.75	82.17	96.22	140.49	222	675	675	CONC	0.15	77.0	325.5584	0.9098	1.4106	0.681
	21	22	0.99	0.65	1.79	5.44			0.00	0.00			0.00	0.00			0.00	0.00	16.85	57.72	78.02	91.34	133.35	314	825	825	CONC	0.11	64.5	476.0801	0.8906	1.2071	0.659
	22	23			0.00	5.44			0.00	0.00			0.00	0.00			0.00	0.00	18.06	55.38	74.83	87.59	127.84	301	825	825	CONC	0.11	19.5	476.0801	0.8906	0.3649	0.633
	23	105	1.96	0.65	3.54	8.98			0.00	0.00			0.00	0.00			0.00	0.00	18.42	54.72	73.92	86.52	126.27	491	900	900	CONC	0.11	26.5	600.4123	0.9438	0.4680	0.818
	105	106			0.00	8.98			0.00	0.00			0.00	0.00			0.00	0.00	18.89	53.89	72.79	85.19	124.32	484	900	900	CONC	0.11	62.5	600.4123	0.9438	1.1037	0.806
	106	108			0.00	8.98			0.00	0.00			0.00	0.00			0.00	0.00	19.99	52.04	70.27	82.23	119.98	467	900	900	CONC	0.11	69.5	600.4123	0.9438	1.2273	0.778
To TRUNK 108, Pipe 108 - 109						8.98				0.00				0.00				0.00	21.22														
TRUNK 108																																	
	217	218	0.45	0.65	0.81	0.81			0.00	0.00			0.00	0.00			0.00	0.00	10.00	76.81	104.19	122.14	178.56	62	450	450	CONC	0.20	115.5	127.5033	0.8017	2.4012	0.490
	218	219			0.00	0.81			0.00	0.00			0.00	0.00			0.00	0.00	12.40	68.67	93.02	108.98	159.23	56	450	450	CONC	0.20	11.5	127.5033	0.8017	0.2391	0.438
	219	220	0.54	0.65	0.98	1.79			0.00	0.00			0.00	0.00			0.00	0.00	12.40	68.67	93.02	108.98	159.23	123	525	525	CONC	0.20	66.5	192.3297	0.8885	1.2475	0.639
			0.00	0.00	0.00	1.79			0.00	0.00			0.00	0.00			0.00	0.00	13.96														
			0.13	0.65	0.23	2.02			0.00	0.00			0.00	0.00			0.00	0.00															
	220	221	1.25	0.65	2.26	4.28			0.00	0.00			0.00	0.00			0.00	0.00	13.96	64.32	87.06	101.97	148.94	275	675	675	CONC	0.20	66.0	375.9224	1.0505	1.0471	0.733
			0.00	0.00	0.00	4.28			0.00	0.00			0.00	0.00			0.00	0.00	10.84														
	221	222	0.97	0.65	1.75	6.04			0.00	0.00			0.00	0.00			0.00	0.00	15.01	61.74	83.52	97.81	142.83	373	750	750	CONC	0.20	119.0	497.8726	1.1270	1.7599	0.748
	222	223			0.00	6.04			0.00	0.00			0.00	0.00			0.00	0.00	16.77	57.88	78.24	91.60	133.72	349	825	825	CONC	0.15	13.5	555.9418	1.0400	0.2163	0.628
	223	25	0.76	0.65	1.37	7.41			0.00	0.00			0.00	0.00			0.00	0.00	16.99	57.44	77.64	90.89	132.68	426	900	900	CONC	0.19	68.5	789.0963	1.2404	0.9204	0.539
			0.65	0.65	1.17	8.58			0.00	0.00			0.00	0.00			0.00	0.00															
	25	26			0.00	8.58	1.07	0.65	1.93	1.93			0.00	0.00			0.00	0.00	17.91	55.66	75.20	88.03	128.48	623	1050	1050	PVC	0.11	75.0	905.6791	1.0459	1.1951	0.688
			0.81	0.65	1.46	10.05			0.00	1.93			0.00	0.00			0.00	0.00															
	26	27	0.95	0.65	1.72	11.76			0.00	1.93			0.00	0.00			0.00	0.00	19.10	53.52	72.28	84.60	123.45	769	1200	1200	PVC	0.11	81.0	1293.0625	1.1433	1.1808	0.595
	27	107	0.27	0.65	0.49	12.25			0.00	1.93			0.00	0.00			0.00	0.00	20.28	51.58	69.63	81.48	118.88	767	1200	1200	PVC	0.11	75.0	1293.0625	1.1433	1.0933	0.593
	107	1070			0.00	12.25			0.00	1.93			0.00	0.00			0.00	0.00	21.38	49.92	67.36	78.82	114.98	742	1200	1200	PVC	0.11	7.0	1293.0625	1.1433	0.1020	0.574
	1070	108	1.30	0.65	2.35	14.60			0.00	1.93			0.00	0.00			0.00	0.00	21.48	49.77	67.16	78.58	114.63	856	1200	1200	PVC	0.11	44.5	1293.0625	1.1433	0.6487	0.662
Contribution From TRUNK 107, Pipe 106 - 108						8.98				0.00				0.00				0.00	21.22														
	108	109			0.00	23.58			0.00	1.93			0.00	0.00			0.00	0.00	22.13	48.84	65.90	77.10	112.46	1279	1350	1350	PVC	0.11	10.5	1770.2160	1.2367	0.1415	0.723
	109	HW (Pond1)			0.00	23.58			0.00	1.93			0.00	0.00			0.00	0.00	22.27	48.64	65.63	76.79	112.00	1274	1350	1350	CONC	0.11	6.0	1770.2160	1.2367	0.0809	0.720

Definitions:
Q = 2.78 AIR, where
Q = Peak Flow in Litres per second (L/s)
A = Areas in hectares (ha)
I = Rainfall Intensity (mm/h)
R = Runoff Coefficient

Notes:
1) Ottawa Rainfall-Intensity Curve
2) Min. Velocity = 0.80 m/s

LICENSED PROFESSIONAL ENGINEER
W. LIU
100167932
Oct 10, 2019
PROVINCE OF ONTARIO

Designed: AK	PROJECT: WESTERN DEVELOPMENT LANDS		
Checked: WL	LOCATION: City of Ottawa		
Dwg. Reference: Dwg 3	File Ref: 17-977	Date: Oct 2019	Sheet No. SHEET 4 OF 4

APPENDIX I

JFSA Hydrologic / Hydraulic Modeling

J.F. Sabourin and Associates Inc.
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS

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Ottawa (Stittsville), ON K2S 1B9
TEL: (613) 836-3884
FAX: (613) 836-0332
WEB: www.jfsa.com

January 10, 2014

David Schaeffer Engineering Ltd.
120 Iber Road, Unit 203
Ottawa, Ontario K2S 1E9

Attention: **Kevin Murphy, P.Eng.**

Subject: **Richmond Village (South) Limited Subdivision / Preliminary Stormwater Management Plan** *our file: 922-11*

As requested by your office, we have evaluated, based on the provided information as described below; (i) the adequacy of the proposed minor system to convey the 5- and 100-year storm flows from within the development to the stormwater management (SWM) facilities; (ii) the capacity of the proposed major system to safely convey the excess 100-year flows to the SWM facilities; (iii) the operation of the proposed SWM facilities based on quality, erosion and quantity control requirements; and (iv) the hydraulic impact of the proposed subdivision and SWM facilities on the Van Gaal Drain.

The proposed Richmond Village (South) development consists of a 126.81 ha drainage area to be treated by two Stormwater Management (SWM) facilities; SWM Facility 1 (91.82 ha at 51% imperviousness) discharging to Van Gaal Drain, and SWM Facility 2 (34.99 ha at 51% imperviousness) discharging to the Jock River. It should be noted that excess major system flows from 36.63 ha, 30.79 ha, 21.75 ha and 2.65 ha of the Pond 1 subdivision area will discharge to Pond 1, to the Van Gaal Drain, to the Moore Drain Tributary, and to the Moore Drain, respectively. Additionally, of the undeveloped lands south of the proposed subdivision, 97.50 ha will drain through SWM Facility 1, 71.8 ha will drain through SWM Facility 2, and 94.2 ha will be conveyed through the subdivision by a tributary of the Moore Drain. Refer to Figures 1A and 1B of Attachment 1 for the existing and proposed subject site drainage areas, respectively.

SWM Facility 1 is a wet pond discharging to the Van Gaal Drain and requires quality, erosion and quantity control, and SWM Facility 2 is a wetland discharging to the Jock River and requires quality control only. Quality control will be provided for SWM Facilities 1 and 2 by permanent pools and 40 m^3/ha of active storage volume (released over 24 hours) in accordance with Ministry of the Environment enhanced protection requirements. Erosion control for SWM Facility 1 will be provided by controlling the 2-year release rate to 330 L/s or less, where 330 L/s is the erosion threshold for the Van Gaal Drain identifed by Parish Geomorphic in the *Natural Environment & Impact Assessment Study for the Mattamy Richmond Lands* (March 2009). Furthermore, the October 26, 2012 *Van Gaal Drain Erosion Assessment* memo by JTB Environmental Systems Inc. indicates that the 2-year outflows from SWM Facility 1 should discharge to the Van Gaal Drain at a velocity of 0.225 m/s or less. This may be achieved by a plunge pool or other velocity reduction measures at the SWM Facility 1 extended detention outlet pipe to the Van Gaal Drain. Quantity control will be provided for SWM Facility 1 to limit the 2- to 100-year release rates to pre-development levels.

The SWMHYMO program was used to simulate the major system flows and minor system inflows for the drainage area to the SWM facilities, to estimate the quantity control target release rates for SWM Facility 1 based on existing conditions, and to simulate proposed conditions flows on the Van Gaal Drain and Jock River. The XPSWMM program was used to model the conveyance of the minor system flows and the operation of the SWM facilities. The HEC-RAS program was used to simulate water levels on the Van Gaal Drain and Jock River. Refer to Attachment 2 for a schematic of the XPSWMM model; digital SWMHYMO, XPSWMM and HEC-RAS models are attached.

PROPOSED MINOR AND MAJOR SYSTEM DRAINAGE

The proposed minor and major system drainage routes are shown in plan view in Figure 1B of Attachment 1. The catchments shown in Figure 1B were divided into front yard / non-residential areas and rear yard areas for the SWMHYMO model, where rear yard areas are equal to approximately 37.5% of residential catchments based on a typical subdivision layout.

In accordance with City of Ottawa standards, the minor system has been designed to accommodate the 5-year post-development flows from within the site. For modelling purposes, minor system captures rates on front yard / non-residential areas were limited to 112% of the 5-year flows simulated in SWMHYMO, in order to account for additional flows captured by standard inlet control devices and catchbasins during the 100-year storm. In accordance with the potential design approach suggested in the October 2012 *City of Ottawa Sewer Design Guidelines*, 100% of the 100-year flows simulated in the rear yard areas are to be captured to the minor system. Additionally, 100% of the 100-year flows on Ottawa Street and Perth Street are to be captured to the minor system to prevent flows from crossing these roads.

The street segments within the proposed development are to be designed using a 'saw tooth' or 'sagged' road profile. The runoff from within front yard / non-residential areas will be conveyed to catchbasins located at low points on the street. Flows in excess of the minor system capture rate are temporarily stored within approximately 30 m^3/ha of surface storage and released slowly to the storm sewers and then, when that storage is surpassed, conveyed overland to the next downstream catchment. A 0.5% longitudinal slope, 3% road cross-slope and 3.5% shoulder cross-slope were assumed for the purposes of modelling the routing of major system flows along the main streets in the development. Road widths are as provided by DSEL. Refer to Table 1A of Attachment 2 for a summary of the subdivision drainage areas as modelled in SWMHYMO.

The proposed storm sewers will convey 100% of the 100-year flows generated on 97.5 ha of undeveloped lands south of the subject site to SWM Facility 1, and on 71.8 ha of undeveloped lands south of the subject site to SWM Facility 2. Total drainage areas through the subject site under existing and proposed conditions, including undeveloped lands and the proposed subdivision drainage areas, are summarized in Tables 1B and 1C of Attachment 2.

We understand that homes in the proposed subdivision are to be serviced by sump pumps. It is estimated that sump pumps will contribute approximately 0.23 L/s/ha of flow to the proposed storm sewer based on a average development density of approximately 27.8 lots/ha, where 50% of sump pumps are on at any given time, and a flow contribution of 1.44 m^3/day/lot per the October 3, 2012 *Updated Assessment of Subsurface Drainage and Analysis of 100 Year Flood Event - Proposed Village of Richmond Development* memo by Golder Associates Limited. Sump pump flows have been accounted for in evaluating the operations of the proposed minor system.

In addition to the standard City of Ottawa 3-hour Chicago and 24-hour SCS Type II design storms, the performances of the SWM facilities were also assessed for the 100-year 10-day spring snowmelt plus rainfall event based on AES Ottawa CDA snowmelt plus rainfall IDF curves. This is in keeping with the previous floodplain mapping studies for the Van Gaal Drain and the Jock River, where the spring snowmelt plus rainfall events resulted in the highest flows and water levels on the watercourses, both at and downstream of the SWM facility outfalls.

Several modifications were made to the drainage area characteristics in the spring SWMHYMO models in order to best represent spring conditions. An SCS curve number (CN) of 95 was selected for undeveloped lands to model the limited infiltration capacity of the frozen soils. Similarly, the Horton's minimum and maximum infiltration parameters for the sudivision drainage areas were set to 2.4 mm/hour; the lowest infiltration rate in the *SWMHYMO User's Manual* (May 2000, JFSA). Furthermore, it was assumed, according to generally accepted practice, that half of the volume in the snowmelt plus rainfall event may be attributed to snowmelt, and half to rainfall. As it is expected that most of the snow on impervious areas like roads, driveways and roofs would have melted prior to such an event, half of the impervious area was removed from each developed drainage area such that only the runoff resulting from rainfall, not snowmelt, is simulated for impervious areas.

The SWMHYMO and XPSWMM analyses, discussed in the next sections, demonstrate that it is possible for the proposed drainage systems for the development to control the excess flow during a 100-year storm and safely capture and convey the minor system flows to the SWM facility.

ASSUMPTIONS AND SOURCES OF DATA USED

The following parameters and assumptions used in the analysis are based on City of Ottawa standards and generally accepted stormwater management design guidelines.

- Stormwater Management Model:	*SWMHYMO (version 5.02), XPSWMM (version 10), HEC-RAS (version 4.1.0)*
- Minor System Design:	*1:5 year*
- Major System Design:	*1:100 year*
- Max. Allowable Flow Depth:	*30 cm above gutter.*
- Extent of Major System:	*Must be contained within the municipal right-of-way.*
- SWMHYMO Model Parameters:	*Fo = 76.2 mm/hr, Fc = 13.2 mm/hr, DCAY = 4.14/hr, D.Stor.Imp. = 1.57 mm, D.Stor.Per. = 4.67 mm (as per 2012 City of Ottawa Guidelines).*
- Undeveloped Area Characteristics:	*As per "Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond" (November 2009, JFSA).*
- Imperviousness:	*SWM Facilities: based on SWM block layout.* *Front Yard / Non-Residential: based on runoff coefficient (C) where Percent Imperviousness = (C - 0.2) / 0.7 x 100%.* *Rear Yard: equal to half of the front yard percent imperviousness. Half of that rear yard impervious area is assumed to be indirectly connected.*
- Design Storms:	*Chicago 3-hour and SCS Type II 24-hour design storms based on 2012 City of Ottawa Sewer Design Guidelines; maximum intensity averaged over 10 minutes.* *SCS Type II 24-hour design storms based on AES Ottawa CDA IDF curves; maximum intensity averaged over 10 minutes (for Jock River simulation only).* *10-day snowmelt plus rainfall events based on AES Ottawa CDA snowmelt plus rainfall IDF curves; maximum intensity averaged over 1 hour.*
- Historical Events:	*July 1st, 1979 event per 2012 City of Ottawa Sewer Design Guidelines.*
- Climate Change Street Test:	*20% increase in the 100-year, 3-hour Chicago and 100-year, 24-hour SCS storms, as per 2012 City of Ottawa Sewer Design Guidelines.*
- Manning's Roughness Coeff.:	*0.013 for concrete pipes (free flow).*
- Minor System Losses:	*Refer to Attachment 2 for manhole loss coefficients.*
- Sump Pump Flows:	*0.23 L/s/ha based on 27.8 lot/ha, 1.44 m^3/day/lot (per October 3, 2012 "Updated Assessment of Subsurface Drainage and Analysis of 100 Year Flood Event - Proposed Village of Richmond Development" memo by Golder Associates Limited), and 50% of sump pumps on.*
- Downstream HGL:	*Jock River water levels at SWM Facility 2 outlet as per "Jock River Flood Risk Mapping (within the City of Ottawa) Hydraulics Report" (November 2004, PSR Group Ltd. and JFSA).* *Van Gaal Drain water levels at SWM Facility 1 outlet as per HEC-RAS models from "Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond" (November 2009, JFSA) with proposed Fortune Street culvert improvements in place.*

MAJOR SYSTEM CONVEYANCE

As per City standards, the total 100-year depth of water (static and dynamic) on the street must be retained within the right-of-way and should not exceed 30 cm. Although static ponding depths are unknown at this stage of the design, the dynamic flow depths at a typical low point were estimated in SWMHYMO based on the excess major system flows in a front yard / non-residential catchment and an assumed longitudinal street slope of 0.15% from high point to high point. The results of this analysis are presented in Table 2A of Attachment 3 for the 100-year 3-hour Chicago storm. As may be seen in Attachment 3, the dynamic flow depths on all catchments are below 30 cm, allowing for some static ponding depth to be incorporated into the detailed design without exceeding City standards for total depth of water. In general, it may be concluded that it is possible to provide a total 100-year depth of water that is less than 30 cm and retained within the right-of-way, in accordance with City standards.

Table 2B of Attachment 3 presents the simulated dynamic flow depths for the development based on a 20% increase in the 100-year 3-hour Chicago storm, in accordance with the climate change stress test prescribed in the October 2012 *City of Ottawa Sewer Design Guidelines*. As shown in Table 2B, the maximum dynamic flow depth at a typical low point was estimated as approximately 28.6 cm under these conditions.

STORMWATER MANAGEMENT FACILITIES

As previously noted, 99.82 ha of the subdivision at 51% imperviousness are serviced by SWM Facility 1; and 34.99 ha at 51% imperviousness are serviced by SWM Facility 2. As previously noted, excess major system flows from 36.63 ha, 30.79 ha, 21.75 ha and 2.65 ha of the Pond 1 subdivision area will discharge to Pond 1, to the Van Gaal Drain, to the Moore Drain Tributary, and to the Moore Drain, respectively. Additionally, 97.5 ha of undeveloped lands to the south of the proposed subdivision will drain to SWM Facility 1, and 71.8 ha of undeveloped lands to the south of the proposed subdivision will drain to SWM Facility 2. Refer to Tables 3A and 3B of Attachment 4 for a summary of the proposed operating conditions for SWM Facilities 1 and 2, respectively. Major system outflows from the proposed subdivision to the Van Gaal Drain, Moore Drain Tributary and Moore Drain are also presented in Table 3A of Attachment 4.

The permanent pool volumes of SWM Facilities 1 and 2 are sufficient to provide an enhanced protection level (80% long-term suspended solids removal) according to Ministry of the Environment standards for wet ponds and wetlands, respectively. Active storage volumes of 40 m^3/ha minimum were also provided for quality control in SWM Facilities 1 and 2 and detained for approximately 24 hours. Drawdown time calculations for SWM Facilities 1 and 2 are presented in Tables 4A and 4B of Attachment 4.

Erosion control for SWM Facility 1 will be provided by controlling the 2-year release rate to 330 L/s or less, where 330 L/s is the erosion threshold for the Van Gaal Drain identifed by Parish Geomorphic in the *Natural Environment & Impact Assessment Study for the Mattamy Richmond Lands* (March 2009). Furthermore, the October 26, 2012 *Van Gaal Drain Erosion Assessment* memo by JTB Environmental Systems Inc. indicates that the 2-year outflows from SWM Facility 1 should discharge to the Van Gaal Drain at a velocity of 0.225 m/s or less. This may be achieved by a plunge pool or other velocity reduction measures at the SWM Facility 1 extended detention outlet pipe to the Van Gaal Drain. We understand that erosion control is not required for SWM Facility 2, which discharges to the Jock River.

Quantity control for SWM Facility 1 is to be provided by controlling post-development outflows to pre-development levels for the 2- to 100-year 24-hour SCS design storms, taking into account the uncontrolled major system flows to the Van Gaal Drain Moore Drain Tributary, and Moore Drain. Pre-development flows from the site were estimated in SWMHYMO based on the undeveloped drainage area characteristics presented in Figure 1A of Attachment 1 and Table 1B of Attachment 2. We understand that quantity control is not required for SWM Facility 2, which discharges to the Jock River; however, the 100-year release rate from SWM Facility 2 has been limited to a maximum of 2.235 m^3/s based on the capacity of the 1500 mm diameter (at 0.1% slope) outlet pipe to the Jock

River. Refer to Tables 5A and 5B of Attachment 4 for the outlet control design and stage-storage-discharge relationships for SWM Facilities 1 and 2, respectively.

The performances of the SWM facilities were analyzed in XPSWMM based on both free outfall and restrictive downstream conditions. Restrictive downstream conditions for the outlet of SWM Facility 2 to the Jock River are based on the *Jock River Flood Risk Mapping (within the City of Ottawa) Hydraulics Report* (November 2004, PSR Group Ltd. and JFSA). During the 100-year 10-day spring snowmelt plus rainfall event, the water level on the Jock River at the outlet of SWM Facility 2 (Jock River Lower Reach 2 cross-section 19353) is 94.18 m. During the 100-year 24-hour SCS design storm, the water level on the Jock River at this location is below the permanent pool elevation of SWM Facility 2 and therefore does not affect the operation of the SWM facility.

Restrictive downstream conditions for the outlet of SWM Facility 1 to the Van Gaal Drain are based on the existing conditions HEC-RAS models from *Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond* (November 2009, JFSA) with proposed Fortune Street culvert improvements in place. It is proposed that the width of the Fortune Street culvert on the Van Gaal Drain be increased from 4.2 m to 6.3 m. Under these conditions, the water level on the Van Gaal Drain at the outlet of SWM Facility 1 (Van Gaal Drain Reach 2 cross-section 961) is 93.68 m for the 100-year 24-hour SCS design storm and 94.11 m for the 100-year 10-day spring snowmelt plus rainfall event.

HYDRAULIC GRADELINE ANALYSIS

The minor system and hydraulic gradeline analysis was completed for the proposed systems discharging to SWM Facility 1 and 2 using the XPSWMM program based on the 100-year 3-hour Chicago and 100-year 24-hour SCS design storms, the 100-year 10-day spring snowmelt plus rainfall event and for the July 1st 1979 historical event. Attachment 5 summarizes the hydraulic simulation results for the proposed systems under restrictive downstream conditions. Note that the flowing full pipe velocities are not less than 0.8 m/s and no greater than 6.0 m/s for all proposed pipes. Also note that all manholes where the 100-year hydraulic gradeline is less than 0.5 m below the ground elevation are located within the pond block, and do not have storm sewer connections to buildings; therefore a high 100-year hydraulic gradeline at these locations will not have any negative impacts.

Attachment 5 also presents the hydraulic simulation results for the climate change stress test based on a 20% increase in the 100-year 3-hour Chicago and 100-year 24-hour SCS design storms, as per the October 2012 *City of Ottawa Sewer Design Guidelines*.

DOWNSTREAM HYDRAULIC IMPACTS

The impact of the proposed subdivision and SWM facility designs on the flows and flood levels on the downstream Van Gaal Drain was evaluated using the existing conditions SWMHYMO and HEC-RAS models from *Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond* (November 2009, JFSA). Note that summer flows on the Van Gaal Drain were generated using 24-hour SCS Type II design storms based on IDF curves provided in the October 2012 *City of Ottawa Sewer Design Guidelines*, while summer flows on the Jock River were generated using 24-hour SCS Type II design storms based on AES Ottawa CDA IDF curves, in accordance with the November 2009 *Floodplain Mapping Report*. Spring flows on both the Van Gaal Drain and the Jock River were generated using 10-day spring snowmelt plus rainfall events based on AES Ottawa CDA snowmelt plus rainfall IDF curves.

The SWMHYMO models from the November 2009 *Floodplain Mapping Report* were modified to include the proposed subdivision and SWM facility storage-discharge curves, as well as route reservoir commands to split major and minor system flows for those areas where major system flows drain directly to the adjacent watercourses, based on the minor system capture and major system storage data presented in Table 1A of Attachment 2. The resultant proposed conditions flows entered into the HEC-RAS models. The HEC-RAS models were also modified to include the proposed Fortune Street culvert improvements; as noted above, it is proposed that the width of the Fortune Street culvert on the Van Gaal Drain be increased from 4.2 m to 6.3 m.

As previously noted, 94.2 ha of undeveloped lands to the southwest of the proposed subdivision will be conveyed through the subject site by a tributary of the Moore Drain. The Moore Drain tributary is to be reconstructed in accordance with the channel profile and proposed culverts provided by DSEL. Furthermore, the Van Gaal Drain north of Perth Street, currently crossing through the proposed development lands, is to be realigned to follow the boundary of the subject site in accordance with the November 5, 2012 *Richmond Village Development / Proposed Realignment of Van Gaal Drain* memo by JFSA. The November 2009 SWMHYMO and HEC-RAS models have been modified to reflect these proposed conditions.

Attachment 6 presents a comparison of the existing and proposed conditions 100-year flows and water levels on the Van Gaal Drain. Three different scenarios are considered, as per the November 2009 report; (1) When the Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River; (2) When the Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River; and (4) When the Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain. Attachment 6 also includes descriptions of the flow change node locations in relation to the HEC-RAS models, SWMHYMO models, and nearby road crossings.

Existing and proposed conditions flows and water levels on the Van Gaal Drain during the 2-, 5-, 10- and 25-year events are summarized in Attachment 7.

Note that 100-year flows and water levels on the Van Gaal Drain generally decrease between existing and proposed conditions. This result is expected, as the provided release rates from SWM Facility 1 to the Van Gaal Drain are well below pre-development levels owing to the real-world limitations of the outlet controls. That is, the 45 m long quantity control weir for SWM Facility 1 is set 1.33 m above the permanent pool elevation at an invert of 93.68 m to match the 100-year 24-hour SCS water level on the Van Gaal Drain (per existing conditions with the Fortune Street culvert improvements in place). This results in minimal head over the quantity control weir and consequently lower release rates. Additionally, approximately 54.71 ha of land that currently drains to the Van Gaal Drain under existing conditions (area VG-7 and part of area VG-8, as shown in Figure 1A of Attachment 1 and described in Table 1B of Attachment 2) will be redirected to the Jock River through Pond 2 under proposed conditions, further reducing flows in the Van Gaal Drain.

As may be seen from Attachment 6, proposed conditions 100-year peak flows on the Van Gaal Drain, Moore Drain and Joy's Road Tributary are equal to or less than existing peak flows, and proposed conditions 100-year water levels are equal to or less than existing levels, except for minor 1 cm increases in water level at Van Gaal Drain cross-sections 3185 and 647, and a 10 cm increase at Van Gaal Drain cross-section 0 (owing to a difference in peak timing in relation to the Jock River for Scenario (1), and not to a true increase in flow). All of these increases take place during less critical events; that is, the increased proposed conditions water level is below the maximum existing conditions flood level of the three scenarios considered, which defines the Regulatory flood level. Note that proposed conditions 100-year water levels on the Moore Drain tributary though the subject site are higher than existing levels; this is not a concern since only the subject site is affected by this increase in water levels.

Yours truly,
J.F. Sabourin and Associates Inc.

L. Pipkins

Laura Pipkins, P.Eng.

LICENSED PROFESSIONAL ENGINEER
L. E. PIPKINS
100173786
PROVINCE OF ONTARIO

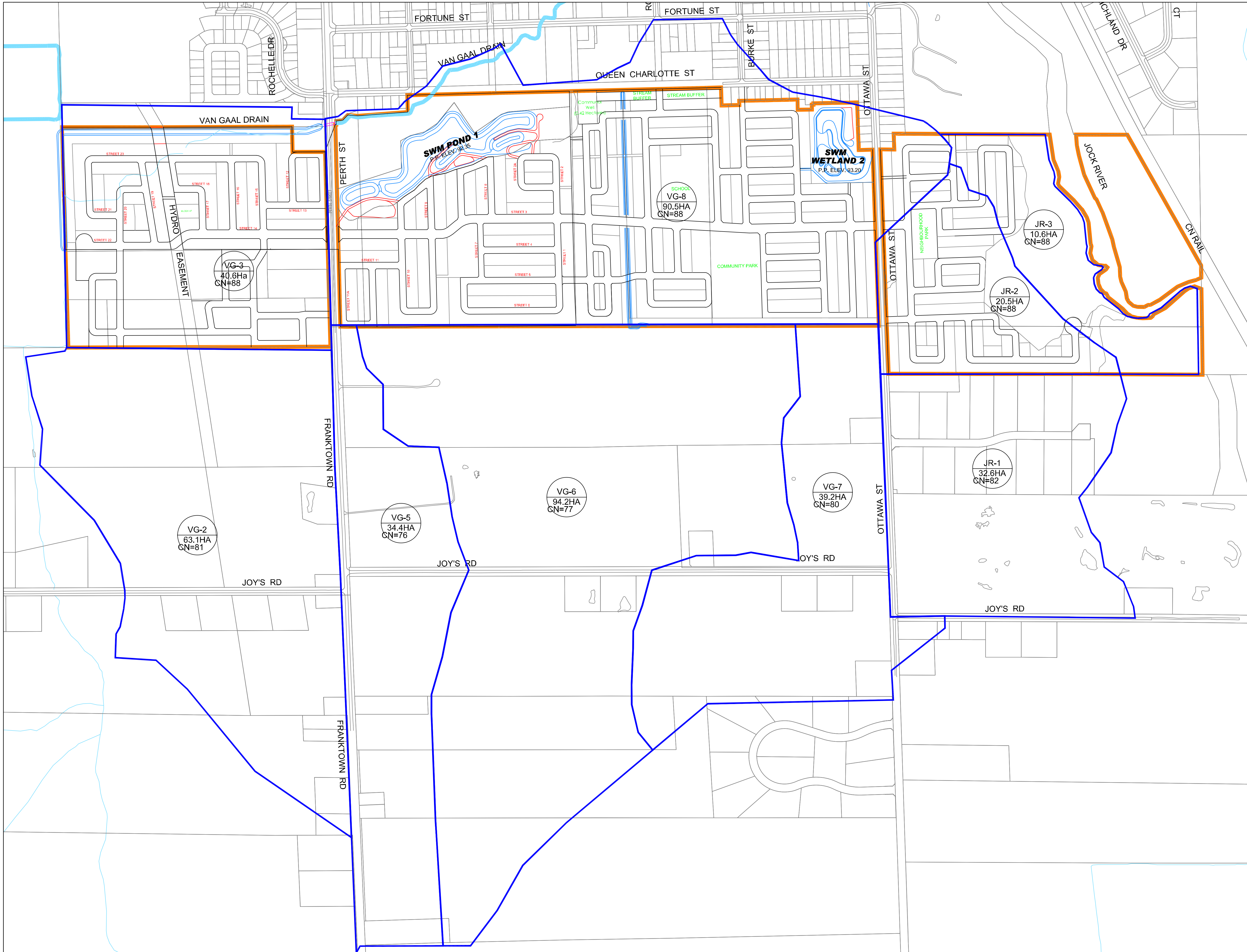
cc: J.F. Sabourin, M.Eng, P.Eng.
Director of Water Resources Projects

Attachment 1: Drainage Area to SWM Facilities
Attachment 2: Summary of Drainage Area to SWM Facilities; XPSWMM Model Schematic; and Minor System Loss Coefficients
Attachment 3: Major System Results
Attachment 4: SWM Facility Operating Conditions
Attachment 5: Pipe Data and Hydraulic Simulation Results
Attachment 6: 100-Year Flows and Water Levels on the Van Gaal Drain Under Existing and Proposed Conditions
Attachment 7: 2 to 25-Year Flows and Water Levels on the Van Gaal Drain Under Existing and Proposed Conditions

ATTACHMENT 1

DRAINAGE AREA TO SWM FACILITIES

JFSA Water Resources and Environmental Consultants



LEGEND :

SUBCATCHMENT BOUNDARY (PER DEC 2009 RICHMOND FLOODPLAIN STUDY)

JR-3 / 10.6HA / CN=88 — SUBCATCHMENT ID, SUBCATCHMENT AREA, CURVE NUMBER (CN)

SCALE :

0 100 200 300 400 500m

J.F. Sabourin & Associates Inc.
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS
OTTAWA (613) 836-3884
GATINEAU (819) 243-6858

CLIENT :

DSEL
david schaeffer engineering ltd
600 ALDEN ROAD., SUITE 500
MARKHAM, ONTARIO., L3R 0E7
(905) 475-3080

PROJECT :

RICHMOND VILLAGE (SOUTH) LIMITED SUBDIVISION

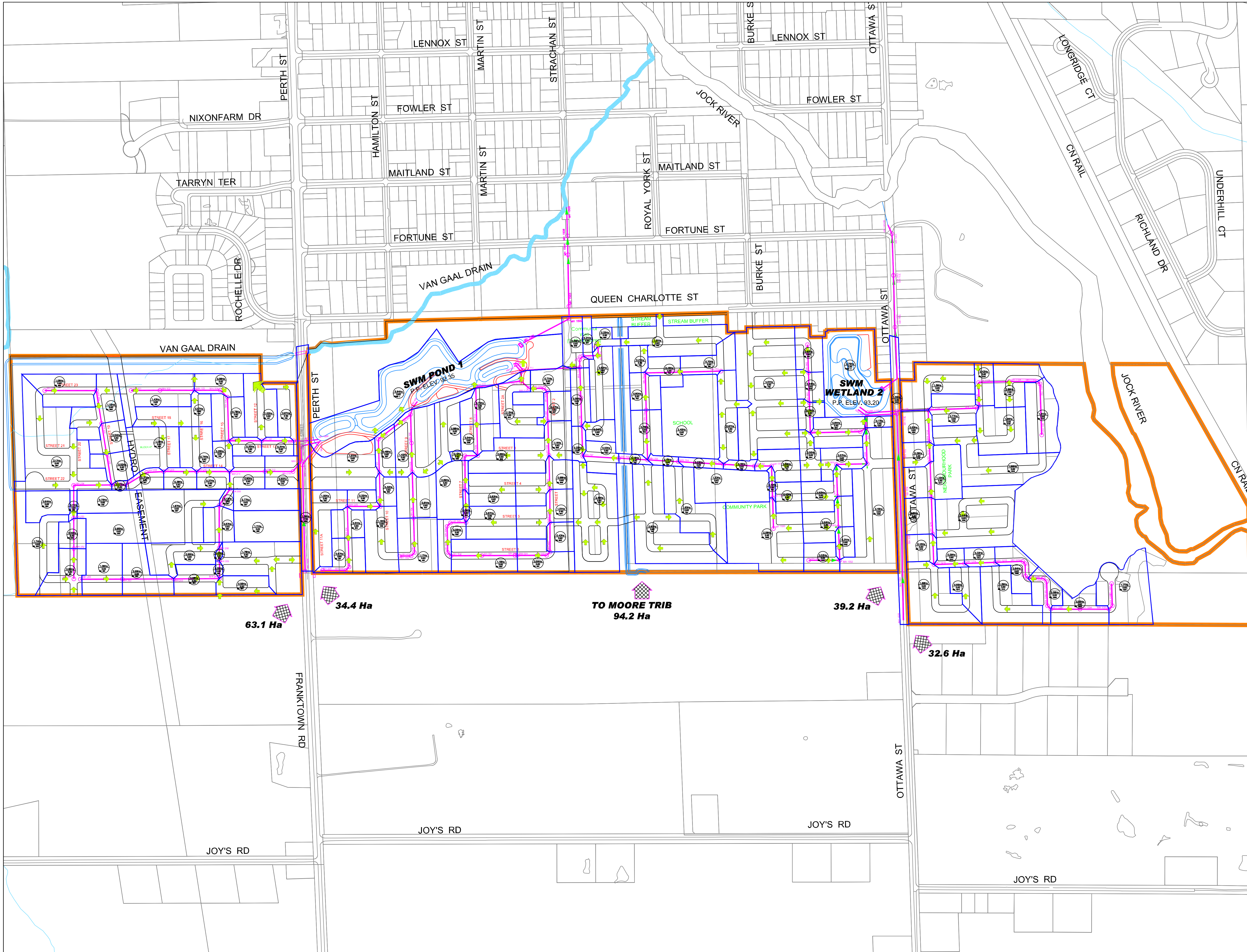
BY	DATE	DESCRIPTION	BY

EXISTING DRAINAGE AREAS THROUGH SUBJECT SITE

FIGURE 1A

DESIGNED:	
DRAWN:	LP
VERIFIED:	JFS
APPROVED:	JFS
DATE	PROJECT No.
Jan/14	922-11

DRAWING REF.
922-11\201401 FSR\Design\CAD\JFSA Figures.dwg



LEGEND :

SUBCATCHMENT BOUNDARY (PER DSEL)

SUB-CATCHMENT AREA
RUNOFF COEFFICIENT
UPSTREAM MANHOLE

MAJOR SYSTEM FLOW DIRECTION

63.1 Ha UNDEVELOPED DRAINAGE AREA

SCALE :

0 100 200 300 400 500m

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PROJECT :

RICHMOND VILLAGE (SOUTH) LIMITED SUBDIVISION

BY	DATE	DESCRIPTION	BY

PROPOSED DRAINAGE AREA TO SWM FACILITIES

FIGURE 1B

DESIGNED:	
DRAWN:	LP
VERIFIED:	JFS
APPROVED:	JFS

DRAWING REF.
922-11\201401 FSR\Design\CAD\JFSA Figures.dwg

DATE	PROJECT No.
Jan/14	922-11

ATTACHMENT 2

SUMMARY OF DRAINAGE AREA TO SWM FACILITIES

XPSWMM MODEL SCHEMATIC

MINOR SYSTEM LOSS COEFFICIENTS

JFSA Water Resources and Environmental Consultants

Table 1A: Proposed Subdivision Drainage Area to SWM Facilities 1 and 2

MH	SWMHYMO ID	Total Area	Front Yard / Non-Resid.	Rear Yard (1)	Runoff Coefficient	Front Yard / Non-Residential Area Parameters							Sump Pump Flow (2)
		(ha)	(ha)	(ha)		Imperviousness (%)	Storage (m^3)	5-Year Flow (m^3/s)	Minor Capture (m^3/s)	Road Width (m)	Length (m)	Downstream Segment	(m^3/s)
101	101a	1.43	0.894	0.536	0.62	60	26.82	0.155	0.174	8.5	219	VGaal	0.00033
103	103a	0.56	0.455	0.105	0.62	60	13.65	0.081	0.091	8.5	87	105a	0.00013
103	103b	0.97	0.606	0.364	0.62	60	18.18	0.107	0.120	8.5	85	VGaal	0.00022
105	105a	0.78	0.487	0.293	0.62	60	14.61	0.086	0.096	8.5	101	106b	0.00018
106	106a	0.29	0.181	0.109	0.62	60	5.43	0.032	0.036	8.5	71	106b	0.00007
106	106b	0.30	0.244	0.056	0.62	60	7.32	0.043	0.048	8.5	77	107b	0.00007
107	107a	0.31	0.252	0.058	0.62	60	7.56	0.045	0.050	8.5	75	1500a	0.00007
107	107b	1.02	0.637	0.383	0.62	60	19.11	0.112	0.125	8.5	128	VGaal	0.00023
108	108a	0.67	0.544	0.126	0.62	60	16.32	0.096	0.108	8.5	186	1500a	0.00015
202	202a	1.06	0.662	0.398	0.62	60	19.86	0.116	0.130	8.5	136	203a	0.00024
203	203a	1.10	0.687	0.413	0.62	60	20.61	0.120	0.134	8.5	77	204a	0.00025
204	204a	0.54	0.337	0.203	0.62	60	10.11	0.060	0.067	8.5	72	205a	0.00012
205	205a	0.52	0.325	0.195	0.62	60	9.75	0.058	0.065	8.5	72	206a	0.00012
206	206a	0.07	0.070	0.000	0.62	60	2.10	0.013	0.015	8.5	34	207a	0.00002
206	206b	0.75	0.469	0.281	0.62	60	14.07	0.083	0.093	8.5	53	207a	0.00017
207	207a	0.37	0.301	0.069	0.62	60	9.03	0.054	0.060	8.5	95	209a	0.00009
209	209a	0.38	0.309	0.071	0.62	60	9.27	0.055	0.062	8.5	77	210a	0.00009
209	209b	1.15	0.719	0.431	0.62	60	21.57	0.126	0.141	8.5	104	209a	0.00026
210	210a	0.37	0.301	0.069	0.62	60	9.03	0.054	0.060	8.5	77	106a	0.00009
210	210b	0.74	0.462	0.278	0.62	60	13.86	0.082	0.092	8.5	106	210a	0.00017
211	211a	0.60	0.375	0.225	0.62	60	11.25	0.067	0.075	8.5	82	106a	0.00014
212	212a	0.60	0.375	0.225	0.62	60	11.25	0.067	0.075	8.5	78	1500a	0.00014
251	251a	0.86	0.537	0.323	0.62	60	16.11	0.095	0.106	8.5	137	252a	0.00020
252	252a	0.42	0.262	0.158	0.62	60	7.86	0.047	0.053	8.5	70	253a	0.00010
253	253a	0.11	0.089	0.021	0.62	60	2.67	0.016	0.018	8.5	64	206a	0.00003
253	253b	0.95	0.594	0.356	0.62	60	17.82	0.105	0.118	8.5	70	253a	0.00022
253	253c	1.74	1.087	0.653	0.62	60	32.61	0.187	0.209	8.5	194	253a	0.00040
254	254a	0.64	0.400	0.240	0.62	60	12.00	0.071	0.080	8.5	56	206a	0.00015
254	254b	3.17	1.981	1.189	0.62	60	59.43	0.333	0.373	8.5	375	206a	0.00073
261	261a	1.06	0.662	0.398	0.62	60	19.86	0.116	0.130	8.5	94	262a	0.00024
262	262a	0.99	0.619	0.371	0.62	60	18.57	0.109	0.122	8.5	119	263a	0.00023
263	263a	0.68	0.425	0.255	0.62	60	12.75	0.075	0.084	8.5	106	264a	0.00016
264	264a	0.05	0.050	0.000	0.62	60	1.50	0.009	0.010	8.5	41	265a	0.00001
264	264b	0.55	0.447	0.103	0.62	60	13.41	0.079	0.088	8.5	151	264a	0.00013
265	265a	0.05	0.050	0.000	0.62	60	1.50	0.009	0.010	8.5	31	266a	0.00001
265	265b	1.76	1.100	0.660	0.62	60	33.00	0.189	0.212	8.5	191	265a	0.00040
266	266a	0.57	0.356	0.214	0.62	60	10.68	0.063	0.071	8.5	85	267a	0.00013
266	266b	0.99	0.619	0.371	0.62	60	18.57	0.109	0.122	8.5	182	266a	0.00023
266	266c	1.11	0.694	0.416	0.62	60	20.82	0.122	0.137	8.5	73	267a	0.00026
267	267a	0.12	0.120	0.000	0.62	60	3.60	0.021	0.024	8.5	45	106a	0.00003

Table 1A: Proposed Subdivision Drainage Area to SWM Facilities 1 and 2

MH	SWMHYMO ID	Total Area (ha)	Front Yard / Non-Resid. (ha)	Rear Yard (1) (ha)	Runoff Coefficient	Front Yard / Non-Residential Area Parameters							Sump Pump Flow (2) (m^3/s)
						Imperviousness (%)	Storage (m^3)	5-Year Flow (m^3/s)	Minor Capture (m^3/s)	Road Width (m)	Length (m)	Downstream Segment	
267	267b	0.77	0.481	0.289	0.62	60	14.43	0.085	0.095	8.5	50	1500a	0.00018
267	267c	1.97	1.231	0.739	0.62	60	36.93	0.211	0.236	8.5	158	267a	0.00045
301	301a	0.67	0.419	0.251	0.62	60	12.57	0.074	0.083	8.5	146	304a	0.00015
304	304a	0.51	0.319	0.191	0.62	60	9.57	0.057	0.064	8.5	74	305a	0.00012
305	305a	0.32	0.260	0.060	0.62	60	7.80	0.046	0.052	8.5	76	306a	0.00007
305	305b	1.00	0.812	0.188	0.62	60	24.36	0.141	0.158	8.5	213	305a	0.00023
306	306a	0.32	0.260	0.060	0.62	60	7.80	0.046	0.052	8.5	80	307a	0.00007
306	306b	1.16	0.725	0.435	0.62	60	21.75	0.127	0.142	8.5	148	306a	0.00027
307	307a	0.48	0.390	0.090	0.62	60	11.70	0.069	0.077	8.5	124	Pond1a	0.00011
307	307b	1.51	0.944	0.566	0.62	60	28.32	0.163	0.183	8.5	160	307a	0.00035
401	401a	1.17	0.731	0.439	0.62	60	21.93	0.128	0.143	8.5	121	404a	0.00027
404	404a	0.91	0.569	0.341	0.62	60	17.07	0.100	0.112	8.5	106	405a	0.00021
405	405a	1.42	0.887	0.533	0.62	60	26.61	0.154	0.172	8.5	146	Pond1a	0.00033
500	500a	1.18	0.737	0.443	0.62	60	22.11	0.129	0.144	8.5	153	502a	0.00027
502	502a	0.55	0.447	0.103	0.62	60	13.41	0.079	0.088	8.5	118	506a	0.00013
506	506a	0.09	0.090	0.000	0.62	60	2.70	0.016	0.018	8.5	76	507b	0.00002
506	506b	0.87	0.544	0.326	0.62	60	16.32	0.096	0.108	8.5	117	506a	0.00020
507	507a	0.83	0.519	0.311	0.62	60	15.57	0.092	0.103	8.5	109	507b	0.00019
507	507b	0.89	0.723	0.167	0.62	60	21.69	0.127	0.142	8.5	69	509a	0.00020
508	508a	0.12	0.120	0.000	0.62	60	3.60	0.021	0.024	8.5	61	509a	0.00003
509	509a	0.54	0.337	0.203	0.62	60	10.11	0.060	0.067	8.5	73	510a	0.00012
509	509b	0.66	0.412	0.248	0.62	60	12.36	0.073	0.082	8.5	86	509a	0.00015
510	510a	0.70	0.437	0.263	0.62	60	13.11	0.077	0.086	8.5	84	Pond1a	0.00016
511	511a	0.88	0.550	0.330	0.62	60	16.50	0.097	0.109	8.5	223	Pond1a	0.00020
601	601a	0.84	0.525	0.315	0.62	60	15.75	0.093	0.104	8.5	79	603a	0.00019
603	603a	0.43	0.430	0.000	0.62	60	12.90	0.076	0.085	8.5	69	604a	0.00010
604	604a	1.01	0.631	0.379	0.62	60	18.93	0.111	0.124	8.5	76	605a	0.00023
605	605a	0.98	0.612	0.368	0.62	60	18.36	0.108	0.121	8.5	79	606a	0.00023
606	606a	1.14	0.712	0.428	0.62	60	21.36	0.125	0.140	8.5	78	607a	0.00026
607	607a	0.47	0.382	0.088	0.62	60	11.46	0.068	0.076	8.5	68	609a	0.00011
609	609a	0.71	0.444	0.266	0.62	60	13.32	0.079	0.088	8.5	42	Pond1a	0.00016
610	610a	1.13	0.706	0.424	0.62	60	21.18	0.124	0.139	8.5	179	Pond1a	0.00026
700	700a	0.10	0.100	0.000	0.62	60	3.00	0.018	0.020	8.5	74	702a	0.00002
700	700b	0.43	0.269	0.161	0.62	60	8.07	0.048	0.054	8.5	61	700a	0.00010
701	701a	0.66	0.412	0.248	0.62	60	12.36	0.073	0.082	8.5	108	702a	0.00015
702	702a	0.16	0.160	0.000	0.62	60	4.80	0.029	0.032	8.5	71	703a	0.00004
702	702b	4.01	2.506	1.504	0.62	60	75.18	0.410	0.459	8.5	377	702a	0.00092
703	703a	0.22	0.220	0.000	0.62	60	6.60	0.039	0.044	8.5	105	704a	0.00005
703	703b	0.97	0.788	0.182	0.62	60	23.64	0.137	0.153	8.5	215	703a	0.00022
703	703c	1.33	1.330	0.000	0.62	60	39.90	0.228	0.255	8.5	125	703a	0.00031

Table 1A: Proposed Subdivision Drainage Area to SWM Facilities 1 and 2

MH	SWMHYMO ID	Total Area (ha)	Front Yard / Non-Resid. (ha)	Rear Yard (1) (ha)	Runoff Coefficient	Front Yard / Non-Residential Area Parameters: Imperviousness (%)	Storage (m^3)	5-Year Flow (m^3/s)	Minor Capture (m^3/s)	Road Width (m)	Length (m)	Downstream Segment	Sump Pump Flow (2) (m^3/s)
704	704a	0.16	0.160	0.000	0.62	60	4.80	0.029	0.032	8.5	72	705a	0.00004
704	704b	1.65	1.031	0.619	0.62	60	30.93	0.178	0.199	8.5	260	704a	0.00038
704	704c	2.40	2.400	0.000	0.62	60	72.00	0.394	0.441	8.5	163	704a	0.00055
705	705a	0.15	0.150	0.000	0.62	60	4.50	0.027	0.030	8.5	67	MTrib	0.00003
705	705b	2.60	1.625	0.975	0.62	60	48.75	0.275	0.308	8.5	332	705a	0.00060
706	706a	0.53	0.331	0.199	0.62	60	9.93	0.059	0.066	8.5	85	606a	0.00012
707	707a	0.25	0.203	0.047	0.62	60	6.09	0.036	0.040	8.5	69	606a	0.00006
707	707b	2.46	1.537	0.923	0.62	60	46.11	0.261	0.292	8.5	237	604a	0.00057
708	708a	0.34	0.276	0.064	0.62	60	8.28	0.049	0.055	8.5	54	708b	0.00008
708	708b	0.59	0.369	0.221	0.62	60	11.07	0.065	0.073	8.5	135	Moore	0.00014
751	751a	0.70	0.569	0.131	0.62	60	17.07	0.100	0.112	8.5	156	752a	0.00016
752	752a	0.48	0.300	0.180	0.62	60	9.00	0.053	0.059	8.5	83	753a	0.00011
753	753a	0.27	0.219	0.051	0.62	60	6.57	0.039	0.044	8.5	63	MTrib	0.00006
753	753b	0.60	0.375	0.225	0.62	60	11.25	0.067	0.075	8.5	88	753a	0.00014
753	753c	1.51	0.944	0.566	0.62	60	28.32	0.163	0.183	8.5	231	MTrib	0.00035
754	754a	0.76	0.475	0.285	0.62	60	14.25	0.084	0.094	8.5	115	753b	0.00017
806	806a	0.25	0.203	0.047	0.62	60	6.09	0.036	0.040	8.5	59	807a	0.00006
807	807a	0.21	0.171	0.039	0.62	60	5.13	0.031	0.035	8.5	23	808a	0.00005
807	807b	0.92	0.575	0.345	0.62	60	17.25	0.101	0.113	8.5	150	807a	0.00021
808	808a	0.59	0.369	0.221	0.62	60	11.07	0.065	0.073	8.5	32	Moore	0.00014
901	901a	0.60	0.375	0.225	0.62	60	11.25	0.067	0.075	8.5	96	902a	0.00014
902	902a	0.44	0.275	0.165	0.62	60	8.25	0.049	0.055	8.5	70	Pond2a	0.00010
903	903a	0.34	0.212	0.128	0.62	60	6.36	0.038	0.043	8.5	71	Pond2a	0.00008
904	904a	0.50	0.312	0.188	0.62	60	9.36	0.055	0.062	8.5	99	903a	0.00012
904	904b	0.84	0.525	0.315	0.62	60	15.75	0.093	0.104	8.5	127	Pond2a	0.00019
1001	1001a	0.53	0.331	0.199	0.62	60	9.93	0.059	0.066	8.5	83	1002a	0.00012
1002	1002a	0.31	0.252	0.058	0.62	60	7.56	0.045	0.050	8.5	77	1003a	0.00007
1003	1003a	0.84	0.525	0.315	0.62	60	15.75	0.093	0.104	8.5	71	1004a	0.00019
1004	1004a	0.83	0.519	0.311	0.62	60	15.57	0.092	0.103	8.5	74	1005a	0.00019
1005	1005a	0.57	0.463	0.107	0.62	60	13.89	0.082	0.092	8.5	71	Pond2a	0.00013
1006	1006a	3.15	1.969	1.181	0.62	60	59.07	0.331	0.371	8.5	375	Pond2a	0.00072
1007	1007a	0.17	0.138	0.032	0.62	60	4.14	0.025	0.028	8.5	26	Pond2a	0.00004
1101	1101a	1.21	0.756	0.454	0.62	60	22.68	0.132	0.148	8.5	169	1103a	0.00028
1103	1103a	0.89	0.556	0.334	0.62	60	16.68	0.098	0.110	8.5	133	1106b	0.00020
1104	1104a	0.43	0.349	0.081	0.62	60	10.47	0.062	0.069	8.5	99	1106a	0.00010
1106	1106a	0.77	0.481	0.289	0.62	60	14.43	0.085	0.095	8.5	112	1600a	0.00018
1106	1106b	1.26	0.787	0.473	0.62	60	23.61	0.137	0.153	8.5	209	1219a	0.00029
1108	1108a	1.39	0.869	0.521	0.62	60	26.07	0.151	0.169	8.5	179	1600a	0.00032
1201	1201a	1.71	1.069	0.641	0.62	60	32.07	0.184	0.206	8.5	112	1203a	0.00039
1203	1203a	0.85	0.531	0.319	0.62	60	15.93	0.094	0.105	8.5	135	1205a	0.00020

Table 1A: Proposed Subdivision Drainage Area to SWM Facilities 1 and 2

MH	SWMHYMO ID	Total Area (ha)	Front Yard / Non-Resid. (ha)	Rear Yard [1] (ha)	Runoff Coefficient	Front Yard / Non-Residential Area Parameters							Sump Pump Flow [2] (m^3/s)
						Imperviousness (%)	Storage (m^3)	5-Year Flow (m^3/s)	Minor Capture (m^3/s)	Road Width (m)	Length (m)	Downstream Segment	
1205	1205a	0.58	0.362	0.218	0.62	60	10.86	0.064	0.072	8.5	117	1209a	0.00013
1209	1209a	0.64	0.400	0.240	0.62	60	12.00	0.071	0.080	8.5	108	1213a	0.00015
1213	1213a	0.32	0.260	0.060	0.62	60	7.80	0.046	0.052	8.5	71	1214a	0.00007
1213	1213b	1.39	0.869	0.521	0.62	60	26.07	0.151	0.169	8.5	202	1213a	0.00032
1214	1214a	0.29	0.236	0.054	0.62	60	7.08	0.042	0.047	8.5	71	1215a	0.00007
1214	1214b	0.65	0.406	0.244	0.62	60	12.18	0.072	0.081	8.5	93	1214a	0.00015
1215	1215a	0.45	0.366	0.084	0.62	60	10.98	0.065	0.073	8.5	71	1216a	0.00010
1215	1215b	1.68	1.050	0.630	0.62	60	31.50	0.181	0.203	8.5	169	1215a	0.00039
1216	1216a	0.61	0.496	0.114	0.62	60	14.88	0.088	0.099	8.5	85	1217a	0.00014
1216	1216b	2.44	1.525	0.915	0.62	60	45.75	0.259	0.290	8.5	227	1216a	0.00056
1217	1217a	1.33	1.081	0.249	0.62	60	32.43	0.186	0.208	8.5	82	1218a	0.00031
1218	1218a	0.39	0.317	0.073	0.62	60	9.51	0.056	0.063	8.5	47	1219a	0.00009
1219	1219a	0.53	0.431	0.099	0.62	60	12.93	0.076	0.085	8.5	74	1600a	0.00012
1219	1219b	1.96	1.225	0.735	0.62	60	36.75	0.210	0.235	8.5	350	1219a	0.00045
1500 [3]	1500a	1.36	1.360	0.000	0.62	60	40.80	0.232	100% Capt.	8.5	287	N/A	0.00031
1600 [3]	1600a	1.35	1.350	0.000	0.62	60	40.50	0.231	100% Capt.	8.5	489	N/A	0.00031
7000	7000a	2.59	2.104	0.486	0.62	60	63.12	0.352	0.394	8.5	213	700a	0.00060
Pond1	Pond1a	5.94	5.940	0.000	0.62	60	N/A	0.906	N/A	N/A	N/A	N/A	0.00000
Pond2	Pond2a	2.75	2.750	0.000	0.62	60	N/A	0.447	N/A	N/A	N/A	N/A	0.00000
		126.810	**89.059**	**37.751**									

(1) Rear yard imperviousness is equal to half of the front yard imperviousness, and half of that rear yard impervious area is assumed to be indirectly connected.
100% of the 100-year flows generated on the rear yards are captured to the minor system.

(2) 0.23 L/s/ha based on approximately 1.44 m^3/day/lot (per October 3, 2012 "*Updated Assessment of Subsurface Drainage and Analysis of 100 Year Flood Event - Proposed Village of Richmond Development* " by Golder Associates Limited), 27.8 lots/ha, and 50% of sump pumps on at any given time.

(3) 100% capture of the 100-year flows on Ottawa Street and Perth Street to prevent flow across roads.

Table 1B: Summary of Study Area under Existing Conditions (Drains to SWM Facilities 1 and 2 in Future)

Area ID In future drains to:	VG-2 Pond 1	VG-3 (1) Pond 1	VG-5 Pond 1	VG-7 Pond 2	VG-8 (1) Pond 1	VG-8 (1) Pond 2	JR-1 Pond 2	JR-2 (1) Pond 2	JR-3 (1) Pond 2
A (ha)	63.1	33.327	34.4	39.2	58.393	15.510	32.6	15.747	3.833
CN (-)	81	88	76	80	88	88	82	88	88
Ia	2.8	2.5	3.0	3.5	2.6	2.6	3.5	2.5	2.5
L (m)	1220	630	1540	1520	1160	420	790	330	150
S (%)	0.4	0.2	0.4	0.2	0.2	0.2	0.2	0.1	0.6
Tc (min)	147.6	96.5	207.1	256.9	157.3	69.8	142.8	81.3	17.7
Tp (hrs)	1.6	1.1	2.3	2.9	1.7	0.8	1.6	0.9	0.2

(1) Proposed subdivision drainage area.

(2) Characteristics of undeveloped lands as per *Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond* dated November 2009 by JFSA.

Table 1C: Summary of Study Area under Proposed Conditions (Drains to SWM Facilities 1 and 2)

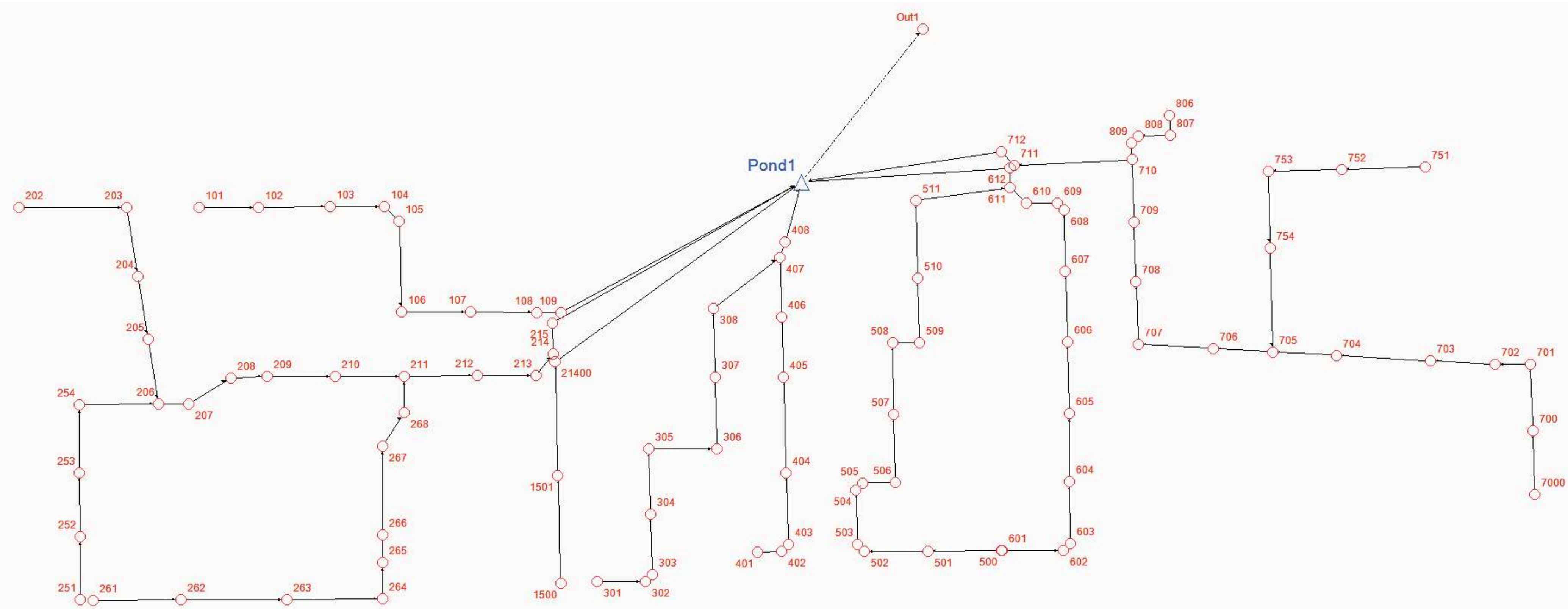
Area ID Drains to:	VG-2 Pond 1	VG-5 Pond 1	VG-7 Pond 2	JR-1 Pond 2	Pond 1 (1) Pond 1	Pond 2 (1) Pond 2
A (ha)	63.1	34.4	39.2	32.6	91.82	34.99
CN (-)	81	76	80	82	N/A	N/A
Ia	2.8	3.0	3.5	3.5	N/A	N/A
L (m)	1220	1540	1520	790	N/A	N/A
S (%)	0.4	0.4	0.2	0.2	0.5	0.5
Tc (min)	147.6	207.1	256.9	142.8	N/A	N/A
Tp (hrs)	1.6	2.3	2.9	1.6	N/A	N/A
TIMP	N/A	N/A	N/A	N/A	51.1	50.9
XIMP	N/A	N/A	N/A	N/A	46.7	46.4

(1) Proposed subdivision drainage area; major system flows from 36.63 ha, 30.79 ha, 21.75 ha and 2.65 ha of the Pond 1 subdivision area will discharge to Pond 1, to the Van Gaal Drain, to the Moore Drain Tributary, and to the Moore Drain, respectively.

(2) Characteristics of undeveloped lands as per *Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond* dated November 2009 by JFSA.

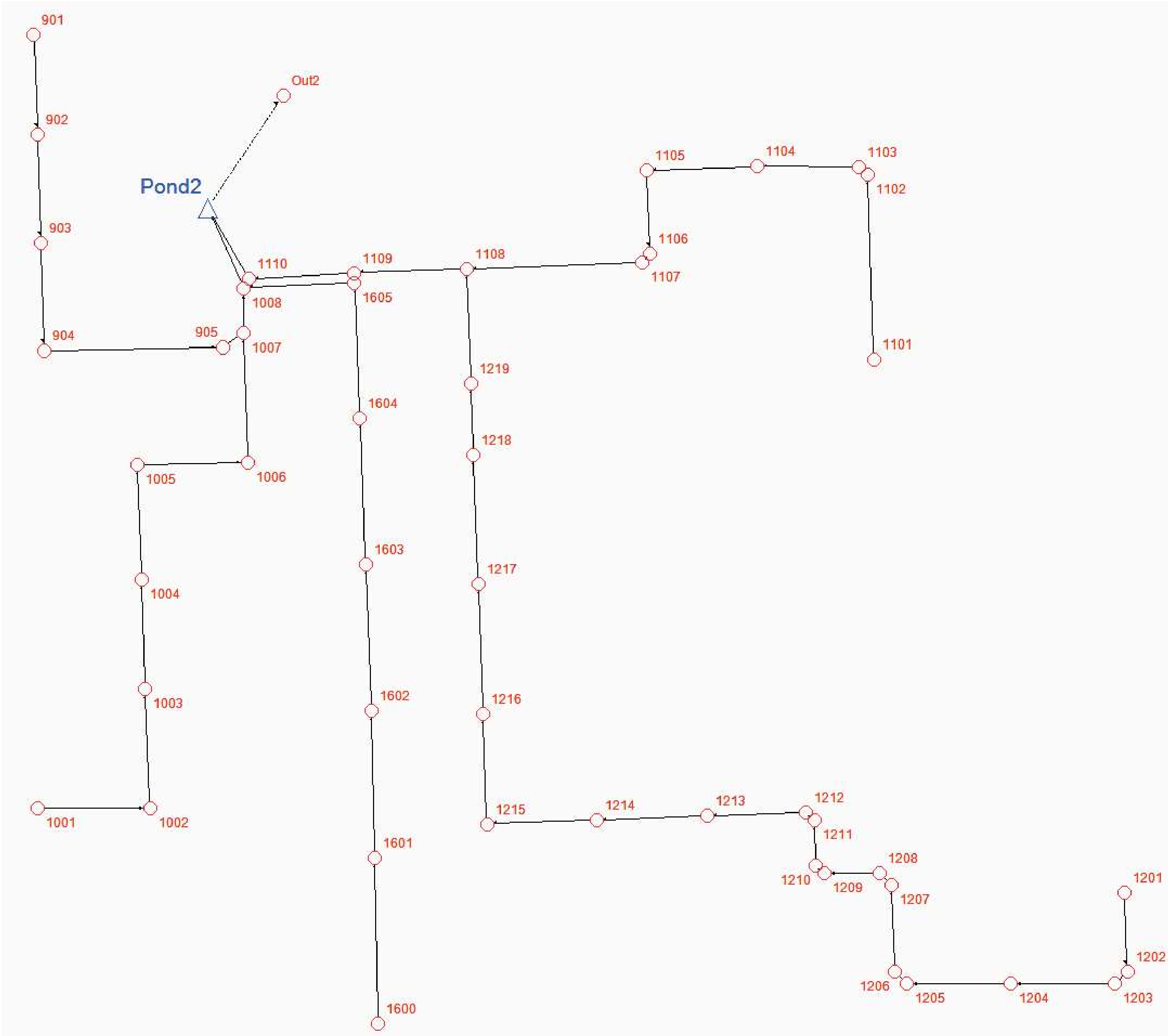
XPSWMM MODEL SCHEMATIC - SWMF 1

JFSA Water Resources and Environmental Consultants



XPSWMM MODEL SCHEMATIC - SWMF 2

JFSA Water Resources and Environmental Consultants



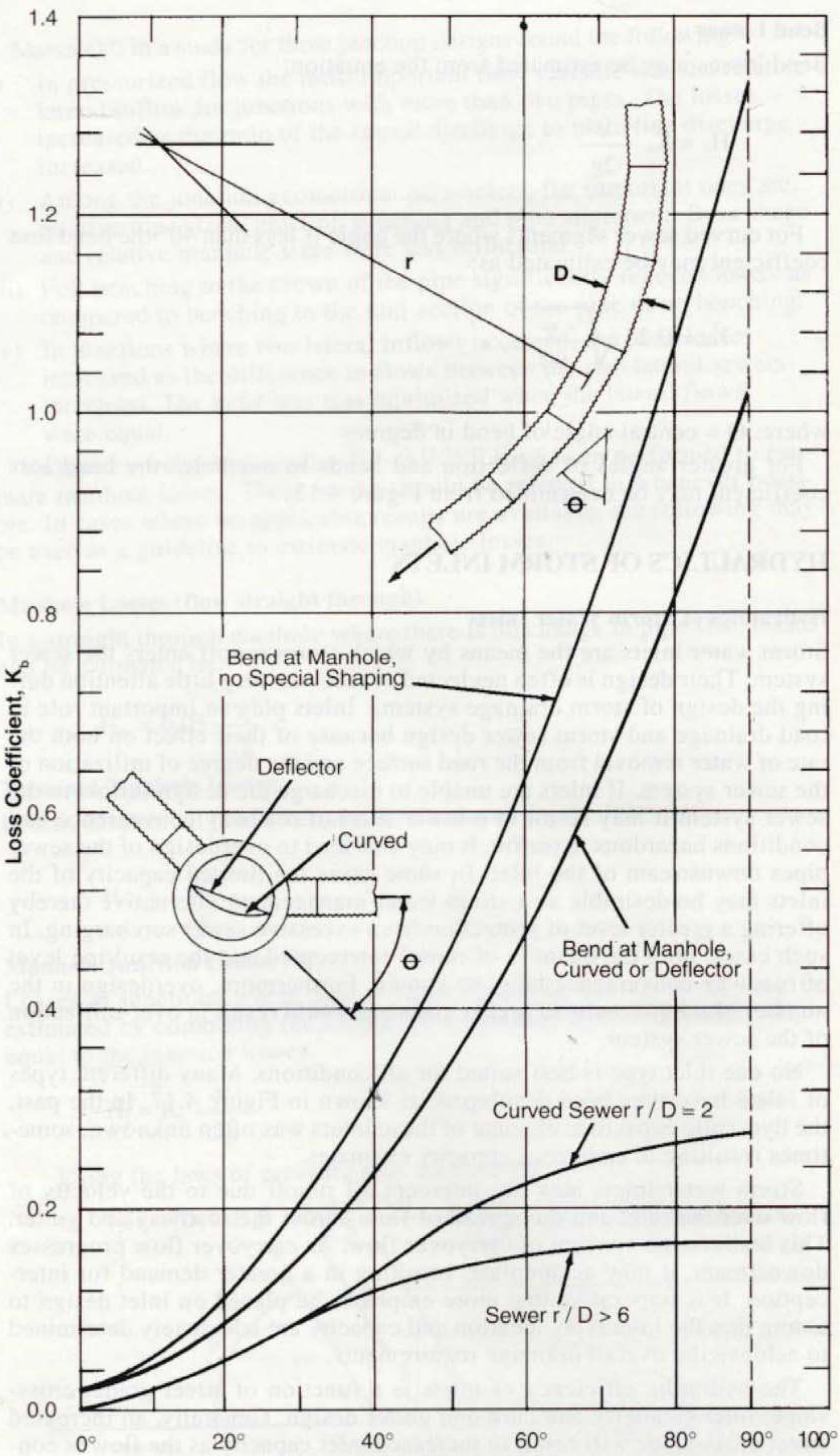


Figure 4.13 Sewer bend loss coefficient[16]

Manhole Loss Coefficient as per Nomograph

Angle (^{o})	MH Loss Coef
0	0.02
5	0.035
10	0.055
15	0.08
20	0.11
25	0.16
30	0.21
35	0.26
40	0.32
45	0.39
50	0.47
55	0.54
60	0.635
65	0.73
70	0.84
75	0.95
80	1.07
85	1.19
90	1.33

ATTACHMENT 3

MAJOR SYSTEM RESULTS

Table 2A: Major System Results for the 100-Year, 3-Hour Chicago Storm

MH	SWMHYMO ID	Flow (m^3/s)	Flow Depth (m)	Velocity (m/s)	V*D (m^2/s)
101	101a	0.298	0.133	0.500	0.067
103	103a	0.153	0.105	0.416	0.044
103	103b	0.203	0.115	0.443	0.051
105	105a	0.164	0.107	0.422	0.045
106	106a	0.645	0.174	0.666	0.116
106	106b	0.638	0.173	0.663	0.115
107	107a	0.087	0.084	0.356	0.030
107	107b	0.689	0.178	0.682	0.121
108	108a	0.183	0.111	0.432	0.048
202	202a	0.222	0.119	0.454	0.054
203	203a	0.319	0.136	0.510	0.069
204	204a	0.237	0.122	0.463	0.056
205	205a	0.209	0.116	0.446	0.052
206	206a	0.643	0.173	0.665	0.115
206	206b	0.158	0.106	0.419	0.044
207	207a	0.677	0.177	0.677	0.120
209	209a	0.562	0.165	0.636	0.105
209	209b	0.241	0.123	0.465	0.057
210	210a	0.506	0.159	0.618	0.098
210	210b	0.155	0.105	0.418	0.044
211	211a	0.128	0.097	0.391	0.038
212	212a	0.128	0.097	0.391	0.038
251	251a	0.180	0.110	0.431	0.047
252	252a	0.162	0.107	0.421	0.045
253	253a	0.328	0.137	0.515	0.071
253	253b	0.199	0.114	0.441	0.050
253	253c	0.361	0.141	0.532	0.075
254	254a	0.137	0.100	0.400	0.040
254	254b	0.637	0.173	0.663	0.115
261	261a	0.222	0.119	0.454	0.054
262	262a	0.296	0.133	0.499	0.066
263	263a	0.243	0.123	0.467	0.057
264	264a	0.160	0.106	0.420	0.045
264	264b	0.150	0.104	0.413	0.043
265	265a	0.283	0.131	0.493	0.065
265	265b	0.366	0.142	0.535	0.076
266	266a	0.433	0.150	0.574	0.086
266	266b	0.207	0.116	0.446	0.052
266	266c	0.232	0.121	0.460	0.056
267	267a	0.443	0.152	0.580	0.088
267	267b	0.162	0.107	0.421	0.045
267	267c	0.408	0.147	0.559	0.082
301	301a	0.143	0.102	0.406	0.041
304	304a	0.168	0.108	0.424	0.046
305	305a	0.269	0.128	0.483	0.062
305	305b	0.271	0.129	0.485	0.063
306	306a	0.295	0.133	0.499	0.066
306	306b	0.243	0.123	0.466	0.057
307	307a	0.388	0.145	0.547	0.079
307	307b	0.315	0.135	0.508	0.069
401	401a	0.245	0.123	0.467	0.057
404	404a	0.289	0.132	0.496	0.065
405	405a	0.391	0.145	0.549	0.080

Table 2A: Major System Results for the 100-Year, 3-Hour Chicago Storm

MH	SWMHYMO ID	Flow (m^3/s)	Flow Depth (m)	Velocity (m/s)	V*D (m^2/s)
500	500a	0.247	0.124	0.469	0.058
502	502a	0.250	0.124	0.471	0.058
506	506a	0.181	0.111	0.431	0.048
506	506b	0.183	0.111	0.432	0.048
507	507a	0.174	0.109	0.428	0.047
507	507b	0.403	0.146	0.556	0.081
508	508a	0.041	0.062	0.288	0.018
509	509a	0.369	0.142	0.536	0.076
509	509b	0.141	0.101	0.404	0.041
510	510a	0.347	0.139	0.525	0.073
511	511a	0.185	0.111	0.433	0.048
601	601a	0.176	0.110	0.429	0.047
603	603a	0.217	0.118	0.451	0.053
604	604a	0.505	0.159	0.618	0.098
605	605a	0.423	0.149	0.567	0.084
606	606a	0.451	0.153	0.585	0.090
607	607a	0.361	0.141	0.532	0.075
609	609a	0.329	0.137	0.515	0.071
610	610a	0.236	0.122	0.462	0.056
700	700a	0.342	0.139	0.522	0.073
700	700b	0.092	0.085	0.360	0.031
701	701a	0.141	0.101	0.404	0.041
702	702a	0.582	0.167	0.643	0.107
702	702b	0.800	0.189	0.717	0.136
703	703a	0.654	0.174	0.669	0.116
703	703b	0.263	0.127	0.479	0.061
703	703c	0.440	0.151	0.578	0.087
704	704a	0.778	0.187	0.712	0.133
704	704b	0.343	0.139	0.523	0.073
704	704c	0.767	0.186	0.710	0.132
705	705a	0.841	0.192	0.725	0.139
705	705b	0.526	0.161	0.624	0.100
706	706a	0.113	0.092	0.378	0.035
707	707a	0.070	0.078	0.340	0.027
707	707b	0.498	0.158	0.615	0.097
708	708a	0.095	0.086	0.362	0.031
708	708b	0.165	0.107	0.423	0.045
751	751a	0.191	0.113	0.436	0.049
752	752a	0.179	0.110	0.430	0.047
753	753a	0.228	0.120	0.458	0.055
753	753b	0.192	0.113	0.437	0.049
753	753c	0.315	0.135	0.508	0.069
754	754a	0.160	0.106	0.420	0.045
806	806a	0.070	0.078	0.340	0.027
807	807a	0.165	0.107	0.423	0.045
807	807b	0.193	0.113	0.437	0.049
808	808a	0.250	0.124	0.471	0.058
901	901a	0.128	0.097	0.391	0.038
902	902a	0.146	0.103	0.409	0.042
903	903a	0.116	0.093	0.381	0.035
904	904a	0.107	0.090	0.372	0.033
904	904b	0.176	0.110	0.429	0.047
1001	1001a	0.113	0.092	0.378	0.035

Table 2A: Major System Results for the 100-Year, 3-Hour Chicago Storm

MH	SWMHYMO ID	Flow (m^3/s)	Flow Depth (m)	Velocity (m/s)	V*D (m^2/s)
1002	1002a	0.132	0.098	0.395	0.039
1003	1003a	0.231	0.121	0.459	0.056
1004	1004a	0.269	0.128	0.483	0.062
1005	1005a	0.269	0.128	0.483	0.062
1006	1006a	0.634	0.172	0.661	0.114
1007	1007a	0.048	0.065	0.298	0.019
1101	1101a	0.253	0.125	0.473	0.059
1103	1103a	0.288	0.132	0.496	0.065
1104	1104a	0.120	0.094	0.383	0.036
1106	1106a	0.211	0.117	0.447	0.052
1106	1106b	0.353	0.140	0.528	0.074
1108	1108a	0.290	0.132	0.496	0.065
1201	1201a	0.356	0.140	0.529	0.074
1203	1203a	0.323	0.136	0.512	0.070
1205	1205a	0.231	0.121	0.459	0.056
1209	1209a	0.215	0.117	0.450	0.053
1213	1213a	0.282	0.131	0.492	0.064
1213	1213b	0.290	0.132	0.496	0.065
1214	1214a	0.267	0.128	0.482	0.062
1214	1214b	0.139	0.100	0.402	0.040
1215	1215a	0.388	0.145	0.547	0.079
1215	1215b	0.349	0.140	0.526	0.074
1216	1216a	0.569	0.166	0.639	0.106
1216	1216b	0.494	0.158	0.614	0.097
1217	1217a	0.600	0.169	0.649	0.110
1218	1218a	0.373	0.143	0.539	0.077
1219	1219a	0.605	0.169	0.651	0.110
1219	1219b	0.406	0.147	0.558	0.082
7000	7000a	0.676	0.177	0.677	0.120

Table 2B: Major System Results for the 100-Year, 3-Hour Chicago Storm +20%

MH	SWMHYMO ID	Flow (m^3/s)	Flow Depth (m)	Velocity (m/s)	V*D (m^2/s)
101	101a	0.373	0.143	0.539	0.077
103	103a	0.196	0.114	0.439	0.050
103	103b	0.260	0.126	0.477	0.060
105	105a	0.209	0.116	0.447	0.052
106	106a	2.113	0.281	0.900	0.253
106	106b	2.155	0.283	0.904	0.256
107	107a	0.109	0.091	0.374	0.034
107	107b	2.209	0.286	0.908	0.260
108	108a	0.234	0.121	0.461	0.056
202	202a	0.284	0.131	0.493	0.065
203	203a	0.443	0.152	0.580	0.088
204	204a	0.416	0.148	0.563	0.083
205	205a	0.414	0.148	0.562	0.083
206	206a	1.321	0.231	0.816	0.188
206	206b	0.202	0.115	0.442	0.051
207	207a	1.437	0.239	0.833	0.199
209	209a	1.449	0.240	0.835	0.200
209	209b	0.308	0.134	0.505	0.068
210	210a	1.410	0.237	0.830	0.197
210	210b	0.199	0.114	0.441	0.050
211	211a	0.162	0.107	0.421	0.045
212	212a	0.162	0.107	0.421	0.045
251	251a	0.231	0.121	0.459	0.056
252	252a	0.234	0.121	0.461	0.056
253	253a	0.562	0.165	0.636	0.105
253	253b	0.255	0.125	0.474	0.059
253	253c	0.452	0.153	0.586	0.090
254	254a	0.172	0.109	0.426	0.046
254	254b	0.810	0.190	0.719	0.137
261	261a	0.284	0.131	0.493	0.065
262	262a	0.414	0.148	0.562	0.083
263	263a	0.415	0.148	0.562	0.083
264	264a	0.373	0.143	0.538	0.077
264	264b	0.192	0.113	0.437	0.049
265	265a	0.571	0.166	0.639	0.106
265	265b	0.458	0.153	0.589	0.090
266	266a	0.802	0.189	0.717	0.136
266	266b	0.265	0.128	0.481	0.062
266	266c	0.297	0.133	0.500	0.067
267	267a	1.030	0.209	0.770	0.161
267	267b	0.207	0.116	0.445	0.052
267	267c	0.511	0.160	0.620	0.099
301	301a	0.180	0.110	0.431	0.047
304	304a	0.232	0.121	0.460	0.056
305	305a	0.438	0.151	0.577	0.087
305	305b	0.347	0.139	0.525	0.073
306	306a	0.591	0.168	0.646	0.109
306	306b	0.310	0.135	0.506	0.068
307	307a	0.813	0.190	0.719	0.137
307	307b	0.394	0.145	0.550	0.080
401	401a	0.313	0.135	0.507	0.068
404	404a	0.409	0.147	0.559	0.082
405	405a	0.609	0.170	0.652	0.111

Table 2B: Major System Results for the 100-Year, 3-Hour Chicago Storm +20%

MH	SWMHYMO ID	Flow (m^3/s)	Flow Depth (m)	Velocity (m/s)	V*D (m^2/s)
500	500a	0.315	0.135	0.509	0.069
502	502a	0.358	0.141	0.531	0.075
506	506a	0.368	0.142	0.536	0.076
506	506b	0.234	0.121	0.461	0.056
507	507a	0.223	0.119	0.454	0.054
507	507b	0.701	0.179	0.687	0.123
508	508a	0.052	0.068	0.306	0.021
509	509a	0.704	0.180	0.688	0.124
509	509b	0.177	0.110	0.429	0.047
510	510a	0.716	0.181	0.693	0.125
511	511a	0.236	0.122	0.462	0.056
601	601a	0.225	0.119	0.456	0.054
603	603a	0.303	0.134	0.503	0.067
604	604a	0.793	0.188	0.715	0.134
605	605a	0.855	0.194	0.729	0.141
606	606a	0.968	0.203	0.755	0.153
607	607a	0.836	0.192	0.724	0.139
609	609a	0.829	0.191	0.723	0.138
610	610a	0.302	0.134	0.502	0.067
700	700a	0.553	0.164	0.633	0.104
700	700b	0.116	0.093	0.380	0.035
701	701a	0.177	0.110	0.429	0.047
702	702a	1.138	0.217	0.788	0.171
702	702b	1.000	0.206	0.762	0.157
703	703a	1.470	0.241	0.837	0.202
703	703b	0.337	0.138	0.519	0.072
703	703c	0.551	0.164	0.633	0.104
704	704a	1.940	0.271	0.886	0.240
704	704b	0.429	0.150	0.571	0.086
704	704c	0.976	0.204	0.757	0.154
705	705a	2.058	0.278	0.895	0.249
705	705b	0.671	0.176	0.675	0.119
706	706a	0.143	0.102	0.405	0.041
707	707a	0.088	0.084	0.357	0.030
707	707b	0.635	0.173	0.662	0.115
708	708a	0.119	0.094	0.383	0.036
708	708b	0.221	0.119	0.453	0.054
751	751a	0.244	0.123	0.467	0.057
752	752a	0.258	0.126	0.476	0.060
753	753a	0.417	0.148	0.564	0.083
753	753b	0.268	0.128	0.483	0.062
753	753c	0.394	0.145	0.550	0.080
754	754a	0.204	0.115	0.444	0.051
806	806a	0.088	0.084	0.357	0.030
807	807a	0.250	0.124	0.471	0.058
807	807b	0.247	0.124	0.469	0.058
808	808a	0.363	0.141	0.533	0.075
901	901a	0.162	0.107	0.421	0.045
902	902a	0.203	0.115	0.443	0.051
903	903a	0.162	0.107	0.421	0.045
904	904a	0.135	0.099	0.397	0.039
904	904b	0.225	0.119	0.456	0.054
1001	1001a	0.143	0.102	0.405	0.041

Table 2B: Major System Results for the 100-Year, 3-Hour Chicago Storm +20%

MH	SWMHYMO ID	Flow (m^3/s)	Flow Depth (m)	Velocity (m/s)	V*D (m^2/s)
1002	1002a	0.183	0.111	0.432	0.048
1003	1003a	0.341	0.139	0.521	0.072
1004	1004a	0.424	0.149	0.568	0.085
1005	1005a	0.464	0.154	0.593	0.091
1006	1006a	0.805	0.189	0.718	0.136
1007	1007a	0.060	0.072	0.320	0.023
1101	1101a	0.323	0.136	0.513	0.070
1103	1103a	0.408	0.147	0.559	0.082
1104	1104a	0.150	0.104	0.413	0.043
1106	1106a	0.286	0.132	0.495	0.065
1106	1106b	0.561	0.165	0.636	0.105
1108	1108a	0.363	0.141	0.533	0.075
1201	1201a	0.445	0.152	0.581	0.088
1203	1203a	0.460	0.154	0.591	0.091
1205	1205a	0.411	0.147	0.560	0.082
1209	1209a	0.391	0.145	0.549	0.080
1213	1213a	0.478	0.156	0.603	0.094
1213	1213b	0.363	0.141	0.533	0.075
1214	1214a	0.529	0.162	0.625	0.101
1214	1214b	0.175	0.109	0.428	0.047
1215	1215a	0.762	0.186	0.708	0.132
1215	1215b	0.437	0.151	0.576	0.087
1216	1216a	1.087	0.213	0.780	0.166
1216	1216b	0.631	0.172	0.660	0.114
1217	1217a	1.243	0.225	0.804	0.181
1218	1218a	1.023	0.208	0.768	0.160
1219	1219a	1.364	0.234	0.823	0.193
1219	1219b	0.509	0.159	0.619	0.098
7000	7000a	0.859	0.194	0.729	0.141

ATTACHMENT

4

SWM FACILITY OPERATING CONDITIONS

JFSA Water Resources and Environmental Consultants

Table 3A: Summary of SWM Facility 1 Operating Characteristics [1]

Pond Component	Pre-Development Outflow (m^3/s)	Major System Outflow [2] (m^3/s)			Pond Level (m)	Pond Outflow (m^3/s)	Volume Used [3] (m^3)
		Van Gaal Drain	Moore Drain Tributary	Moore Drain			
Permanent Pool	N/A	N/A	N/A	N/A	92.35	N/A	27226
Quality Control	N/A	N/A	N/A	N/A	92.50	0.038	4443
2-Year, 24-Hour SCS	2.767	0.000	0.000	0.000	93.15	0.295	26917
5-Year, 24-Hour SCS	4.290	0.000	0.000	0.000	93.52	0.377	41388
10-Year, 24-Hour SCS	5.348	0.000	0.000	0.000	93.71	0.753	49336
25-Year, 24-Hour SCS	6.694	0.000	0.000	0.109	93.76	2.017	51535
50-Year, 24-Hour SCS	7.749	1.514	0.356	0.214	93.78	2.832	52536
100-Year, 24-Hour SCS	8.894	2.420	1.619	0.296	93.80	3.577	53449
100-Year, 24-Hour SCS [4]	8.894	2.420	2.420	2.420	93.81	3.665	53946
100-Year, 10-Year Spring [4]	N/A	0.000	0.000	0.000	94.22	2.908	72715

(1) Based on 24 hour detention of 40 m^3/ha quality control volume, erosion control of 2-year release rate to 330 L/s (as per Parish Geomorphic threshold) and quantity control of 5- to 100-year release rates to pre-development levels as modelled in SWMHYMO Rtar_F.*.

(2) Major system flows from 36.63 ha, 30.79 ha, 21.75 ha and 2.65 ha of the Pond 1 subdivision area will discharge to Pond 1, to the Van Gaal Drain, to the Moore Drain Tributary, and to the Moore Drain, respectively, as modelled in SWMHYMO Rtar_F.*.

(3) Volumes used are active storage only for all pond components except the permanent pool.

(4) Restrictive downstream conditions; Summer = 93.68 m, Spring = 94.11 m. All other results based on free outfall conditions.

Table 3B: Summary of SWM Facility 2 Operating Characteristics [1]

Pond Component	Pre-Development Outflow (m^3/s)	Pond Level (m)	Pond Outflow (m^3/s)	Volume Used [2] (m^3)
Permanent Pool	N/A	93.20	N/A	2990
Quality Control	N/A	93.35	0.038	1837
2-Year, 24-Hour SCS	0.705	93.68	0.594	6643
5-Year, 24-Hour SCS	1.094	93.82	0.955	9040
10-Year, 24-Hour SCS	1.364	93.91	1.206	10594
25-Year, 24-Hour SCS	1.708	94.03	1.527	12506
50-Year, 24-Hour SCS	1.976	94.11	1.782	13986
100-Year, 24-Hour SCS	2.267	94.20	2.059	15570
100-Year, 10-Year Spring [3]	N/A	94.84	1.460	27487

(1) Based on 24 hour detention of 40 m^3/ha quality control volume and quantity control of 100-year release rate to capacity of 1500 mm outlet pipe at 0.1% slope (2.235 m^3/s). No erosion control is provided. Pre-development flows as modelled in SWMHYMO Rtar_F.*.

(2) Volumes used are active storage only for all pond components except the permanent pool.

(3) Restrictive downstream conditions; Spring = 94.18 m. All other results based on free outfall conditions.

Table 4A: Extended Detention Parameters for SWM Facility 1

Permanent Pool Parameters			Quality Orifice Parameters		
Area (C3)	27226.15	m^2	Diameter	0.300	m
Volume	39222.65	m^3			
PP Elev	92.35	m	Area	0.07069	m^2
QC Elev	92.50	m	Invert	92.35	m
h (m)	0.15	m	C_o	0.620	

Notes: C3 is the intercept from the area-depth linear regression
PP Elev indicates the elevation of the permanent pool
QC Elev indicates the elevation of the storage volume required by MOE for quality control
h is the maximum water elevation above the orifice (m)

Table 4B: Extended Detention Drawdown Time for SWM Facility 1

Elev. (m)	Active Storage			C2 (m^2/m)	Drawdown Time (h)	Drawdown Time (days)	Flow (m^3/s)	Demarkation Point
	V (m^3)	A (m^2)	depth (m)					
92.35	**0.00**	**27226.15**	**0.00**				**0.000**	**PP Elev**
92.40	1436.02	28902.23	0.05	33522	17.75	0.74	0.013	
92.45	2929.23	29951.41	0.10	27253	25.42	1.06	0.025	
92.50	**4443.44**	**30505.36**	**0.15**	**21861**	**31.33**	**1.31**	**0.038**	**QC Elev**
92.55	5991.84	31236.19	0.20	20050	36.49	1.52	0.050	

Notes: C2 is the slope coefficient from the area-depth linear regression
QC Elev indicates the elevation of the quality control volume required by MOE

Table 4C: Extended Detention Parameters for SWM Facility 2

Permanent Pool Parameters			Quality Orifice Parameters		
Area (C3)	11075.10	m^2	Diameter	0.300	m
Volume	2990.03	m^3			
PP Elev	93.20	m	Area	0.07069	m^2
QC Elev	93.35	m	Invert	93.20	m
h (m)	0.15	m	C_o	0.620	

Notes: C3 is the intercept from the area-depth linear regression
PP Elev indicates the elevation of the permanent pool
QC Elev indicates the elevation of the storage volume required by MOE for quality control
h is the maximum water elevation above the orifice (m)

Table 4D: Extended Detention Drawdown Time for SWM Facility 2

Elev. (m)	Active Storage			C2 (m^2/m)	Drawdown Time (h)	Drawdown Time (days)	Flow (m^3/s)	Demarkation Point
	V (m^3)	A (m^2)	depth (m)					
93.20	**0.00**	**11075.10**	**0.00**				**0.000**	**PP Elev**
93.25	573.33	11836.91	0.90	846	30.71	1.28	0.013	
93.30	1196.62	12676.33	0.95	1685	32.32	1.35	0.025	
93.35	**1836.54**	**12867.85**	**1.00**	**1793**	**33.34**	**1.39**	**0.038**	**QC Elev**
93.40	2504.49	13398.14	1.05	2212	34.68	1.44	0.050	

Notes: C2 is the slope coefficient from the area-depth linear regression
QC Elev indicates the elevation of the quality control volume required by MOE

Table 5A: Stage-Storage-Outflow Curve for SWM Facility 1

			Quality Control 1		Erosion Control 1		Quantity Control 1			
			Vertical Orifice		Vertical Orifice		Rectangular Weir			
			Dia (m)	0.300	Dia (m)	0.300	L (m)	45.000		
			Area (m^2)	0.071	Area (m^2)	0.071				
			Invert (m)	92.35	Invert (m)	92.50	C_w	1.700		
			C_o	0.62	C_o	0.62	Invert (m)	93.68		
			Q @ D	0.075	Q @ D	0.075	n contr.	2		
Elevation (m)	Active Sto. (m^3)	Demarkation Points	Head (m)	Outflow (m^3/s)	Head (m)	Outflow (m^3/s)	Head (m)	Outflow (m^3/s)	Outflow (m^3/s)	Storage (ha·m)
92.35	**0**	**PP Elev**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
92.40	1436		0.050	0.013	0.000	0.000	0.000	0.000	0.013	0.144
92.45	2929		0.100	0.025	0.000	0.000	0.000	0.000	0.025	0.293
92.50	**4443**	**QC Elev**	**0.150**	**0.038**	**0.000**	**0.000**	**0.000**	**0.000**	**0.038**	**0.444**
92.55	5992		0.200	0.050	0.050	0.013	0.000	0.000	0.063	0.599
92.60	7560		0.250	0.063	0.100	0.025	0.000	0.000	0.088	0.756
92.65	9168		0.300	0.075	0.150	0.038	0.000	0.000	0.113	0.917
92.70	10802		0.350	0.087	0.200	0.050	0.000	0.000	0.137	1.080
92.75	12459		0.400	0.097	0.250	0.063	0.000	0.000	0.160	1.246
92.80	14148		0.450	0.106	0.300	0.075	0.000	0.000	0.182	1.415
92.85	15867		0.500	0.115	0.350	0.087	0.000	0.000	0.202	1.587
92.90	17620		0.550	0.123	0.400	0.097	0.000	0.000	0.220	1.762
92.95	19390		0.600	0.130	0.450	0.106	0.000	0.000	0.237	1.939
93.00	21197		0.650	0.137	0.500	0.115	0.000	0.000	0.252	2.120
93.05	23028		0.700	0.144	0.550	0.123	0.000	0.000	0.267	2.303
93.10	24894		0.750	0.150	0.600	0.130	0.000	0.000	0.281	2.489
93.15	26779		0.800	0.157	0.650	0.137	0.000	0.000	0.294	2.678
93.20	28700		0.850	0.162	0.700	0.144	0.000	0.000	0.306	2.870
93.25	30634		0.900	0.168	0.750	0.150	0.000	0.000	0.318	3.063
93.30	32587		0.950	0.174	0.800	0.157	0.000	0.000	0.330	3.259
93.35	34548		1.000	0.179	0.850	0.162	0.000	0.000	0.341	3.455
93.40	36547		1.050	0.184	0.900	0.168	0.000	0.000	0.352	3.655
93.45	38559		1.100	0.189	0.950	0.174	0.000	0.000	0.363	3.856
93.50	40641		1.150	0.194	1.000	0.179	0.000	0.000	0.373	4.064
93.55	42717		1.200	0.199	1.050	0.184	0.000	0.000	0.383	4.272
93.60	44822		1.250	0.204	1.100	0.189	0.000	0.000	0.393	4.482
93.65	46961		1.300	0.208	1.150	0.194	0.000	0.000	0.402	4.696
93.68	**48248**	**Ext. Det.**	**1.330**	**0.211**	**1.180**	**0.197**	**0.000**	**0.000**	**0.408**	**4.825**
93.70	49106		1.350	0.213	1.200	0.199	0.020	0.216	0.628	4.911
93.75	51313		1.400	0.217	1.250	0.204	0.070	1.416	1.837	5.131
93.80	53489		1.450	0.221	1.300	0.208	0.120	3.178	3.608	5.349
93.85	55848		1.500	0.226	1.350	0.213	0.170	5.358	5.796	5.585
93.90	58767		1.550	0.230	1.400	0.217	0.220	7.886	8.333	5.877
93.95	60124		1.600	0.234	1.450	0.221	0.270	10.720	11.175	6.012
94.00	**62403**	**Top of Berm**	**1.650**	**0.238**	**1.500**	**0.226**	**0.320**	**13.828**	**14.292**	**6.240**
94.05	64689		1.700	0.242	1.550	0.230	0.370	17.189	17.660	6.469
94.10	67024		1.750	0.246	1.600	0.234	0.420	20.784	21.263	6.702
94.11	**67493**	**100-Yr Spr**	**1.760**	**0.246**	**1.610**	**0.235**	**0.430**	**21.529**	**22.010**	**6.749**
94.15	69372		1.800	0.249	1.650	0.238	0.470	24.598	25.085	6.937
94.20	71747		1.850	0.253	1.700	0.242	0.520	28.619	29.114	7.175
94.25	74132		1.900	0.257	1.750	0.246	0.570	32.838	33.340	7.413
94.30	76504		1.950	0.260	1.800	0.249	0.620	37.244	37.753	7.650
94.35	78940		2.000	0.264	1.850	0.253	0.670	41.829	42.346	7.894
94.40	81361		2.050	0.268	1.900	0.257	0.720	46.587	47.112	8.136
94.45	83758		2.100	0.271	1.950	0.260	0.770	51.512	52.044	8.376
94.50	86225		2.150	0.275	2.000	0.264	0.820	56.597	57.136	8.622

Notes :
- PP Elev indicates the elevation of the permanent pool.
- QC Elev indicates the elevation of the storage volume provided for quality control according to MOE requirements.
- Ext. Det. indicates the elevation of extended detention provided, and of the Van Gaal Drain floodplain during the 100-year summer (SCS) event.
- 100-Yr Spr indicates the elevation of the Van Gaal Drain floodplain during the 100-year spring (snow+rain) event.
- Top of Berm indicates the elevation at the top of the berm.

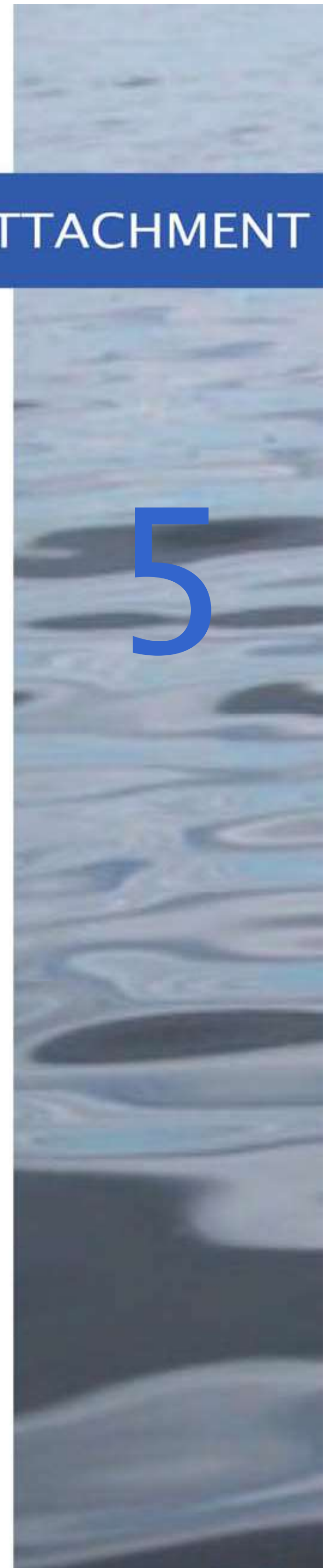
Table 5B: Stage-Storage-Outflow Curve for SWM Facility 2

			Quality Control 1		Quantity Control 1			
			Vertical Orifice		Rectangular Weir			
			Dia (m)	0.300	L (m)	1.500		
			Area (m^2)	0.071				
			Invert (m)	93.20	C_w	1.800		
			C_o	0.62	Invert (m)	93.35		
			Q @ D	0.075	n contr.	2		
Elevation (m)	Active Sto. (m^3)	Demarkation Points	Head (m)	Outflow (m^3/s)	Head (m)	Outflow (m^3/s)	Outflow (m^3/s)	Storage (ha·m)
93.20	**0**	**PP Elev**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
93.25	573		0.050	0.013	0.000	0.000	0.013	0.057
93.30	1197		0.100	0.025	0.000	0.000	0.025	0.120
93.35	**1837**	**QC Elev**	**0.150**	**0.038**	**0.000**	**0.000**	**0.038**	**0.184**
93.40	2504		0.200	0.050	0.050	0.030	0.080	0.250
93.45	3183		0.250	0.063	0.100	0.084	0.147	0.318
93.50	3889		0.300	0.075	0.150	0.154	0.229	0.389
93.55	4649		0.350	0.087	0.200	0.235	0.322	0.465
93.60	5428		0.400	0.097	0.250	0.326	0.423	0.543
93.65	6210		0.450	0.106	0.300	0.426	0.532	0.621
93.70	7016		0.500	0.115	0.350	0.533	0.648	0.702
93.75	7835		0.550	0.123	0.400	0.647	0.769	0.783
93.80	8666		0.600	0.130	0.450	0.766	0.896	0.867
93.85	9502		0.650	0.137	0.500	0.891	1.028	0.950
93.90	10346		0.700	0.144	0.550	1.021	1.165	1.035
93.95	11191		0.750	0.150	0.600	1.154	1.305	1.119
94.00	12047		0.800	0.157	0.650	1.292	1.449	1.205
94.05	12914		0.850	0.162	0.700	1.434	1.596	1.291
94.10	13785		0.900	0.168	0.750	1.578	1.746	1.378
94.15	14663		0.950	0.174	0.800	1.726	1.900	1.466
94.18	**15193**	**100-Yr Spr**	**0.980**	**0.177**	**0.830**	**1.816**	**1.993**	**1.519**
94.20	15547		1.000	0.179	0.850	1.876	2.055	1.555
94.25	16438		1.050	0.184	0.900	2.029	2.213	1.644
94.30	17336		1.100	0.189	0.950	2.183	2.373	1.734
94.35	18242		1.150	0.194	1.000	2.340	2.534	1.824
94.40	19153		1.200	0.199	1.050	2.498	2.697	1.915
94.45	20072		1.250	0.204	1.100	2.658	2.862	2.007
94.50	20997		1.300	0.208	1.150	2.819	3.027	2.100
94.55	21930		1.350	0.213	1.200	2.981	3.194	2.193
94.60	22870		1.400	0.217	1.250	3.144	3.362	2.287
94.65	23817		1.450	0.221	1.300	3.308	3.530	2.382
94.70	24770		1.500	0.226	1.350	3.473	3.698	2.477
94.75	25732		1.550	0.230	1.400	3.638	3.867	2.573
94.81	26699		1.609	0.234	1.459	3.833	4.067	2.670
94.85	27675		1.650	0.238	1.500	3.968	4.206	2.767
94.90	28654		1.700	0.242	1.550	4.133	4.375	2.865
94.95	29644		1.750	0.246	1.600	4.299	4.544	2.964
95.00	30645		1.800	0.249	1.650	4.464	4.713	3.064
95.05	31649		1.850	0.253	1.700	4.628	4.881	3.165
95.10	32661		1.900	0.257	1.750	4.792	5.049	3.266
95.15	33688		1.950	0.260	1.800	4.955	5.216	3.369
95.20	34713		2.000	0.264	1.850	5.118	5.382	3.471
95.25	35748		2.050	0.268	1.900	5.280	5.547	3.575
95.30	36756		2.100	0.271	1.950	5.441	5.712	3.676
95.35	37820		2.150	0.275	2.000	5.600	5.875	3.782
95.40	38883		2.200	0.278	2.050	5.759	6.037	3.888
95.45	39936		2.250	0.281	2.100	5.916	6.197	3.994
95.50	40980		2.300	0.285	2.150	6.072	6.356	4.098
95.55	42077		2.350	0.288	2.200	6.226	6.514	4.208
95.60	43165		2.400	0.291	2.250	6.379	6.670	4.317
95.65	44262		2.450	0.294	2.300	6.530	6.824	4.426

Table 5B: Stage-Storage-Outflow Curve for SWM Facility 2

			Quality Control 1		Quantity Control 1			
			Vertical Orifice		Rectangular Weir			
			Dia (m)	0.300	L (m)	1.500		
			Area (m^2)	0.071				
			Invert (m)	93.20	C_w	1.800		
			C_o	0.62	Invert (m)	93.35		
			Q @ D	0.075	n contr.	2		
Elevation	Active Sto.	Demarkation Points	Head	Outflow	Head	Outflow	Outflow	Storage
(m)	(m^3)		(m)	(m^3/s)	(m)	(m^3/s)	(m^3/s)	(ha·m)
95.70	45394		2.500	0.298	2.350	6.679	6.977	4.539
95.75	46502		2.550	0.301	2.400	6.826	7.127	4.650
95.80	47623		2.600	0.304	2.450	6.972	7.276	4.762
95.85	48764		2.650	0.307	2.500	7.115	7.422	4.876
95.90	51022		2.700	0.310	2.550	7.256	7.566	5.102
95.95	50837		2.750	0.313	2.600	7.395	7.708	5.084
96.00	**51987**	**Top of Berm**	**2.800**	**0.316**	**2.650**	**7.532**	**7.848**	**5.199**

Notes :
- PP Elev indicates the elevation of the permanent pool.
- QC Elev indicates the elevation of the storage volume provided for quality control according to MOE requirements.
- 100-Yr Spr indicates the elevation of the Jock River floodplain during the 100-year spring (snow+rain) event.
- Top of Berm indicates the elevation at the top of the berm.



ATTACHMENT 5

PIPE DATA AND HYDRAULIC SIMULATION RESULTS

JFSA Water Resources and Environmental Consultants

Table 6: Pipe Data and Hydraulic Simulation Results (1)

													100-year, 3-hour Chicago Storm							100-year, 12-hour SCS Type II Storm							100-year, 10-day Spring Snowmelt + Rainfall Event						
U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Diameter / Height (m)	Pipe Width (m)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Velocity (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (2) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (2) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (2) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)
101	102	93.228	93.161	0.825	N/A	67.0	0.1	0.013	95.598	95.587	0.85	0.45	0.29	0.64	-0.28	1.1	93.78	93.78	1.82	0.29	0.64	-0.24	12.0	93.82	93.81	1.78	0.02	0.04	0.17	109.0	94.22	94.22	1.38
102	103	93.141	93.061	0.825	N/A	80.0	0.1	0.013	95.587	95.470	0.85	0.45	0.29	0.64	-0.19	1.1	93.78	93.78	1.81	0.28	0.62	-0.15	12.1	93.81	93.81	1.77	0.02	0.04	0.26	108.9	94.22	94.22	1.37
103	104	92.911	92.850	0.975	N/A	60.5	0.1	0.013	95.470	95.373	0.95	0.71	0.60	0.85	-0.11	1.1	93.78	93.77	1.69	0.58	0.82	-0.07	12.1	93.81	93.81	1.66	0.04	0.06	0.34	109.0	94.22	94.22	1.25
104	105	92.820	92.796	0.975	N/A	23.5	0.1	0.013	95.373	95.331	0.95	0.71	0.60	0.85	-0.02	1.1	93.77	93.77	1.60	0.58	0.82	0.02	12.1	93.81	93.81	1.56	0.04	0.06	0.43	109.0	94.22	94.22	1.15
105	106	92.721	92.619	1.050	N/A	101.5	0.1	0.013	95.331	95.180	1.00	0.86	0.76	0.88	0.00	1.1	93.77	93.77	1.56	0.72	0.83	0.04	12.1	93.81	93.81	1.52	0.05	0.06	0.45	109.0	94.22	94.22	1.11
106	107	92.559	92.483	1.050	N/A	76.5	0.1	0.013	95.180	95.070	1.00	0.86	0.87	1.01	0.16	1.1	93.77	93.77	1.41	0.82	0.95	0.20	12.1	93.81	93.81	1.37	0.05	0.06	0.61	109.0	94.22	94.22	0.96
107	108	92.333	92.258	1.200	N/A	74.5	0.1	0.013	95.070	95.057	1.09	1.23	1.14	0.92	0.24	1.1	93.77	93.77	1.30	1.06	0.86	0.28	12.1	93.81	93.81	1.26	0.07	0.06	0.69	109.0	94.22	94.22	0.85
108	109	92.238	92.211	1.200	N/A	26.5	0.1	0.013	95.057	95.487	1.09	1.23	1.27	1.03	0.33	1.1	93.77	93.77	1.29	1.17	0.95	0.37	12.1	93.81	93.81	1.25	0.08	0.06	0.78	109.0	94.22	94.22	0.84
109	Pond1	92.181	92.150	1.200	N/A	31.0	0.1	0.013	95.487	94.500	1.09	1.23	1.26	1.02	0.39	1.1	93.77	93.77	1.72	1.16	0.94	0.43	12.1	93.81	93.81	1.68	0.08	0.1	0.84	109.0	94.22	94.22	1.27
202	203	93.826	93.706	0.675	N/A	120.0	0.1	0.013	96.212	96.030	0.74	0.27	0.21	0.79	-0.16	1.1	94.34	94.24	1.87	0.21	0.79	0.02	12.0	94.52	94.46	1.69	0.01	0.04	-0.28	109.1	94.23	94.23	1.99
203	204	93.556	93.479	0.825	N/A	77.0	0.1	0.013	96.030	95.920	0.85	0.45	0.43	0.95	-0.14	1.1	94.24	94.19	1.79	0.42	0.93	0.08	12.0	94.46	94.40	1.57	0.03	0.07	-0.16	109.1	94.23	94.23	1.81
204	205	93.404	93.332	0.900	N/A	72.0	0.1	0.013	95.920	95.812	0.90	0.57	0.53	0.93	-0.12	1.1	94.19	94.14	1.74	0.52	0.91	0.10	12.2	94.40	94.35	1.52	0.03	0.05	-0.08	109.1	94.23	94.22	1.70
205	206	93.257	93.184	0.975	N/A	73.0	0.1	0.013	95.812	95.700	0.95	0.71	0.62	0.87	-0.10	1.1	94.14	94.05	1.68	0.61	0.86	0.11	12.2	94.35	94.26	1.47	0.04	0.06	-0.01	109.1	94.22	94.22	1.59
206	207	92.959	92.925	1.200	1.800	34.0	0.1	0.013	95.700	95.898	1.23	2.66	2.27	0.85	-0.11	1.1	94.05	94.02	1.65	2.20	0.83	0.10	12.2	94.26	94.23	1.44	0.15	0.06	0.06	109.1	94.22	94.22	1.48
207	208	92.875	92.819	1.200	1.800	55.5	0.1	0.013	95.898	95.684	1.23	2.66	2.31	0.87	-0.06	1.1	94.02	93.96	1.88	2.27	0.85	0.15	12.2	94.23	94.18	1.67	0.15	0.06	0.15	109.0	94.22	94.22	1.67
208	209	92.769	92.729	1.200	1.800	39.5	0.1	0.013	95.684	95.520	1.23	2.66	2.32	0.87	-0.01	1.3	93.96	93.93	1.72	2.27	0.85	0.21	12.2	94.18	94.15	1.51	0.15	0.06	0.25	109.0	94.22	94.22	1.46
209	210	92.679	92.603	1.200	1.800	76.5	0.1	0.013	95.520	95.410	1.23	2.66	2.59	0.97	0.05	1.3	93.93	93.86	1.59	2.49	0.94	0.27	12.2	94.15	94.08	1.37	0.17	0.06	0.34	109.1	94.22	94.22	1.30
210	211	92.583	92.507	1.200	1.800	76.5	0.1	0.013	95.410	95.290	1.23	2.66	2.79	1.05	0.08	1.2	93.86	93.78	1.55	2.68	1.01	0.30	12.2	94.08	94.00	1.33	0.18	0.07	0.44	109.0	94.22	94.22	1.19
211	212	92.487	92.389	1.200	2.400	82.0	0.1	0.013	95.290	95.165	1.45	4.17	4.92	1.18	0.09	1.2	93.78	93.77	1.51	4.71	1.13	0.32	12.2	94.00	93.88	1.29	0.32	0.08	0.54	109.0	94.22	94.22	1.07
212	213	92.369	92.290	1.200	2.400	65.5	0.1	0.013	95.165	95.108	1.45	4.17	5.03	1.21	0.20	1.2	93.77	93.77	1.39	4.83	1.16	0.31	12.2	93.88	93.81	1.29	0.33	0.08	0.65	109.0	94.22	94.22	0.94
213	214	92.210	92.172	1.200	2.400	31.5	0.1	0.013	95.108	95.454	1.45	4.17	5.02	1.20	0.36	1.2	93.77	93.77	1.34	4.82	1.16	0.40	12.2	93.81	93.81	1.30	0.33	0.08	0.81	109.0	94.22	94.22	0.89
214	215	92.122	92.081	1.200	2.400	34.5	0.1	0.013	95.454	95.479	1.45	4.17	5.00	1.20	0.45	1.2	93.77	93.77	1.68	4.82	1.16	0.49	12.2	93.81	93.81	1.64	0.33	0.08	0.90	109.0	94.22	94.22	1.23
215	Pond1	92.001	91.950	1.200	2.400	42.5	0.1	0.013	95.479	94.500	1.45	4.17	4.96	1.19	0.57	1.2	93.77	93.77	1.71	4.82	1.16	0.61	12.2	93.81	93.81	1.67	0.33	0.08	1.02	109.0	94.22	94.22	1.26
251	252	93.818	93.748	0.675	N/A	70.5	0.1	0.013	96.160	96.054	0.74	0.27	0.18	0.68	-0.22	1.1	94.28	94.24	1.88	0.17	0.64	-0.03	12.0	94.47	94.44	1.69	0.01	0.04	-0.27	109.1	94.23	94.23	1.94
252	253	93.673	93.603	0.750	N/A	70.5	0.1	0.013	96.054	95.949	0.80	0.35	0.26	0.74	-0.18	1.1	94.24	94.20	1.82	0.25	0.71	0.02	12.0	94.44	94.40	1.61	0.02	0.06	-0.20	109.1	94.23	94.23	1.83
253	254	93.303	93.227	1.050	N/A	76.5	0.1	0.013	95.949	95.834	1.00	0.86	0.82	0.95	-0.15	1.1	94.20	94.07	1.75	0.79	0.91	0.05	12.0	94.40	94.29	1.55	0.05	0.06	-0.13	109.0	94.23	94.22	1.72
254	206	93.077	92.989	1.200	1.800	88.0	0.1	0.013	95.834	95.700	1.23	2.66	1.53	0.58	-0.21	1.1	94.07	94.05	1.76	1.47	0.55	0.01	12.0	94.29	94.26	1.55	0.10	0.04	-0.05	109.0	94.22	94.22	1.61
261	262	93.851	93.753	0.675	N/A	97.5	0.1	0.013	96.161	96.015	0.74	0.27	0.21	0.79	-0.13	1.1	94.39	94.34	1.77	0.21	0.79	0.05	12.0	94.58	94.53	1.58	0.01	0.04	-0.30	109.1	94.23	94.23	1.94
262	263	93.603	93.484	0.825	N/A	119.0	0.1	0.013	96.015	95.837	0.85	0.45	0.40	0.88	-0.09	1.1	94.34	94.27	1.68	0.38	0.84	0.10	12.0	94.53	94.45	1.48	0.03	0.07	-0.20	109.1	94.23	94.23	1.79
263	264	93.409	93.302	0.900	N/A	107.0	0.1	0.013	95.837	95.676	0.90	0.57	0.56	0.98	-0.04	1.3	94.27	94.14	1.57	0.54	0.94	0.14	12.2	94.45	94.33	1.39	0.03	0.05	-0.08	109.1	94.23	94.22	1.61
264	265	93.222	93.182	0.900	N/A	40.5	0.1	0.013	95.676	95.616	0.90	0.57	0.67	1.17	0.02	1.3	94.14	94.09	1.53	0.64	1.12	0.21	12.2	94.33	94.29	1.35	0.04	0.07	0.10	109.1	94.22	94.22	1.45
265	266	93.032	93.002	1.050	N/A	30.0	0.1	0.013	95.616	95.571	1.00	0.86	1.01	1.17	0.01	1.3	94.09	94.05	1.52	0.99	1.15	0.21	12.2	94.29	94.26	1.33	0.06	0.07	0.14	109.1	94.22	94.22	1.39
266	267	92.852	92.753	1.200	N/A	99.0	0.1	0.013	95.571	95.421	1.09	1.23	1.52	1.23	0.00	1.1	94.05	93.89	1.52	1.44	1.17	0.20	12.2	94.26	94.12	1.32	0.10	0.08	0.17	109.0	94.22	94.22	1.35
267	268	92.703	92.657	1.200	1.800	45.5	0.1	0.013	95.421	95.342	1.23	2.66	2.07	0.78	-0.01	1.1	93.89	93.85	1.53	1.96	0.74	0.21	12.1	94.12	94.08	1.30	0.13	0.05	0.32	109.0	94.22	94.22	1.20
268	211	92.607	92.567	1.200	1.800	40.5	0.1	0.013	95.342	95.290	1.23	2.66	2.05	0.77	0.05	1.1	93.85	93.78	1.49	1.96	0.74	0.27	12.1	94.08	94.00	1.26	0.13	0.05	0.42	109.0	94.22	94.22	1.12
301	302	93.248	93.194	0.600	N/A	54.0	0.1	0.013	95.797	95.829	0.69	0.19	0.14	0.72	-0.08	1.1	93.77	93.77	2.02	0.14	0.72	-0.03	12.0	93.81	93.81	1.98	0.01	0.05	0.37	108.9	94.22	94.22	1.58
302	303	93.164	93.153	0.600	N/A	11.0	0.1	0.013	95.829	95.808	0.69	0.19	0.14	0.72	0.01	1.1	93.77	93.77	2.06	0.13	0.67	0.05	12.0	93.81	93.81	2.02	0.01	0.05	0.46	109.0	94.22	94.22	1.61
303	304	93.123	93.055	0.600	N/A	67.5	0.1	0.013	95.808	95.729	0.69	0.19	0.14	0.72	0.05	1.1	93.77	93.77	2.04	0.13	0.67	0.09	12.1	93.81	93.81	2.00	0.01	0.05	0.50	108.9	94.22	94.22	1.59
304	305	92.980	92.906	0.675	N/A	73.5	0.1	0.013	95.729	95.410	0.74	0.27	0.24	0.90	0.12	1.1	93.77	93.77	1.96	0.23	0.87	0.16	12.1	93.81	93.81	1.92	0.01	0.04	0.57	108.9	94.22	94.22	1.51
305	306	92.681	92.605	0.900	N/A	76.5	0.1	0.013	95.410	95.300	0.90	0.57	0.50	0.87	0.19	1.1	93.77	93.77	1.64	0.48	0.84	0.23	12.1	93.81	93.81	1.60	0.03	0.05	0.64	108.9	94.22	94.22	1.19
306	307	92.545	92.465	0.900	1.800	79.5	0.1	0.013	95.300	94.860	1.09	1.77	0.79	0.45	0.33	1.1	93.77	93.77	1.53	0.73	0.41	0.36	12.0	93.81	93.81	1.49	0.05	0.03	0.78	109.0	94.22	94.22	1.08
307	308	92.445	92.368	0.900	1.800	77.0	0.1	0.013	94.860	94.823	1.09	1.77	1.18	0.67	0.43	1.1	93.77	93.77	1.09	1.09	0.62	0.47	12.2	93.81	93.81	1.05	0.07	0.04	0.88	109.0	94.22	94.22	0.64
308	407	92.338	92.244	0.900	1.800	94.5	0.1	0.013	94.823	95.199	1.09	1.77	1.14	0.65	0.53	1.1	93.77	93.77	1.05	1.08	0.61	0.57	12.2	93.81	93.81	1.01	0.07	0.04	0.98	109.0	94.22	94.22	0.60
401	402	92.920	92.891	0.675	N/A	26.5	0.1	0.013	95.844	95.746	0.78	0.28	0.24	0.86	0.18	1.1	93.78	93.78	2.07	0.23	0.82	0.22	12.0	93.81	93.81	2.03	0.01	0.04	0.63	109.0	94.22	94.22	1.62
402	403	92.816	92.805	0.750	N/A	11.0	0.1	0.013	95.746	95.689	0.80	0.35	0.24	0.68	0.21	1.1	93.78	93.78	1.97	0.23	0.65	0.25	12.0	93.81	93.81	1.93	0.01	0.03	0.66	108.8	94.22	94.22	1.52
403	404	92.775	92.695	0.750	N/A	80.0	0.1	0.013	95.689	95.577	0.80	0.35	0.24	0.68	0.25	1.1	93.78	93.78	1.91	0.22	0.62	0.29	12.1	93.81	93.81	1.88	0.01	0.03	0.70	109.0	94.22	94.22	1.47
404	405	92.620	92.513	0.825	N/A	106.5	0.1	0.013	95.577	95.150	0.85	0.45	0.42	0.93	0.33	1.1	93.78	93.77	1.80	0.39	0.86	0.37	12.1	93.81	93.81	1.77	0.03	0.07	0.78	109.0	94.22	94.22	1.36
405	406	92.438	92.350	0.900	N/A	68.0	0.1	0.013	95.150	95.005	1.03	0.65	0.70	1.07	0.44	1.1	93.77	93.77	1.38	0.65	1.00	0.47	12.1	93.81	93.81	1.34	0.04	0.06	0.88	109.0	94.22	94.22	0.93
406	407	92.330	92.244	0.900	N/A	66.5	0.1	0.013	95.005	95.199	1.03	0.65	0.69	1.06	0.54	1.1	93.77	93.77	1.23	0.64	0.98	0.58	12.1	93.81	93.81	1.19	0.04	0.06	0.99	109.0	94.22	94.22	0.78
407	408	92.214	92.196	0.900	1.800	17.5	0.1	0.013	95.199	94.558	1.09	1.77	1.78	1.01	0.66	1.1	93.77	93.77	1.43	1.71	0.97	0.70	12.2	93.81	93.81	1.39	0.12	0.07	1.11	109.0	94.22	94.22	0.98
408	Pond1	92.166	92.150	0.900	1.800	16.5	0.1	0.013	94.558	94.500	1.09	1.77	1.76	1.00	0.71	1.1	93.77	93.77	0.79	1.71	0.97	0.74	12.2	93.81	93.81	0.75	0.12	0.07	1.16	109.0	94.22	94.22	0.34
500	501	93.525	93.444	0.750	N/A	81.0	0.1	0.013	96.026	95.903	0.80	0.35	0.24	0.68	-0.25	1.1	94.03	93.98	2.00	0.23	0.65	-0.13	12.0	94.15	94.12	1.88	0.01	0.03	-0.05	109.0	94.22	94.22	1.80
501	502	93.424	93.352	0.750	N/A	71.5	0.1	0.013	95.903	95.772	0.80	0.35	0.23	0.65	-0.19	1.2	93.98	93.94	1.92	0.21	0.60	-0.06	12.0	94.12	94.09	1.78	0.01	0.03	0.05	109.0	94.22	94.22	1.68
502	503	93.277	93.266	0.825	N/A	11.0	0.1	0.013	95.772	95.653	0.85	0.45	0.33	0.73	-0.16	1.2	93.94	93.92	1.83	0.32	0.70	-0.01	12.2	94.09	94.08	1.68	0.02	0.04	0.12	109.1	94.22	94.22	1.55
503	504	93.236	93.175	0.825	N/A	61.0	0.1	0.013	95.653	95.567	0.85	0.45	0.34	0.75	-0.14	1.3	93.92	93.88	1.73	0.33	0.73	0.02	12.2	94.08	94.05	1.57	0.02	0.04	0.16	109.0	94.22	94.22	1.43
504	505	93.145	93.134	0.825	N/A	11.0	0.1	0.013	95.567	95.525	0.85	0.45	0.35	0.77	-0.09	1.3	93.88	93.87	1.69	0.34	0.75	0.08	12.2	94.05	94.04	1.52	0.02	0.04	0.25	109.0	94.22	94.22	1.34

Table 6: Pipe Data and Hydraulic Simulation Results (1)

													100-year, 3-hour Chicago Storm							100-year, 12-hour SCS Type II Storm							100-year, 10-day Spring Snowmelt + Rainfall Event						
U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Diameter / Height (m)	Pipe Width (m)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Velocity (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (2) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (2) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (2) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)
505	506	93.104	93.068	0.825	N/A	36.0	0.1	0.013	95.525	95.404	0.85	0.45	0.36	0.79	-0.06	1.3	93.87	93.82	1.66	0.35	0.77	0.11	12.2	94.04	94.00	1.49	0.02	0.04	0.29	109.1	94.22	94.22	1.30
506	507	92.993	92.917	0.900	N/A	76.0	0.1	0.013	95.404	95.290	0.90	0.57	0.52	0.91	-0.07	1.2	93.82	93.77	1.58	0.49	0.86	0.11	12.2	94.00	93.95	1.41	0.03	0.05	0.33	109.0	94.22	94.22	1.18
507	508	92.767	92.687	1.050	N/A	79.5	0.1	0.013	95.290	95.170	1.00	0.86	0.86	1.00	-0.04	1.2	93.77	93.77	1.52	0.80	0.93	0.13	12.2	93.95	93.83	1.34	0.05	0.06	0.41	109.0	94.22	94.22	1.07
508	509	92.627	92.597	1.050	N/A	30.0	0.1	0.013	95.170	95.121	1.00	0.86	0.88	1.02	0.10	1.2	93.77	93.77	1.40	0.82	0.95	0.15	12.2	93.83	93.81	1.34	0.06	0.07	0.55	109.0	94.22	94.22	0.95
509	510	92.447	92.374	1.200	N/A	72.5	0.1	0.013	95.121	95.016	1.09	1.23	1.12	0.91	0.13	1.2	93.77	93.77	1.35	1.04	0.84	0.16	12.1	93.81	93.81	1.31	0.07	0.06	0.57	109.0	94.22	94.22	0.90
510	511	92.354	92.267	1.200	N/A	86.5	0.1	0.013	95.016	94.413	1.09	1.23	1.25	1.01	0.22	1.2	93.77	93.77	1.24	1.16	0.94	0.26	12.1	93.81	93.81	1.21	0.08	0.06	0.67	109.0	94.22	94.22	0.79
511	611	92.207	92.100	1.200	N/A	106.5	0.1	0.013	94.413	94.667	1.09	1.23	1.41	1.14	0.37	1.2	93.77	93.77	0.64	1.31	1.06	0.40	12.1	93.81	93.81	0.60	0.09	0.07	0.81	109.0	94.22	94.22	0.19
601	602	93.362	93.294	0.600	N/A	68.5	0.1	0.013	96.029	95.603	0.69	0.19	0.17	0.88	-0.18	1.1	93.78	93.78	2.25	0.17	0.88	-0.13	12.0	93.83	93.81	2.20	0.01	0.05	0.26	109.0	94.22	94.22	1.81
602	603	93.264	93.253	0.600	N/A	11.0	0.1	0.013	95.603	95.530	0.69	0.19	0.17	0.88	-0.09	1.1	93.78	93.78	1.83	0.16	0.82	-0.05	12.0	93.81	93.81	1.79	0.01	0.05	0.36	108.7	94.22	94.22	1.38
603	604	93.103	93.035	0.750	N/A	68.5	0.1	0.013	95.530	95.400	0.80	0.35	0.26	0.74	-0.08	1.1	93.78	93.78	1.75	0.24	0.68	-0.04	12.1	93.81	93.81	1.72	0.02	0.06	0.37	109.1	94.22	94.22	1.31
604	605	92.885	92.809	0.900	N/A	76.5	0.1	0.013	95.400	95.290	0.90	0.57	0.46	0.80	-0.01	1.1	93.78	93.78	1.63	0.43	0.75	0.03	12.1	93.81	93.81	1.59	0.03	0.05	0.44	108.9	94.22	94.22	1.18
605	606	92.734	92.654	0.975	N/A	79.5	0.1	0.013	95.290	95.170	0.95	0.71	0.65	0.92	0.07	1.1	93.78	93.77	1.52	0.61	0.86	0.10	12.1	93.81	93.81	1.48	0.04	0.06	0.51	109.0	94.22	94.22	1.07
606	607	92.579	92.499	1.050	N/A	79.5	0.1	0.013	95.170	95.050	1.00	0.86	0.88	1.02	0.15	1.1	93.77	93.77	1.40	0.82	0.95	0.18	12.1	93.81	93.81	1.36	0.05	0.06	0.59	109.0	94.22	94.22	0.95
607	608	92.479	92.410	1.050	N/A	69.0	0.1	0.013	95.050	94.944	1.00	0.86	0.97	1.12	0.24	1.1	93.77	93.77	1.28	0.90	1.04	0.28	12.1	93.81	93.81	1.24	0.06	0.07	0.69	109.0	94.22	94.22	0.83
608	609	92.380	92.369	1.050	N/A	11.0	0.1	0.013	94.944	94.835	1.00	0.86	0.96	1.11	0.34	1.1	93.77	93.77	1.17	0.89	1.03	0.38	12.1	93.81	93.81	1.13	0.06	0.07	0.79	109.0	94.22	94.22	0.72
609	610	92.219	92.185	1.200	N/A	34.5	0.1	0.013	94.835	94.875	1.09	1.23	1.10	0.89	0.35	1.1	93.77	93.77	1.06	1.03	0.84	0.39	12.1	93.81	93.81	1.02	0.07	0.06	0.80	109.0	94.22	94.22	0.61
610	611	92.125	92.100	1.200	N/A	25.0	0.1	0.013	94.875	94.667	1.09	1.23	1.32	1.07	0.45	1.1	93.77	93.77	1.10	1.24	1.01	0.48	12.1	93.81	93.81	1.07	0.08	0.06	0.90	109.0	94.22	94.22	0.65
611	612	92.070	92.048	1.200	1.800	22.0	0.1	0.013	94.667	94.113	1.23	2.66	2.70	1.02	0.50	1.1	93.77	93.77	0.90	2.53	0.95	0.54	12.1	93.81	93.81	0.86	0.17	0.06	0.95	109.0	94.22	94.22	0.45
612	Pond1	92.018	92.000	1.200	1.800	18.0	0.1	0.013	94.113	94.500	1.23	2.66	2.68	1.01	0.55	1.1	93.77	93.77	0.34	2.52	0.95	0.59	12.1	93.81	93.81	0.30	0.17	0.06	1.00	109.0	94.22	94.22	-0.11
700	701	93.517	93.443	0.975	N/A	74.0	0.1	0.013	96.786	96.740	0.95	0.71	0.64	0.90	0.63	1.1	95.12	94.96	1.66	0.65	0.92	0.73	12.1	95.22	95.11	1.57	0.06	0.08	-0.27	0.0	94.23	94.23	2.56
701	702	93.368	93.328	1.050	N/A	40.0	0.1	0.013	96.740	96.530	1.00	0.86	0.80	0.93	0.55	1.1	94.96	94.91	1.78	0.81	0.94	0.69	12.1	95.11	95.08	1.63	0.07	0.08	-0.19	0.0	94.23	94.23	2.51
702	703	93.178	93.106	1.200	1.800	71.5	0.1	0.013	96.530	96.420	1.23	2.66	1.62	0.61	0.53	1.1	94.91	94.86	1.62	1.64	0.62	0.70	12.1	95.08	95.05	1.45	0.10	0.04	-0.15	109.1	94.23	94.23	2.30
703	704	93.086	92.980	1.200	1.800	105.5	0.1	0.013	96.420	96.260	1.23	2.66	2.13	0.80	0.57	1.1	94.86	94.75	1.56	2.17	0.82	0.77	12.1	95.05	94.98	1.37	0.13	0.05	-0.06	109.1	94.23	94.23	2.19
704	705	92.960	92.888	1.200	1.800	71.5	0.1	0.013	96.260	96.150	1.23	2.66	2.95	1.11	0.59	1.1	94.75	94.64	1.51	2.98	1.12	0.82	12.1	94.98	94.88	1.28	0.18	0.07	0.06	109.1	94.23	94.23	2.04
705	706	92.868	92.801	1.200	2.400	67.0	0.1	0.013	96.150	95.902	1.32	3.80	4.35	1.14	0.57	1.1	94.64	94.54	1.51	4.26	1.12	0.81	12.1	94.88	94.78	1.27	0.26	0.07	0.16	109.0	94.23	94.23	1.93
706	707	92.781	92.697	1.200	2.400	83.5	0.1	0.013	95.902	95.430	1.32	3.80	4.47	1.18	0.56	1.1	94.54	94.27	1.36	4.38	1.15	0.80	12.1	94.78	94.51	1.12	0.27	0.07	0.24	109.0	94.23	94.23	1.68
707	708	92.637	92.567	1.200	2.400	70.0	0.1	0.013	95.430	95.320	1.32	3.80	5.02	1.32	0.43	1.1	94.27	94.12	1.16	4.90	1.29	0.67	12.1	94.51	94.36	0.92	0.30	0.08	0.39	109.0	94.23	94.22	1.21
708	709	92.547	92.481	1.200	2.400	66.0	0.1	0.013	95.320	95.221	1.32	3.80	5.22	1.37	0.37	1.1	94.12	93.97	1.20	5.09	1.34	0.61	12.1	94.36	94.20	0.96	0.31	0.08	0.48	109.1	94.22	94.22	1.10
709	710	92.461	92.391	1.200	2.400	70.5	0.1	0.013	95.221	95.112	1.32	3.80	5.22	1.37	0.31	1.1	93.97	93.77	1.25	5.09	1.34	0.54	12.1	94.20	93.82	1.02	0.31	0.08	0.56	109.0	94.22	94.22	1.00
710	711	92.331	92.200	1.200	2.400	131.0	0.1	0.013	95.112	94.385	1.32	3.80	5.57	1.46	0.24	1.1	93.77	93.77	1.34	5.46	1.44	0.29	12.1	93.82	93.81	1.29	0.34	0.09	0.69	109.0	94.22	94.22	0.89
711	712	92.140	92.118	1.200	2.400	21.5	0.1	0.013	94.385	94.000	1.32	3.80	5.50	1.45	0.43	1.1	93.77	93.78	0.61	5.44	1.43	0.47	12.1	93.81	93.81	0.57	0.34	0.09	0.88	109.0	94.22	94.22	0.16
712	Pond1	92.058	92.050	1.200	2.400	8.5	0.1	0.013	94.000	94.500	1.32	3.80	5.50	1.45	0.52	1.1	93.78	93.77	0.22	5.42	1.43	0.55	12.1	93.81	93.81	0.19	0.33	0.09	0.96	109.1	94.22	94.22	-0.22
751	752	93.846	93.752	0.600	N/A	94.0	0.1	0.013	96.720	96.579	0.69	0.19	0.17	0.88	0.78	1.1	95.23	95.02	1.49	0.15	0.77	0.57	12.1	95.02	94.95	1.70	0.02	0.10	-0.22	0.1	94.23	94.23	2.49
752	753	93.602	93.520	0.750	N/A	82.0	0.1	0.013	96.579	96.452	0.80	0.35	0.28	0.80	0.67	1.1	95.02	94.93	1.56	0.27	0.77	0.60	12.1	94.95	94.97	1.63	-0.03	-0.09	-0.13	0.2	94.23	94.23	2.35
753	754	93.295	93.209	0.975	N/A	86.0	0.1	0.013	96.452	96.324	0.95	0.71	0.77	1.09	0.66	1.1	94.93	94.82	1.53	0.75	1.06	0.70	12.1	94.97	94.96	1.49	0.04	0.06	-0.04	109.0	94.23	94.23	2.23
754	705	93.134	93.018	1.050	N/A	116.0	0.1	0.013	96.324	96.150	1.00	0.86	0.93	1.08	0.64	1.1	94.82	94.64	1.51	0.92	1.07	0.78	12.1	94.96	94.88	1.36	0.05	0.06	0.04	109.0	94.23	94.23	2.10
806	807	93.069	93.047	0.600	N/A	21.5	0.1	0.013	95.186	95.180	0.69	0.19	0.06	0.31	0.10	1.1	93.77	93.77	1.41	0.05	0.26	0.22	12.1	93.89	93.89	1.29	0.00	0.00	0.55	108.6	94.22	94.22	0.96
807	808	92.897	92.861	0.750	N/A	35.5	0.1	0.013	95.180	95.133	0.80	0.35	0.30	0.85	0.13	1.1	93.77	93.77	1.41	0.27	0.77	0.24	12.1	93.89	93.87	1.29	0.02	0.06	0.58	108.9	94.22	94.22	0.96
808	809	92.786	92.775	0.825	N/A	11.0	0.1	0.013	95.133	95.095	0.85	0.45	0.43	0.95	0.16	1.1	93.77	93.77	1.36	0.39	0.86	0.26	12.1	93.87	93.86	1.26	0.02	0.04	0.61	109.0	94.22	94.22	0.91
809	710	92.725	92.706	0.825	N/A	18.5	0.1	0.013	95.095	95.112	0.85	0.45	0.44	0.97	0.22	1.1	93.77	93.77	1.32	0.39	0.86	0.31	12.1	93.86	93.82	1.24	0.02	0.04	0.67	109.0	94.22	94.22	0.87
901	902	94.501	94.436	0.600	N/A	65.0	0.1	0.013	96.268	96.259	0.69	0.19	0.12	0.62	-0.16	1.1	94.94	94.91	1.33	0.12	0.62	-0.17	12.0	94.93	94.90	1.34	0.01	0.05	-0.26	107.9	94.84	94.84	1.42
902	903	94.416	94.346	0.675	N/A	70.0	0.1	0.013	96.259	96.151	0.74	0.27	0.21	0.79	-0.18	1.1	94.91	94.85	1.35	0.21	0.79	-0.19	12.1	94.90	94.84	1.36	0.01	0.04	-0.25	107.6	94.84	94.84	1.42
903	904	94.271	94.201	0.750	N/A	69.5	0.1	0.013	96.151	96.259	0.80	0.35	0.29	0.82	-0.17	1.1	94.85	94.75	1.30	0.28	0.80	-0.18	12.1	94.84	94.74	1.31	0.01	0.03	-0.18	109.0	94.84	94.84	1.31
904	905	94.121	94.005	0.900	N/A	116.0	0.1	0.013	96.259	96.162	0.90	0.57	0.56	0.98	-0.27	1.1	94.75	94.52	1.51	0.55	0.96	-0.28	12.1	94.74	94.51	1.52	0.03	0.05	-0.18	109.1	94.84	94.84	1.42
905	1007	93.955	93.939	0.900	N/A	16.0	0.1	0.013	96.162	96.196	0.90	0.57	0.56	0.98	-0.34	1.1	94.52	94.31	1.65	0.55	0.96	-0.35	12.1	94.51	94.30	1.65	0.03	0.05	-0.01	111.2	94.84	94.85	1.32
1001	1002	94.618	94.545	0.525	N/A	72.5	0.1	0.013	96.638	96.632	0.63	0.14	0.11	0.81	-0.14	1.1	95.00	94.90	1.64	0.11	0.81	-0.15	12.0	94.99	94.89	1.65	0.01	0.07	-0.30	108.5	94.84	94.84	1.79
1002	1003	94.465	94.388	0.600	N/A	77.0	0.1	0.013	96.632	96.593	0.69	0.19	0.17	0.88	-0.16	1.1	94.90	94.82	1.73	0.17	0.88	-0.17	12.1	94.89	94.81	1.74	0.01	0.05	-0.22	108.0	94.84	94.84	1.79
1003	1004	94.238	94.166	0.750	N/A	71.5	0.1	0.013	96.593	96.490	0.80	0.35	0.34	0.97	-0.17	1.1	94.82	94.74	1.77	0.34	0.97	-0.18	12.1	94.81	94.73	1.79	0.02	0.06	-0.14	108.1	94.84	94.84	1.75
1004	1005	94.016	93.942	0.900	N/A	74.0	0.1	0.013	96.490	96.380	0.90	0.57	0.51	0.89	-0.18	1.1	94.74	94.61	1.75	0.50	0.87	-0.19	12.1	94.73	94.59	1.76	0.03	0.05	-0.07	109.1	94.84	94.84	1.65
1005	1006	93.862	93.791	0.975	N/A	71.0	0.1	0.013	96.380	96.270	0.95	0.71	0.63	0.89	-0.23	1.2	94.61	94.44	1.77	0.61	0.86	-0.24	12.1	94.59	94.43	1.79	0.03	0.04	0.01	109.1	94.84	94.84	1.54
1006	1007	93.566	93.482	1.200	N/A	83.5	0.1	0.013	96.270	96.196	1.09	1.23	1.24	1.01	-0.33	1.1	94.44	94.31	1.83	1.22	0.99	-0.34	12.1	94.43	94.30	1.84	0.07	0.06	0.08	109.1	94.84	94.85	1.43
1007	1008	93.361	93.303	1.200	N/A	29.0	0.2	0.013	96.196	96.057	1.54	1.74	1.84	1.06	-0.25	1.2	94.31	94.04	1.88	1.80	1.03	-0.26	12.1	94.30	94.21	1.89	0.10	0.06	0.28	109.1	94.85	94.85	1.35
1008	Pond2	93.223	93.200	1.200	2.400	23.0	0.1	0.013	96.057	96.000	1.32	3.80	2.61	0.69	-0.38	1.1	94.04	94.04	2.01	2.55	0.67	-0.22	12.1	94.21	94.20	1.85	1.41	0.37	0.42	111.1	94.85	94.84	1.21
1101	1102	95.258	95.139	0.750	N/A	119.0	0.1	0.013	97.798	97.953	0.80	0.35	0.25	0.71	-0.29	1.1	95.72	95.57	2.08	0.24	0.68	-0.29	12.0	95.71	95.56	2.08	0.01	0.03	-0.64	109.0	95.37	95.20	2.43
1102	1103	95.109	95.101	0.750	N/A	8.0	0.1	0.013	97.953	97.864	0.80	0.35	0.25	0.71	-0.29	1.1	95.57	95.54	2.38	0.24	0.68	-0.30	12.1	95.56	95.53	2.39	0.01	0.03	-0.66	109.0	95.20	95.08	2.75
1103	1104	94.951	94.885	0.900	N/A	65.5	0.1	0.013	97.864	98.100	0.90	0.57	0.43	0.75	-0.31	1.1	95.54	95.48	2.32	0.42	0.73	-0.32	12.1	95.53	95.47	2.33	0.03	0.05	-0.77	109.0	95.08	94.98	2.78

Table 6: Pipe Data and Hydraulic Simulation Results [(1)]

													100-year, 3-hour Chicago Storm							100-year, 12-hour SCS Type II Storm							100-year, 10-day Spring Snowmelt + Rainfall Event						
U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Diameter / Height (m)	Pipe Width (m)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Velocity (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [(2)] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [(2)] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [(2)] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)
1104	1105	94.825	94.753	0.900	N/A	71.5	0.1	0.013	98.100	98.730	0.90	0.57	0.52	0.91	-0.25	1.1	95.48	95.27	2.62	0.51	0.89	-0.25	12.1	95.47	95.26	2.63	0.03	0.05	-0.75	109.0	94.98	94.85	3.13
1105	1106	94.673	94.619	0.900	N/A	54.5	0.1	0.013	98.730	98.710	0.90	0.57	0.52	0.91	-0.31	1.2	95.27	95.14	3.46	0.51	0.89	-0.31	12.1	95.26	95.13	3.47	0.03	0.05	-0.73	109.1	94.85	94.84	3.88
1106	1107	94.469	94.462	1.050	N/A	7.0	0.1	0.013	98.710	98.708	1.00	0.86	0.93	1.08	-0.38	1.1	95.14	95.03	3.57	0.91	1.05	-0.39	12.1	95.13	95.02	3.58	0.06	0.07	-0.68	109.0	94.84	94.84	3.87
1107	1108	94.432	93.978	1.050	N/A	113.5	0.4	0.013	98.708	96.666	1.99	1.73	0.92	0.53	-0.45	1.1	95.03	94.78	3.68	0.90	0.52	-0.46	12.1	95.02	94.77	3.69	0.05	0.03	-0.64	109.0	94.84	94.84	3.87
1108	1109	93.528	93.381	1.500	N/A	73.5	0.2	0.013	96.666	96.511	1.79	3.16	4.22	1.33	-0.24	1.2	94.78	94.24	1.88	4.15	1.31	-0.26	12.1	94.77	94.26	1.90	0.24	0.08	-0.19	109.1	94.84	94.84	1.83
1109	1110	93.351	93.283	1.500	2.400	67.5	0.1	0.013	96.511	95.479	1.45	5.23	4.22	0.81	-0.62	1.2	94.24	94.04	2.28	4.14	0.79	-0.59	12.1	94.26	94.20	2.25	0.24	0.05	-0.01	109.1	94.84	94.84	1.67
1110	Pond2	93.223	93.200	1.500	2.400	22.5	0.1	0.013	95.479	96.000	1.45	5.23	4.21	0.80	-0.69	1.2	94.04	94.04	1.44	4.11	0.79	-0.52	12.1	94.20	94.20	1.28	0.24	0.05	0.12	109.1	94.84	94.84	0.64
1201	1202	95.554	95.502	0.825	N/A	51.5	0.1	0.013	98.081	98.047	0.85	0.45	0.34	0.75	-0.28	1.1	96.10	96.04	1.98	0.34	0.75	-0.30	12.0	96.08	96.02	2.00	0.02	0.04	-0.70	109.0	95.68	95.58	2.41
1202	1203	95.472	95.461	0.825	N/A	11.0	0.1	0.013	98.047	98.014	0.85	0.45	0.34	0.75	-0.25	1.1	96.04	96.02	2.00	0.33	0.73	-0.28	12.0	96.02	95.99	2.03	0.02	0.04	-0.72	109.0	95.58	95.45	2.47
1203	1204	95.311	95.243	0.975	N/A	67.5	0.1	0.013	98.014	97.847	0.95	0.71	0.51	0.72	-0.27	1.1	96.02	95.98	1.99	0.50	0.71	-0.30	12.0	95.99	95.95	2.02	0.03	0.04	-0.84	109.0	95.45	95.36	2.56
1204	1205	95.223	95.149	0.975	N/A	67.5	0.1	0.013	97.847	97.741	1.00	0.74	0.49	0.66	-0.21	1.1	95.98	95.94	1.86	0.49	0.66	-0.25	12.2	95.95	95.90	1.90	0.03	0.04	-0.84	109.1	95.36	95.26	2.49
1205	1206	95.119	95.108	0.975	N/A	11.0	0.1	0.013	97.741	97.718	0.95	0.71	0.60	0.85	-0.15	1.1	95.94	95.92	1.80	0.59	0.83	-0.19	12.1	95.90	95.87	1.84	0.04	0.06	-0.83	109.0	95.26	95.23	2.48
1206	1207	95.078	95.022	0.975	N/A	56.0	0.1	0.013	97.718	97.549	0.95	0.71	0.61	0.86	-0.14	1.3	95.92	95.87	1.80	0.59	0.83	-0.18	12.2	95.87	95.82	1.85	0.04	0.06	-0.82	109.0	95.23	95.13	2.49
1207	1208	94.992	94.981	0.975	N/A	11.0	0.1	0.013	97.549	97.613	0.95	0.71	0.62	0.87	-0.10	1.3	95.87	95.85	1.68	0.61	0.86	-0.15	12.2	95.82	95.79	1.73	0.04	0.06	-0.83	109.1	95.13	95.10	2.42
1208	1209	94.951	94.915	0.975	N/A	36.0	0.1	0.013	97.613	97.564	0.95	0.71	0.63	0.89	-0.08	1.3	95.85	95.81	1.77	0.62	0.87	-0.13	12.2	95.79	95.76	1.82	0.04	0.06	-0.82	109.1	95.10	94.99	2.51
1209	1210	94.840	94.832	1.050	N/A	7.5	0.1	0.013	97.564	97.551	1.00	0.86	0.75	0.87	-0.08	1.3	95.81	95.79	1.75	0.72	0.83	-0.13	12.2	95.76	95.74	1.81	0.05	0.06	-0.90	109.0	94.99	94.96	2.57
1210	1211	94.802	94.773	1.050	N/A	29.0	0.1	0.013	97.551	96.869	1.00	0.86	0.76	0.88	-0.06	1.3	95.79	95.76	1.76	0.73	0.85	-0.12	12.2	95.74	95.70	1.82	0.05	0.06	-0.89	109.0	94.96	94.89	2.59
1211	1212	94.743	94.735	1.050	N/A	7.5	0.1	0.013	96.869	96.861	1.00	0.86	0.77	0.89	-0.03	1.3	95.76	95.74	1.11	0.74	0.86	-0.09	12.2	95.70	95.68	1.17	0.05	0.06	-0.90	109.0	94.89	94.87	1.97
1212	1213	94.705	94.641	1.050	N/A	64.0	0.1	0.013	96.861	97.400	1.00	0.86	0.80	0.93	-0.01	1.3	95.74	95.70	1.12	0.76	0.88	-0.07	12.2	95.68	95.65	1.18	0.05	0.06	-0.89	109.1	94.87	94.84	1.99
1213	1214	94.491	94.419	1.200	N/A	71.5	0.1	0.013	97.400	97.290	1.09	1.23	1.09	0.88	0.01	1.3	95.70	95.65	1.70	1.05	0.85	-0.05	12.2	95.65	95.60	1.76	0.07	0.06	-0.85	109.0	94.84	94.84	2.56
1214	1215	94.399	94.327	1.200	N/A	71.5	0.1	0.013	97.290	97.190	1.09	1.23	1.24	1.01	0.05	1.2	95.65	95.50	1.64	1.21	0.98	0.00	12.2	95.60	95.45	1.69	0.08	0.06	-0.76	109.0	94.84	94.84	2.45
1215	1216	94.177	94.105	1.350	N/A	71.5	0.1	0.013	97.190	97.080	1.18	1.69	1.64	0.97	-0.03	1.2	95.50	95.44	1.69	1.62	0.96	-0.08	12.2	95.45	95.39	1.74	0.10	0.06	-0.69	109.0	94.84	94.84	2.35
1216	1217	93.955	93.871	1.500	N/A	84.5	0.1	0.013	97.080	96.955	1.26	2.24	2.22	0.99	-0.02	1.2	95.44	95.35	1.65	2.19	0.98	-0.06	12.2	95.39	95.32	1.69	0.13	0.06	-0.61	109.0	94.84	94.84	2.24
1217	1218	93.851	93.768	1.500	N/A	83.0	0.1	0.013	96.955	96.830	1.26	2.24	2.47	1.10	0.00	1.2	95.35	95.25	1.60	2.45	1.10	-0.03	12.2	95.32	95.22	1.64	0.15	0.07	-0.51	109.1	94.84	94.84	2.11
1218	1219	93.748	93.702	1.500	N/A	46.5	0.1	0.013	96.830	96.760	1.26	2.24	2.55	1.14	0.00	1.2	95.25	95.19	1.58	2.53	1.13	-0.02	12.2	95.22	95.17	1.61	0.15	0.07	-0.41	109.1	94.84	94.84	1.99
1219	1108	93.682	93.608	1.500	N/A	74.0	0.1	0.013	96.760	96.666	1.26	2.24	3.03	1.36	0.00	1.2	95.19	94.78	1.57	2.99	1.34	-0.02	12.2	95.17	94.77	1.59	0.18	0.08	-0.34	109.1	94.84	94.84	1.92
1600	1601	94.197	94.025	1.200	N/A	107.5	0.2	0.013	97.015	96.875	1.38	1.56	1.60	1.03	-0.14	3.4	95.26	95.09	1.76	2.02	1.30	0.59	14.0	95.99	95.70	1.03	1.31	0.84	0.14	111.3	95.54	95.43	1.47
1601	1602	94.025	93.873	1.200	N/A	95.0	0.2	0.013	96.875	96.627	1.38	1.56	1.60	1.03	-0.13	3.4	95.09	94.95	1.78	2.02	1.30	0.47	14.0	95.70	95.44	1.18	1.31	0.84	0.20	111.2	95.43	95.33	1.44
1602	1603	93.873	93.721	1.200	N/A	95.0	0.2	0.013	96.627	96.665	1.38	1.56	1.60	1.03	-0.12	3.4	94.95	94.81	1.68	2.02	1.30	0.37	14.0	95.44	95.18	1.19	1.33	0.85	0.26	111.2	95.33	95.26	1.30
1603	1604	93.721	93.569	1.200	N/A	95.0	0.2	0.013	96.665	96.891	1.38	1.56	1.60	1.03	-0.11	3.4	94.81	94.67	1.86	2.02	1.30	0.26	14.0	95.18	94.95	1.48	1.34	0.86	0.33	111.2	95.26	95.14	1.41
1604	1605	93.569	93.431	1.200	N/A	86.5	0.2	0.013	96.891	96.700	1.38	1.56	1.60	1.03	-0.10	3.4	94.67	94.32	2.22	2.02	1.30	0.18	14.1	94.95	94.50	1.95	1.33	0.85	0.37	111.2	95.14	94.98	1.75
1605	1008	93.431	93.316	1.200	N/A	72.0	0.2	0.013	96.700	96.057	1.38	1.56	1.60	1.03	-0.31	3.4	94.32	94.04	2.38	2.02	1.30	-0.14	14.1	94.50	94.21	2.21	1.34	0.86	0.35	111.2	94.98	94.85	1.72
7000	700	93.664	93.592	0.900	N/A	71.5	0.1	0.013	96.997	96.786	0.90	0.57	0.52	0.91	0.67	1.1	95.23	95.12	1.77	0.52	0.91	0.71	12.1	95.27	95.22	1.72	0.07	0.12	-0.34	0.0	94.23	94.23	2.77
Pond1	Out1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.17	N/A	N/A	N/A	N/A	N/A	N/A	3.66	N/A	N/A	N/A	N/A	N/A	N/A	2.91	N/A	N/A	N/A	N/A	N/A	N/A
Pond2	Out2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.56	N/A	N/A	N/A	N/A	N/A	N/A	2.06	N/A	N/A	N/A	N/A	N/A	N/A	1.46	N/A	N/A	N/A	N/A	N/A	N/A
1500	1501	92.698	92.577	1.200	1.800	120.0	0.1	0.013	95.914	95.720	1.23	2.66	2.56	0.96	0.16	3.0	94.06	93.95	1.86	3.20	1.20	0.41	13.8	94.31	94.13	1.61	1.87	0.70	0.49	110.6	94.39	94.33	1.53
1501	21400	92.577	92.450	1.200	1.800	127.0	0.1	0.013	95.720	95.562	1.23	2.66	2.56	0.96	0.17	3.0	93.95	93.82	1.77	3.20	1.20	0.35	13.8	94.13	93.91	1.59	1.87	0.70	0.55	110.6	94.33	94.26	1.39
21400	Pond1	92.420	92.350	1.200	1.800	70.0	0.1	0.013	95.562	94.500	1.23	2.66	2.56	0.96	0.20	3.0	93.82	93.77	1.74	3.20	1.20	0.29	13.8	93.91	93.81	1.65	1.87	0.70	0.63	110.6	94.26	94.22	1.31

Note: [(1)] Based on restrictive downstream conditions; Summer = 93.68 m / Spring = 94.11 m for SWM Facility 1, and Spring = 94.18 m for Pond 2. All other results based on free outfall conditions.

[(2)] A negative surcharge implies that the pipe is not flowing full

0.22 Freeboard less than 0.5 m.

Table 6: Pipe Data and Hydraulic Simulation Results [1]

													100-year, 3-hour Chicago Storm + 20%							100-year, 12-hour SCS Type II Storm + 20%							July 1st, 1979 Historical Event						
U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Diameter / Height (m)	Pipe Width (m)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Velocity (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [2] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [2] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [2] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)
101	102	93.228	93.161	0.825	N/A	67.0	0.1	0.013	95.598	95.587	0.85	0.45	0.33	0.73	-0.23	1.1	93.83	93.82	1.77	0.31	0.68	-0.08	12.0	93.97	93.95	1.63	0.27	0.59	-0.24	1.7	93.81	93.81	1.79
102	103	93.141	93.061	0.825	N/A	80.0	0.1	0.013	95.587	95.470	0.85	0.45	0.33	0.73	-0.14	1.1	93.82	93.82	1.76	0.30	0.66	-0.02	12.2	93.95	93.93	1.64	0.28	0.62	-0.15	1.7	93.81	93.81	1.77
103	104	92.911	92.850	0.975	N/A	60.5	0.1	0.013	95.470	95.373	0.95	0.71	0.67	0.95	-0.06	1.1	93.82	93.82	1.65	0.61	0.86	0.04	12.1	93.93	93.88	1.55	0.56	0.79	-0.07	1.7	93.81	93.81	1.66
104	105	92.820	92.796	0.975	N/A	23.5	0.1	0.013	95.373	95.331	0.95	0.71	0.67	0.95	0.03	1.1	93.82	93.82	1.55	0.60	0.85	0.09	12.1	93.88	93.86	1.49	0.55	0.78	0.02	1.7	93.81	93.81	1.56
105	106	92.721	92.619	1.050	N/A	101.5	0.1	0.013	95.331	95.180	1.00	0.86	0.85	0.98	0.05	1.1	93.82	93.82	1.51	0.76	0.88	0.09	12.1	93.86	93.85	1.47	0.69	0.80	0.04	1.6	93.81	93.81	1.52
106	107	92.559	92.483	1.050	N/A	76.5	0.1	0.013	95.180	95.070	1.00	0.86	0.98	1.13	0.21	1.1	93.82	93.81	1.36	0.86	1.00	0.24	12.1	93.85	93.85	1.33	0.78	0.90	0.20	1.6	93.81	93.81	1.37
107	108	92.333	92.258	1.200	N/A	74.5	0.1	0.013	95.070	95.057	1.09	1.23	1.27	1.03	0.28	1.1	93.81	93.81	1.26	1.12	0.91	0.32	12.0	93.85	93.85	1.22	1.01	0.82	0.28	1.6	93.81	93.81	1.26
108	109	92.238	92.211	1.200	N/A	26.5	0.1	0.013	95.057	95.487	1.09	1.23	1.40	1.14	0.38	1.1	93.81	93.81	1.24	1.24	1.01	0.41	12.1	93.85	93.85	1.21	1.13	0.92	0.37	1.6	93.81	93.81	1.25
109	Pond1	92.181	92.150	1.200	N/A	31.0	0.1	0.013	95.487	94.500	1.09	1.23	1.39	1.13	0.43	1.1	93.81	93.81	1.68	1.24	1.01	0.47	12.0	93.85	93.85	1.64	1.11	0.90	0.43	1.6	93.81	93.81	1.68
202	203	93.826	93.706	0.675	N/A	120.0	0.1	0.013	96.212	96.030	0.74	0.27	0.27	1.02	0.84	1.1	95.34	95.07	0.87	0.24	0.90	1.25	12.0	95.75	95.69	0.46	0.20	0.75	-0.15	1.6	94.35	94.28	1.86
203	204	93.556	93.479	0.825	N/A	77.0	0.1	0.013	96.030	95.920	0.85	0.45	0.52	1.15	0.69	1.1	95.07	94.99	0.96	0.50	1.10	1.31	12.0	95.69	95.57	0.34	0.40	0.88	-0.11	1.6	94.28	94.23	1.76
204	205	93.404	93.332	0.900	N/A	72.0	0.1	0.013	95.920	95.812	0.90	0.57	0.65	1.14	0.69	1.1	94.99	94.90	0.93	0.65	1.14	1.27	12.0	95.57	95.40	0.35	0.49	0.86	-0.08	1.6	94.23	94.19	1.69
205	206	93.257	93.184	0.975	N/A	73.0	0.1	0.013	95.812	95.700	0.95	0.71	0.77	1.09	0.67	1.1	94.90	94.71	0.91	0.79	1.11	1.17	12.0	95.40	95.15	0.41	0.57	0.80	-0.05	1.6	94.19	94.12	1.63
206	207	92.959	92.925	1.200	1.800	34.0	0.1	0.013	95.700	95.898	1.23	2.66	2.79	1.05	0.55	1.1	94.71	94.65	0.99	2.74	1.03	0.99	12.0	95.15	95.08	0.55	2.10	0.79	-0.04	1.5	94.12	94.09	1.58
207	208	92.875	92.819	1.200	1.800	55.5	0.1	0.013	95.898	95.684	1.23	2.66	2.89	1.09	0.57	1.1	94.65	94.55	1.25	2.82	1.06	1.00	12.0	95.08	94.96	0.82	2.15	0.81	0.01	1.7	94.09	94.04	1.81
208	209	92.769	92.729	1.200	1.800	39.5	0.1	0.013	95.684	95.520	1.23	2.66	2.90	1.09	0.58	1.1	94.55	94.49	1.14	2.81	1.06	0.99	12.0	94.96	94.88	0.72	2.15	0.81	0.07	1.7	94.04	94.02	1.64
209	210	92.679	92.603	1.200	1.800	76.5	0.1	0.013	95.520	95.410	1.23	2.66	3.26	1.23	0.61	1.1	94.49	94.35	1.03	3.15	1.18	1.00	12.0	94.88	94.71	0.64	2.37	0.89	0.14	1.7	94.02	93.95	1.51
210	211	92.583	92.507	1.200	1.800	76.5	0.1	0.013	95.410	95.290	1.23	2.66	3.52	1.32	0.56	1.1	94.35	94.18	1.07	3.39	1.27	0.92	12.0	94.71	94.51	0.70	2.54	0.96	0.17	1.7	93.95	93.88	1.46
211	212	92.487	92.389	1.200	2.400	82.0	0.1	0.013	95.290	95.165	1.45	4.17	6.05	1.45	0.49	1.1	94.18	93.95	1.11	5.93	1.42	0.82	12.1	94.51	94.26	0.78	4.57	1.10	0.19	1.7	93.88	93.81	1.41
212	213	92.369	92.290	1.200	2.400	65.5	0.1	0.013	95.165	95.108	1.45	4.17	6.19	1.49	0.38	1.1	93.95	93.81	1.22	6.07	1.46	0.69	12.1	94.26	94.02	0.90	4.68	1.12	0.24	1.7	93.81	93.81	1.36
213	214	92.210	92.172	1.200	2.400	31.5	0.1	0.013	95.108	95.454	1.45	4.17	6.19	1.49	0.40	1.1	93.81	93.81	1.30	6.07	1.46	0.61	12.1	94.02	93.91	1.09	4.68	1.12	0.40	1.7	93.81	93.81	1.30
214	215	92.122	92.081	1.200	2.400	34.5	0.1	0.013	95.454	95.479	1.45	4.17	6.20	1.49	0.49	1.1	93.81	93.81	1.64	6.07	1.46	0.58	12.1	93.91	93.85	1.55	4.68	1.12	0.49	1.7	93.81	93.81	1.65
215	Pond1	92.001	91.950	1.200	2.400	42.5	0.1	0.013	95.479	94.500	1.45	4.17	6.25	1.50	0.61	1.1	93.81	93.81	1.67	6.07	1.46	0.65	12.1	93.85	93.85	1.63	4.67	1.12	0.61	1.7	93.81	93.81	1.67
251	252	93.818	93.748	0.675	N/A	70.5	0.1	0.013	96.160	96.054	0.74	0.27	0.22	0.83	0.60	1.1	95.10	95.08	1.06	0.21	0.79	0.82	12.0	95.32	95.28	0.84	0.16	0.60	-0.21	1.6	94.29	94.26	1.88
252	253	93.673	93.603	0.750	N/A	70.5	0.1	0.013	96.054	95.949	0.80	0.35	0.32	0.91	0.66	1.1	95.08	94.95	0.98	0.30	0.85	0.86	12.0	95.28	95.30	0.77	0.24	0.68	-0.17	1.6	94.26	94.23	1.80
253	254	93.303	93.227	1.050	N/A	76.5	0.1	0.013	95.949	95.834	1.00	0.86	0.96	1.11	0.59	1.1	94.95	94.76	1.00	0.93	1.08	0.95	12.1	95.30	95.18	0.65	0.75	0.87	-0.12	1.6	94.23	94.14	1.72
254	206	93.077	92.989	1.200	1.800	88.0	0.1	0.013	95.834	95.700	1.23	2.66	1.83	0.69	0.48	1.1	94.76	94.71	1.08	1.76	0.66	0.90	12.1	95.18	95.15	0.66	1.42	0.53	-0.14	1.6	94.14	94.12	1.70
261	262	93.851	93.753	0.675	N/A	97.5	0.1	0.013	96.161	96.015	0.74	0.27	0.26	0.98	0.66	1.1	95.18	95.08	0.98	0.25	0.94	0.83	12.1	95.36	95.27	0.81	0.20	0.75	-0.10	1.6	94.43	94.38	1.74
262	263	93.603	93.484	0.825	N/A	119.0	0.1	0.013	96.015	95.837	0.85	0.45	0.49	1.08	0.65	1.1	95.08	94.92	0.94	0.49	1.08	0.84	12.1	95.27	95.14	0.75	0.37	0.82	-0.05	1.6	94.38	94.31	1.63
263	264	93.409	93.302	0.900	N/A	107.0	0.1	0.013	95.837	95.676	0.90	0.57	0.65	1.14	0.61	1.1	94.92	94.71	0.92	0.65	1.14	0.83	12.1	95.14	94.94	0.70	0.50	0.87	0.00	1.7	94.31	94.20	1.53
264	265	93.222	93.182	0.900	N/A	40.5	0.1	0.013	95.676	95.616	0.90	0.57	0.78	1.36	0.59	1.1	94.71	94.64	0.97	0.78	1.36	0.82	12.1	94.94	94.89	0.74	0.60	1.05	0.08	1.8	94.20	94.16	1.48
265	266	93.032	93.002	1.050	N/A	30.0	0.1	0.013	95.616	95.571	1.00	0.86	1.19	1.38	0.56	1.1	94.64	94.58	0.98	1.18	1.37	0.81	12.1	94.89	94.85	0.72	0.93	1.08	0.08	1.7	94.16	94.12	1.46
266	267	92.852	92.753	1.200	N/A	99.0	0.1	0.013	95.571	95.421	1.09	1.23	1.81	1.47	0.53	1.1	94.58	94.35	0.99	1.77	1.44	0.80	12.1	94.85	94.66	0.72	1.41	1.14	0.07	1.6	94.12	93.99	1.45
267	268	92.703	92.657	1.200	1.800	45.5	0.1	0.013	95.421	95.342	1.23	2.66	2.47	0.93	0.45	1.1	94.35	94.30	1.07	2.40	0.90	0.75	12.1	94.66	94.62	0.76	1.93	0.73	0.08	1.7	93.99	93.95	1.44
268	211	92.607	92.567	1.200	1.800	40.5	0.1	0.013	95.342	95.290	1.23	2.66	2.48	0.93	0.49	1.1	94.30	94.18	1.05	2.41	0.91	0.81	12.1	94.62	94.51	0.73	1.93	0.73	0.14	1.7	93.95	93.88	1.39
301	302	93.248	93.194	0.600	N/A	54.0	0.1	0.013	95.797	95.829	0.69	0.19	0.16	0.82	-0.03	1.1	93.82	93.82	1.98	0.15	0.77	0.12	12.1	93.97	93.94	1.83	0.13	0.67	-0.03	1.7	93.82	93.81	1.98
302	303	93.164	93.153	0.600	N/A	11.0	0.1	0.013	95.829	95.808	0.69	0.19	0.16	0.82	0.06	1.1	93.82	93.82	2.01	0.14	0.72	0.18	12.1	93.94	93.93	1.89	0.13	0.67	0.05	1.6	93.81	93.81	2.02
303	304	93.123	93.055	0.600	N/A	67.5	0.1	0.013	95.808	95.729	0.69	0.19	0.16	0.82	0.10	1.1	93.82	93.82	1.99	0.14	0.72	0.21	12.2	93.93	93.91	1.88	0.13	0.67	0.09	1.6	93.81	93.81	2.00
304	305	92.980	92.906	0.675	N/A	73.5	0.1	0.013	95.729	95.410	0.74	0.27	0.27	1.02	0.16	1.1	93.82	93.82	1.91	0.24	0.90	0.25	12.1	93.91	93.86	1.82	0.22	0.83	0.16	1.6	93.81	93.81	1.92
305	306	92.681	92.605	0.900	N/A	76.5	0.1	0.013	95.410	95.300	0.90	0.57	0.55	0.96	0.23	1.1	93.82	93.81	1.59	0.51	0.89	0.27	12.1	93.86	93.85	1.55	0.47	0.82	0.23	1.6	93.81	93.81	1.60
306	307	92.545	92.465	0.900	1.800	79.5	0.1	0.013	95.300	94.860	1.09	1.77	0.88	0.50	0.37	1.1	93.81	93.81	1.49	0.82	0.46	0.41	12.1	93.85	93.85	1.45	0.71	0.40	0.37	1.6	93.81	93.81	1.49
307	308	92.445	92.368	0.900	1.800	77.0	0.1	0.013	94.860	94.823	1.09	1.77	1.30	0.74	0.47	1.1	93.81	93.81	1.05	1.25	0.71	0.51	12.0	93.85	93.85	1.01	1.04	0.59	0.47	1.5	93.81	93.81	1.05
308	407	92.338	92.244	0.900	1.800	94.5	0.1	0.013	94.823	95.199	1.09	1.77	1.25	0.71	0.58	1.1	93.81	93.81	1.01	1.25	0.71	0.61	12.0	93.85	93.85	0.97	1.00	0.57	0.57	1.7	93.81	93.81	1.01
401	402	92.920	92.891	0.675	N/A	26.5	0.1	0.013	95.844	95.746	0.78	0.28	0.27	0.97	0.22	1.0	93.81	93.81	2.03	0.27	0.97	0.44	12.0	94.03	94.01	1.81	0.22	0.79	0.22	1.7	93.81	93.81	2.03
402	403	92.816	92.805	0.750	N/A	11.0	0.1	0.013	95.746	95.689	0.80	0.35	0.27	0.77	0.25	1.1	93.81	93.81	1.93	0.27	0.77	0.44	12.0	94.01	94.00	1.74	0.22	0.62	0.24	1.7	93.81	93.81	1.94
403	404	92.775	92.695	0.750	N/A	80.0	0.1	0.013	95.689	95.577	0.80	0.35	0.27	0.77	0.29	1.1	93.81	93.81	1.88	0.27	0.77	0.48	12.0	94.00	93.96	1.68	0.21	0.60	0.28	1.7	93.81	93.81	1.88
404	405	92.620	92.513	0.825	N/A	106.5	0.1	0.013	95.577	95.150	0.85	0.45	0.47	1.04	0.37	1.1	93.81	93.81	1.77	0.48	1.06	0.51	12.0	93.96	93.87	1.62	0.37	0.82	0.36	1.7	93.81	93.81	1.77
405	406	92.438	92.350	0.900	N/A	68.0	0.1	0.013	95.150	95.005	1.03	0.65	0.79	1.21	0.47	1.1	93.81	93.81	1.34	0.79	1.21	0.53	12.0	93.87	93.85	1.28	0.63	0.97	0.47	1.7	93.81	93.81	1.34
406	407	92.330	92.244	0.900	N/A	66.5	0.1	0.013	95.005	95.199	1.03	0.65	0.78	1.20	0.58	1.1	93.81	93.81	1.19	0.79	1.21	0.62	12.0	93.85	93.85	1.16	0.62	0.95	0.58	1.7	93.81	93.81	1.20
407	408	92.214	92.196	0.900	1.800	17.5	0.1	0.013	95.199	94.558	1.09	1.77	1.98	1.12	0.70	1.1	93.81	93.81	1.39	2.04	1.16	0.73	12.0	93.85	93.85	1.35	1.62	0.92	0.69	1.7	93.81	93.81	1.39
408	Pond1	92.166	92.150	0.900	1.800	16.5	0.1	0.013	94.558	94.500	1.09	1.77	1.96	1.11	0.75	1.1	93.81	93.81	0.75	2.04	1.16	0.78	12.0	93.85	93.85	0.71	1.62	0.92	0.74	1.7	93.81	93.81	0.75
500	501	93.525	93.444	0.750	N/A	81.0	0.1	0.013	96.026	95.903	0.80	0.35	0.27	0.77	-0.07	1.0	94.21	94.18	1.82	0.27	0.77	0.43	12.1	94.71	94.67	1.32	0.22	0.62	-0.21	1.6	94.06	94.03	1.96
501	502	93.424	93.352	0.750	N/A	71.5	0.1	0.013	95.903	95.772	0.80	0.35	0.25	0.71	0.00	1.2	94.18	94.13	1.73	0.26	0.74	0.49	12.1	94.67	94.62	1.24	0.22	0.62	-0.14	1.7	94.03	94.00	1.87
502	503	93.277	93.266	0.825	N/A	11.0	0.1	0.013	95.772	95.653	0.85	0.45	0.36	0.79	0.03	1.2	94.13	94.12	1.64	0.38	0.84	0.51	12.1	94.62	94.60	1.16	0.31	0.68	-0.11	1.6	94.00	93.99	1.78
503	504	93.236	93.175	0.825	N/A	61.0	0.1	0.013	95.653	95.567	0.85	0.45	0.36	0.79	0.06	1.2	94.12	94.07	1.54	0.38	0.84	0.53	12.1	94.60	94.54	1.06	0.32	0.70	-0.08	1.7	93.99	93.95	1.67
504	505	93.145	93.134	0.825	N/A	11.0	0.1	0.013	95.567	95.525	0.85	0.45	0.36	0.79	0.10	1.2	94.07	94.06	1.49	0.38	0.84	0.57	12.1	94.54	94.52	1.03	0.33	0.73	-0.02	1.7	93.95	93.94	1.61

Table 6: Pipe Data and Hydraulic Simulation Results [1]

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Diameter / Height (m)	Pipe Width (m)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Velocity (m/s)	Design Flow (m^3/s)	100-year, 3-hour Chicago Storm + 20%							100-year, 12-hour SCS Type II Storm + 20%							July 1st, 1979 Historical Event						
													Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [2] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [2] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [2] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)
505	506	93.104	93.068	0.825	N/A	36.0	0.1	0.013	95.525	95.404	0.85	0.45	0.37	0.82	0.13	1.3	94.06	94.01	1.47	0.38	0.84	0.59	12.1	94.52	94.46	1.00	0.33	0.73	0.01	1.7	93.94	93.91	1.58
506	507	92.993	92.917	0.900	N/A	76.0	0.1	0.013	95.404	95.290	0.90	0.57	0.56	0.98	0.12	1.2	94.01	93.94	1.39	0.59	1.03	0.56	12.1	94.46	94.38	0.95	0.48	0.84	0.01	1.7	93.91	93.86	1.50
507	508	92.767	92.687	1.050	N/A	79.5	0.1	0.013	95.290	95.170	1.00	0.86	0.93	1.08	0.13	1.2	93.94	93.81	1.35	0.96	1.11	0.57	12.1	94.38	94.22	0.91	0.79	0.91	0.04	1.6	93.86	93.81	1.43
508	509	92.627	92.597	1.050	N/A	30.0	0.1	0.013	95.170	95.121	1.00	0.86	0.95	1.10	0.14	1.2	93.81	93.81	1.36	0.98	1.13	0.55	12.1	94.22	94.11	0.95	0.80	0.93	0.13	1.6	93.81	93.81	1.36
509	510	92.447	92.374	1.200	N/A	72.5	0.1	0.013	95.121	95.016	1.09	1.23	1.21	0.98	0.17	1.1	93.81	93.81	1.31	1.25	1.01	0.46	12.1	94.11	94.05	1.01	1.02	0.83	0.16	1.6	93.81	93.81	1.31
510	511	92.354	92.267	1.200	N/A	86.5	0.1	0.013	95.016	94.413	1.09	1.23	1.35	1.09	0.26	1.1	93.81	93.81	1.20	1.40	1.14	0.50	12.1	94.05	93.89	0.97	1.14	0.92	0.25	1.6	93.81	93.81	1.21
511	611	92.207	92.100	1.200	N/A	106.5	0.1	0.013	94.413	94.667	1.09	1.23	1.54	1.25	0.40	1.1	93.81	93.81	0.60	1.60	1.30	0.48	12.1	93.89	93.85	0.52	1.28	1.04	0.40	1.7	93.81	93.81	0.60
601	602	93.362	93.294	0.600	N/A	68.5	0.1	0.013	96.029	95.603	0.69	0.19	0.20	1.03	-0.14	1.1	93.82	93.82	2.21	0.18	0.93	0.25	12.1	94.21	94.15	1.82	0.16	0.82	-0.15	1.6	93.81	93.81	2.22
602	603	93.264	93.253	0.600	N/A	11.0	0.1	0.013	95.603	95.530	0.69	0.19	0.19	0.98	-0.04	1.1	93.82	93.82	1.78	0.18	0.93	0.28	12.1	94.15	94.13	1.46	0.16	0.82	-0.05	1.6	93.81	93.81	1.79
603	604	93.103	93.035	0.750	N/A	68.5	0.1	0.013	95.530	95.400	0.80	0.35	0.28	0.80	-0.03	1.1	93.82	93.82	1.71	0.27	0.77	0.28	12.1	94.13	94.09	1.40	0.24	0.68	-0.04	1.6	93.81	93.81	1.72
604	605	92.885	92.809	0.900	N/A	76.5	0.1	0.013	95.400	95.290	0.90	0.57	0.50	0.87	0.03	1.1	93.82	93.82	1.58	0.49	0.86	0.30	12.1	94.09	94.04	1.31	0.42	0.73	0.03	1.6	93.81	93.81	1.59
605	606	92.734	92.654	0.975	N/A	79.5	0.1	0.013	95.290	95.170	0.95	0.71	0.72	1.02	0.11	1.1	93.82	93.82	1.47	0.71	1.00	0.33	12.1	94.04	93.98	1.25	0.60	0.85	0.10	1.6	93.81	93.81	1.48
606	607	92.579	92.499	1.050	N/A	79.5	0.1	0.013	95.170	95.050	1.00	0.86	0.98	1.13	0.19	1.1	93.82	93.82	1.35	0.95	1.10	0.35	12.1	93.98	93.91	1.19	0.80	0.93	0.18	1.6	93.81	93.81	1.36
607	608	92.479	92.410	1.050	N/A	69.0	0.1	0.013	95.050	94.944	1.00	0.86	1.07	1.24	0.29	1.1	93.82	93.81	1.24	1.05	1.22	0.38	12.1	93.91	93.86	1.14	0.87	1.01	0.28	1.6	93.81	93.81	1.24
608	609	92.380	92.369	1.050	N/A	11.0	0.1	0.013	94.944	94.835	1.00	0.86	1.06	1.23	0.38	1.1	93.81	93.81	1.13	1.05	1.22	0.43	12.1	93.86	93.86	1.09	0.86	1.00	0.38	1.6	93.81	93.81	1.14
609	610	92.219	92.185	1.200	N/A	34.5	0.1	0.013	94.835	94.875	1.09	1.23	1.22	0.99	0.39	1.1	93.81	93.81	1.02	1.20	0.97	0.44	12.1	93.86	93.85	0.98	0.99	0.80	0.39	1.6	93.81	93.81	1.03
610	611	92.125	92.100	1.200	N/A	25.0	0.1	0.013	94.875	94.667	1.09	1.23	1.47	1.19	0.49	1.1	93.81	93.81	1.06	1.44	1.17	0.52	12.1	93.85	93.85	1.03	1.20	0.97	0.48	1.7	93.81	93.81	1.07
611	612	92.070	92.048	1.200	1.800	22.0	0.1	0.013	94.667	94.113	1.23	2.66	2.98	1.12	0.54	1.1	93.81	93.81	0.86	2.99	1.12	0.58	12.1	93.85	93.85	0.82	2.47	0.93	0.54	1.7	93.81	93.81	0.86
612	Pond1	92.018	92.000	1.200	1.800	18.0	0.1	0.013	94.113	94.500	1.23	2.66	2.96	1.11	0.59	1.1	93.81	93.81	0.30	2.99	1.12	0.63	12.1	93.85	93.85	0.27	2.46	0.93	0.59	1.7	93.81	93.81	0.30
700	701	93.517	93.443	0.975	N/A	74.0	0.1	0.013	96.786	96.740	0.95	0.71	0.80	1.13	1.61	1.0	96.10	95.68	0.68	0.66	0.93	0.88	12.0	95.38	95.26	1.41	0.62	0.87	0.56	1.8	95.05	94.91	1.74
701	702	93.368	93.328	1.050	N/A	40.0	0.1	0.013	96.740	96.530	1.00	0.86	1.02	1.18	1.27	1.0	95.68	95.59	1.06	0.81	0.94	0.84	12.0	95.26	95.22	1.48	0.76	0.88	0.49	1.6	94.91	94.85	1.83
702	703	93.178	93.106	1.200	1.800	71.5	0.1	0.013	96.530	96.420	1.23	2.66	1.96	0.74	1.21	1.0	95.59	95.45	0.94	1.70	0.64	0.85	12.0	95.22	95.19	1.31	1.53	0.58	0.47	1.6	94.85	94.80	1.68
703	704	93.086	92.980	1.200	1.800	105.5	0.1	0.013	96.420	96.260	1.23	2.66	2.53	0.95	1.16	1.0	95.45	95.27	0.97	2.20	0.83	0.91	12.0	95.19	95.11	1.23	2.03	0.76	0.52	1.6	94.80	94.71	1.62
704	705	92.960	92.888	1.200	1.800	71.5	0.1	0.013	96.260	96.150	1.23	2.66	3.38	1.27	1.11	1.1	95.27	95.19	0.99	3.04	1.14	0.95	12.0	95.11	95.02	1.15	2.81	1.06	0.55	1.6	94.71	94.63	1.55
705	706	92.868	92.801	1.200	2.400	67.0	0.1	0.013	96.150	95.902	1.32	3.80	4.83	1.27	1.12	1.1	95.19	95.05	0.96	4.61	1.21	0.96	12.0	95.02	94.93	1.13	4.13	1.09	0.56	1.6	94.63	94.55	1.52
706	707	92.781	92.697	1.200	2.400	83.5	0.1	0.013	95.902	95.430	1.32	3.80	4.97	1.31	1.07	1.1	95.05	94.67	0.85	4.73	1.24	0.95	12.0	94.93	94.67	0.97	4.23	1.11	0.56	1.6	94.55	94.30	1.36
707	708	92.637	92.567	1.200	2.400	70.0	0.1	0.013	95.430	95.320	1.32	3.80	5.61	1.48	0.83	1.1	94.67	94.48	0.76	5.32	1.40	0.83	12.0	94.67	94.55	0.76	4.75	1.25	0.47	1.6	94.30	94.18	1.13
708	709	92.547	92.481	1.200	2.400	66.0	0.1	0.013	95.320	95.221	1.32	3.80	5.88	1.55	0.73	1.1	94.48	94.31	0.84	5.52	1.45	0.80	12.0	94.55	94.42	0.77	4.94	1.30	0.43	1.6	94.18	94.05	1.14
709	710	92.461	92.391	1.200	2.400	70.5	0.1	0.013	95.221	95.112	1.32	3.80	5.92	1.56	0.64	1.1	94.31	93.87	0.92	5.52	1.45	0.76	12.0	94.42	94.09	0.80	4.94	1.30	0.39	1.6	94.05	93.81	1.17
710	711	92.331	92.200	1.200	2.400	131.0	0.1	0.013	95.112	94.385	1.32	3.80	6.20	1.63	0.34	1.1	93.87	93.84	1.24	6.03	1.59	0.56	12.0	94.09	93.85	1.02	5.34	1.40	0.28	1.6	93.81	93.81	1.30
711	712	92.140	92.118	1.200	2.400	21.5	0.1	0.013	94.385	94.000	1.32	3.80	6.12	1.61	0.49	1.1	93.84	93.82	0.55	6.03	1.59	0.51	12.0	93.85	93.85	0.53	5.36	1.41	0.47	1.6	93.81	93.81	0.58
712	Pond1	92.058	92.050	1.200	2.400	8.5	0.1	0.013	94.000	94.500	1.32	3.80	6.12	1.61	0.56	1.1	93.82	93.81	0.18	6.01	1.58	0.59	12.0	93.85	93.85	0.15	5.35	1.41	0.55	1.6	93.81	93.81	0.19
751	752	93.846	93.752	0.600	N/A	94.0	0.1	0.013	96.720	96.579	0.69	0.19	0.23	1.18	1.54	1.1	95.99	95.64	0.73	0.15	0.77	1.62	12.0	96.07	95.67	0.65	0.16	0.82	0.71	1.6	95.15	95.02	1.57
752	753	93.602	93.520	0.750	N/A	82.0	0.1	0.013	96.579	96.452	0.80	0.35	0.35	0.99	1.28	1.1	95.64	95.52	0.94	0.26	0.74	1.32	12.0	95.67	95.45	0.91	0.26	0.74	0.66	1.6	95.02	94.89	1.56
753	754	93.295	93.209	0.975	N/A	86.0	0.1	0.013	96.452	96.324	0.95	0.71	0.91	1.28	1.25	1.1	95.52	95.36	0.93	0.79	1.11	1.18	12.0	95.45	95.25	1.00	0.73	1.03	0.62	1.6	94.89	94.79	1.56
754	705	93.134	93.018	1.050	N/A	116.0	0.1	0.013	96.324	96.150	1.00	0.86	1.09	1.26	1.18	1.1	95.36	95.19	0.96	0.97	1.12	1.07	12.0	95.25	95.02	1.07	0.88	1.02	0.61	1.6	94.79	94.63	1.53
806	807	93.069	93.047	0.600	N/A	21.5	0.1	0.013	95.186	95.180	0.69	0.19	0.12	0.62	0.63	1.1	94.30	94.16	0.89	0.10	0.52	0.59	12.0	94.26	94.18	0.92	0.06	0.31	0.25	1.6	93.92	93.87	1.27
807	808	92.897	92.861	0.750	N/A	35.5	0.1	0.013	95.180	95.133	0.80	0.35	0.41	1.16	0.51	1.1	94.16	94.01	1.03	0.37	1.05	0.53	12.0	94.18	94.15	1.00	0.29	0.82	0.23	1.6	93.87	93.81	1.31
808	809	92.786	92.775	0.825	N/A	11.0	0.1	0.013	95.133	95.095	0.85	0.45	0.56	1.23	0.40	1.1	94.01	94.00	1.13	0.50	1.10	0.54	12.0	94.15	94.14	0.98	0.42	0.93	0.20	1.6	93.81	93.81	1.32
809	710	92.725	92.706	0.825	N/A	18.5	0.1	0.013	95.095	95.112	0.85	0.45	0.57	1.26	0.45	1.1	94.00	93.87	1.10	0.51	1.12	0.59	12.0	94.14	94.09	0.96	0.42	0.93	0.26	1.6	93.81	93.81	1.29
901	902	94.501	94.436	0.600	N/A	65.0	0.1	0.013	96.268	96.259	0.69	0.19	0.14	0.72	-0.10	1.1	95.00	94.97	1.27	0.14	0.72	-0.13	12.0	94.98	94.95	1.29	0.12	0.62	-0.19	1.7	94.92	94.88	1.35
902	903	94.416	94.346	0.675	N/A	70.0	0.1	0.013	96.259	96.151	0.74	0.27	0.24	0.90	-0.12	1.1	94.97	94.91	1.29	0.23	0.87	-0.15	12.0	94.95	94.89	1.31	0.20	0.75	-0.21	1.7	94.88	94.83	1.38
903	904	94.271	94.201	0.750	N/A	69.5	0.1	0.013	96.151	96.259	0.80	0.35	0.32	0.91	-0.11	1.1	94.91	94.80	1.24	0.31	0.88	-0.13	12.1	94.89	94.78	1.26	0.27	0.77	-0.20	1.7	94.83	94.73	1.33
904	905	94.121	94.005	0.900	N/A	116.0	0.1	0.013	96.259	96.162	0.90	0.57	0.64	1.12	-0.22	1.1	94.80	94.56	1.46	0.61	1.07	-0.24	12.1	94.78	94.54	1.48	0.53	0.93	-0.29	1.7	94.73	94.50	1.53
905	1007	93.955	93.939	0.900	N/A	16.0	0.1	0.013	96.162	96.196	0.90	0.57	0.64	1.12	-0.30	1.1	94.56	94.38	1.61	0.61	1.07	-0.31	12.1	94.54	94.39	1.62	0.53	0.93	-0.36	1.7	94.50	94.28	1.67
1001	1002	94.618	94.545	0.525	N/A	72.5	0.1	0.013	96.638	96.632	0.63	0.14	0.12	0.88	-0.09	1.1	95.06	94.97	1.58	0.12	0.88	-0.11	12.0	95.03	94.94	1.61	0.10	0.74	-0.16	1.7	94.98	94.88	1.66
1002	1003	94.465	94.388	0.600	N/A	77.0	0.1	0.013	96.632	96.593	0.69	0.19	0.19	0.98	-0.10	1.1	94.97	94.90	1.66	0.18	0.93	-0.13	12.1	94.94	94.87	1.69	0.16	0.82	-0.19	1.7	94.88	94.79	1.76
1003	1004	94.238	94.166	0.750	N/A	71.5	0.1	0.013	96.593	96.490	0.80	0.35	0.38	1.08	-0.09	1.1	94.90	94.82	1.70	0.37	1.05	-0.12	12.1	94.87	94.79	1.73	0.33	0.94	-0.20	1.7	94.79	94.71	1.80
1004	1005	94.016	93.942	0.900	N/A	74.0	0.1	0.013	96.490	96.380	0.90	0.57	0.57	1.00	-0.10	1.1	94.82	94.68	1.67	0.55	0.96	-0.13	12.1	94.79	94.65	1.70	0.49	0.86	-0.20	1.7	94.71	94.58	1.78
1005	1006	93.862	93.791	0.975	N/A	71.0	0.1	0.013	96.380	96.270	0.95	0.71	0.70	0.99	-0.16	1.1	94.68	94.51	1.70	0.67	0.95	-0.18	12.1	94.65	94.49	1.73	0.60	0.85	-0.26	1.7	94.58	94.41	1.80
1006	1007	93.566	93.482	1.200	N/A	83.5	0.1	0.013	96.270	96.196	1.09	1.23	1.40	1.14	-0.25	1.1	94.51	94.38	1.76	1.34	1.09	-0.28	12.1	94.49	94.39	1.78	1.18	0.96	-0.36	1.7	94.41	94.28	1.86
1007	1008	93.361	93.303	1.200	N/A	29.0	0.2	0.013	96.196	96.057	1.54	1.74	2.07	1.19	-0.18	1.1	94.38	94.21	1.81	1.99	1.14	-0.17	12.1	94.39	94.39	1.80	1.74	1.00	-0.28	1.7	94.28	94.23	1.91
1008	Pond2	93.223	93.200	1.200	2.400	23.0	0.1	0.013	96.057	96.000	1.32	3.80	3.73	0.98	-0.21	1.1	94.21	94.20	1.85	3.51	0.92	-0.03	12.1	94.39	94.38	1.67	2.24	0.59	-0.20	1.7	94.23	94.22	1.83
1101	1102	95.258	95.139	0.750	N/A	119.0	0.1	0.013	97.798	97.953	0.80	0.35	0.28	0.80	-0.24	1.1	95.77	95.63	2.03	0.27	0.77	-0.26	12.0	95.75	95.61	2.05	0.23	0.65	-0.31	1.7	95.70	95.55	2.10
1102	1103	95.109	95.101	0.750	N/A	8.0	0.1	0.013	97.953	97.864	0.80	0.35	0.28	0.80	-0.23	1.1	95.63	95.60	2.33	0.27	0.77	-0.25	12.1	95.61	95.58	2.35	0.24	0.68	-0.31	1.7	95.55	95.52	2.41
1103	1104	94.951	94.885	0.900	N/A	65.5	0.1	0.013	97.864	98.100	0.90	0.57	0.49	0.86	-0.25	1.1	95.60	95.54	2.27	0.47	0.82	-0.27	12.1	95.58	95.52	2.28	0.40	0.70	-0.33	1.7	95.52	95.46	2.35

Table 6: Pipe Data and Hydraulic Simulation Results [1]

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Diameter / Height (m)	Pipe Width (m)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Velocity (m/s)	Design Flow (m^3/s)	100-year, 3-hour Chicago Storm + 20%							100-year, 12-hour SCS Type II Storm + 20%							July 1st, 1979 Historical Event						
													Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [2] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [2] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [2] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard U/S HGL and MH Cover (m)
1104	1105	94.825	94.753	0.900	N/A	71.5	0.1	0.013	98.100	98.730	0.90	0.57	0.58	1.01	-0.19	1.1	95.54	95.33	2.56	0.56	0.98	-0.21	12.1	95.52	95.31	2.58	0.49	0.86	-0.27	1.7	95.46	95.25	2.65
1105	1106	94.673	94.619	0.900	N/A	54.5	0.1	0.013	98.730	98.710	0.90	0.57	0.58	1.01	-0.25	1.1	95.33	95.20	3.41	0.56	0.98	-0.27	12.1	95.31	95.18	3.43	0.49	0.86	-0.33	1.7	95.25	95.11	3.49
1106	1107	94.469	94.462	1.050	N/A	7.0	0.1	0.013	98.710	98.708	1.00	0.86	1.04	1.20	-0.32	1.1	95.20	95.10	3.51	1.00	1.16	-0.34	12.1	95.18	95.07	3.53	0.87	1.01	-0.41	1.7	95.11	95.01	3.60
1107	1108	94.432	93.978	1.050	N/A	113.5	0.4	0.013	98.708	96.666	1.99	1.73	1.04	0.60	-0.38	1.1	95.10	94.89	3.61	1.00	0.58	-0.41	12.1	95.07	94.85	3.63	0.87	0.50	-0.48	1.7	95.01	94.76	3.70
1108	1109	93.528	93.381	1.500	N/A	73.5	0.2	0.013	96.666	96.511	1.79	3.16	4.75	1.50	-0.14	1.2	94.89	94.31	1.78	4.56	1.44	-0.18	12.1	94.85	94.38	1.82	4.09	1.29	-0.27	1.7	94.76	94.25	1.91
1109	1110	93.351	93.283	1.500	2.400	67.5	0.1	0.013	96.511	95.479	1.45	5.23	4.75	0.91	-0.55	1.2	94.31	94.20	2.21	4.54	0.87	-0.47	12.1	94.38	94.38	2.13	4.08	0.78	-0.61	1.7	94.25	94.22	2.27
1110	Pond2	93.223	93.200	1.500	2.400	22.5	0.1	0.013	95.479	96.000	1.45	5.23	4.74	0.91	-0.52	1.2	94.20	94.20	1.28	4.50	0.86	-0.34	12.1	94.38	94.38	1.10	4.05	0.77	-0.50	1.7	94.22	94.22	1.26
1201	1202	95.554	95.502	0.825	N/A	51.5	0.1	0.013	98.081	98.047	0.85	0.45	0.39	0.86	0.03	1.0	96.41	96.37	1.67	0.37	0.82	-0.11	12.0	96.27	96.23	1.81	0.32	0.70	-0.31	1.7	96.07	96.00	2.01
1202	1203	95.472	95.461	0.825	N/A	11.0	0.1	0.013	98.047	98.014	0.85	0.45	0.39	0.86	0.07	1.0	96.37	96.35	1.68	0.36	0.79	-0.07	12.0	96.23	96.22	1.82	0.33	0.73	-0.30	1.7	96.00	95.97	2.05
1203	1204	95.311	95.243	0.975	N/A	67.5	0.1	0.013	98.014	97.847	0.95	0.71	0.57	0.80	0.07	1.0	96.35	96.32	1.66	0.54	0.76	-0.07	12.0	96.22	96.18	1.80	0.48	0.68	-0.32	1.7	95.97	95.92	2.05
1204	1205	95.223	95.149	0.975	N/A	67.5	0.1	0.013	97.847	97.741	1.00	0.74	0.56	0.75	0.12	1.2	96.32	96.27	1.53	0.53	0.71	-0.01	12.2	96.18	96.14	1.66	0.48	0.65	-0.28	1.7	95.92	95.86	1.93
1205	1206	95.119	95.108	0.975	N/A	11.0	0.1	0.013	97.741	97.718	0.95	0.71	0.69	0.97	0.17	1.2	96.27	96.24	1.47	0.65	0.92	0.04	12.2	96.14	96.11	1.61	0.58	0.82	-0.23	1.7	95.86	95.84	1.88
1206	1207	95.078	95.022	0.975	N/A	56.0	0.1	0.013	97.718	97.549	0.95	0.71	0.69	0.97	0.19	1.2	96.24	96.18	1.48	0.66	0.93	0.06	12.2	96.11	96.05	1.61	0.58	0.82	-0.22	1.7	95.84	95.78	1.88
1207	1208	94.992	94.981	0.975	N/A	11.0	0.1	0.013	97.549	97.613	0.95	0.71	0.70	0.99	0.21	1.2	96.18	96.15	1.37	0.67	0.95	0.09	12.3	96.05	96.03	1.50	0.58	0.82	-0.19	1.7	95.78	95.75	1.77
1208	1209	94.951	94.915	0.975	N/A	36.0	0.1	0.013	97.613	97.564	0.95	0.71	0.70	0.99	0.23	1.2	96.15	96.11	1.46	0.69	0.97	0.10	12.3	96.03	95.99	1.58	0.59	0.83	-0.18	1.7	95.75	95.71	1.86
1209	1210	94.840	94.832	1.050	N/A	7.5	0.1	0.013	97.564	97.551	1.00	0.86	0.84	0.97	0.22	1.2	96.11	96.08	1.46	0.81	0.94	0.10	12.3	95.99	95.97	1.58	0.69	0.80	-0.18	1.7	95.71	95.69	1.86
1210	1211	94.802	94.773	1.050	N/A	29.0	0.1	0.013	97.551	96.869	1.00	0.86	0.84	0.97	0.23	1.2	96.08	96.04	1.47	0.83	0.96	0.11	12.3	95.97	95.93	1.59	0.69	0.80	-0.17	1.7	95.69	95.65	1.87
1211	1212	94.743	94.735	1.050	N/A	7.5	0.1	0.013	96.869	96.861	1.00	0.86	0.84	0.97	0.25	1.2	96.04	96.02	0.83	0.84	0.97	0.14	12.3	95.93	95.91	0.94	0.70	0.81	-0.14	1.8	95.65	95.63	1.22
1212	1213	94.705	94.641	1.050	N/A	64.0	0.1	0.013	96.861	97.400	1.00	0.86	0.85	0.98	0.26	1.4	96.02	95.96	0.84	0.86	1.00	0.15	12.3	95.91	95.86	0.95	0.72	0.83	-0.13	1.8	95.63	95.59	1.23
1213	1214	94.491	94.419	1.200	N/A	71.5	0.1	0.013	97.400	97.290	1.09	1.23	1.20	0.97	0.27	1.2	95.96	95.89	1.44	1.14	0.92	0.17	12.2	95.86	95.80	1.54	1.02	0.83	-0.10	1.7	95.59	95.55	1.81
1214	1215	94.399	94.327	1.200	N/A	71.5	0.1	0.013	97.290	97.190	1.09	1.23	1.40	1.14	0.29	1.2	95.89	95.71	1.40	1.34	1.09	0.20	12.2	95.80	95.64	1.49	1.19	0.97	-0.05	1.7	95.55	95.41	1.74
1215	1216	94.177	94.105	1.350	N/A	71.5	0.1	0.013	97.190	97.080	1.18	1.69	1.85	1.10	0.19	1.2	95.71	95.63	1.48	1.78	1.05	0.11	12.1	95.64	95.56	1.55	1.59	0.94	-0.12	1.7	95.41	95.35	1.78
1216	1217	93.955	93.871	1.500	N/A	84.5	0.1	0.013	97.080	96.955	1.26	2.24	2.51	1.12	0.18	1.2	95.63	95.53	1.45	2.41	1.08	0.11	12.1	95.56	95.47	1.52	2.15	0.96	-0.10	1.7	95.35	95.29	1.73
1217	1218	93.851	93.768	1.500	N/A	83.0	0.1	0.013	96.955	96.830	1.26	2.24	2.79	1.25	0.18	1.2	95.53	95.41	1.42	2.68	1.20	0.12	12.1	95.47	95.35	1.49	2.41	1.08	-0.07	1.7	95.29	95.20	1.67
1218	1219	93.748	93.702	1.500	N/A	46.5	0.1	0.013	96.830	96.760	1.26	2.24	2.87	1.28	0.16	1.2	95.41	95.34	1.42	2.76	1.23	0.10	12.1	95.35	95.28	1.48	2.48	1.11	-0.05	1.7	95.20	95.15	1.63
1219	1108	93.682	93.608	1.500	N/A	74.0	0.1	0.013	96.760	96.666	1.26	2.24	3.41	1.53	0.16	1.2	95.34	94.89	1.42	3.28	1.47	0.10	12.1	95.28	94.85	1.48	2.95	1.32	-0.04	1.7	95.15	94.76	1.61
1600	1601	94.197	94.025	1.200	N/A	107.5	0.2	0.013	97.015	96.875	1.38	1.56	2.11	1.35	0.75	3.3	96.14	95.83	0.87	2.51	1.61	1.67	14.6	97.06	96.62	-0.05	2.12	1.36	0.78	3.5	96.18	95.86	0.84
1601	1602	94.025	93.873	1.200	N/A	95.0	0.2	0.013	96.875	96.627	1.38	1.56	2.11	1.35	0.60	3.3	95.83	95.55	1.05	2.51	1.61	1.40	14.6	96.62	96.23	0.25	2.12	1.36	0.63	3.5	95.86	95.58	1.02
1602	1603	93.873	93.721	1.200	N/A	95.0	0.2	0.013	96.627	96.665	1.38	1.56	2.11	1.35	0.48	3.3	95.55	95.27	1.08	2.51	1.61	1.15	14.6	96.23	95.83	0.40	2.12	1.36	0.50	3.5	95.58	95.29	1.05
1603	1604	93.721	93.569	1.200	N/A	95.0	0.2	0.013	96.665	96.891	1.38	1.56	2.11	1.35	0.35	3.3	95.27	95.00	1.40	2.51	1.61	0.91	14.6	95.83	95.44	0.83	2.12	1.36	0.37	3.5	95.29	95.01	1.37
1604	1605	93.569	93.431	1.200	N/A	86.5	0.2	0.013	96.891	96.700	1.38	1.56	2.11	1.35	0.23	3.3	95.00	94.52	1.89	2.51	1.61	0.67	14.6	95.44	94.77	1.46	2.12	1.36	0.24	3.5	95.01	94.53	1.88
1605	1008	93.431	93.316	1.200	N/A	72.0	0.2	0.013	96.700	96.057	1.38	1.56	2.10	1.35	-0.11	3.3	94.52	94.21	2.18	2.51	1.61	0.13	14.6	94.77	94.39	1.94	2.12	1.36	-0.10	3.5	94.53	94.23	2.17
7000	700	93.664	93.592	0.900	N/A	71.5	0.1	0.013	96.997	96.786	0.90	0.57	0.62	1.08	1.74	1.0	96.31	96.10	0.69	0.53	0.93	0.87	12.0	95.44	95.38	1.56	0.50	0.87	0.57	1.8	95.13	95.05	1.86
Pond1	Out1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.75	N/A	N/A	N/A	N/A	N/A	N/A	5.32	N/A	N/A	N/A	N/A	N/A	N/A	3.60	N/A	N/A	N/A	N/A	N/A	N/A
Pond2	Out2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.06	N/A	N/A	N/A	N/A	N/A	N/A	2.64	N/A	N/A	N/A	N/A	N/A	N/A	2.12	N/A	N/A	N/A	N/A	N/A	N/A
1500	1501	92.698	92.577	1.200	1.800	120.0	0.1	0.013	95.914	95.720	1.23	2.66	3.38	1.27	0.47	3.0	94.37	94.17	1.55	4.14	1.56	0.77	13.8	94.67	94.37	1.25	3.43	1.29	0.48	3.3	94.38	94.18	1.54
1501	21400	92.577	92.450	1.200	1.800	127.0	0.1	0.013	95.720	95.562	1.23	2.66	3.38	1.27	0.39	3.0	94.17	93.93	1.55	4.14	1.56	0.60	13.8	94.37	94.01	1.35	3.43	1.29	0.40	3.3	94.18	93.93	1.54
21400	Pond1	92.420	92.350	1.200	1.800	70.0	0.1	0.013	95.562	94.500	1.23	2.66	3.38	1.27	0.31	3.0	93.93	93.81	1.64	4.14	1.56	0.39	13.8	94.01	93.85	1.55	3.43	1.29	0.31	3.3	93.93	93.81	1.64

Note: [1] Based on restrictive downstream conditions; Summer = 93.68 m / Spring = 94.11 m for SWM Facility 1, and Spring = 94.18 m for Pond 2. All other results based on free outfall conditions.

[2] A negative surcharge implies that the pipe is not flowing full

0.22 Freeboard less than 0.5 m.

ATTACHMENT 6

100-YEAR FLOWS AND WATER LEVELS ON THE VAN GAAL DRAIN UNDER EXISTING AND PROPOSED CONDITIONS

JFSA Water Resources and Environmental Consultants

Table 7A: Existing and Proposed Conditions Flows on the Van Gaal Drain, Arbuckle Drain and Jock River [(1)]

HEC-RAS Location			Flow (m^3/s)						Difference in Flow (%)			SWMHYMO Node ID	Location Description
River	Reach	River Station	Existing Conditions			Proposed Conditions							
			1	2	4	1	2	4	1	2	4		
Jock River	Reach 1	22026	5.540	167.682	156.00	5.568	162.984	156.00	0.5	-2.8	0.0	N7	Upstream Extent of Modelling of Jock River
Jock River	Reach 2	21359	5.773	74.628	161.76	5.811	72.528	161.76	0.7	-2.8	0.0	RES_RF	At Outlet of Richmond Fen
Jock River	Reach 3	18677	17.624	88.341	166.76	20.131	86.554	166.76	14.2	-2.0	0.0	S_N6	At Confluence with Van Gaal Drain
Jock River	Reach 4	16872	15.385	85.979	181.76	18.387	84.530	181.76	19.5	-1.7	0.0	N5	At Confluence with Flowing Creek
Jock River	Reach 5	16112	16.168	143.467	180.00	19.376	142.546	180.00	19.8	-0.6	0.0	S_N5A	At Confluence with Tributary D
Jock River	Reach 6	11769	10.864	153.565	185.00	14.225	152.969	185.00	30.9	-0.4	0.0	S_N4	At Confluence with Leamy Creek
Jock River	Reach 7	10144	8.741	152.939	196.00	11.960	152.260	196.00	36.8	-0.4	0.0	N2	At Confluence with Monaghan Drain
Jock River	Reach 7	6550	9.652	189.823	201.00	12.871	189.905	201.00	33.3	0.0	0.0	S_N2	At Moodie Drive
Jock River	Reach 7	3699	5.067	211.402	205.00	6.297	210.531	205.00	24.3	-0.4	0.0	N1	At Confluence with Ottawa River
Joys Road Trib	Reach 1	705	2.619	3.166	0.883	2.523	3.160	0.883	-3.7	-0.2	0.0	VG1-3	Upstream End of Joy's Road Tributary
Moore Drain	Reach 2	555	0.9	0.683	0.033	0.083	0.102	0.001	-90.8	-85.1	-97.0	VG-8MB	At Confluence with Moore Drain Tributary
Moore Drain	Reach 1	298	2.172	2.132	0.322	1.937	1.699	0.143	-10.8	-20.3	-55.6	Moore	Upstream Extent of Modelling on Moore Drain
Moore Drain Trib	Reach 1	311 / 599	1.866	1.594	0.259	1.836	1.586	0.122	-1.6	-0.5	-52.8	MTrib	Upstream End of Moore Drain Tributary
Van Gaal Drain	Reach 3	3494	3.701	4.228	1.636	3.330	4.073	1.636	-10.0	-3.7	0.0	VG-1A	Upstream Extent of Modelling on Van Gaal Drain
Van Gaal Drain	Reach 3	3322	4.021	4.588	1.651	3.778	4.488	1.651	-6.0	-2.2	0.0	VG1-1	Upstream of Driveway Culvert on Garvin Road
Van Gaal Drain	Reach 3	3175	4.813	5.235	1.653	4.809	5.225	1.653	-0.1	-0.2	0.0	VG1-2	Upstream of Garvin Road
Van Gaal Drain	Reach 2	2554	7.272	8.316	2.857	6.937	8.182	2.857	-4.6	-1.6	0.0	VG1-4	At Confluence with Joy's Road Tributary
Van Gaal Drain	Reach 2	2076	9.543	10.808	3.286	9.357	9.973	3.286	-1.9	-7.7	0.0	VG1	Upstream of Proposed Bend Around Property Line
Van Gaal Drain	Reach 2	1340	11.434	11.619	3.426	9.318	10.024	3.424	-18.5	-13.7	-0.1	PERTHST	Upstream of Perth Street
Van Gaal Drain	Reach 2	1312	12.2	12.204	3.439	9.318	10.024	3.424	-23.6	-17.9	-0.5	PERTHST	Downstream of Perth Street
Van Gaal Drain	Reach 1	746	16.377	15.739	4.056	13.208	13.801	4.229	-19.4	-12.3	4.3	FORTUNE	Upstream of Fortune Street
Van Gaal Drain	Reach 1	666	16.377	15.739	4.056	13.208	13.801	4.229	-19.4	-12.3	4.3	FORTUNE	Downstream of Fortune Street
Van Gaal Drain	Reach 1	226	16.419	15.777	4.371	13.221	13.866	4.499	-19.5	-12.1	2.9	VG	Confluence with Jock River

[(1)] Scenario Descriptions:

1. The Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River.
2. The Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River.
4. The Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain.

Table 7B: Existing and Proposed Conditions Water Levels on the Van Gaal and Arbuckle Drains [1]

River	Reach	River Station	Maximum Water Surface Elevation (m)								
			Existing Conditions			Proposed Conditions			Difference		
			1	2	4	1	2	4	1	2	4
Van Gaal Drain	Reach 3	3494	97.56	97.60	97.16	97.53	97.59	97.16	-0.03	-0.01	0.00
Van Gaal Drain	Reach 3	3322	97.43	97.47	97.06	97.41	97.47	97.06	-0.02	0.00	0.00
Van Gaal Drain	Reach 3	3312	97.42	97.45	97.05	97.40	97.45	97.05	-0.02	0.00	0.00
Van Gaal Drain	Reach 3	3311	Culvert								
Van Gaal Drain	Reach 3	3302	97.33	97.35	97.01	97.31	97.35	97.01	-0.02	0.00	0.00
Van Gaal Drain	Reach 3	3297	97.27	97.32	96.98	97.26	97.32	96.98	-0.01	0.00	0.00
Van Gaal Drain	Reach 3	3185	97.17	97.26	96.56	97.18	97.26	96.56	0.01	0.00	0.00
Van Gaal Drain	Reach 3	3175	97.16	97.23	96.59	97.15	97.23	96.59	-0.01	0.00	0.00
Van Gaal Drain	Reach 3	3174	Culvert								
Van Gaal Drain	Reach 3	3165	96.75	96.74	96.55	96.75	96.74	96.55	0.00	0.00	0.00
Van Gaal Drain	Reach 3	3149	96.72	96.72	96.51	96.72	96.72	96.51	0.00	0.00	0.00
Van Gaal Drain	Reach 3	3086	96.65	96.63	96.40	96.65	96.63	96.40	0.00	0.00	0.00
Van Gaal Drain	Reach 3	3016	96.61	96.59	96.33	96.61	96.59	96.32	0.00	0.00	-0.01
Van Gaal Drain	Reach 3	2980	96.57	96.56	96.28	96.57	96.56	96.27	0.00	0.00	-0.01
Van Gaal Drain	Reach 3	2851	96.41	96.42	96.03	96.40	96.41	95.99	-0.01	-0.01	-0.04
Van Gaal Drain	Reach 3	2808	96.38	96.39	96.01	96.37	96.39	95.95	-0.01	0.00	-0.06
Van Gaal Drain	Reach 3	2658	96.28	96.29	95.95	96.25	96.28	95.88	-0.03	-0.01	-0.07
Van Gaal Drain	Reach 2	2554	96.27	96.29	95.94	96.24	96.28	95.86	-0.03	-0.01	-0.08
Van Gaal Drain	Reach 2	2478	96.16	96.15	95.88	96.11	96.14	95.77	-0.05	-0.01	-0.11
Van Gaal Drain	Reach 2	2427.58*	N/A	N/A	N/A	96.03	96.04	95.71	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2377.17*	N/A	N/A	N/A	95.94	95.95	95.63	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2326.76*	N/A	N/A	N/A	95.86	95.87	95.53	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2276.35*	N/A	N/A	N/A	95.50	95.65	95.14	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2252	N/A	N/A	N/A	95.57	95.40	94.95	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2237	N/A	N/A	N/A	95.55	95.38	94.93	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2217	N/A	N/A	N/A	95.52	95.35	94.90	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2197	N/A	N/A	N/A	95.50	95.32	94.87	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2177	N/A	N/A	N/A	95.47	95.29	94.83	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2157	95.47	95.48	95.03	95.45	95.26	94.80	-0.02	-0.22	-0.23
Van Gaal Drain	Reach 2	2154	N/A	N/A	N/A	95.43	95.23	94.77	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2153	N/A	N/A	N/A	95.38	95.18	94.73	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2152	N/A	N/A	N/A	95.34	95.14	94.69	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2132	N/A	N/A	N/A	95.30	95.10	94.64	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2112	N/A	N/A	N/A	95.26	95.06	94.60	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2092	N/A	N/A	N/A	95.22	95.02	94.57	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2072	N/A	N/A	N/A	95.18	94.98	94.53	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2052	N/A	N/A	N/A	95.14	94.94	94.49	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2032	N/A	N/A	N/A	95.10	94.90	94.45	N/A	N/A	N/A
Van Gaal Drain	Reach 2	2002	N/A	N/A	N/A	95.04	94.85	94.40	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1982	N/A	N/A	N/A	95.00	94.81	94.37	N/A	N/A	N/A

Table 7B: Existing and Proposed Conditions Water Levels on the Van Gaal and Arbuckle Drains [(1)]

River	Reach	River Station	Maximum Water Surface Elevation (m)								
			Existing Conditions			Proposed Conditions			Difference		
			1	2	4	1	2	4	1	2	4
Van Gaal Drain	Reach 2	1962	N/A	N/A	N/A	94.96	94.77	94.34	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1942	N/A	N/A	N/A	94.92	94.73	94.32	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1922	N/A	N/A	N/A	94.88	94.70	94.29	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1902	N/A	N/A	N/A	94.84	94.66	94.27	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1882	N/A	N/A	N/A	94.81	94.63	94.25	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1862	N/A	N/A	N/A	94.77	94.60	94.23	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1842	N/A	N/A	N/A	94.73	94.56	94.22	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1822	N/A	N/A	N/A	94.70	94.53	94.21	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1802	N/A	N/A	N/A	94.66	94.50	94.20	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1782	N/A	N/A	N/A	94.63	94.48	94.19	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1762	N/A	N/A	N/A	94.60	94.45	94.18	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1742	N/A	N/A	N/A	94.57	94.42	94.17	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1722	N/A	N/A	N/A	94.54	94.40	94.17	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1702	N/A	N/A	N/A	94.51	94.38	94.16	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1682	N/A	N/A	N/A	94.48	94.36	94.16	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1662	N/A	N/A	N/A	94.45	94.34	94.15	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1642	N/A	N/A	N/A	94.42	94.32	94.15	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1622	N/A	N/A	N/A	94.40	94.30	94.15	N/A	N/A	N/A
Van Gaal Drain	Reach 2	1615	94.60	94.61	94.24	94.39	94.30	94.15	-0.21	-0.31	-0.09
Van Gaal Drain	Reach 2	1555	94.53	94.55	94.21	94.32	94.26	94.14	-0.21	-0.29	-0.07
Van Gaal Drain	Reach 2	1488	94.45	94.45	94.18	94.26	94.22	94.14	-0.19	-0.23	-0.04
Van Gaal Drain	Reach 2	1416	94.39	94.41	94.14	94.21	94.19	94.13	-0.18	-0.22	-0.01
Van Gaal Drain	Reach 2	1400	94.36	94.36	94.14	94.19	94.18	94.13	-0.17	-0.18	-0.01
Van Gaal Drain	Reach 2	1364	94.31	94.29	94.13	94.17	94.17	94.13	-0.14	-0.12	0.00
Van Gaal Drain	Reach 2	1340	94.21	94.19	94.13	94.06	94.06	94.12	-0.15	-0.13	-0.01
Van Gaal Drain	Reach 2	1339	Culvert								
Van Gaal Drain	Reach 2	1312	94.14	94.12	94.12	94.05	94.04	94.12	-0.09	-0.08	0.00
Van Gaal Drain	Reach 2	1302	94.15	94.14	94.12	94.04	94.04	94.12	-0.11	-0.10	0.00
Van Gaal Drain	Reach 2	1268	94.14	94.14	94.12	94.01	94.01	94.12	-0.13	-0.13	0.00
Van Gaal Drain	Reach 2	1212	94.10	94.11	94.12	93.93	93.96	94.11	-0.17	-0.15	-0.01
Van Gaal Drain	Reach 2	1169	94.04	94.08	94.12	93.85	93.89	94.11	-0.19	-0.19	-0.01
Van Gaal Drain	Reach 2	1091	93.97	94.04	94.12	93.73	93.83	94.11	-0.24	-0.21	-0.01
Van Gaal Drain	Reach 2	1002	93.93	94.02	94.12	93.60	93.78	94.11	-0.33	-0.24	-0.01
Van Gaal Drain	Reach 2	961	93.92	94.02	94.12	93.52	93.77	94.11	-0.40	-0.25	-0.01
Van Gaal Drain	Reach 2	910	93.91	94.02	94.12	93.46	93.77	94.11	-0.45	-0.25	-0.01
Van Gaal Drain	Reach 2	840	93.91	94.02	94.12	93.44	93.76	94.11	-0.47	-0.26	-0.01
Van Gaal Drain	Reach 1	746	93.90	94.01	94.12	93.42	93.76	94.11	-0.48	-0.25	-0.01
Van Gaal Drain	Reach 1	705	93.89	94.01	94.11	93.39	93.75	94.11	-0.50	-0.26	0.00
Van Gaal Drain	Reach 1	668	93.84	93.99	94.11	93.21	93.73	94.11	-0.63	-0.26	0.00
Van Gaal Drain	Reach 1	666	93.32	93.68	94.10	92.96	93.59	94.10	-0.36	-0.09	0.00

Table 7B: Existing and Proposed Conditions Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Maximum Water Surface Elevation (m)								
			Existing Conditions			Proposed Conditions			Difference		
			1	*2*	*4*	*1*	*2*	*4*	*1*	*2*	*4*
Van Gaal Drain	Reach 1	656	Culvert								
Van Gaal Drain	Reach 1	647	93.07	93.58	94.10	93.04	93.59	94.10	-0.03	0.01	0.00
Van Gaal Drain	Reach 1	645	93.23	93.67	94.10	93.05	93.61	94.10	-0.18	-0.06	0.00
Van Gaal Drain	Reach 1	592	93.28	93.70	94.10	93.07	93.63	94.10	-0.21	-0.07	0.00
Van Gaal Drain	Reach 1	521	93.26	93.70	94.10	93.05	93.63	94.10	-0.21	-0.07	0.00
Van Gaal Drain	Reach 1	277	92.96	93.66	94.10	92.79	93.60	94.10	-0.17	-0.06	0.00
Van Gaal Drain	Reach 1	275	92.87	93.51	94.09	92.72	93.48	94.09	-0.15	-0.03	0.00
Van Gaal Drain	Reach 1	269	Culvert								
Van Gaal Drain	Reach 1	263	92.58	93.39	94.09	92.55	93.39	94.09	-0.03	0.00	0.00
Van Gaal Drain	Reach 1	226	92.40	93.44	94.09	92.24	93.43	94.09	-0.16	-0.01	0.00
Van Gaal Drain	Reach 1	0	91.28	93.45	94.09	91.38	93.43	94.09	0.10	-0.02	0.00
Moore Drain Trib	Reach 1	600	N/A	N/A	N/A	95.89	95.80	95.15	N/A	N/A	N/A
Moore Drain Trib	Reach 1	553	N/A	N/A	N/A	95.87	95.78	95.11	N/A	N/A	N/A
Moore Drain Trib	Reach 1	503	N/A	N/A	N/A	95.85	95.76	95.07	N/A	N/A	N/A
Moore Drain Trib	Reach 1	492	N/A	N/A	N/A	95.78	95.70	95.06	N/A	N/A	N/A
Moore Drain Trib	Reach 1	477	Culvert								
Moore Drain Trib	Reach 1	462	N/A	N/A	N/A	95.65	95.58	94.99	N/A	N/A	N/A
Moore Drain Trib	Reach 1	453	N/A	N/A	N/A	95.67	95.60	94.98	N/A	N/A	N/A
Moore Drain Trib	Reach 1	403	N/A	N/A	N/A	95.65	95.57	94.94	N/A	N/A	N/A
Moore Drain Trib	Reach 1	353	N/A	N/A	N/A	95.53	95.46	94.88	N/A	N/A	N/A
Moore Drain Trib	Reach 1	338.5	Culvert								
Moore Drain Trib	Reach 1	324	N/A	N/A	N/A	95.28	95.24	94.80	N/A	N/A	N/A
Moore Drain Trib	Reach 1	311	94.60	94.58	94.48	95.30	95.25	94.77	0.70	0.67	0.29
Moore Drain Trib	Reach 1	290	N/A	N/A	N/A	95.27	95.21	94.73	N/A	N/A	N/A
Moore Drain Trib	Reach 1	240	N/A	N/A	N/A	95.20	95.14	94.63	N/A	N/A	N/A
Moore Drain Trib	Reach 1	190	N/A	N/A	N/A	95.15	95.08	94.53	N/A	N/A	N/A
Moore Drain Trib	Reach 1	140	N/A	N/A	N/A	95.10	95.03	94.43	N/A	N/A	N/A
Moore Drain Trib	Reach 1	90	94.20	94.18	94.11	95.08	95.00	94.37	0.88	0.82	0.26
Moore Drain Trib	Reach 1	83	N/A	N/A	N/A	94.99	94.93	94.35	N/A	N/A	N/A
Moore Drain Trib	Reach 1	68	Culvert								
Moore Drain Trib	Reach 1	53	N/A	N/A	N/A	94.71	94.68	94.20	N/A	N/A	N/A
Moore Drain Trib	Reach 1	14	N/A	N/A	N/A	94.27	94.24	94.11	N/A	N/A	N/A
Moore Drain	Reach 2	555	94.67	94.63	94.33	94.39	94.41	94.21	-0.28	-0.22	-0.12
Moore Drain	Reach 2	500	94.44	94.41	94.23	94.26	94.28	94.17	-0.18	-0.13	-0.06
Moore Drain	Reach 1	298	93.90	94.02	94.12	93.85	93.82	94.11	-0.05	-0.20	-0.01
Moore Drain	Reach 1	130	93.91	94.02	94.12	93.44	93.76	94.11	-0.47	-0.26	-0.01
Joys Road Trib	Reach 1	705	97.59	97.79	97.11	97.56	97.78	97.11	-0.03	-0.01	0.00
Joys Road Trib	Reach 1	664	97.60	97.79	97.04	97.57	97.79	97.04	-0.03	0.00	0.00
Joys Road Trib	Reach 1	635	97.50	97.68	97.00	97.47	97.67	97.00	-0.03	-0.01	0.00
Joys Road Trib	Reach 1	634	Culvert								

Table 7B: Existing and Proposed Conditions Water Levels on the Van Gaal and Arbuckle Drains [1]

River	Reach	River Station	Maximum Water Surface Elevation (m)								
			Existing Conditions			Proposed Conditions			Difference		
			1	*2*	*4*	*1*	*2*	*4*	*1*	*2*	*4*
Joys Road Trib	Reach 1	622	97.21	97.26	96.96	97.20	97.26	96.96	-0.01	0.00	0.00
Joys Road Trib	Reach 1	602	97.21	97.27	96.95	97.20	97.27	96.95	-0.01	0.00	0.00
Joys Road Trib	Reach 1	322	96.65	96.71	96.45	96.64	96.71	96.45	-0.01	0.00	0.00
Joys Road Trib	Reach 1	275	96.50	96.56	96.20	96.48	96.56	96.20	-0.02	0.00	0.00
Joys Road Trib	Reach 1	30	96.29	96.30	95.95	96.26	96.29	95.88	-0.03	-0.01	-0.07

[1] Scenario Descriptions:

1. The Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River.
2. The Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River.
4. The Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain.

ATTACHMENT

7

2 TO 25-YEAR FLOWS AND WATER LEVELS ON THE VAN GAAL DRAIN UNDER EXISTING AND PROPOSED CONDITIONS

JFSA Water Resources and Environmental Consultants

Table 8A: Existing Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	2	4	1	2	4
Van Gaal Drain	Reach 3	3494	2-Year	0.96	2.09	2.06	97.01	97.27	97.26
Van Gaal Drain	Reach 3	3494	5-Year	1.60	2.68	1.13	97.18	97.37	97.04
Van Gaal Drain	Reach 3	3494	10-Year	2.06	3.06	0.91	97.28	97.43	96.98
Van Gaal Drain	Reach 3	3494	25-Year	2.67	3.53	1.27	97.39	97.50	97.08
Van Gaal Drain	Reach 3	3322	2-Year	1.05	2.27	2.21	96.92	97.16	97.16
Van Gaal Drain	Reach 3	3322	5-Year	1.73	2.90	1.15	97.07	97.26	96.95
Van Gaal Drain	Reach 3	3322	10-Year	2.24	3.32	0.92	97.17	97.31	96.90
Van Gaal Drain	Reach 3	3322	25-Year	2.90	3.83	1.29	97.28	97.38	96.98
Van Gaal Drain	Reach 3	3312	2-Year	1.05	2.27	2.21	96.92	97.16	97.15
Van Gaal Drain	Reach 3	3312	5-Year	1.73	2.90	1.15	97.07	97.24	96.95
Van Gaal Drain	Reach 3	3312	10-Year	2.24	3.32	0.92	97.17	97.29	96.90
Van Gaal Drain	Reach 3	3312	25-Year	2.90	3.83	1.29	97.27	97.36	96.98
Van Gaal Drain	Reach 3	3311	Culvert						
Van Gaal Drain	Reach 3	3302	2-Year	1.05	2.27	2.21	96.91	97.08	97.08
Van Gaal Drain	Reach 3	3302	5-Year	1.73	2.90	1.15	97.03	97.14	96.93
Van Gaal Drain	Reach 3	3302	10-Year	2.24	3.32	0.92	97.09	97.17	96.89
Van Gaal Drain	Reach 3	3302	25-Year	2.90	3.83	1.29	97.17	97.24	96.96
Van Gaal Drain	Reach 3	3297	2-Year	1.05	2.27	2.21	96.87	97.04	97.05
Van Gaal Drain	Reach 3	3297	5-Year	1.73	2.90	1.15	96.98	97.09	96.91
Van Gaal Drain	Reach 3	3297	10-Year	2.24	3.32	0.92	97.04	97.13	96.87
Van Gaal Drain	Reach 3	3297	25-Year	2.90	3.83	1.29	97.11	97.20	96.93
Van Gaal Drain	Reach 3	3185	2-Year	1.05	2.27	2.21	96.52	96.72	96.68
Van Gaal Drain	Reach 3	3185	5-Year	1.73	2.90	1.15	96.65	96.87	96.46
Van Gaal Drain	Reach 3	3185	10-Year	2.24	3.32	0.92	96.76	96.97	96.39
Van Gaal Drain	Reach 3	3185	25-Year	2.90	3.83	1.29	96.93	97.09	96.49
Van Gaal Drain	Reach 3	3175	2-Year	1.33	2.59	2.40	96.53	96.74	96.70
Van Gaal Drain	Reach 3	3175	5-Year	2.15	3.31	1.17	96.67	96.87	96.49
Van Gaal Drain	Reach 3	3175	10-Year	2.74	3.79	0.92	96.77	96.96	96.43
Van Gaal Drain	Reach 3	3175	25-Year	3.51	4.37	1.30	96.93	97.07	96.53
Van Gaal Drain	Reach 3	3174	Culvert						
Van Gaal Drain	Reach 3	3165	2-Year	1.33	2.59	2.40	96.50	96.65	96.64
Van Gaal Drain	Reach 3	3165	5-Year	2.15	3.31	1.17	96.61	96.70	96.47
Van Gaal Drain	Reach 3	3165	10-Year	2.74	3.79	0.92	96.67	96.72	96.42
Van Gaal Drain	Reach 3	3165	25-Year	3.51	4.37	1.30	96.72	96.74	96.50
Van Gaal Drain	Reach 3	3149	2-Year	1.33	2.59	2.40	96.46	96.60	96.58
Van Gaal Drain	Reach 3	3149	5-Year	2.15	3.31	1.17	96.57	96.64	96.43
Van Gaal Drain	Reach 3	3149	10-Year	2.74	3.79	0.92	96.62	96.66	96.37
Van Gaal Drain	Reach 3	3149	25-Year	3.51	4.37	1.30	96.66	96.68	96.46
Van Gaal Drain	Reach 3	3086	2-Year	1.33	2.59	2.40	96.35	96.50	96.49
Van Gaal Drain	Reach 3	3086	5-Year	2.15	3.31	1.17	96.47	96.55	96.31
Van Gaal Drain	Reach 3	3086	10-Year	2.74	3.79	0.92	96.53	96.58	96.25
Van Gaal Drain	Reach 3	3086	25-Year	3.51	4.37	1.30	96.58	96.60	96.34
Van Gaal Drain	Reach 3	3016	2-Year	1.33	2.59	2.40	96.26	96.46	96.44

Table 8A: Existing Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains [(1)]

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	2	4	1	2	4
Van Gaal Drain	Reach 3	3016	5-Year	2.15	3.31	1.17	96.41	96.52	96.23
Van Gaal Drain	Reach 3	3016	10-Year	2.74	3.79	0.92	96.48	96.54	96.17
Van Gaal Drain	Reach 3	3016	25-Year	3.51	4.37	1.30	96.54	96.56	96.26
Van Gaal Drain	Reach 3	2980	2-Year	1.33	2.59	2.40	96.21	96.42	96.40
Van Gaal Drain	Reach 3	2980	5-Year	2.15	3.31	1.17	96.36	96.49	96.18
Van Gaal Drain	Reach 3	2980	10-Year	2.74	3.79	0.92	96.44	96.51	96.12
Van Gaal Drain	Reach 3	2980	25-Year	3.51	4.37	1.30	96.51	96.54	96.21
Van Gaal Drain	Reach 3	2851	2-Year	1.33	2.59	2.40	95.90	96.21	96.19
Van Gaal Drain	Reach 3	2851	5-Year	2.15	3.31	1.17	96.10	96.29	95.89
Van Gaal Drain	Reach 3	2851	10-Year	2.74	3.79	0.92	96.21	96.34	95.80
Van Gaal Drain	Reach 3	2851	25-Year	3.51	4.37	1.30	96.31	96.38	95.93
Van Gaal Drain	Reach 3	2808	2-Year	1.33	2.59	2.40	95.86	96.18	96.16
Van Gaal Drain	Reach 3	2808	5-Year	2.15	3.31	1.17	96.07	96.26	95.86
Van Gaal Drain	Reach 3	2808	10-Year	2.74	3.79	0.92	96.18	96.31	95.76
Van Gaal Drain	Reach 3	2808	25-Year	3.51	4.37	1.30	96.28	96.35	95.90
Van Gaal Drain	Reach 3	2658	2-Year	1.33	2.59	2.40	95.78	96.11	96.10
Van Gaal Drain	Reach 3	2658	5-Year	2.15	3.31	1.17	95.99	96.18	95.80
Van Gaal Drain	Reach 3	2658	10-Year	2.74	3.79	0.92	96.10	96.22	95.70
Van Gaal Drain	Reach 3	2658	25-Year	3.51	4.37	1.30	96.19	96.25	95.85
Van Gaal Drain	Reach 2	2554	2-Year	1.95	4.13	3.97	95.77	96.10	96.09
Van Gaal Drain	Reach 2	2554	5-Year	3.20	5.24	2.02	95.98	96.17	95.79
Van Gaal Drain	Reach 2	2554	10-Year	4.11	6.00	1.57	96.09	96.21	95.69
Van Gaal Drain	Reach 2	2554	25-Year	5.28	6.94	2.25	96.18	96.24	95.84
Van Gaal Drain	Reach 2	2478	2-Year	1.95	4.13	3.97	95.72	96.03	96.02
Van Gaal Drain	Reach 2	2478	5-Year	3.20	5.24	2.02	95.92	96.08	95.74
Van Gaal Drain	Reach 2	2478	10-Year	4.11	6.00	1.57	96.02	96.11	95.64
Van Gaal Drain	Reach 2	2478	25-Year	5.28	6.94	2.25	96.09	96.13	95.78
Van Gaal Drain	Reach 2	2157	2-Year	1.95	4.13	3.97	94.93	95.19	95.17
Van Gaal Drain	Reach 2	2157	5-Year	3.20	5.24	2.02	95.12	95.34	94.94
Van Gaal Drain	Reach 2	2157	10-Year	4.11	6.00	1.57	95.25	95.38	94.88
Van Gaal Drain	Reach 2	2157	25-Year	5.28	6.94	2.25	95.37	95.43	94.97
Van Gaal Drain	Reach 2	2076	2-Year	2.80	5.00	4.78	94.74	95.03	95.01
Van Gaal Drain	Reach 2	2076	5-Year	4.41	6.32	2.33	94.97	95.13	94.65
Van Gaal Drain	Reach 2	2076	10-Year	5.53	7.24	1.78	95.08	95.17	94.53
Van Gaal Drain	Reach 2	2076	25-Year	6.96	8.38	2.60	95.17	95.21	94.70
Van Gaal Drain	Reach 2	1974	2-Year	2.80	5.00	4.78	94.61	94.89	94.87
Van Gaal Drain	Reach 2	1974	5-Year	4.41	6.32	2.33	94.84	94.97	94.50
Van Gaal Drain	Reach 2	1974	10-Year	5.53	7.24	1.78	94.93	95.02	94.37
Van Gaal Drain	Reach 2	1974	25-Year	6.96	8.38	2.60	95.01	95.06	94.56
Van Gaal Drain	Reach 2	1922	2-Year	2.80	5.00	4.78	94.55	94.82	94.81
Van Gaal Drain	Reach 2	1922	5-Year	4.41	6.32	2.33	94.79	94.89	94.44
Van Gaal Drain	Reach 2	1922	10-Year	5.53	7.24	1.78	94.85	94.92	94.30
Van Gaal Drain	Reach 2	1922	25-Year	6.96	8.38	2.60	94.92	94.95	94.50
Van Gaal Drain	Reach 2	1833	2-Year	2.80	5.00	4.78	94.47	94.71	94.71

Table 8A: Existing Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	2	4	1	2	4
Van Gaal Drain	Reach 2	1833	5-Year	4.41	6.32	2.33	94.69	94.76	94.35
Van Gaal Drain	Reach 2	1833	10-Year	5.53	7.24	1.78	94.74	94.78	94.20
Van Gaal Drain	Reach 2	1833	25-Year	6.96	8.38	2.60	94.78	94.80	94.42
Van Gaal Drain	Reach 2	1796	2-Year	2.80	5.00	4.78	94.44	94.68	94.68
Van Gaal Drain	Reach 2	1796	5-Year	4.41	6.32	2.33	94.66	94.73	94.32
Van Gaal Drain	Reach 2	1796	10-Year	5.53	7.24	1.78	94.70	94.74	94.16
Van Gaal Drain	Reach 2	1796	25-Year	6.96	8.38	2.60	94.74	94.77	94.39
Van Gaal Drain	Reach 2	1735	2-Year	2.80	5.00	4.78	94.41	94.64	94.64
Van Gaal Drain	Reach 2	1735	5-Year	4.41	6.32	2.33	94.63	94.67	94.28
Van Gaal Drain	Reach 2	1735	10-Year	5.53	7.24	1.78	94.65	94.68	94.12
Van Gaal Drain	Reach 2	1735	25-Year	6.96	8.38	2.60	94.68	94.69	94.36
Van Gaal Drain	Reach 2	1728	2-Year	2.80	5.00	4.78	94.41	94.64	94.63
Van Gaal Drain	Reach 2	1728	5-Year	4.41	6.32	2.33	94.62	94.67	94.28
Van Gaal Drain	Reach 2	1728	10-Year	5.53	7.24	1.78	94.65	94.67	94.11
Van Gaal Drain	Reach 2	1728	25-Year	6.96	8.38	2.60	94.67	94.68	94.35
Van Gaal Drain	Reach 2	1727	Culvert						
Van Gaal Drain	Reach 2	1717	2-Year	2.80	5.00	4.78	94.15	94.42	94.40
Van Gaal Drain	Reach 2	1717	5-Year	4.41	6.32	2.33	94.37	94.55	94.05
Van Gaal Drain	Reach 2	1717	10-Year	5.53	7.24	1.78	94.49	94.59	93.92
Van Gaal Drain	Reach 2	1717	25-Year	6.96	8.38	2.60	94.59	94.63	94.10
Van Gaal Drain	Reach 2	1615	2-Year	2.80	5.00	4.78	94.04	94.29	94.26
Van Gaal Drain	Reach 2	1615	5-Year	4.41	6.32	2.33	94.24	94.40	93.92
Van Gaal Drain	Reach 2	1615	10-Year	5.53	7.24	1.78	94.36	94.46	93.78
Van Gaal Drain	Reach 2	1615	25-Year	6.96	8.38	2.60	94.46	94.52	93.98
Van Gaal Drain	Reach 2	1555	2-Year	2.80	5.00	4.78	93.99	94.22	94.19
Van Gaal Drain	Reach 2	1555	5-Year	4.41	6.32	2.33	94.19	94.33	93.87
Van Gaal Drain	Reach 2	1555	10-Year	5.53	7.24	1.78	94.29	94.39	93.72
Van Gaal Drain	Reach 2	1555	25-Year	6.96	8.38	2.60	94.40	94.45	93.93
Van Gaal Drain	Reach 2	1488	2-Year	2.80	5.00	4.78	93.96	94.16	94.13
Van Gaal Drain	Reach 2	1488	5-Year	4.41	6.32	2.33	94.13	94.26	93.82
Van Gaal Drain	Reach 2	1488	10-Year	5.53	7.24	1.78	94.23	94.31	93.66
Van Gaal Drain	Reach 2	1488	25-Year	6.96	8.38	2.60	94.33	94.36	93.88
Van Gaal Drain	Reach 2	1416	2-Year	2.80	5.00	4.78	93.89	94.02	93.99
Van Gaal Drain	Reach 2	1416	5-Year	4.41	6.32	2.33	94.03	94.10	93.74
Van Gaal Drain	Reach 2	1416	10-Year	5.53	7.24	1.78	94.10	94.17	93.58
Van Gaal Drain	Reach 2	1416	25-Year	6.96	8.38	2.60	94.20	94.25	93.81
Van Gaal Drain	Reach 2	1400	2-Year	2.80	5.00	4.78	93.89	94.02	93.99
Van Gaal Drain	Reach 2	1400	5-Year	4.41	6.32	2.33	94.03	94.11	93.74
Van Gaal Drain	Reach 2	1400	10-Year	5.53	7.24	1.78	94.11	94.16	93.58
Van Gaal Drain	Reach 2	1400	25-Year	6.96	8.38	2.60	94.20	94.23	93.80
Van Gaal Drain	Reach 2	1364	2-Year	2.80	5.00	4.78	93.87	93.99	93.96
Van Gaal Drain	Reach 2	1364	5-Year	4.41	6.32	2.33	94.00	94.06	93.72
Van Gaal Drain	Reach 2	1364	10-Year	5.53	7.24	1.78	94.07	94.11	93.56
Van Gaal Drain	Reach 2	1364	25-Year	6.96	8.38	2.60	94.16	94.18	93.79

Table 8A: Existing Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains [1]

River	Reach	River Station	Profile	Flow (m^3/s) 1	Flow (m^3/s) 2	Flow (m^3/s) 4	Maximum Water Level (m) 1	Maximum Water Level (m) 2	Maximum Water Level (m) 4
Van Gaal Drain	Reach 2	1340	2-Year	3.64	5.79	5.26	93.85	93.96	93.93
Van Gaal Drain	Reach 2	1340	5-Year	5.57	7.32	2.44	93.97	94.01	93.71
Van Gaal Drain	Reach 2	1340	10-Year	6.92	8.33	1.86	94.03	94.05	93.55
Van Gaal Drain	Reach 2	1340	25-Year	8.58	9.65	2.71	94.09	94.10	93.78
Van Gaal Drain	Reach 2	1339	Culvert						
Van Gaal Drain	Reach 2	1312	2-Year	3.87	6.08	5.46	93.84	93.94	93.91
Van Gaal Drain	Reach 2	1312	5-Year	5.93	7.69	2.47	93.95	93.98	93.71
Van Gaal Drain	Reach 2	1312	10-Year	7.38	8.76	1.87	94.00	94.01	93.55
Van Gaal Drain	Reach 2	1312	25-Year	9.17	10.15	2.73	94.05	94.04	93.77
Van Gaal Drain	Reach 2	1302	2-Year	3.87	6.08	5.46	93.81	93.91	93.89
Van Gaal Drain	Reach 2	1302	5-Year	5.93	7.69	2.47	93.92	93.97	93.68
Van Gaal Drain	Reach 2	1302	10-Year	7.38	8.76	1.87	93.98	94.00	93.51
Van Gaal Drain	Reach 2	1302	25-Year	9.17	10.15	2.73	94.04	94.04	93.75
Van Gaal Drain	Reach 2	1268	2-Year	3.87	6.08	5.46	93.75	93.87	93.84
Van Gaal Drain	Reach 2	1268	5-Year	5.93	7.69	2.47	93.88	93.93	93.59
Van Gaal Drain	Reach 2	1268	10-Year	7.38	8.76	1.87	93.94	93.96	93.44
Van Gaal Drain	Reach 2	1268	25-Year	9.17	10.15	2.73	94.01	94.00	93.69
Van Gaal Drain	Reach 2	1212	2-Year	3.87	6.08	5.46	93.61	93.78	93.74
Van Gaal Drain	Reach 2	1212	5-Year	5.93	7.69	2.47	93.78	93.85	93.41
Van Gaal Drain	Reach 2	1212	10-Year	7.38	8.76	1.87	93.85	93.89	93.32
Van Gaal Drain	Reach 2	1212	25-Year	9.17	10.15	2.73	93.93	93.94	93.58
Van Gaal Drain	Reach 2	1169	2-Year	3.87	6.08	5.46	93.53	93.70	93.67
Van Gaal Drain	Reach 2	1169	5-Year	5.93	7.69	2.47	93.70	93.76	93.32
Van Gaal Drain	Reach 2	1169	10-Year	7.38	8.76	1.87	93.77	93.80	93.26
Van Gaal Drain	Reach 2	1169	25-Year	9.17	10.15	2.73	93.85	93.87	93.54
Van Gaal Drain	Reach 2	1091	2-Year	3.87	6.08	5.46	93.40	93.57	93.54
Van Gaal Drain	Reach 2	1091	5-Year	5.93	7.69	2.47	93.57	93.64	93.19
Van Gaal Drain	Reach 2	1091	10-Year	7.38	8.76	1.87	93.65	93.69	93.17
Van Gaal Drain	Reach 2	1091	25-Year	9.17	10.15	2.73	93.75	93.78	93.50
Van Gaal Drain	Reach 2	1002	2-Year	3.87	6.08	5.46	93.21	93.38	93.33
Van Gaal Drain	Reach 2	1002	5-Year	5.93	7.69	2.47	93.39	93.49	93.01
Van Gaal Drain	Reach 2	1002	10-Year	7.38	8.76	1.87	93.50	93.59	93.09
Van Gaal Drain	Reach 2	1002	25-Year	9.17	10.15	2.73	93.65	93.71	93.47
Van Gaal Drain	Reach 2	961	2-Year	3.87	6.08	5.46	93.14	93.28	93.23
Van Gaal Drain	Reach 2	961	5-Year	5.93	7.69	2.47	93.31	93.41	92.97
Van Gaal Drain	Reach 2	961	10-Year	7.38	8.76	1.87	93.44	93.52	93.06
Van Gaal Drain	Reach 2	961	25-Year	9.17	10.15	2.73	93.61	93.69	93.46
Van Gaal Drain	Reach 2	910	2-Year	3.87	6.08	5.46	93.07	93.22	93.17
Van Gaal Drain	Reach 2	910	5-Year	5.93	7.69	2.47	93.25	93.38	92.91
Van Gaal Drain	Reach 2	910	10-Year	7.38	8.76	1.87	93.40	93.49	93.05
Van Gaal Drain	Reach 2	910	25-Year	9.17	10.15	2.73	93.59	93.68	93.46
Van Gaal Drain	Reach 2	840	2-Year	3.87	6.08	5.46	93.00	93.18	93.11
Van Gaal Drain	Reach 2	840	5-Year	5.93	7.69	2.47	93.22	93.35	92.83

Table 8A: Existing Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	*2*	*4*	*1*	*2*	*4*
Van Gaal Drain	Reach 2	840	10-Year	7.38	8.76	1.87	93.38	93.48	93.03
Van Gaal Drain	Reach 2	840	25-Year	9.17	10.15	2.73	93.58	93.67	93.45
Van Gaal Drain	Reach 1	746	2-Year	5.36	7.86	7.06	92.96	93.17	93.10
Van Gaal Drain	Reach 1	746	5-Year	8.09	9.97	2.99	93.20	93.35	92.82
Van Gaal Drain	Reach 1	746	10-Year	10.02	11.34	2.11	93.37	93.48	93.03
Van Gaal Drain	Reach 1	746	25-Year	12.40	13.11	3.31	93.57	93.67	93.45
Van Gaal Drain	Reach 1	705	2-Year	5.36	7.86	7.06	92.88	93.14	93.06
Van Gaal Drain	Reach 1	705	5-Year	8.09	9.97	2.99	93.16	93.34	92.78
Van Gaal Drain	Reach 1	705	10-Year	10.02	11.34	2.11	93.34	93.47	93.03
Van Gaal Drain	Reach 1	705	25-Year	12.40	13.11	3.31	93.55	93.66	93.45
Van Gaal Drain	Reach 1	668	2-Year	5.36	7.86	7.06	92.72	93.05	92.94
Van Gaal Drain	Reach 1	668	5-Year	8.09	9.97	2.99	93.04	93.28	92.74
Van Gaal Drain	Reach 1	668	10-Year	10.02	11.34	2.11	93.25	93.42	93.02
Van Gaal Drain	Reach 1	668	25-Year	12.40	13.11	3.31	93.48	93.63	93.45
Van Gaal Drain	Reach 1	666	2-Year	5.36	7.86	7.06	92.48	92.64	92.59
Van Gaal Drain	Reach 1	666	5-Year	8.09	9.97	2.99	92.66	92.83	92.72
Van Gaal Drain	Reach 1	666	10-Year	10.02	11.34	2.11	92.80	93.01	93.01
Van Gaal Drain	Reach 1	666	25-Year	12.40	13.11	3.31	93.03	93.26	93.43
Van Gaal Drain	Reach 1	656	Culvert						
Van Gaal Drain	Reach 1	647	2-Year	5.36	7.86	7.06	92.51	92.59	92.58
Van Gaal Drain	Reach 1	647	5-Year	8.09	9.97	2.99	92.66	92.78	92.72
Van Gaal Drain	Reach 1	647	10-Year	10.02	11.34	2.11	92.77	92.92	93.01
Van Gaal Drain	Reach 1	647	25-Year	12.40	13.11	3.31	92.90	93.17	93.43
Van Gaal Drain	Reach 1	645	2-Year	5.36	7.86	7.06	92.53	92.66	92.63
Van Gaal Drain	Reach 1	645	5-Year	8.09	9.97	2.99	92.72	92.87	92.72
Van Gaal Drain	Reach 1	645	10-Year	10.02	11.34	2.11	92.85	93.02	93.01
Van Gaal Drain	Reach 1	645	25-Year	12.40	13.11	3.31	93.00	93.26	93.43
Van Gaal Drain	Reach 1	592	2-Year	5.36	7.86	7.06	92.42	92.66	92.62
Van Gaal Drain	Reach 1	592	5-Year	8.09	9.97	2.99	92.68	92.89	92.73
Van Gaal Drain	Reach 1	592	10-Year	10.02	11.34	2.11	92.84	93.05	93.01
Van Gaal Drain	Reach 1	592	25-Year	12.40	13.11	3.31	93.02	93.29	93.44
Van Gaal Drain	Reach 1	521	2-Year	5.36	7.86	7.06	92.41	92.65	92.61
Van Gaal Drain	Reach 1	521	5-Year	8.09	9.97	2.99	92.67	92.88	92.72
Van Gaal Drain	Reach 1	521	10-Year	10.02	11.34	2.11	92.83	93.04	93.01
Van Gaal Drain	Reach 1	521	25-Year	12.40	13.11	3.31	93.00	93.29	93.43
Van Gaal Drain	Reach 1	277	2-Year	5.36	7.86	7.06	92.24	92.49	92.48
Van Gaal Drain	Reach 1	277	5-Year	8.09	9.97	2.99	92.46	92.74	92.71
Van Gaal Drain	Reach 1	277	10-Year	10.02	11.34	2.11	92.61	92.89	93.01
Van Gaal Drain	Reach 1	277	25-Year	12.40	13.11	3.31	92.76	93.19	93.43
Van Gaal Drain	Reach 1	275	2-Year	5.36	7.86	7.06	92.24	92.46	92.46
Van Gaal Drain	Reach 1	275	5-Year	8.09	9.97	2.99	92.45	92.68	92.70
Van Gaal Drain	Reach 1	275	10-Year	10.02	11.34	2.11	92.57	92.83	93.01
Van Gaal Drain	Reach 1	275	25-Year	12.40	13.11	3.31	92.69	93.09	93.43

Table 8A: Existing Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	2	4	1	2	4
Van Gaal Drain	Reach 1	269	Culvert						
Van Gaal Drain	Reach 1	263	2-Year	5.36	7.86	7.06	92.20	92.39	92.41
Van Gaal Drain	Reach 1	263	5-Year	8.09	9.97	2.99	92.38	92.60	92.70
Van Gaal Drain	Reach 1	263	10-Year	10.02	11.34	2.11	92.47	92.75	93.01
Van Gaal Drain	Reach 1	263	25-Year	12.40	13.11	3.31	92.54	93.00	93.42
Van Gaal Drain	Reach 1	226	2-Year	5.37	7.88	7.23	92.14	92.35	92.37
Van Gaal Drain	Reach 1	226	5-Year	8.11	10.01	3.23	92.31	92.59	92.70
Van Gaal Drain	Reach 1	226	10-Year	10.03	11.37	2.30	92.41	92.76	93.01
Van Gaal Drain	Reach 1	226	25-Year	12.43	13.14	3.54	92.47	93.04	93.42
Van Gaal Drain	Reach 1	0	2-Year	5.37	7.88	7.23	91.09	92.41	92.42
Van Gaal Drain	Reach 1	0	5-Year	8.11	10.01	3.23	91.11	92.63	92.70
Van Gaal Drain	Reach 1	0	10-Year	10.03	11.37	2.30	91.13	92.79	93.01
Van Gaal Drain	Reach 1	0	25-Year	12.43	13.14	3.54	91.17	93.06	93.42
Moore Drain Trib	Reach 1	311	2-Year	0.52	0.79	0.62	94.55	94.56	94.55
Moore Drain Trib	Reach 1	311	5-Year	0.84	1.01	0.17	94.57	94.56	94.48
Moore Drain Trib	Reach 1	311	10-Year	1.07	1.33	0.10	94.57	94.57	94.42
Moore Drain Trib	Reach 1	311	25-Year	1.36	1.33	0.15	94.58	94.57	94.47
Moore Drain Trib	Reach 1	90	2-Year	0.52	0.79	0.62	94.01	94.07	94.04
Moore Drain Trib	Reach 1	90	5-Year	0.84	1.01	0.17	94.08	94.15	93.89
Moore Drain Trib	Reach 1	90	10-Year	1.07	1.33	0.10	94.16	94.17	93.85
Moore Drain Trib	Reach 1	90	25-Year	1.36	1.33	0.15	94.18	94.17	93.88
Moore Drain	Reach 2	555	2-Year	0.26	0.34	0.24	94.50	94.53	94.49
Moore Drain	Reach 2	555	5-Year	0.41	0.43	1755.00	94.56	94.56	96.67
Moore Drain	Reach 2	555	10-Year	0.52	0.49	0.02	94.59	94.58	94.32
Moore Drain	Reach 2	555	25-Year	0.66	0.57	0.05	94.63	94.60	94.35
Moore Drain	Reach 2	500	2-Year	0.26	0.34	0.24	94.33	94.35	94.33
Moore Drain	Reach 2	500	5-Year	0.41	0.43	1755.00	94.37	94.37	95.87
Moore Drain	Reach 2	500	10-Year	0.52	0.49	0.02	94.39	94.38	94.22
Moore Drain	Reach 2	500	25-Year	0.66	0.57	0.05	94.41	94.40	94.24
Moore Drain	Reach 1	298	2-Year	0.67	1.07	1.01	93.68	93.79	93.78
Moore Drain	Reach 1	298	5-Year	1.05	1.36	0.37	93.78	93.81	93.60
Moore Drain	Reach 1	298	10-Year	1.32	1.55	0.15	93.81	93.82	93.52
Moore Drain	Reach 1	298	25-Year	1.64	1.78	0.36	93.83	93.83	93.60
Moore Drain	Reach 1	130	2-Year	0.67	1.07	1.01	93.00	93.18	93.11
Moore Drain	Reach 1	130	5-Year	1.05	1.36	0.37	93.22	93.36	92.84
Moore Drain	Reach 1	130	10-Year	1.32	1.55	0.15	93.38	93.48	93.03
Moore Drain	Reach 1	130	25-Year	1.64	1.78	0.36	93.58	93.67	93.45
Joys Road Trib	Reach 1	705	2-Year	0.66	1.57	1.46	97.07	97.24	97.20
Joys Road Trib	Reach 1	705	5-Year	1.11	2.00	0.69	97.14	97.39	97.08
Joys Road Trib	Reach 1	705	10-Year	1.44	2.29	0.51	97.19	97.49	97.04
Joys Road Trib	Reach 1	705	25-Year	1.87	2.64	0.75	97.35	97.60	97.08
Joys Road Trib	Reach 1	664	2-Year	0.66	1.57	1.46	96.97	97.26	97.23
Joys Road Trib	Reach 1	664	5-Year	1.11	2.00	0.69	97.12	97.40	96.98
Joys Road Trib	Reach 1	664	10-Year	1.44	2.29	0.51	97.22	97.49	96.92

Table 8A: Existing Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	*2*	*4*	*1*	*2*	*4*
Joys Road Trib	Reach 1	664	25-Year	1.87	2.64	0.75	97.36	97.61	97.00
Joys Road Trib	Reach 1	635	2-Year	0.66	1.57	1.46	96.94	97.19	97.16
Joys Road Trib	Reach 1	635	5-Year	1.11	2.00	0.69	97.07	97.31	96.95
Joys Road Trib	Reach 1	635	10-Year	1.44	2.29	0.51	97.16	97.40	96.89
Joys Road Trib	Reach 1	635	25-Year	1.87	2.64	0.75	97.28	97.50	96.96
Joys Road Trib	Reach 1	634	Culvert						
Joys Road Trib	Reach 1	622	2-Year	0.66	1.57	1.46	96.91	97.08	97.06
Joys Road Trib	Reach 1	622	5-Year	1.11	2.00	0.69	97.00	97.14	96.92
Joys Road Trib	Reach 1	622	10-Year	1.44	2.29	0.51	97.06	97.18	96.87
Joys Road Trib	Reach 1	622	25-Year	1.87	2.64	0.75	97.13	97.21	96.93
Joys Road Trib	Reach 1	602	2-Year	0.66	1.57	1.46	96.90	97.07	97.05
Joys Road Trib	Reach 1	602	5-Year	1.11	2.00	0.69	96.99	97.14	96.91
Joys Road Trib	Reach 1	602	10-Year	1.44	2.29	0.51	97.05	97.17	96.86
Joys Road Trib	Reach 1	602	25-Year	1.87	2.64	0.75	97.12	97.22	96.92
Joys Road Trib	Reach 1	322	2-Year	0.66	1.57	1.46	96.41	96.54	96.53
Joys Road Trib	Reach 1	322	5-Year	1.11	2.00	0.69	96.49	96.58	96.41
Joys Road Trib	Reach 1	322	10-Year	1.44	2.29	0.51	96.53	96.61	96.38
Joys Road Trib	Reach 1	322	25-Year	1.87	2.64	0.75	96.57	96.65	96.42
Joys Road Trib	Reach 1	275	2-Year	0.66	1.57	1.46	96.18	96.31	96.28
Joys Road Trib	Reach 1	275	5-Year	1.11	2.00	0.69	96.23	96.39	96.19
Joys Road Trib	Reach 1	275	10-Year	1.44	2.29	0.51	96.28	96.44	96.16
Joys Road Trib	Reach 1	275	25-Year	1.87	2.64	0.75	96.37	96.49	96.19
Joys Road Trib	Reach 1	30	2-Year	0.66	1.57	1.46	95.78	96.12	96.10
Joys Road Trib	Reach 1	30	5-Year	1.11	2.00	0.69	96.00	96.19	95.80
Joys Road Trib	Reach 1	30	10-Year	1.44	2.29	0.51	96.11	96.22	95.70
Joys Road Trib	Reach 1	30	25-Year	1.87	2.64	0.75	96.20	96.26	95.85

(1) Scenario Descriptions:

1. The Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River.
2. The Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River.
4. The Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain.

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	*2*	*4*	*1*	*2*	*4*
Van Gaal Drain	Reach 3	3494	2-Year	0.91	2.08	0.87	97.00	97.27	96.98
Van Gaal Drain	Reach 3	3494	5-Year	1.55	2.68	0.79	97.17	97.37	96.95
Van Gaal Drain	Reach 3	3494	10-Year	1.92	2.97	0.91	97.26	97.42	96.98
Van Gaal Drain	Reach 3	3494	25-Year	2.43	3.40	1.06	97.37	97.49	97.02
Van Gaal Drain	Reach 3	3322	2-Year	1.02	2.27	0.90	96.91	97.16	96.89
Van Gaal Drain	Reach 3	3322	5-Year	1.71	2.90	0.80	97.07	97.26	96.87
Van Gaal Drain	Reach 3	3322	10-Year	2.16	3.27	0.92	97.15	97.30	96.90
Van Gaal Drain	Reach 3	3322	25-Year	2.75	3.75	1.07	97.26	97.37	96.93
Van Gaal Drain	Reach 3	3312	2-Year	1.02	2.27	0.90	96.91	97.16	96.89
Van Gaal Drain	Reach 3	3312	5-Year	1.71	2.90	0.80	97.07	97.24	96.88
Van Gaal Drain	Reach 3	3312	10-Year	2.16	3.27	0.92	97.15	97.29	96.90
Van Gaal Drain	Reach 3	3312	25-Year	2.75	3.75	1.07	97.25	97.35	96.93
Van Gaal Drain	Reach 3	3311	Culvert						
Van Gaal Drain	Reach 3	3302	2-Year	1.02	2.27	0.90	96.90	97.08	96.88
Van Gaal Drain	Reach 3	3302	5-Year	1.71	2.90	0.80	97.02	97.14	96.87
Van Gaal Drain	Reach 3	3302	10-Year	2.16	3.27	0.92	97.08	97.17	96.89
Van Gaal Drain	Reach 3	3302	25-Year	2.75	3.75	1.07	97.15	97.24	96.92
Van Gaal Drain	Reach 3	3297	2-Year	1.02	2.27	0.90	96.87	97.04	96.86
Van Gaal Drain	Reach 3	3297	5-Year	1.71	2.90	0.80	96.98	97.09	96.85
Van Gaal Drain	Reach 3	3297	10-Year	2.16	3.27	0.92	97.03	97.13	96.87
Van Gaal Drain	Reach 3	3297	25-Year	2.75	3.75	1.07	97.10	97.20	96.90
Van Gaal Drain	Reach 3	3185	2-Year	1.02	2.27	0.90	96.51	96.72	96.39
Van Gaal Drain	Reach 3	3185	5-Year	1.71	2.90	0.80	96.64	96.86	96.35
Van Gaal Drain	Reach 3	3185	10-Year	2.16	3.27	0.92	96.76	96.97	96.39
Van Gaal Drain	Reach 3	3185	25-Year	2.75	3.75	1.07	96.93	97.09	96.43
Van Gaal Drain	Reach 3	3175	2-Year	1.30	2.58	0.90	96.53	96.73	96.43
Van Gaal Drain	Reach 3	3175	5-Year	2.09	3.25	0.80	96.66	96.86	96.40
Van Gaal Drain	Reach 3	3175	10-Year	2.71	3.78	0.92	96.77	96.96	96.43
Van Gaal Drain	Reach 3	3175	25-Year	3.50	4.36	1.07	96.92	97.07	96.47
Van Gaal Drain	Reach 3	3174	Culvert						
Van Gaal Drain	Reach 3	3165	2-Year	1.30	2.58	0.90	96.50	96.65	96.41
Van Gaal Drain	Reach 3	3165	5-Year	2.09	3.25	0.80	96.61	96.70	96.38
Van Gaal Drain	Reach 3	3165	10-Year	2.71	3.78	0.92	96.67	96.72	96.42
Van Gaal Drain	Reach 3	3165	25-Year	3.50	4.36	1.07	96.72	96.74	96.45
Van Gaal Drain	Reach 3	3149	2-Year	1.30	2.58	0.90	96.46	96.60	96.37
Van Gaal Drain	Reach 3	3149	5-Year	2.09	3.25	0.80	96.56	96.64	96.34
Van Gaal Drain	Reach 3	3149	10-Year	2.71	3.78	0.92	96.62	96.66	96.37
Van Gaal Drain	Reach 3	3149	25-Year	3.50	4.36	1.07	96.66	96.68	96.41
Van Gaal Drain	Reach 3	3086	2-Year	1.30	2.58	0.90	96.34	96.50	96.25
Van Gaal Drain	Reach 3	3086	5-Year	2.09	3.25	0.80	96.46	96.55	96.22
Van Gaal Drain	Reach 3	3086	10-Year	2.71	3.78	0.92	96.52	96.58	96.25
Van Gaal Drain	Reach 3	3086	25-Year	3.50	4.36	1.07	96.58	96.60	96.29
Van Gaal Drain	Reach 3	3016	2-Year	1.30	2.58	0.90	96.26	96.45	96.17

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	*2*	*4*	*1*	*2*	*4*
Van Gaal Drain	Reach 3	3016	5-Year	2.09	3.25	0.80	96.40	96.51	96.14
Van Gaal Drain	Reach 3	3016	10-Year	2.71	3.78	0.92	96.47	96.54	96.17
Van Gaal Drain	Reach 3	3016	25-Year	3.50	4.36	1.07	96.54	96.56	96.21
Van Gaal Drain	Reach 3	2980	2-Year	1.30	2.58	0.90	96.21	96.41	96.12
Van Gaal Drain	Reach 3	2980	5-Year	2.09	3.25	0.80	96.35	96.48	96.09
Van Gaal Drain	Reach 3	2980	10-Year	2.71	3.78	0.92	96.43	96.51	96.12
Van Gaal Drain	Reach 3	2980	25-Year	3.50	4.36	1.07	96.51	96.54	96.16
Van Gaal Drain	Reach 3	2851	2-Year	1.30	2.58	0.90	95.87	96.17	95.77
Van Gaal Drain	Reach 3	2851	5-Year	2.09	3.25	0.80	96.06	96.27	95.73
Van Gaal Drain	Reach 3	2851	10-Year	2.71	3.78	0.92	96.17	96.32	95.77
Van Gaal Drain	Reach 3	2851	25-Year	3.50	4.36	1.07	96.28	96.37	95.82
Van Gaal Drain	Reach 3	2808	2-Year	1.30	2.58	0.90	95.82	96.13	95.72
Van Gaal Drain	Reach 3	2808	5-Year	2.09	3.25	0.80	96.02	96.24	95.69
Van Gaal Drain	Reach 3	2808	10-Year	2.71	3.78	0.92	96.13	96.29	95.73
Van Gaal Drain	Reach 3	2808	25-Year	3.50	4.36	1.07	96.24	96.34	95.78
Van Gaal Drain	Reach 3	2658	2-Year	1.30	2.58	0.90	95.71	96.05	95.63
Van Gaal Drain	Reach 3	2658	5-Year	2.09	3.25	0.80	95.92	96.14	95.59
Van Gaal Drain	Reach 3	2658	10-Year	2.71	3.78	0.92	96.03	96.19	95.64
Van Gaal Drain	Reach 3	2658	25-Year	3.50	4.36	1.07	96.14	96.24	95.70
Van Gaal Drain	Reach 2	2554	2-Year	1.94	4.13	1.55	95.71	96.03	95.63
Van Gaal Drain	Reach 2	2554	5-Year	3.20	5.22	1.36	95.91	96.13	95.58
Van Gaal Drain	Reach 2	2554	10-Year	4.03	5.93	1.57	96.02	96.18	95.63
Van Gaal Drain	Reach 2	2554	25-Year	5.10	6.83	1.84	96.12	96.23	95.69
Van Gaal Drain	Reach 2	2478	2-Year	1.94	4.13	1.55	95.62	95.93	95.55
Van Gaal Drain	Reach 2	2478	5-Year	3.20	5.22	1.36	95.82	96.01	95.51
Van Gaal Drain	Reach 2	2478	10-Year	4.03	5.93	1.57	95.92	96.06	95.55
Van Gaal Drain	Reach 2	2478	25-Year	5.10	6.83	1.84	96.01	96.09	95.61
Van Gaal Drain	Reach 2	2427.58*	2-Year	1.94	4.13	1.55	95.56	95.85	95.49
Van Gaal Drain	Reach 2	2427.58*	5-Year	3.20	5.22	1.36	95.76	95.94	95.45
Van Gaal Drain	Reach 2	2427.58*	10-Year	4.03	5.93	1.57	95.85	95.97	95.49
Van Gaal Drain	Reach 2	2427.58*	25-Year	5.10	6.83	1.84	95.94	96.00	95.55
Van Gaal Drain	Reach 2	2377.17*	2-Year	1.94	4.13	1.55	95.49	95.77	95.42
Van Gaal Drain	Reach 2	2377.17*	5-Year	3.20	5.22	1.36	95.68	95.85	95.38
Van Gaal Drain	Reach 2	2377.17*	10-Year	4.03	5.93	1.57	95.77	95.88	95.43
Van Gaal Drain	Reach 2	2377.17*	25-Year	5.10	6.83	1.84	95.85	95.92	95.48
Van Gaal Drain	Reach 2	2326.76*	2-Year	1.94	4.13	1.55	95.41	95.67	95.34
Van Gaal Drain	Reach 2	2326.76*	5-Year	3.20	5.22	1.36	95.58	95.76	95.30
Van Gaal Drain	Reach 2	2326.76*	10-Year	4.03	5.93	1.57	95.66	95.80	95.34
Van Gaal Drain	Reach 2	2326.76*	25-Year	5.10	6.83	1.84	95.75	95.85	95.39
Van Gaal Drain	Reach 2	2276.35*	2-Year	1.94	4.13	1.55	95.05	95.25	95.00
Van Gaal Drain	Reach 2	2276.35*	5-Year	3.20	5.22	1.36	95.18	95.33	94.97
Van Gaal Drain	Reach 2	2276.35*	10-Year	4.03	5.93	1.57	95.25	95.38	95.00
Van Gaal Drain	Reach 2	2276.35*	25-Year	5.10	6.83	1.84	95.32	95.45	95.04
Van Gaal Drain	Reach 2	2252	2-Year	1.94	4.13	1.55	94.97	95.08	94.80

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains [(1)]

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	2	4	1	2	4
Van Gaal Drain	Reach 2	2252	5-Year	3.20	5.22	1.36	95.15	95.17	94.77
Van Gaal Drain	Reach 2	2252	10-Year	4.03	5.93	1.57	95.26	95.23	94.80
Van Gaal Drain	Reach 2	2252	25-Year	5.10	6.83	1.84	95.38	95.27	94.83
Van Gaal Drain	Reach 2	2237	2-Year	1.94	4.13	1.55	94.95	95.06	94.78
Van Gaal Drain	Reach 2	2237	5-Year	3.20	5.22	1.36	95.13	95.15	94.75
Van Gaal Drain	Reach 2	2237	10-Year	4.03	5.93	1.57	95.24	95.21	94.78
Van Gaal Drain	Reach 2	2237	25-Year	5.10	6.83	1.84	95.36	95.24	94.81
Van Gaal Drain	Reach 2	2217	2-Year	1.94	4.13	1.55	94.93	95.03	94.75
Van Gaal Drain	Reach 2	2217	5-Year	3.20	5.22	1.36	95.11	95.12	94.72
Van Gaal Drain	Reach 2	2217	10-Year	4.03	5.93	1.57	95.22	95.18	94.75
Van Gaal Drain	Reach 2	2217	25-Year	5.10	6.83	1.84	95.33	95.21	94.78
Van Gaal Drain	Reach 2	2197	2-Year	1.94	4.13	1.55	94.90	95.00	94.71
Van Gaal Drain	Reach 2	2197	5-Year	3.20	5.22	1.36	95.08	95.09	94.69
Van Gaal Drain	Reach 2	2197	10-Year	4.03	5.93	1.57	95.19	95.15	94.72
Van Gaal Drain	Reach 2	2197	25-Year	5.10	6.83	1.84	95.31	95.17	94.74
Van Gaal Drain	Reach 2	2177	2-Year	1.94	4.13	1.55	94.87	94.97	94.68
Van Gaal Drain	Reach 2	2177	5-Year	3.20	5.22	1.36	95.06	95.06	94.65
Van Gaal Drain	Reach 2	2177	10-Year	4.03	5.93	1.57	95.16	95.12	94.68
Van Gaal Drain	Reach 2	2177	25-Year	5.10	6.83	1.84	95.28	95.13	94.70
Van Gaal Drain	Reach 2	2157	2-Year	1.94	4.13	1.55	94.85	94.94	94.64
Van Gaal Drain	Reach 2	2157	5-Year	3.20	5.22	1.36	95.03	95.03	94.61
Van Gaal Drain	Reach 2	2157	10-Year	4.03	5.93	1.57	95.14	95.09	94.65
Van Gaal Drain	Reach 2	2157	25-Year	5.10	6.83	1.84	95.26	95.09	94.66
Van Gaal Drain	Reach 2	2154	2-Year	1.94	4.13	1.55	94.83	94.91	94.61
Van Gaal Drain	Reach 2	2154	5-Year	3.20	5.22	1.36	95.01	95.00	94.58
Van Gaal Drain	Reach 2	2154	10-Year	4.03	5.93	1.57	95.12	95.06	94.61
Van Gaal Drain	Reach 2	2154	25-Year	5.10	6.83	1.84	95.24	95.05	94.61
Van Gaal Drain	Reach 2	2153	2-Year	2.78	4.99	1.78	94.79	94.86	94.57
Van Gaal Drain	Reach 2	2153	5-Year	4.38	6.30	1.50	94.97	94.96	94.54
Van Gaal Drain	Reach 2	2153	10-Year	5.52	7.15	1.78	95.07	95.01	94.57
Van Gaal Drain	Reach 2	2153	25-Year	6.89	7.11	1.78	95.19	95.01	94.57
Van Gaal Drain	Reach 2	2152	2-Year	2.78	4.99	1.78	94.75	94.82	94.53
Van Gaal Drain	Reach 2	2152	5-Year	4.38	6.30	1.50	94.92	94.92	94.49
Van Gaal Drain	Reach 2	2152	10-Year	5.52	7.15	1.78	95.03	94.97	94.53
Van Gaal Drain	Reach 2	2152	25-Year	6.89	7.11	1.78	95.15	94.97	94.53
Van Gaal Drain	Reach 2	2132	2-Year	2.78	4.99	1.78	94.71	94.78	94.49
Van Gaal Drain	Reach 2	2132	5-Year	4.38	6.30	1.50	94.88	94.87	94.45
Van Gaal Drain	Reach 2	2132	10-Year	5.52	7.15	1.78	94.99	94.93	94.49
Van Gaal Drain	Reach 2	2132	25-Year	6.89	7.11	1.78	95.11	94.93	94.49
Van Gaal Drain	Reach 2	2112	2-Year	2.78	4.99	1.78	94.66	94.74	94.44
Van Gaal Drain	Reach 2	2112	5-Year	4.38	6.30	1.50	94.84	94.83	94.41
Van Gaal Drain	Reach 2	2112	10-Year	5.52	7.15	1.78	94.95	94.89	94.44
Van Gaal Drain	Reach 2	2112	25-Year	6.89	7.11	1.78	95.07	94.89	94.44
Van Gaal Drain	Reach 2	2092	2-Year	2.78	4.99	1.78	94.62	94.70	94.40

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s) 1	Flow (m^3/s) 2	Flow (m^3/s) 4	Maximum Water Level (m) 1	Maximum Water Level (m) 2	Maximum Water Level (m) 4
Van Gaal Drain	Reach 2	2092	5-Year	4.38	6.30	1.50	94.80	94.79	94.37
Van Gaal Drain	Reach 2	2092	10-Year	5.52	7.15	1.78	94.91	94.85	94.40
Van Gaal Drain	Reach 2	2092	25-Year	6.89	7.11	1.78	95.03	94.85	94.40
Van Gaal Drain	Reach 2	2072	2-Year	2.78	4.99	1.78	94.58	94.66	94.36
Van Gaal Drain	Reach 2	2072	5-Year	4.38	6.30	1.50	94.76	94.75	94.33
Van Gaal Drain	Reach 2	2072	10-Year	5.52	7.15	1.78	94.87	94.81	94.36
Van Gaal Drain	Reach 2	2072	25-Year	6.89	7.11	1.78	94.99	94.81	94.36
Van Gaal Drain	Reach 2	2052	2-Year	2.78	4.99	1.78	94.54	94.62	94.32
Van Gaal Drain	Reach 2	2052	5-Year	4.38	6.30	1.50	94.72	94.71	94.28
Van Gaal Drain	Reach 2	2052	10-Year	5.52	7.15	1.78	94.83	94.77	94.32
Van Gaal Drain	Reach 2	2052	25-Year	6.89	7.11	1.78	94.95	94.77	94.32
Van Gaal Drain	Reach 2	2032	2-Year	2.78	4.99	1.78	94.50	94.57	94.28
Van Gaal Drain	Reach 2	2032	5-Year	4.38	6.30	1.50	94.68	94.67	94.24
Van Gaal Drain	Reach 2	2032	10-Year	5.52	7.15	1.78	94.79	94.73	94.28
Van Gaal Drain	Reach 2	2032	25-Year	6.89	7.11	1.78	94.91	94.73	94.28
Van Gaal Drain	Reach 2	2002	2-Year	2.78	4.99	1.78	94.44	94.51	94.21
Van Gaal Drain	Reach 2	2002	5-Year	4.38	6.30	1.50	94.62	94.61	94.18
Van Gaal Drain	Reach 2	2002	10-Year	5.52	7.15	1.78	94.73	94.67	94.21
Van Gaal Drain	Reach 2	2002	25-Year	6.89	7.11	1.78	94.85	94.67	94.21
Van Gaal Drain	Reach 2	1982	2-Year	2.78	4.99	1.78	94.40	94.48	94.17
Van Gaal Drain	Reach 2	1982	5-Year	4.38	6.30	1.50	94.58	94.57	94.14
Van Gaal Drain	Reach 2	1982	10-Year	5.52	7.15	1.78	94.69	94.63	94.17
Van Gaal Drain	Reach 2	1982	25-Year	6.89	7.11	1.78	94.81	94.63	94.17
Van Gaal Drain	Reach 2	1962	2-Year	2.78	4.99	1.78	94.36	94.44	94.13
Van Gaal Drain	Reach 2	1962	5-Year	4.38	6.30	1.50	94.54	94.53	94.09
Van Gaal Drain	Reach 2	1962	10-Year	5.52	7.15	1.78	94.65	94.59	94.13
Van Gaal Drain	Reach 2	1962	25-Year	6.89	7.11	1.78	94.77	94.60	94.13
Van Gaal Drain	Reach 2	1942	2-Year	2.78	4.99	1.78	94.32	94.40	94.09
Van Gaal Drain	Reach 2	1942	5-Year	4.38	6.30	1.50	94.50	94.50	94.05
Van Gaal Drain	Reach 2	1942	10-Year	5.52	7.15	1.78	94.61	94.56	94.09
Van Gaal Drain	Reach 2	1942	25-Year	6.89	7.11	1.78	94.73	94.56	94.09
Van Gaal Drain	Reach 2	1922	2-Year	2.78	4.99	1.78	94.28	94.36	94.05
Van Gaal Drain	Reach 2	1922	5-Year	4.38	6.30	1.50	94.46	94.46	94.01
Van Gaal Drain	Reach 2	1922	10-Year	5.52	7.15	1.78	94.57	94.52	94.05
Van Gaal Drain	Reach 2	1922	25-Year	6.89	7.11	1.78	94.69	94.53	94.05
Van Gaal Drain	Reach 2	1902	2-Year	2.78	4.99	1.78	94.24	94.33	94.00
Van Gaal Drain	Reach 2	1902	5-Year	4.38	6.30	1.50	94.42	94.43	93.97
Van Gaal Drain	Reach 2	1902	10-Year	5.52	7.15	1.78	94.54	94.48	94.00
Van Gaal Drain	Reach 2	1902	25-Year	6.89	7.11	1.78	94.66	94.49	94.01
Van Gaal Drain	Reach 2	1882	2-Year	2.78	4.99	1.78	94.20	94.29	93.96
Van Gaal Drain	Reach 2	1882	5-Year	4.38	6.30	1.50	94.39	94.39	93.93
Van Gaal Drain	Reach 2	1882	10-Year	5.52	7.15	1.78	94.50	94.45	93.96
Van Gaal Drain	Reach 2	1882	25-Year	6.89	7.11	1.78	94.62	94.46	93.98
Van Gaal Drain	Reach 2	1862	2-Year	2.78	4.99	1.78	94.16	94.26	93.92

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains [(1)]

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	*2*	*4*	*1*	*2*	*4*
Van Gaal Drain	Reach 2	1862	5-Year	4.38	6.30	1.50	94.35	94.36	93.89
Van Gaal Drain	Reach 2	1862	10-Year	5.52	7.15	1.78	94.46	94.42	93.92
Van Gaal Drain	Reach 2	1862	25-Year	6.89	7.11	1.78	94.58	94.43	93.94
Van Gaal Drain	Reach 2	1842	2-Year	2.78	4.99	1.78	94.13	94.23	93.88
Van Gaal Drain	Reach 2	1842	5-Year	4.38	6.30	1.50	94.32	94.33	93.85
Van Gaal Drain	Reach 2	1842	10-Year	5.52	7.15	1.78	94.43	94.39	93.88
Van Gaal Drain	Reach 2	1842	25-Year	6.89	7.11	1.78	94.55	94.40	93.91
Van Gaal Drain	Reach 2	1822	2-Year	2.78	4.99	1.78	94.10	94.20	93.84
Van Gaal Drain	Reach 2	1822	5-Year	4.38	6.30	1.50	94.28	94.30	93.80
Van Gaal Drain	Reach 2	1822	10-Year	5.52	7.15	1.78	94.40	94.36	93.85
Van Gaal Drain	Reach 2	1822	25-Year	6.89	7.11	1.78	94.51	94.37	93.88
Van Gaal Drain	Reach 2	1802	2-Year	2.78	4.99	1.78	94.06	94.17	93.81
Van Gaal Drain	Reach 2	1802	5-Year	4.38	6.30	1.50	94.25	94.27	93.77
Van Gaal Drain	Reach 2	1802	10-Year	5.52	7.15	1.78	94.36	94.33	93.81
Van Gaal Drain	Reach 2	1802	25-Year	6.89	7.11	1.78	94.48	94.34	93.86
Van Gaal Drain	Reach 2	1782	2-Year	2.78	4.99	1.78	94.04	94.14	93.77
Van Gaal Drain	Reach 2	1782	5-Year	4.38	6.30	1.50	94.22	94.24	93.73
Van Gaal Drain	Reach 2	1782	10-Year	5.52	7.15	1.78	94.33	94.30	93.77
Van Gaal Drain	Reach 2	1782	25-Year	6.89	7.11	1.78	94.45	94.32	93.83
Van Gaal Drain	Reach 2	1762	2-Year	2.78	4.99	1.78	94.01	94.12	93.74
Van Gaal Drain	Reach 2	1762	5-Year	4.38	6.30	1.50	94.19	94.22	93.69
Van Gaal Drain	Reach 2	1762	10-Year	5.52	7.15	1.78	94.30	94.27	93.74
Van Gaal Drain	Reach 2	1762	25-Year	6.89	7.11	1.78	94.42	94.30	93.82
Van Gaal Drain	Reach 2	1742	2-Year	2.78	4.99	1.78	93.98	94.10	93.70
Van Gaal Drain	Reach 2	1742	5-Year	4.38	6.30	1.50	94.16	94.19	93.66
Van Gaal Drain	Reach 2	1742	10-Year	5.52	7.15	1.78	94.27	94.25	93.71
Van Gaal Drain	Reach 2	1742	25-Year	6.89	7.11	1.78	94.39	94.28	93.80
Van Gaal Drain	Reach 2	1722	2-Year	2.78	4.99	1.78	93.96	94.08	93.68
Van Gaal Drain	Reach 2	1722	5-Year	4.38	6.30	1.50	94.14	94.17	93.63
Van Gaal Drain	Reach 2	1722	10-Year	5.52	7.15	1.78	94.25	94.23	93.69
Van Gaal Drain	Reach 2	1722	25-Year	6.89	7.11	1.78	94.36	94.26	93.79
Van Gaal Drain	Reach 2	1702	2-Year	2.78	4.99	1.78	93.94	94.06	93.65
Van Gaal Drain	Reach 2	1702	5-Year	4.38	6.30	1.50	94.11	94.15	93.60
Van Gaal Drain	Reach 2	1702	10-Year	5.52	7.15	1.78	94.22	94.21	93.66
Van Gaal Drain	Reach 2	1702	25-Year	6.89	7.11	1.78	94.33	94.24	93.78
Van Gaal Drain	Reach 2	1682	2-Year	2.78	4.99	1.78	93.92	94.05	93.63
Van Gaal Drain	Reach 2	1682	5-Year	4.38	6.30	1.50	94.09	94.14	93.58
Van Gaal Drain	Reach 2	1682	10-Year	5.52	7.15	1.78	94.20	94.19	93.64
Van Gaal Drain	Reach 2	1682	25-Year	6.89	7.11	1.78	94.31	94.22	93.77
Van Gaal Drain	Reach 2	1662	2-Year	2.78	4.99	1.78	93.90	94.03	93.61
Van Gaal Drain	Reach 2	1662	5-Year	4.38	6.30	1.50	94.07	94.12	93.56
Van Gaal Drain	Reach 2	1662	10-Year	5.52	7.15	1.78	94.17	94.17	93.63
Van Gaal Drain	Reach 2	1662	25-Year	6.89	7.11	1.78	94.28	94.21	93.76
Van Gaal Drain	Reach 2	1642	2-Year	2.78	4.99	1.78	93.89	94.02	93.60

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains [(1)]

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	2	4	1	2	4
Van Gaal Drain	Reach 2	1642	5-Year	4.38	6.30	1.50	94.05	94.11	93.54
Van Gaal Drain	Reach 2	1642	10-Year	5.52	7.15	1.78	94.15	94.16	93.62
Van Gaal Drain	Reach 2	1642	25-Year	6.89	7.11	1.78	94.26	94.19	93.76
Van Gaal Drain	Reach 2	1622	2-Year	2.78	4.99	1.78	93.87	94.01	93.59
Van Gaal Drain	Reach 2	1622	5-Year	4.38	6.30	1.50	94.04	94.09	93.53
Van Gaal Drain	Reach 2	1622	10-Year	5.52	7.15	1.78	94.13	94.14	93.61
Van Gaal Drain	Reach 2	1622	25-Year	6.89	7.11	1.78	94.24	94.18	93.75
Van Gaal Drain	Reach 2	1615	2-Year	2.78	4.99	1.78	93.87	94.01	93.59
Van Gaal Drain	Reach 2	1615	5-Year	4.38	6.30	1.50	94.03	94.09	93.53
Van Gaal Drain	Reach 2	1615	10-Year	5.52	7.15	1.78	94.13	94.14	93.60
Van Gaal Drain	Reach 2	1615	25-Year	6.89	7.11	1.78	94.23	94.18	93.75
Van Gaal Drain	Reach 2	1555	2-Year	2.78	4.99	1.78	93.84	93.98	93.56
Van Gaal Drain	Reach 2	1555	5-Year	4.38	6.30	1.50	93.99	94.06	93.50
Van Gaal Drain	Reach 2	1555	10-Year	5.52	7.15	1.78	94.08	94.11	93.58
Van Gaal Drain	Reach 2	1555	25-Year	6.89	7.11	1.78	94.18	94.15	93.74
Van Gaal Drain	Reach 2	1488	2-Year	2.78	4.99	1.78	93.82	93.96	93.55
Van Gaal Drain	Reach 2	1488	5-Year	4.38	6.30	1.50	93.96	94.03	93.49
Van Gaal Drain	Reach 2	1488	10-Year	5.52	7.15	1.78	94.04	94.08	93.57
Van Gaal Drain	Reach 2	1488	25-Year	6.89	7.11	1.78	94.12	94.12	93.74
Van Gaal Drain	Reach 2	1416	2-Year	2.78	4.99	1.78	93.80	93.95	93.54
Van Gaal Drain	Reach 2	1416	5-Year	4.38	6.30	1.50	93.93	94.02	93.48
Van Gaal Drain	Reach 2	1416	10-Year	5.52	7.15	1.78	94.01	94.06	93.56
Van Gaal Drain	Reach 2	1416	25-Year	6.89	7.11	1.78	94.09	94.11	93.74
Van Gaal Drain	Reach 2	1400	2-Year	2.78	4.99	1.78	93.80	93.94	93.54
Van Gaal Drain	Reach 2	1400	5-Year	4.38	6.30	1.50	93.92	94.01	93.48
Van Gaal Drain	Reach 2	1400	10-Year	5.52	7.15	1.78	94.00	94.05	93.56
Van Gaal Drain	Reach 2	1400	25-Year	6.89	7.11	1.78	94.07	94.10	93.73
Van Gaal Drain	Reach 2	1364	2-Year	2.78	4.99	1.78	93.79	93.94	93.54
Van Gaal Drain	Reach 2	1364	5-Year	4.38	6.30	1.50	93.91	94.00	93.48
Van Gaal Drain	Reach 2	1364	10-Year	5.52	7.15	1.78	93.98	94.04	93.56
Van Gaal Drain	Reach 2	1364	25-Year	6.89	7.11	1.78	94.06	94.09	93.73
Van Gaal Drain	Reach 2	1340	2-Year	2.83	5.05	1.84	93.78	93.90	93.53
Van Gaal Drain	Reach 2	1340	5-Year	4.44	6.34	1.58	93.88	93.95	93.47
Van Gaal Drain	Reach 2	1340	10-Year	5.57	7.21	1.86	93.94	93.98	93.55
Van Gaal Drain	Reach 2	1340	25-Year	6.93	8.32	2.19	93.99	94.01	93.72
Van Gaal Drain	Reach 2	1339	Culvert						
Van Gaal Drain	Reach 2	1312	2-Year	2.83	5.05	1.84	93.77	93.90	93.52
Van Gaal Drain	Reach 2	1312	5-Year	4.44	6.34	1.58	93.88	93.94	93.47
Van Gaal Drain	Reach 2	1312	10-Year	5.57	7.21	1.86	93.93	93.97	93.55
Van Gaal Drain	Reach 2	1312	25-Year	6.93	8.32	2.19	93.98	94.00	93.72
Van Gaal Drain	Reach 2	1302	2-Year	2.83	5.05	1.84	93.75	93.87	93.48
Van Gaal Drain	Reach 2	1302	5-Year	4.44	6.34	1.58	93.84	93.92	93.42
Van Gaal Drain	Reach 2	1302	10-Year	5.57	7.21	1.86	93.90	93.95	93.51
Van Gaal Drain	Reach 2	1302	25-Year	6.93	8.32	2.19	93.96	93.99	93.70

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	*2*	*4*	*1*	*2*	*4*
Van Gaal Drain	Reach 2	1268	2-Year	2.83	5.05	1.84	93.67	93.82	93.40
Van Gaal Drain	Reach 2	1268	5-Year	4.44	6.34	1.58	93.79	93.88	93.34
Van Gaal Drain	Reach 2	1268	10-Year	5.57	7.21	1.86	93.86	93.91	93.43
Van Gaal Drain	Reach 2	1268	25-Year	6.93	8.32	2.19	93.92	93.95	93.63
Van Gaal Drain	Reach 2	1212	2-Year	2.83	5.05	1.84	93.47	93.72	93.26
Van Gaal Drain	Reach 2	1212	5-Year	4.44	6.34	1.58	93.67	93.79	93.20
Van Gaal Drain	Reach 2	1212	10-Year	5.57	7.21	1.86	93.75	93.83	93.32
Van Gaal Drain	Reach 2	1212	25-Year	6.93	8.32	2.19	93.83	93.87	93.53
Van Gaal Drain	Reach 2	1169	2-Year	2.83	5.05	1.84	93.38	93.64	93.17
Van Gaal Drain	Reach 2	1169	5-Year	4.44	6.34	1.58	93.59	93.71	93.13
Van Gaal Drain	Reach 2	1169	10-Year	5.57	7.21	1.86	93.68	93.75	93.26
Van Gaal Drain	Reach 2	1169	25-Year	6.93	8.32	2.19	93.75	93.79	93.50
Van Gaal Drain	Reach 2	1091	2-Year	2.83	5.05	1.84	93.24	93.51	93.04
Van Gaal Drain	Reach 2	1091	5-Year	4.44	6.34	1.58	93.46	93.58	93.01
Van Gaal Drain	Reach 2	1091	10-Year	5.57	7.21	1.86	93.55	93.63	93.17
Van Gaal Drain	Reach 2	1091	25-Year	6.93	8.32	2.19	93.63	93.67	93.46
Van Gaal Drain	Reach 2	1002	2-Year	2.83	5.05	1.84	93.04	93.29	92.86
Van Gaal Drain	Reach 2	1002	5-Year	4.44	6.34	1.58	93.26	93.38	92.87
Van Gaal Drain	Reach 2	1002	10-Year	5.57	7.21	1.86	93.35	93.43	93.09
Van Gaal Drain	Reach 2	1002	25-Year	6.93	8.32	2.19	93.44	93.53	93.44
Van Gaal Drain	Reach 2	961	2-Year	2.83	5.05	1.84	92.99	93.19	92.80
Van Gaal Drain	Reach 2	961	5-Year	4.44	6.34	1.58	93.17	93.27	92.84
Van Gaal Drain	Reach 2	961	10-Year	5.57	7.21	1.86	93.26	93.33	93.07
Van Gaal Drain	Reach 2	961	25-Year	6.93	8.32	2.19	93.36	93.46	93.43
Van Gaal Drain	Reach 2	910	2-Year	2.83	5.05	1.84	92.92	93.11	92.74
Van Gaal Drain	Reach 2	910	5-Year	4.44	6.34	1.58	93.09	93.19	92.80
Van Gaal Drain	Reach 2	910	10-Year	5.57	7.21	1.86	93.19	93.27	93.05
Van Gaal Drain	Reach 2	910	25-Year	6.93	8.32	2.19	93.29	93.43	93.43
Van Gaal Drain	Reach 2	840	2-Year	2.83	5.05	1.84	92.81	93.01	92.63
Van Gaal Drain	Reach 2	840	5-Year	4.44	6.34	1.58	93.00	93.11	92.75
Van Gaal Drain	Reach 2	840	10-Year	5.57	7.21	1.86	93.14	93.22	93.04
Van Gaal Drain	Reach 2	840	25-Year	6.93	8.32	2.19	93.26	93.41	93.43
Van Gaal Drain	Reach 1	746	2-Year	3.68	6.19	2.36	92.78	92.99	92.62
Van Gaal Drain	Reach 1	746	5-Year	5.67	8.10	2.11	92.96	93.10	92.74
Van Gaal Drain	Reach 1	746	10-Year	7.81	9.87	2.41	93.11	93.21	93.04
Van Gaal Drain	Reach 1	746	25-Year	9.91	11.49	2.79	93.24	93.41	93.43
Van Gaal Drain	Reach 1	705	2-Year	3.68	6.19	2.36	92.67	92.90	92.53
Van Gaal Drain	Reach 1	705	5-Year	5.67	8.10	2.11	92.86	93.05	92.72
Van Gaal Drain	Reach 1	705	10-Year	7.81	9.87	2.41	93.04	93.18	93.03
Van Gaal Drain	Reach 1	705	25-Year	9.91	11.49	2.79	93.18	93.39	93.43
Van Gaal Drain	Reach 1	668	2-Year	3.68	6.19	2.36	92.43	92.52	92.39
Van Gaal Drain	Reach 1	668	5-Year	5.67	8.10	2.11	92.49	92.71	92.69
Van Gaal Drain	Reach 1	668	10-Year	7.81	9.87	2.41	92.60	93.01	93.02
Van Gaal Drain	Reach 1	668	25-Year	9.91	11.49	2.79	92.76	93.32	93.43

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	2	4	1	2	4
Van Gaal Drain	Reach 1	666	2-Year	3.68	6.19	2.36	92.33	92.50	92.38
Van Gaal Drain	Reach 1	666	5-Year	5.67	8.10	2.11	92.47	92.71	92.69
Van Gaal Drain	Reach 1	666	10-Year	7.81	9.87	2.41	92.59	92.90	93.02
Van Gaal Drain	Reach 1	666	25-Year	9.91	11.49	2.79	92.69	93.18	93.42
Van Gaal Drain	Reach 1	656	Culvert						
Van Gaal Drain	Reach 1	647	2-Year	3.68	6.19	2.36	92.46	92.61	92.41
Van Gaal Drain	Reach 1	647	5-Year	5.67	8.10	2.11	92.59	92.79	92.69
Van Gaal Drain	Reach 1	647	10-Year	7.81	9.87	2.41	92.71	92.95	93.02
Van Gaal Drain	Reach 1	647	25-Year	9.91	11.49	2.79	92.83	93.19	93.42
Van Gaal Drain	Reach 1	645	2-Year	3.68	6.19	2.36	92.42	92.58	92.39
Van Gaal Drain	Reach 1	645	5-Year	5.67	8.10	2.11	92.55	92.79	92.69
Van Gaal Drain	Reach 1	645	10-Year	7.81	9.87	2.41	92.68	92.96	93.02
Van Gaal Drain	Reach 1	645	25-Year	9.91	11.49	2.79	92.83	93.20	93.42
Van Gaal Drain	Reach 1	592	2-Year	3.68	6.19	2.36	92.21	92.57	92.38
Van Gaal Drain	Reach 1	592	5-Year	5.67	8.10	2.11	92.45	92.81	92.69
Van Gaal Drain	Reach 1	592	10-Year	7.81	9.87	2.41	92.62	92.98	93.02
Van Gaal Drain	Reach 1	592	25-Year	9.91	11.49	2.79	92.81	93.23	93.42
Van Gaal Drain	Reach 1	521	2-Year	3.68	6.19	2.36	92.22	92.56	92.38
Van Gaal Drain	Reach 1	521	5-Year	5.67	8.10	2.11	92.44	92.80	92.69
Van Gaal Drain	Reach 1	521	10-Year	7.81	9.87	2.41	92.61	92.97	93.02
Van Gaal Drain	Reach 1	521	25-Year	9.91	11.49	2.79	92.79	93.22	93.42
Van Gaal Drain	Reach 1	277	2-Year	3.68	6.19	2.36	92.07	92.44	92.35
Van Gaal Drain	Reach 1	277	5-Year	5.67	8.10	2.11	92.27	92.69	92.68
Van Gaal Drain	Reach 1	277	10-Year	7.81	9.87	2.41	92.38	92.85	93.02
Van Gaal Drain	Reach 1	277	25-Year	9.91	11.49	2.79	92.56	93.14	93.42
Van Gaal Drain	Reach 1	275	2-Year	3.68	6.19	2.36	92.07	92.43	92.35
Van Gaal Drain	Reach 1	275	5-Year	5.67	8.10	2.11	92.27	92.66	92.68
Van Gaal Drain	Reach 1	275	10-Year	7.81	9.87	2.41	92.38	92.81	93.01
Van Gaal Drain	Reach 1	275	25-Year	9.91	11.49	2.79	92.53	93.07	93.42
Van Gaal Drain	Reach 1	269	Culvert						
Van Gaal Drain	Reach 1	263	2-Year	3.68	6.19	2.36	92.05	92.39	92.34
Van Gaal Drain	Reach 1	263	5-Year	5.67	8.10	2.11	92.23	92.61	92.68
Van Gaal Drain	Reach 1	263	10-Year	7.81	9.87	2.41	92.30	92.74	93.01
Van Gaal Drain	Reach 1	263	25-Year	9.91	11.49	2.79	92.42	93.00	93.41
Van Gaal Drain	Reach 1	226	2-Year	3.70	6.22	2.49	92.00	92.37	92.34
Van Gaal Drain	Reach 1	226	5-Year	5.69	8.11	2.26	92.16	92.61	92.68
Van Gaal Drain	Reach 1	226	10-Year	7.82	9.90	2.57	92.18	92.75	93.01
Van Gaal Drain	Reach 1	226	25-Year	9.93	11.53	2.97	92.03	93.03	93.41
Van Gaal Drain	Reach 1	0	2-Year	3.70	6.22	2.49	91.07	92.40	92.35
Van Gaal Drain	Reach 1	0	5-Year	5.69	8.11	2.26	91.09	92.63	92.68
Van Gaal Drain	Reach 1	0	10-Year	7.82	9.90	2.57	91.16	92.78	93.01
Van Gaal Drain	Reach 1	0	25-Year	9.93	11.53	2.97	91.25	93.04	93.41

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	*2*	*4*	*1*	*2*	*4*
Moore Drain Trib	Reach 1	600	2-Year	0.49	0.74	0.13	95.38	95.50	95.16
Moore Drain Trib	Reach 1	600	5-Year	0.76	0.90	0.08	95.51	95.56	95.11
Moore Drain Trib	Reach 1	600	10-Year	1.02	1.14	0.09	95.61	95.65	95.12
Moore Drain Trib	Reach 1	600	25-Year	1.33	1.33	0.10	95.72	95.72	95.13
Moore Drain Trib	Reach 1	553	2-Year	0.49	0.74	0.13	95.35	95.47	95.11
Moore Drain Trib	Reach 1	553	5-Year	0.76	0.90	0.08	95.48	95.53	95.06
Moore Drain Trib	Reach 1	553	10-Year	1.02	1.14	0.09	95.58	95.63	95.07
Moore Drain Trib	Reach 1	553	25-Year	1.33	1.33	0.10	95.70	95.69	95.09
Moore Drain Trib	Reach 1	503	2-Year	0.49	0.74	0.13	95.32	95.44	95.08
Moore Drain Trib	Reach 1	503	5-Year	0.76	0.90	0.08	95.45	95.51	95.02
Moore Drain Trib	Reach 1	503	10-Year	1.02	1.14	0.09	95.56	95.60	95.04
Moore Drain Trib	Reach 1	503	25-Year	1.33	1.33	0.10	95.68	95.67	95.05
Moore Drain Trib	Reach 1	492	2-Year	0.49	0.74	0.13	95.29	95.41	95.06
Moore Drain Trib	Reach 1	492	5-Year	0.76	0.90	0.08	95.41	95.47	95.01
Moore Drain Trib	Reach 1	492	10-Year	1.02	1.14	0.09	95.51	95.56	95.02
Moore Drain Trib	Reach 1	492	25-Year	1.33	1.33	0.10	95.62	95.62	95.04
Moore Drain Trib	Reach 1	477	Culvert						
Moore Drain Trib	Reach 1	462	2-Year	0.49	0.74	0.13	95.21	95.31	95.00
Moore Drain Trib	Reach 1	462	5-Year	0.76	0.90	0.08	95.32	95.37	94.95
Moore Drain Trib	Reach 1	462	10-Year	1.02	1.14	0.09	95.41	95.45	94.96
Moore Drain Trib	Reach 1	462	25-Year	1.33	1.33	0.10	95.51	95.51	94.97
Moore Drain Trib	Reach 1	453	2-Year	0.49	0.74	0.13	95.20	95.32	94.99
Moore Drain Trib	Reach 1	453	5-Year	0.76	0.90	0.08	95.32	95.38	94.94
Moore Drain Trib	Reach 1	453	10-Year	1.02	1.14	0.09	95.42	95.46	94.95
Moore Drain Trib	Reach 1	453	25-Year	1.33	1.33	0.10	95.52	95.52	94.96
Moore Drain Trib	Reach 1	403	2-Year	0.49	0.74	0.13	95.17	95.28	94.95
Moore Drain Trib	Reach 1	403	5-Year	0.76	0.90	0.08	95.29	95.34	94.90
Moore Drain Trib	Reach 1	403	10-Year	1.02	1.14	0.09	95.39	95.43	94.91
Moore Drain Trib	Reach 1	403	25-Year	1.33	1.33	0.10	95.49	95.49	94.92
Moore Drain Trib	Reach 1	353	2-Year	0.49	0.74	0.13	95.09	95.19	94.89
Moore Drain Trib	Reach 1	353	5-Year	0.76	0.90	0.08	95.20	95.25	94.84
Moore Drain Trib	Reach 1	353	10-Year	1.02	1.14	0.09	95.29	95.33	94.85
Moore Drain Trib	Reach 1	353	25-Year	1.33	1.33	0.10	95.39	95.39	94.87
Moore Drain Trib	Reach 1	338.5	Culvert						
Moore Drain Trib	Reach 1	324	2-Year	0.49	0.74	0.13	94.96	95.04	94.81
Moore Drain Trib	Reach 1	324	5-Year	0.76	0.90	0.08	95.04	95.08	94.77
Moore Drain Trib	Reach 1	324	10-Year	1.02	1.14	0.09	95.11	95.14	94.78
Moore Drain Trib	Reach 1	324	25-Year	1.33	1.33	0.10	95.19	95.19	94.79
Moore Drain Trib	Reach 1	311	2-Year	0.49	0.74	0.13	94.94	95.02	94.78
Moore Drain Trib	Reach 1	311	5-Year	0.76	0.90	0.08	95.03	95.07	94.74
Moore Drain Trib	Reach 1	311	10-Year	1.02	1.14	0.09	95.11	95.14	94.75
Moore Drain Trib	Reach 1	311	25-Year	1.33	1.33	0.10	95.19	95.19	94.76
Moore Drain Trib	Reach 1	290	2-Year	0.49	0.74	0.13	94.90	94.98	94.73

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	2	4	1	2	4
Moore Drain Trib	Reach 1	290	5-Year	0.76	0.90	0.08	94.99	95.03	94.70
Moore Drain Trib	Reach 1	290	10-Year	1.02	1.14	0.09	95.07	95.10	94.71
Moore Drain Trib	Reach 1	290	25-Year	1.33	1.33	0.10	95.15	95.15	94.72
Moore Drain Trib	Reach 1	240	2-Year	0.49	0.74	0.13	94.80	94.89	94.63
Moore Drain Trib	Reach 1	240	5-Year	0.76	0.90	0.08	94.90	94.94	94.60
Moore Drain Trib	Reach 1	240	10-Year	1.02	1.14	0.09	94.98	95.02	94.60
Moore Drain Trib	Reach 1	240	25-Year	1.33	1.33	0.10	95.07	95.07	94.61
Moore Drain Trib	Reach 1	190	2-Year	0.49	0.74	0.13	94.71	94.81	94.53
Moore Drain Trib	Reach 1	190	5-Year	0.76	0.90	0.08	94.82	94.87	94.50
Moore Drain Trib	Reach 1	190	10-Year	1.02	1.14	0.09	94.91	94.95	94.51
Moore Drain Trib	Reach 1	190	25-Year	1.33	1.33	0.10	95.01	95.00	94.52
Moore Drain Trib	Reach 1	140	2-Year	0.49	0.74	0.13	94.64	94.75	94.44
Moore Drain Trib	Reach 1	140	5-Year	0.76	0.90	0.08	94.76	94.81	94.39
Moore Drain Trib	Reach 1	140	10-Year	1.02	1.14	0.09	94.85	94.89	94.40
Moore Drain Trib	Reach 1	140	25-Year	1.33	1.33	0.10	94.96	94.95	94.41
Moore Drain Trib	Reach 1	90	2-Year	0.49	0.74	0.13	94.60	94.71	94.38
Moore Drain Trib	Reach 1	90	5-Year	0.76	0.90	0.08	94.71	94.77	94.33
Moore Drain Trib	Reach 1	90	10-Year	1.02	1.14	0.09	94.81	94.86	94.34
Moore Drain Trib	Reach 1	90	25-Year	1.33	1.33	0.10	94.92	94.92	94.36
Moore Drain Trib	Reach 1	83	2-Year	0.49	0.74	0.13	94.57	94.67	94.36
Moore Drain Trib	Reach 1	83	5-Year	0.76	0.90	0.08	94.67	94.72	94.32
Moore Drain Trib	Reach 1	83	10-Year	1.02	1.14	0.09	94.76	94.80	94.33
Moore Drain Trib	Reach 1	83	25-Year	1.33	1.33	0.10	94.86	94.86	94.34
Moore Drain Trib	Reach 1	68	Culvert						
Moore Drain Trib	Reach 1	53	2-Year	0.49	0.74	0.13	94.44	94.51	94.29
Moore Drain Trib	Reach 1	53	5-Year	0.76	0.90	0.08	94.52	94.55	94.25
Moore Drain Trib	Reach 1	53	10-Year	1.02	1.14	0.09	94.58	94.60	94.25
Moore Drain Trib	Reach 1	53	25-Year	1.33	1.33	0.10	94.64	94.64	94.26
Moore Drain Trib	Reach 1	14	2-Year	0.49	0.74	0.13	94.08	94.13	94.00
Moore Drain Trib	Reach 1	14	5-Year	0.76	0.90	0.08	94.13	94.15	93.99
Moore Drain Trib	Reach 1	14	10-Year	1.02	1.14	0.09	94.17	94.18	93.99
Moore Drain Trib	Reach 1	14	25-Year	1.33	1.33	0.10	94.21	94.21	93.99
Moore Drain	Reach 2	555	2-Year	0.03	0.04	0.00	94.32	94.34	94.21
Moore Drain	Reach 2	555	5-Year	0.03	0.03	0.00	94.33	94.33	94.21
Moore Drain	Reach 2	555	10-Year	0.05	0.07	0.00	94.35	94.38	94.21
Moore Drain	Reach 2	555	25-Year	0.06	0.09	0.00	94.37	94.39	94.21
Moore Drain	Reach 2	500	2-Year	0.03	0.04	0.00	94.22	94.23	94.17
Moore Drain	Reach 2	500	5-Year	0.03	0.03	0.00	94.23	94.23	94.17
Moore Drain	Reach 2	500	10-Year	0.05	0.07	0.00	94.25	94.26	94.17
Moore Drain	Reach 2	500	25-Year	0.06	0.09	0.00	94.25	94.27	94.17
Moore Drain	Reach 1	298	2-Year	0.52	0.79	0.15	93.72	93.74	93.54
Moore Drain	Reach 1	298	5-Year	0.81	0.95	0.09	93.72	93.77	93.49
Moore Drain	Reach 1	298	10-Year	1.08	1.22	0.10	93.79	93.79	93.50
Moore Drain	Reach 1	298	25-Year	1.41	1.42	0.11	93.81	93.80	93.51

Table 8B: Proposed Conditions Flows and Water Levels on the Van Gaal and Arbuckle Drains (1)

River	Reach	River Station	Profile	Flow (m^3/s)			Maximum Water Level (m)		
				1	2	4	1	2	4
Moore Drain	Reach 1	130	2-Year	0.52	0.79	0.15	92.80	93.01	92.64
Moore Drain	Reach 1	130	5-Year	0.81	0.95	0.09	93.00	93.12	92.76
Moore Drain	Reach 1	130	10-Year	1.08	1.22	0.10	93.14	93.23	93.04
Moore Drain	Reach 1	130	25-Year	1.41	1.42	0.11	93.26	93.41	93.43
Joys Road Trib	Reach 1	705	2-Year	0.66	1.56	0.54	97.07	97.24	97.05
Joys Road Trib	Reach 1	705	5-Year	1.11	1.97	0.45	97.14	97.38	97.03
Joys Road Trib	Reach 1	705	10-Year	1.41	2.29	0.51	97.18	97.49	97.04
Joys Road Trib	Reach 1	705	25-Year	1.82	2.64	0.60	97.33	97.60	97.06
Joys Road Trib	Reach 1	664	2-Year	0.66	1.56	0.54	96.97	97.26	96.93
Joys Road Trib	Reach 1	664	5-Year	1.11	1.97	0.45	97.12	97.39	96.89
Joys Road Trib	Reach 1	664	10-Year	1.41	2.29	0.51	97.21	97.49	96.92
Joys Road Trib	Reach 1	664	25-Year	1.82	2.64	0.60	97.34	97.61	96.95
Joys Road Trib	Reach 1	635	2-Year	0.66	1.56	0.54	96.94	97.19	96.90
Joys Road Trib	Reach 1	635	5-Year	1.11	1.97	0.45	97.06	97.30	96.87
Joys Road Trib	Reach 1	635	10-Year	1.41	2.29	0.51	97.15	97.40	96.89
Joys Road Trib	Reach 1	635	25-Year	1.82	2.64	0.60	97.26	97.50	96.92
Joys Road Trib	Reach 1	634	Culvert						
Joys Road Trib	Reach 1	622	2-Year	0.66	1.56	0.54	96.91	97.08	96.88
Joys Road Trib	Reach 1	622	5-Year	1.11	1.97	0.45	97.00	97.14	96.86
Joys Road Trib	Reach 1	622	10-Year	1.41	2.29	0.51	97.06	97.18	96.87
Joys Road Trib	Reach 1	622	25-Year	1.82	2.64	0.60	97.12	97.21	96.89
Joys Road Trib	Reach 1	602	2-Year	0.66	1.56	0.54	96.90	97.07	96.87
Joys Road Trib	Reach 1	602	5-Year	1.11	1.97	0.45	96.99	97.13	96.84
Joys Road Trib	Reach 1	602	10-Year	1.41	2.29	0.51	97.05	97.17	96.86
Joys Road Trib	Reach 1	602	25-Year	1.82	2.64	0.60	97.11	97.21	96.88
Joys Road Trib	Reach 1	322	2-Year	0.66	1.56	0.54	96.41	96.54	96.38
Joys Road Trib	Reach 1	322	5-Year	1.11	1.97	0.45	96.49	96.58	96.36
Joys Road Trib	Reach 1	322	10-Year	1.41	2.29	0.51	96.52	96.61	96.37
Joys Road Trib	Reach 1	322	25-Year	1.82	2.64	0.60	96.56	96.65	96.39
Joys Road Trib	Reach 1	275	2-Year	0.66	1.56	0.54	96.18	96.31	96.17
Joys Road Trib	Reach 1	275	5-Year	1.11	1.97	0.45	96.23	96.39	96.16
Joys Road Trib	Reach 1	275	10-Year	1.41	2.29	0.51	96.28	96.44	96.17
Joys Road Trib	Reach 1	275	25-Year	1.82	2.64	0.60	96.36	96.49	96.18
Joys Road Trib	Reach 1	30	2-Year	0.66	1.56	0.54	95.72	96.05	95.63
Joys Road Trib	Reach 1	30	5-Year	1.11	1.97	0.45	95.93	96.15	95.59
Joys Road Trib	Reach 1	30	10-Year	1.41	2.29	0.51	96.04	96.20	95.64
Joys Road Trib	Reach 1	30	25-Year	1.82	2.64	0.60	96.15	96.25	95.70

(1) Scenario Descriptions:

1. The Van Gaal Drain 100-year 24-hour SCS peak flow reaches the Jock River.
2. The Van Gaal Drain 100-year spring snowmelt plus rainfall peak flow reaches the Jock River.
4. The Jock River 100-year spring snowmelt plus rainfall peak flow reaches the outlet of the Van Gaal Drain.

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October 9, 2019

David Schaeffer Engineering Ltd.
120 Iber Road, Unit 203
Ottawa, Ontario K2S 1E9

Attention: **Jennifer Ailey, P.Eng.**

Subject: **Richmond Village (South) Limited Subdivision / Addendum to Preliminary Stormwater Management Plan** *our file: 922-11*

As requested by your office, we have evaluated, based on the provided information as described below, the performance of proposed Stormwater Management (SWM) Facility 2 and minor and major drainage systems to Pond 2 based on preliminary drainage areas, storm sewer data and pond stage-storage-area information provided by DSEL. This memo is an addendum to the January 10, 2014 *Richmond Village (South) Limited Subdivision / Preliminary Stormwater Management Plan* memo, which established SWM Requirements and a preliminary design for Pond 2.

The proposed Richmond Village (South) development is to be treated by two Stormwater Management (SWM) facilities. SWM Facility 1 is a wet pond discharging to Van Gaal Drain, and requires quality, erosion and quantity control. SWM Facility 2 is a wet pond discharging to the Jock River, and requires quality control only. The subdivision drainage area to Pond 2 is 38.66 ha at 71% imperviousness based on the updated information provided by DSEL. Additionally, 71.8 ha of undeveloped lands south of the proposed subdivision will drain through SWM Facility 2, for a total drainage area of 110.46 ha at 29% imperviousness.

The Pond 2 design and performance of the minor and major drainage systems were evaluated using the SWMHYMO and XPSWMM programs. The SWMHYMO program was used to model the drainage areas, and the generated minor system inflow hydrographs were then input to the XPSWMM model of the storm sewer system and pond. Digital SWMHYMO and XPSWMM models are attached.

ASSUMPTIONS AND SOURCES OF DATA USED

The following parameters and assumptions used in the analysis are based on City of Ottawa standards and generally accepted stormwater management design guidelines.

- Stormwater Management Model:	*SWMHYMO (version 5.5)*; XPSWMM (version 10)
- SWMHYMO Model Parameters:	*Fo = 76.2 mm/hr, Fc = 13.2 mm/hr, DCAY = 4.14/hr, D.Stor.Imp. = 1.57 mm, D.Stor.Per. = 4.67 mm (as per 2012 City of Ottawa Guidelines).*
- Undeveloped Area Characteristics:	*As per "Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond" (November 2009, JFSA).*
- Imperviousness:	*SWM Facilities: based on SWM block layout.* *Subdivision: based on runoff coefficient (C) where Percent Imperviousness = (C - 0.2) / 0.7 x 100%.*
- Design Storms:	*Chicago 3-hour and SCS Type II 24-hour design storms based on 2012 City of Ottawa Sewer Design Guidelines; maximum intensity averaged over 10 minutes.* *10-day snowmelt plus rainfall events based on AES Ottawa CDA snowmelt*

plus rainfall IDF curves; maximum intensity averaged over 1 hour.

- Downstream HGL: *Jock River water levels at SWM Facility 2 outlet as per "Jock River Flood Risk Mapping (within the City of Ottawa) Hydraulics Report" (November 2004, PSR Group Ltd. and JFSA).*

QUALITY CONTROL

Quality control will be provided for SWM Facility 2 in accordance with Ministry of the Environment enhanced protection requirements (80% long-term suspended solids removal) for a wet pond. Note that the permanent pool volume required was conservatively calculated based on the minimum 35% imperviousness documented in the Ministry of the Environment SWMPD Manual, rather than extrapolated to the proposed 29% imperviousness. The required permanent pool volume is calculated as follows:

$$(140.00\ m^3/ha - 40\ m^3/ha) \times 110.46\ ha = 11{,}046\ m^3$$

A permanent pool volume of 16,669 m^3 is provided in SWM Facility 2 at an elevation of 93.20 m and a depth of 2.00 m, and is greater than the required volume. An active storage volume requirement of 40 m^3/ha is to be released over 24 to 48 hours in accordance with Ministry of the Environment standards. The required active storage volume is calculated as follows:

$$40\ m^3/ha \times 110.46\ ha = 4{,}418\ m^3$$

A quality control volume of 6,446 m^3 is provided in SWM Facility 2 at an elevation of 93.70 m, and is greater than the required volume. The provided quality control volume has a drawdown time of 29.2 hours, as calculated in Table A-2 of Attachment A.

STORMWATER MANAGEMENT FACILITY 2 PERFORMANCE

We understand that quantity control is not required for SWM Facility 2, which discharges to the Jock River; however, the 100-year release rate from SWM Facility 2 has been limited to a maximum of 2.235 m^3/s based on the capacity of the 1500 mm diameter (at 0.1% slope) outlet pipe to the Jock River. Refer to Table A-3 of Attachment A for the outlet control design and stage-storage-discharge relationship for SWM Facility 2 under free outfall conditions.

Restrictive downstream conditions for the outlet of SWM Facility 2 to the Jock River are based on the *Jock River Flood Risk Mapping (within the City of Ottawa) Hydraulics Report* (November 2004, PSR Group Ltd. and JFSA). During the 100-year 10-day spring snowmelt plus rainfall event, the water level on the Jock River at the outlet of SWM Facility 2 (Jock River Lower Reach 2 cross-section 19353) is 94.18 m. During the 100-year 24-hour SCS design storm, the water level on the Jock River at this location is below the permanent pool elevation of SWM Facility 2 and therefore does not affect the operation of the SWM facility. The stage-storage-discharge relationship for SWM facility under restrictive conditions during the 100-year 10-year spring snowmelt plus rainfall event is presented in Table A-4 of Attachment A.

Pond operating characteristics for SWM Facility 2, as simulated in SWMHYMO / XPSWMM, are summarized in Table 1.

Table 1: Summary of SWM Facility 2 Operating Characteristics (1)

Pond Component	Pre-Development Outflow (m^3/s)	Pond Level (m)	Pond Outflow (m^3/s)	Volume Used (2) (m^3)
Permanent Pool	N/A	93.20	N/A	16669
Quality Control	N/A	93.70	0.101	6446
2-Year, 24-Hour SCS	0.705	93.97	0.530	10633
5-Year, 24-Hour SCS	1.094	94.12	0.906	13336
10-Year, 24-Hour SCS	1.364	94.22	1.173	15138
25-Year, 24-Hour SCS	1.708	94.33	1.499	17255
50-Year, 24-Hour SCS	1.976	94.43	1.795	19152
100-Year, 24-Hour SCS	2.267	94.52	2.094	21037
100-Year, 10-Year Spring (3)	N/A	94.80	1.418	27145

(1) Based on 24 hour detention of 40 m^3/ha quality control volume and quantity control of 100-year release rate to capacity of 1500 mm outlet pipe at 0.1% slope (2.235 m^3/s). No erosion control is provided. Pre-development flows as per January 2014 memo.
(2) Volumes used are active storage only for all pond components except the permanent pool.
(3) Restrictive downstream conditions; Spring = 94.18 m. All other results based on free outfall conditions.

As may be seen above, the pond outflows do not exceed the outlet pipe capacity of 2.235 m^3/s. The maximum 100-year pond levels are 94.52 m during the 100-year summer event, and 94.80 m during the 100-year spring event. Both elevations are well below the top of berm elevation of 95.50 m.

POND 2 MINOR SYSTEM ANALYSIS

The minor system and hydraulic gradeline analysis was completed for the proposed storm sewer trunks discharging to SWM Pond 2 using the XPSWMM program based on the 100-year 3-hour Chicago and 100-year 24-hour SCS design storms, and the 100-year 10-day spring snowmelt plus rainfall event. Sump pump flows were included in the XPSWMM model at a rate of 0.23 L/s/ha. Attachment B summarizes the hydraulic simulation results for the proposed systems. Note that the flowing full pipe velocities are not less than 0.8 m/s and no greater than 3.0 m/s for all proposed pipes.

Attachment B also presents the hydraulic simulation results for the climate change stress test based on a 20% increase in the 100-year 3-hour Chicago and 100-year 24-hour SCS design storms, as per the October 2012 City of Ottawa Sewer Design Guidelines.

For the purposes of this hydraulic gradeline analysis, 100% capture of 100-year flows to the minor system has been modelled throughout the subdivision north of Ottawa Street, on Ottawa Street, and for the natural areas external to the subdivision, with surface storage available above the top of manhole elevations to represent future surface storage above catchbasins (to be modelled in detail at detailed design). This is consistent with the approach described in greater detail in the September 2019 *Stormwater Management Report for Fox Run Subdivision Phase 2B*, and is representative of a system with no inlet control devices installed at catchbasins, and with all basements serviced by sump pumps instead of gravity drain connections. As such, the 100-year hydraulic gradeline exceeds the top of manhole elevations in some areas of the storm sewer, by a maximum of 1.7 cm. At detailed design, where catchbasins and surface storage above catchbasins are integrated into the storm sewer model in detail, the system must meet the City of Ottawa design requirement of a 0 m minimum freeboard between the top of manhole elevation and the 100-year HGL elevation.

The preliminary 100-year surface storage estimated in XPSWMM is approximately 297 m^3 of surface storage above catchbasins, or 19 m^3/ha based on a subdivision area of 15.58 ha (excluding the pond block, external natural areas, and the subdivision areas south of Ottawa Street). This amount of surface storage is possible based on the adjacent

Fox Run subdivision design and similar past projects with relatively flat grading. These results should be confirmed at detailed design based on actual surface storage and catchbasin design.

South of Ottawa Street, basements will be serviced by gravity drain connections to the main storm sewer, and catchbasins are to be equipped with inlet control devices to limit minor system capture to the 2-year flow on local streets (including capture of runoff from adjacent residential lots), with no surface storage used during the 2-year storm, and street surface storage of all excess flows during the 100-year storm. The 100-year + 20% stress test storage has been set to 145% of 100-year storage, based on Abbottsville Crossing pilot project. Similarly, 5-year capture is to be provided on the proposed park block south of Ottawa Street, with no surface storage used during the 5-year storm, and on-site storage of all excess flows during the 100-year storm. A minimum freeboard of 0.3 m is provided between the 100-year hydraulic gradeline and future underside of footing elevations south of Ottawa Street (estimated as 1.8 m below ground level), as shown in Attachment B. Similarly, a minimum freeboard of 0 m is provided between the 100-year + 20% stress test hydraulic gradeline and estimated underside of footing elevations south of Ottawa Street, as shown in Attachment B.

POND 1 MINOR SYSTEM ANALYSIS

The modelling of the proposed subdivision serviced by SWM Pond 1 was last updated for the September 2019 *Stormwater Management Report for Fox Run Subdivision Phase 2B* and the September 2019 *Design Brief for Stormwater Management Pond 1 - Western Development Lands - Richmond*. The present analysis includes updated drainage areas and storm trunk sewer design for the future development areas south of Fox Run Subdivision, located to the south of existing Strachan Street and the west of existing Queen Charlotte Street. The updated drainage area to Pond 1 is 185.37 ha at 32% imperviousness based on the updated information, and therefore less critical for the pond design than the 190.45 ha at 31% imperviousness evaluated in the September 2019 *Design Brief*.

The models submitted with the September 2019 SWM Report were updated to reflect the latest information for the future development areas south of the Fox Run Subdivision, and the updated hydraulic simulation results for the 100-year 3-hour Chicago and 100-year 24-hour SCS design storms are presented in Attachment C. Sump pump flows were included in the XPSWMM model at a rate of 0.23 L/s/a. Note that the flowing full pipe velocities are not less than 0.8 m/s and no greater than 3.0 m/s for all proposed pipes. Attachment C also presents the hydraulic simulation results for the climate change stress test based on a 20% increase in the 100-year 3-hour Chicago and 100-year 24-hour SCS design storms.

As above, 100% capture of 100-year flows to the minor system has been modelled throughout the future development south of Fox Run Subdivision, with surface storage available above the top of manhole elevations to represent future surface storage above catchbasins (to be modelled in detail at detailed design). As such, the 100-year hydraulic gradeline exceeds the top of manhole elevations in some areas of the future storm sewer, by a maximum of 7.2 cm. At detailed design, where catchbasins and surface storage above catchbasins are integrated into the storm sewer model in detail, the system must meet the City of Ottawa design requirement of a 0 m minimum freeboard between the top of manhole elevation and the 100-year HGL elevation.

The preliminary 100-year surface storage estimated in XPSWMM for the future development area south of Fox Run Subdivision is approximately 2270 m^3 of surface storage above catchbasins, or 100 m^3/ha based on a subdivision area of 22.81 ha. This amount of surface storage is possible based on the adjacent Fox Run subdivision design and similar past projects with relatively flat grading. These results should be confirmed at detailed design based on actual surface storage and catchbasin design.

MAJOR SYSTEM ANALYSIS

The proposed major system design is intended to provide sufficient surface storage to contain 100-year flows within road surface ponding areas, released slowly to the minor system without spilling overland to the next downstream road ponding area. As such, 100-year water depths on the road will not exceed the static depths of ponding areas to be designed at detailed design to a depth no greater than 35 cm. Under the 100-year + 20% stress tests, some excess flows may spill out of the static ponding areas to the next downstream ponding area and ultimately to the pond. Although the exact flow spills cannot be identified at this preliminary design stage, a high level check was conducted to test feasibility. Of the modelled subcatchments, the maximum increase in flow between the 100-year and 100-year + 20% events is 454 L/s, which corresponds to a spill depth of 15.5 cm based on an 8.5 m wide local road of typical dimension. Assuming a 35 cm maximum static ponding depth, this corresponds to a 100-year + 20% total water depth of 50.5 cm. Final results will depend on the detailed design of the subdivision and ponding areas, but this test demonstrates that it is possible for excess 100-year + 20% flows to be conveyed safely along a typical road without reaching building envelopes.

Yours truly,
J.F. Sabourin and Associates Inc.

Laura Pipkins, P.Eng.

cc: J.F. Sabourin, M.Eng, P.Eng.
Director of Water Resources Projects

Attachment A: Pond 2 Operating Characteristics
Attachment B: Pond 2 Hydraulic Gradeline Results
Attachment C: Pond 1 Hydraulic Gradeline Results

ATTACHMENT

A

Pond 2 Operating Characteristics

JFSA Water Resources and Environmental Consultants

Table A-1: Extended Detention Parameters for SWM Facility 2

Permanent Pool Parameters			Quality Orifice Parameters		
Area (C3)	11624.20	m^2	Diameter	0.280	m
Volume	16668.61	m^3			
PP Elev	93.20	m	Area	0.062	m^2
QC Elev	93.60	m	Invert	93.20	m
h (m)	0.40	m	C_o	0.620	

Notes: C3 is the intercept from the area-depth linear regression
PP Elev indicates the elevation of the permanent pool
QC Elev indicates the elevation of the storage volume required by MOE for quality control
h is the maximum water elevation above the orifice (m)

Table A-2: Extended Detention Drawdown Time for SWM Facility 2

Elev.	Active Storage			C2	Drawdown Time	Drawdown Time	Flow	Demarkation
(m)	V (m^3)	A (m^2)	depth (m)	(m^2/m)	(h)	(days)	(m^3/s)	Point
93.20	**0.00**	**11624.20**	**0.00**				**0.000**	**PP Elev**
93.25	581.49	11634.18	0.05	200	8.53	0.36	0.011	
93.30	1179.62	11965.06	0.10	3409	12.18	0.51	0.023	
93.35	1781.54	12125.52	0.15	3342	14.98	0.62	0.034	
93.40	2396.76	12339.65	0.20	3577	17.40	0.73	0.045	
93.45	3033.16	12813.51	0.25	4757	19.71	0.82	0.056	
93.50	3682.96	13148.19	0.30	5080	21.79	0.91	0.068	
93.55	4349.20	13482.78	0.35	5310	23.75	0.99	0.077	
93.60	5031.49	13813.67	0.40	5474	25.62	1.07	0.086	
93.65	5730.40	14142.56	0.45	5596	27.41	1.14	0.094	
93.70	**6446.23**	**14471.83**	**0.50**	**5695**	**29.15**	**1.21**	**0.101**	**QC Elev**
93.75	7177.92	14800.05	0.55	5774	30.83	1.28	0.108	
93.80	7917.02	15124.00	0.60	5833	32.48	1.35	0.115	
93.85	8733.73	15481.30	0.65	5934	34.11	1.42	0.121	
93.90	9526.51	15794.32	0.70	5957	35.69	1.49	0.127	
93.95	10281.57	16176.98	0.75	6070	37.30	1.55	0.132	
94.00	11088.02	16433.29	0.80	6011	38.77	1.62	0.137	
94.05	11973.99	17832.83	0.85	7304	41.36	1.72	0.142	
94.10	12878.87	18188.42	0.90	7294	42.92	1.79	0.147	
94.15	13797.61	18514.93	0.95	7253	44.44	1.85	0.152	
94.20	14732.60	18825.87	1.00	7202	45.93	1.91	0.155	
94.25	15679.18	19137.56	1.05	7156	47.41	1.98	0.157	

Notes: C2 is the slope coefficient from the area-depth linear regression
QC Elev indicates the elevation of the quality control volume required by MOE

Table A-3: Stage-Storage-Outflow Curve for SWM Facility 2 (Free Outfall Conditions)

			Quality Control 1		Quantity Control 1			
			Vertical Orifice		Rectangular Weir			
			Dia (m)	0.280	L (m)	1.600		
			Area (m^2)	0.062				
			Invert (m)	93.20	C_w	1.800		
			C_o	0.62	Invert (m)	93.70		
			Q @ D	0.063	n contr.	2		
Elevation	Active Sto.	Demarkation	Head	Outflow	Head	Outflow	Outflow	Storage
(m)	(m^3)	Points	(m)	(m^3/s)	(m)	(m^3/s)	(m^3/s)	(ha·m)
93.20	**0**	**PP Elev**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
93.25	581		0.050	0.011	0.000	0.000	0.011	0.058
93.30	1180		0.100	0.023	0.000	0.000	0.023	0.118
93.35	1782		0.150	0.034	0.000	0.000	0.034	0.178
93.40	2397		0.200	0.045	0.000	0.000	0.045	0.240
93.45	3033		0.250	0.056	0.000	0.000	0.056	0.303
93.50	3683		0.300	0.068	0.000	0.000	0.068	0.368
93.55	4349		0.350	0.077	0.000	0.000	0.077	0.435
93.60	5031		0.400	0.086	0.000	0.000	0.086	0.503
93.65	5730		0.450	0.094	0.000	0.000	0.094	0.573
93.70	**6446**	**QC Elev**	**0.500**	**0.101**	**0.000**	**0.000**	**0.101**	**0.645**
93.75	7178		0.550	0.108	0.050	0.032	0.140	0.718
93.80	7917		0.600	0.115	0.100	0.090	0.205	0.792
93.85	8734		0.650	0.121	0.150	0.164	0.285	0.873
93.90	9527		0.700	0.127	0.200	0.251	0.378	0.953
93.95	10282		0.750	0.132	0.250	0.349	0.481	1.028
94.00	11088		0.800	0.137	0.300	0.455	0.593	1.109
94.05	11974		0.850	0.142	0.350	0.570	0.713	1.197
94.10	12879		0.900	0.147	0.400	0.692	0.840	1.288
94.15	13798		0.950	0.152	0.450	0.820	0.973	1.380
94.18	**14359**	**100-Yr Spr**	**0.980**	**0.155**	**0.480**	**0.900**	**1.055**	**1.436**
94.20	14733		1.000	0.157	0.500	0.955	1.111	1.473
94.25	15679		1.050	0.161	0.550	1.094	1.255	1.568
94.30	16642		1.100	0.166	0.600	1.238	1.404	1.664
94.35	17634		1.150	0.170	0.650	1.387	1.557	1.763
94.40	18633		1.200	0.174	0.700	1.539	1.713	1.863
94.45	19642		1.250	0.178	0.750	1.695	1.873	1.964
94.50	20674		1.300	0.182	0.800	1.855	2.037	2.067
94.55	21723		1.350	0.186	0.850	2.017	2.203	2.172
94.60	22790		1.400	0.190	0.900	2.182	2.372	2.279
94.65	23860		1.450	0.194	0.950	2.350	2.544	2.386
94.70	25440		1.500	0.197	1.000	2.520	2.717	2.544
94.75	26748		1.550	0.201	1.050	2.692	2.893	2.675
94.80	27178		1.600	0.204	1.100	2.866	3.070	2.718
94.85	28324		1.650	0.208	1.150	3.041	3.249	2.832
94.90	29579		1.700	0.211	1.200	3.218	3.429	2.958
94.95	30840		1.750	0.215	1.250	3.396	3.611	3.084
95.00	32114		1.800	0.218	1.300	3.575	3.793	3.211
95.05	33383		1.850	0.221	1.350	3.755	3.976	3.338
95.10	34662		1.900	0.224	1.400	3.936	4.160	3.466
95.15	35935		1.950	0.228	1.450	4.117	4.345	3.593
95.20	37229		2.000	0.231	1.500	4.299	4.529	3.723
95.25	38503		2.050	0.234	1.550	4.481	4.715	3.850
95.30	39807		2.100	0.237	1.600	4.663	4.900	3.981
95.35	41133		2.150	0.240	1.650	4.845	5.085	4.113
95.40	42458		2.200	0.243	1.700	5.027	5.270	4.246
95.45	43635		2.250	0.246	1.750	5.209	5.454	4.363
95.50	**44883**	**Top of Berm**	**2.300**	**0.249**	**1.800**	**5.390**	**5.639**	**4.488**

Notes :
- PP Elev indicates the elevation of the permanent pool.
- QC Elev indicates the elevation of the storage volume provided for quality control according to MOE requirements.
- 100-Yr Spr indicates the elevation of the Jock River floodplain during the 100-year spring (snow+rain) event.
- Top of Berm indicates the elevation at the top of the berm.

Table A-4: Stage-Storage-Outflow Curve for SWM Facility 2 (Restrictive D/S Conditions, Spring)

			Quality Control 1		Quantity Control 1			
			Vertical Orifice		Rectangular Weir			
			Dia (m)	0.280	L (m)	1.600		
			Area (m^2)	0.062				
			Invert (m)	94.18	C_w	1.800		
			C_o	0.62	Invert (m)	94.18		
			Q @ D	0.063	n contr.	2		
Elevation (m)	Active Sto. (m^3)	Demarkation Points	Head (m)	Outflow (m^3/s)	Head (m)	Outflow (m^3/s)	Outflow (m^3/s)	Storage (ha·m)
93.20		**PP Elev**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
93.25			0.000	0.000	0.000	0.000	0.000	0.000
93.30			0.000	0.000	0.000	0.000	0.000	0.000
93.35			0.000	0.000	0.000	0.000	0.000	0.000
93.40			0.000	0.000	0.000	0.000	0.000	0.000
93.45			0.000	0.000	0.000	0.000	0.000	0.000
93.50			0.000	0.000	0.000	0.000	0.000	0.000
93.55			0.000	0.000	0.000	0.000	0.000	0.000
93.60			0.000	0.000	0.000	0.000	0.000	0.000
93.65			0.000	0.000	0.000	0.000	0.000	0.000
93.70		**QC Elev**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
93.75			0.000	0.000	0.000	0.000	0.000	0.000
93.80			0.000	0.000	0.000	0.000	0.000	0.000
93.85			0.000	0.000	0.000	0.000	0.000	0.000
93.90			0.000	0.000	0.000	0.000	0.000	0.000
93.95			0.000	0.000	0.000	0.000	0.000	0.000
94.00			0.000	0.000	0.000	0.000	0.000	0.000
94.05			0.000	0.000	0.000	0.000	0.000	0.000
94.10			0.000	0.000	0.000	0.000	0.000	0.000
94.15			0.000	0.000	0.000	0.000	0.000	0.000
94.18	**0**	**100-Yr Spr**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
94.20	374		0.020	0.024	0.020	0.008	0.032	0.037
94.25	1321		0.070	0.045	0.070	0.053	0.098	0.132
94.30	2283		0.120	0.059	0.120	0.118	0.177	0.228
94.35	3275		0.170	0.070	0.170	0.198	0.267	0.328
94.40	4275		0.220	0.079	0.220	0.289	0.368	0.427
94.45	5283		0.270	0.088	0.270	0.390	0.478	0.528
94.50	6315		0.320	0.096	0.320	0.500	0.596	0.632
94.55	7365		0.370	0.103	0.370	0.618	0.721	0.736
94.60	8432		0.420	0.110	0.420	0.743	0.852	0.843
94.65	9501		0.470	0.116	0.470	0.873	0.989	0.950
94.70	11081		0.520	0.122	0.520	1.010	1.132	1.108
94.75	12389		0.570	0.128	0.570	1.151	1.279	1.239
94.80	12820		0.620	0.133	0.620	1.297	1.430	1.282
94.85	13966		0.670	0.138	0.670	1.447	1.586	1.397
94.90	15220		0.720	0.143	0.720	1.601	1.745	1.522
94.95	16481		0.770	0.148	0.770	1.759	1.907	1.648
95.00	17756		0.820	0.153	0.820	1.919	2.072	1.776
95.05	19024		0.870	0.158	0.870	2.083	2.241	1.902
95.10	20304		0.920	0.162	0.920	2.249	2.411	2.030
95.15	21576		0.970	0.167	0.970	2.418	2.584	2.158
95.20	22871		1.020	0.171	1.020	2.589	2.759	2.287
95.25	24145		1.070	0.175	1.070	2.761	2.936	2.414
95.30	25448		1.120	0.179	1.120	2.936	3.115	2.545
95.35	26774		1.170	0.183	1.170	3.112	3.295	2.677
95.40	28100		1.220	0.187	1.220	3.289	3.476	2.810
95.45	29276		1.270	0.191	1.270	3.468	3.658	2.928
95.50	**30525**	**Top of Berm**	**1.320**	**0.194**	**1.320**	**3.647**	**3.841**	**3.052**

Notes :
- PP Elev indicates the elevation of the permanent pool.
- QC Elev indicates the elevation of the storage volume provided for quality control according to MOE requirements.
- 100-Yr Spr indicates the elevation of the Jock River floodplain during the 100-year spring (snow+rain) event.
- Top of Berm indicates the elevation at the top of the berm.

ATTACHMENT

B

Pond 2 Hydraulic Gradeline Results

JFSA Water Resources and Environmental Consultants

Table B-1A: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [(1)] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [(2)] (m)
204	205	94.098	93.943	600	111.0	0.1	0.013	96.300	96.130	0.813	0.230	0.49	2.1	1.617	1.25	96.315	96.141	-0.015
205	207	93.868	93.790	675	65.0	0.1	0.013	96.130	96.030	0.814	0.291	0.64	2.2	1.598	1.15	96.141	96.039	-0.011
207	209	93.715	93.669	750	41.5	0.1	0.013	96.030	95.960	0.836	0.369	0.78	2.1	1.574	1.13	96.039	95.974	-0.009
209	211	93.594	93.516	825	78.0	0.1	0.013	95.960	95.840	0.849	0.454	0.97	2.1	1.558	1.10	95.977	95.844	-0.017
211	219	93.291	93.221	1050	70.0	0.1	0.013	95.840	95.730	0.997	0.864	1.53	1.8	1.503	1.10	95.844	95.545	-0.004
219	222	93.071	93.005	1200	66.0	0.1	0.013	95.730	95.630	1.090	1.233	2.54	2.1	1.275	1.05	95.546	95.266	0.184
222	224	92.985	92.868	1200	78.0	0.2	0.013	95.630	95.510	1.335	1.510	3.33	2.2	1.081	1.02	95.266	94.350	0.364
224	225	92.808	92.755	1200	37.5	0.1	0.013	95.510	95.510	1.290	1.459	3.33	2.3	0.342	1.02	94.350	94.373	1.160
225	Pond2	92.725	92.700	1200	17.5	0.1	0.013	95.510	95.500	1.290	1.459	3.33	2.3	0.448	1.02	94.373	94.345	N/A
301	302	94.230	94.016	1500	119.0	0.2	0.013	97.230	97.160	1.697	2.999	1.01	0.3	-0.814	2.98	94.916	94.822	2.314
302	303	93.996	93.803	1500	96.5	0.2	0.013	97.160	97.060	1.789	3.161	1.59	0.5	-0.674	3.37	94.822	94.699	2.338
303	304	93.783	93.580	1500	96.5	0.2	0.013	97.060	96.970	1.833	3.239	1.59	0.5	-0.584	3.37	94.699	94.621	2.361
304	307	93.560	93.348	1500	96.5	0.2	0.013	96.970	96.800	1.876	3.316	1.59	0.5	-0.439	3.38	94.621	94.484	2.349
307	308	92.922	92.810	1650	70.0	0.2	0.013	96.800	96.330	1.705	3.646	1.59	0.4	-0.088	3.38	94.484	94.432	2.316
308	311	92.660	92.585	1800	74.5	0.1	0.013	96.330	96.200	1.428	3.635	1.59	0.4	-0.028	3.40	94.432	94.418	1.898
311	312	92.565	92.495	1800	70.0	0.1	0.013	96.200	96.110	1.428	3.635	1.59	0.4	0.053	3.40	94.418	94.381	1.782
312	314	92.435	92.396	1800	38.5	0.1	0.013	96.110	96.060	1.428	3.635	1.59	0.4	0.146	3.40	94.381	94.351	1.729
314	Pond2	92.336	92.300	1800	32.5	0.1	0.013	96.060	95.500	1.498	3.812	1.59	0.4	0.215	3.40	94.351	94.345	1.709
401	402	95.318	95.191	600	90.5	0.1	0.013	98.970	98.860	0.813	0.230	0.13	0.6	-0.081	1.13	95.837	95.786	1.333
402	403	95.116	95.010	675	88.5	0.1	0.013	98.860	98.730	0.814	0.291	0.22	0.7	-0.005	1.38	95.786	95.731	1.274
403	404	94.990	94.872	675	78.5	0.2	0.013	98.730	98.620	0.910	0.326	0.29	0.9	0.066	1.40	95.731	95.602	1.199
404	405	94.797	94.748	750	44.5	0.1	0.013	98.620	98.550	0.836	0.369	0.31	0.8	0.055	1.42	95.602	95.558	1.218
405	406	94.673	94.622	825	51.0	0.1	0.013	98.550	98.480	0.849	0.454	0.36	0.8	0.060	1.42	95.558	95.521	1.192
406	407	94.547	94.419	900	127.5	0.1	0.013	98.480	98.290	0.900	0.572	0.50	0.9	0.074	1.42	95.521	95.432	1.159
407	411	94.344	94.260	975	83.5	0.1	0.013	98.290	98.170	0.949	0.709	0.58	0.8	0.113	1.42	95.432	95.343	1.058
411	414	94.185	94.113	1050	72.0	0.1	0.013	98.170	98.060	0.997	0.864	0.98	1.1	0.108	1.37	95.343	95.256	1.027
414	417	93.963	93.895	1200	68.0	0.1	0.013	98.060	97.960	1.090	1.233	1.21	1.0	0.093	1.35	95.256	95.195	1.004
417	420	93.875	93.803	1200	72.0	0.1	0.013	97.960	97.850	1.090	1.233	1.41	1.1	0.120	1.35	95.195	95.107	0.965
420	431	93.653	93.580	1350	73.0	0.1	0.013	97.850	97.740	1.179	1.688	1.63	1.0	0.104	1.33	95.107	95.044	0.943
431	432	93.560	93.473	1350	79.0	0.1	0.013	97.740	97.620	1.237	1.770	2.22	1.3	0.134	1.33	95.044	94.917	0.896
432	444	93.443	93.347	1350	87.5	0.1	0.013	97.620	97.500	1.237	1.770	2.33	1.3	0.124	1.32	94.917	94.604	0.903
444	445	93.197	93.132	1500	64.5	0.1	0.013	97.500	96.710	1.265	2.235	2.88	1.3	-0.093	1.30	94.604	94.514	1.096
445	446	93.102	93.078	1500	23.5	0.1	0.013	96.710	96.710	1.265	2.235	2.87	1.3	-0.088	1.30	94.514	94.478	0.396
446	447	93.048	93.006	1500	38.0	0.1	0.013	96.710	95.500	1.327	2.344	2.97	1.3	-0.070	1.23	94.478	94.426	0.432
447	448	92.976	92.927	1500	44.5	0.1	0.013	95.500	95.500	1.327	2.344	2.96	1.3	-0.050	1.23	94.426	94.346	N/A
448	449	92.867	92.847	1500	18.0	0.1	0.013	95.500	95.500	1.327	2.344	2.95	1.3	-0.021	1.23	94.346	94.346	N/A
449	Pond2	92.817	92.800	1500	15.5	0.1	0.013	95.500	95.500	1.327	2.344	2.95	1.3	0.028	1.25	94.345	94.345	N/A
Pond2	Out	N/A	N/A	N/A	N/A	N/A	N/A	95.500	95.500	N/A	N/A	1.54	N/A	N/A	3.88	94.345	93.200	N/A

Note: [(1)] A negative surcharge implies that the pipe is not flowing full

Table B-1A: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [1] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [2] (m)

[2] Freeboard between upstream hydraulic gradeline elevation and upstream manhole cover elevation for 200 and 300 series trunk sewers. Freeboard between upstream hydraulic gradeline and estimated underside of footing elevation (1.8 m below upstream manhole cover elevation) for 400 series trunk sewers.

[3] Ponding allowed above manholes in undetailed future development areas to represent road surface storage above catchbasins.

Table B-1B: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [1] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [2] (m)
204	205	94.098	93.943	600	111.0	0.1	0.013	96.300	96.130	0.813	0.230	0.46	2.0	1.614	12.13	96.312	96.133	-0.012
205	207	93.868	93.790	675	65.0	0.1	0.013	96.130	96.030	0.814	0.291	0.50	1.7	1.590	12.13	96.133	96.030	-0.003
207	209	93.715	93.669	750	41.5	0.1	0.013	96.030	95.960	0.836	0.369	0.56	1.5	1.565	12.07	96.030	95.958	0.000
209	211	93.594	93.516	825	78.0	0.1	0.013	95.960	95.840	0.849	0.454	0.69	1.5	1.539	12.07	95.958	95.793	0.002
211	219	93.291	93.221	1050	70.0	0.1	0.013	95.840	95.730	0.997	0.864	1.33	1.5	1.452	11.97	95.793	95.486	0.047
219	222	93.071	93.005	1200	66.0	0.1	0.013	95.730	95.630	1.090	1.233	2.25	1.8	1.215	12.02	95.486	95.264	0.244
222	224	92.985	92.868	1200	78.0	0.2	0.013	95.630	95.510	1.335	1.510	2.88	1.9	1.080	12.02	95.265	94.519	0.365
224	225	92.808	92.755	1200	37.5	0.1	0.013	95.510	95.510	1.290	1.459	2.88	2.0	0.511	12.02	94.519	94.518	0.991
225	Pond2	92.725	92.700	1200	17.5	0.1	0.013	95.510	95.500	1.290	1.459	2.88	2.0	0.593	12.02	94.518	94.517	N/A
301	302	94.230	94.016	1500	119.0	0.2	0.013	97.230	97.160	1.697	2.999	1.25	0.4	-0.625	13.62	95.105	95.045	2.125
302	303	93.996	93.803	1500	96.5	0.2	0.013	97.160	97.060	1.789	3.161	2.01	0.6	-0.451	14.07	95.045	94.952	2.115
303	304	93.783	93.580	1500	96.5	0.2	0.013	97.060	96.970	1.833	3.239	2.01	0.6	-0.331	14.07	94.952	94.881	2.108
304	307	93.560	93.348	1500	96.5	0.2	0.013	96.970	96.800	1.876	3.316	2.01	0.6	-0.179	14.07	94.881	94.729	2.089
307	308	92.922	92.810	1650	70.0	0.2	0.013	96.800	96.330	1.705	3.646	2.02	0.6	0.157	14.03	94.729	94.649	2.071
308	311	92.660	92.585	1800	74.5	0.1	0.013	96.330	96.200	1.428	3.635	2.02	0.6	0.189	14.03	94.649	94.629	1.681
311	312	92.565	92.495	1800	70.0	0.1	0.013	96.200	96.110	1.428	3.635	2.03	0.6	0.264	14.05	94.629	94.573	1.571
312	314	92.435	92.396	1800	38.5	0.1	0.013	96.110	96.060	1.428	3.635	2.03	0.6	0.338	14.05	94.573	94.527	1.537
314	Pond2	92.336	92.300	1800	32.5	0.1	0.013	96.060	95.500	1.498	3.812	2.03	0.5	0.391	14.05	94.527	94.517	1.533
401	402	95.318	95.191	600	90.5	0.1	0.013	98.970	98.860	0.813	0.230	0.13	0.5	-0.062	12.07	95.856	95.812	1.314
402	403	95.116	95.010	675	88.5	0.1	0.013	98.860	98.730	0.814	0.291	0.21	0.7	0.021	12.05	95.812	95.763	1.248
403	404	94.990	94.872	675	78.5	0.2	0.013	98.730	98.620	0.910	0.326	0.28	0.8	0.098	12.43	95.763	95.651	1.167
404	405	94.797	94.748	750	44.5	0.1	0.013	98.620	98.550	0.836	0.369	0.29	0.8	0.104	12.37	95.651	95.613	1.169
405	406	94.673	94.622	825	51.0	0.1	0.013	98.550	98.480	0.849	0.454	0.34	0.7	0.115	12.38	95.613	95.581	1.137
406	407	94.547	94.419	900	127.5	0.1	0.013	98.480	98.290	0.900	0.572	0.47	0.8	0.134	12.45	95.581	95.502	1.099
407	411	94.344	94.260	975	83.5	0.1	0.013	98.290	98.170	0.949	0.709	0.55	0.8	0.183	12.33	95.502	95.422	0.988
411	414	94.185	94.113	1050	72.0	0.1	0.013	98.170	98.060	0.997	0.864	0.92	1.1	0.187	12.32	95.422	95.346	0.948
414	417	93.963	93.895	1200	68.0	0.1	0.013	98.060	97.960	1.090	1.233	1.14	0.9	0.183	12.28	95.346	95.293	0.914
417	420	93.875	93.803	1200	72.0	0.1	0.013	97.960	97.850	1.090	1.233	1.33	1.1	0.218	12.28	95.293	95.216	0.867
420	431	93.653	93.580	1350	73.0	0.1	0.013	97.850	97.740	1.179	1.688	1.54	0.9	0.213	12.28	95.216	95.162	0.834
431	432	93.560	93.473	1350	79.0	0.1	0.013	97.740	97.620	1.237	1.770	2.10	1.2	0.251	12.27	95.161	95.052	0.779
432	444	93.443	93.347	1350	87.5	0.1	0.013	97.620	97.500	1.237	1.770	2.21	1.2	0.259	12.27	95.052	94.779	0.768
444	445	93.197	93.132	1500	64.5	0.1	0.013	97.500	96.710	1.265	2.235	2.73	1.2	0.082	12.25	94.779	94.683	0.921
445	446	93.102	93.078	1500	23.5	0.1	0.013	96.710	96.710	1.265	2.235	2.72	1.2	0.081	12.25	94.683	94.646	0.227
446	447	93.048	93.006	1500	38.0	0.1	0.013	96.710	95.500	1.327	2.344	2.85	1.2	0.098	12.03	94.646	94.590	0.264
447	448	92.976	92.927	1500	44.5	0.1	0.013	95.500	95.500	1.327	2.344	2.83	1.2	0.114	12.03	94.590	94.517	N/A
448	449	92.867	92.847	1500	18.0	0.1	0.013	95.500	95.500	1.327	2.344	2.83	1.2	0.150	12.03	94.517	94.517	N/A
449	Pond2	92.817	92.800	1500	15.5	0.1	0.013	95.500	95.500	1.327	2.344	2.82	1.2	0.200	12.03	94.517	94.517	N/A
Pond2	Out	N/A	N/A	N/A	N/A	N/A	N/A	95.500	95.500	N/A	N/A	0.00	N/A	N/A	0.00	94.517	93.200	N/A

Note: [1] A negative surcharge implies that the pipe is not flowing full

Table B-1B: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [(1)] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [(2)] (m)

[(2)] Freeboard between upstream hydraulic gradeline elevation and upstream manhole cover elevation for 200 and 300 series trunk sewers. Freeboard between upstream hydraulic gradeline and estimated underside of footing elevation (1.8 m below upstream manhole cover elevation) for 400 series trunk sewers.

[(3)] Ponding allowed above manholes in undetailed future development areas to represent road surface storage above catchbasins.

Table B-1C: Pipe Data and Hydraulic Simulation Results for the 100-Year, 10-Day Spring Snowmelt + Rainfall Event

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
204	205	94.098	93.943	600	111.0	0.1	0.013	96.300	96.130	0.813	0.230	0.00	0.0	-0.512	0.98	94.186	94.186	2.114
205	207	93.868	93.790	675	65.0	0.1	0.013	96.130	96.030	0.814	0.291	0.00	0.0	-0.357	2.10	94.186	94.186	1.944
207	209	93.715	93.669	750	41.5	0.1	0.013	96.030	95.960	0.836	0.369	0.00	0.0	-0.279	1.62	94.186	94.186	1.844
209	211	93.594	93.516	825	78.0	0.1	0.013	95.960	95.840	0.849	0.454	0.00	0.0	-0.233	0.87	94.186	94.186	1.774
211	219	93.291	93.221	1050	70.0	0.1	0.013	95.840	95.730	0.997	0.864	0.00	0.0	-0.155	0.87	94.186	94.186	1.654
219	222	93.071	93.005	1200	66.0	0.1	0.013	95.730	95.630	1.090	1.233	0.00	0.0	-0.085	1.10	94.186	94.186	1.544
222	224	92.985	92.868	1200	78.0	0.2	0.013	95.630	95.510	1.335	1.510	0.01	0.0	0.001	1.10	94.186	94.186	1.444
224	225	92.808	92.755	1200	37.5	0.1	0.013	95.510	95.510	1.290	1.459	0.01	0.0	0.178	1.10	94.186	94.186	1.324
225	Pond2	92.725	92.700	1200	17.5	0.1	0.013	95.510	95.500	1.290	1.459	0.01	0.0	0.261	0.05	94.186	94.186	N/A
301	302	94.230	94.016	1500	119.0	0.2	0.013	97.230	97.160	1.697	2.999	0.00	0.0	-1.498	28.30	94.232	94.186	2.998
302	303	93.996	93.803	1500	96.5	0.2	0.013	97.160	97.060	1.789	3.161	0.00	0.0	-1.310	235.93	94.186	94.186	2.974
303	304	93.783	93.580	1500	96.5	0.2	0.013	97.060	96.970	1.833	3.239	0.00	0.0	-1.097	119.57	94.186	94.186	2.874
304	307	93.560	93.348	1500	96.5	0.2	0.013	96.970	96.800	1.876	3.316	0.00	0.0	-0.874	235.38	94.186	94.186	2.784
307	308	92.922	92.810	1650	70.0	0.2	0.013	96.800	96.330	1.705	3.646	0.00	0.0	-0.386	202.82	94.186	94.186	2.614
308	311	92.660	92.585	1800	74.5	0.1	0.013	96.330	96.200	1.428	3.635	0.00	0.0	-0.274	171.88	94.186	94.186	2.144
311	312	92.565	92.495	1800	70.0	0.1	0.013	96.200	96.110	1.428	3.635	0.00	0.0	-0.179	26.72	94.186	94.186	2.014
312	314	92.435	92.396	1800	38.5	0.1	0.013	96.110	96.060	1.428	3.635	0.00	0.0	-0.049	35.67	94.186	94.186	1.924
314	Pond2	92.336	92.300	1800	32.5	0.1	0.013	96.060	95.500	1.498	3.812	0.00	0.0	0.050	260.20	94.186	94.186	1.874
401	402	95.318	95.191	600	90.5	0.1	0.013	98.970	98.860	0.813	0.230	0.00	0.0	-0.587	41.17	95.331	95.194	1.839
402	403	95.116	95.010	675	88.5	0.1	0.013	98.860	98.730	0.814	0.291	0.00	0.0	-0.658	41.15	95.133	95.014	1.927
403	404	94.990	94.872	675	78.5	0.2	0.013	98.730	98.620	0.910	0.326	0.00	0.0	-0.655	41.18	95.010	94.878	1.920
404	405	94.797	94.748	750	44.5	0.1	0.013	98.620	98.550	0.836	0.369	0.00	0.0	-0.730	45.90	94.817	94.753	2.003
405	406	94.673	94.622	825	51.0	0.1	0.013	98.550	98.480	0.849	0.454	0.00	0.0	-0.804	41.18	94.694	94.627	2.056
406	407	94.547	94.419	900	127.5	0.1	0.013	98.480	98.290	0.900	0.572	0.00	0.0	-0.874	47.05	94.573	94.425	2.107
407	411	94.344	94.260	975	83.5	0.1	0.013	98.290	98.170	0.949	0.709	0.00	0.0	-0.949	73.97	94.370	94.267	2.120
411	414	94.185	94.113	1050	72.0	0.1	0.013	98.170	98.060	0.997	0.864	0.00	0.0	-1.018	4.43	94.217	94.186	2.153
414	417	93.963	93.895	1200	68.0	0.1	0.013	98.060	97.960	1.090	1.233	0.00	0.0	-0.977	1.98	94.186	94.186	2.074
417	420	93.875	93.803	1200	72.0	0.1	0.013	97.960	97.850	1.090	1.233	0.00	0.0	-0.889	2.82	94.186	94.186	1.974
420	431	93.653	93.580	1350	73.0	0.1	0.013	97.850	97.740	1.179	1.688	0.00	0.0	-0.817	1.48	94.186	94.186	1.864
431	432	93.560	93.473	1350	79.0	0.1	0.013	97.740	97.620	1.237	1.770	0.01	0.0	-0.724	0.95	94.186	94.186	1.754
432	444	93.443	93.347	1350	87.5	0.1	0.013	97.620	97.500	1.237	1.770	0.01	0.0	-0.607	0.95	94.186	94.186	1.634
444	445	93.197	93.132	1500	64.5	0.1	0.013	97.500	96.710	1.265	2.235	0.01	0.0	-0.511	0.68	94.186	94.186	1.514
445	446	93.102	93.078	1500	23.5	0.1	0.013	96.710	96.710	1.265	2.235	0.01	0.0	-0.416	0.68	94.186	94.186	0.724
446	447	93.048	93.006	1500	38.0	0.1	0.013	96.710	95.500	1.327	2.344	0.01	0.0	-0.362	0.68	94.186	94.186	0.724
447	448	92.976	92.927	1500	44.5	0.1	0.013	95.500	95.500	1.327	2.344	0.01	0.0	-0.290	0.68	94.186	94.186	N/A
448	449	92.867	92.847	1500	18.0	0.1	0.013	95.500	95.500	1.327	2.344	0.01	0.0	-0.181	0.68	94.186	94.186	N/A
449	Pond2	92.817	92.800	1500	15.5	0.1	0.013	95.500	95.500	1.327	2.344	0.01	0.0	-0.131	0.68	94.186	94.186	N/A
Pond2	Out	N/A	N/A	N/A	N/A	N/A	N/A	95.500	95.500	N/A	N/A	0.01	N/A	N/A	211.77	94.186	93.200	N/A

Note: (1) A negative surcharge implies that the pipe is not flowing full

Table B-1C: Pipe Data and Hydraulic Simulation Results for the 100-Year, 10-Day Spring Snowmelt + Rainfall Event

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [(1)] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [(2)] (m)

[(2)] Freeboard between upstream hydraulic gradeline elevation and upstream manhole cover elevation for 200 and 300 series trunk sewers. Freeboard between upstream hydraulic gradeline and estimated underside of footing elevation (1.8 m below upstream manhole cover elevation) for 400 series trunk sewers.

[(3)] Ponding allowed above manholes in undetailed future development areas to represent road surface storage above catchbasins.

Table B-1D: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
204	205	94.098	93.943	600	111.0	0.1	0.013	96.300	96.130	0.813	0.230	0.50	2.2	1.641	1.45	96.339	96.151	-0.039
205	207	93.868	93.790	675	65.0	0.1	0.013	96.130	96.030	0.814	0.291	0.67	2.3	1.608	1.33	96.151	96.042	-0.021
207	209	93.715	93.669	750	41.5	0.1	0.013	96.030	95.960	0.836	0.369	0.83	2.2	1.577	1.25	96.042	95.977	-0.012
209	211	93.594	93.516	825	78.0	0.1	0.013	95.960	95.840	0.849	0.454	0.96	2.1	1.558	1.20	95.977	95.875	-0.017
211	219	93.291	93.221	1050	70.0	0.1	0.013	95.840	95.730	0.997	0.864	1.71	2.0	1.534	1.17	95.875	95.695	-0.035
219	222	93.071	93.005	1200	66.0	0.1	0.013	95.730	95.630	1.090	1.233	2.54	2.1	1.425	1.05	95.696	95.420	0.034
222	224	92.985	92.868	1200	78.0	0.2	0.013	95.630	95.510	1.335	1.510	3.50	2.3	1.235	1.02	95.420	94.520	0.210
224	225	92.808	92.755	1200	37.5	0.1	0.013	95.510	95.510	1.290	1.459	3.50	2.4	0.512	1.02	94.520	94.520	0.990
225	Pond2	92.725	92.700	1200	17.5	0.1	0.013	95.510	95.500	1.290	1.459	3.50	2.4	0.593	1.02	94.518	94.515	N/A
301	302	94.230	94.016	1500	119.0	0.2	0.013	97.230	97.160	1.697	2.999	1.33	0.4	-0.586	2.95	95.144	95.083	2.086
302	303	93.996	93.803	1500	96.5	0.2	0.013	97.160	97.060	1.789	3.161	2.09	0.7	-0.413	3.30	95.083	94.989	2.077
303	304	93.783	93.580	1500	96.5	0.2	0.013	97.060	96.970	1.833	3.239	2.09	0.6	-0.294	3.35	94.989	94.915	2.071
304	307	93.560	93.348	1500	96.5	0.2	0.013	96.970	96.800	1.876	3.316	2.09	0.6	-0.145	3.33	94.915	94.752	2.055
307	308	92.922	92.810	1650	70.0	0.2	0.013	96.800	96.330	1.705	3.646	2.09	0.6	0.180	3.33	94.752	94.666	2.048
308	311	92.660	92.585	1800	74.5	0.1	0.013	96.330	96.200	1.428	3.635	2.09	0.6	0.206	3.33	94.666	94.643	1.664
311	312	92.565	92.495	1800	70.0	0.1	0.013	96.200	96.110	1.428	3.635	2.09	0.6	0.278	3.33	94.643	94.580	1.557
312	314	92.435	92.396	1800	38.5	0.1	0.013	96.110	96.060	1.428	3.635	2.09	0.6	0.345	3.33	94.580	94.526	1.530
314	Pond2	92.336	92.300	1800	32.5	0.1	0.013	96.060	95.500	1.498	3.812	2.09	0.5	0.390	3.33	94.526	94.515	1.534
401	402	95.318	95.191	600	90.5	0.1	0.013	98.970	98.860	0.813	0.230	0.14	0.6	0.591	1.27	96.509	96.431	0.661
402	403	95.116	95.010	675	88.5	0.1	0.013	98.860	98.730	0.814	0.291	0.24	0.8	0.640	1.27	96.431	96.354	0.629
403	404	94.990	94.872	675	78.5	0.2	0.013	98.730	98.620	0.910	0.326	0.33	1.0	0.689	1.27	96.354	96.176	0.576
404	405	94.797	94.748	750	44.5	0.1	0.013	98.620	98.550	0.836	0.369	0.35	1.0	0.629	1.27	96.176	96.112	0.644
405	406	94.673	94.622	825	51.0	0.1	0.013	98.550	98.480	0.849	0.454	0.41	0.9	0.614	1.27	96.112	96.061	0.638
406	407	94.547	94.419	900	127.5	0.1	0.013	98.480	98.290	0.900	0.572	0.56	1.0	0.614	1.27	96.061	95.942	0.619
407	411	94.344	94.260	975	83.5	0.1	0.013	98.290	98.170	0.949	0.709	0.66	0.9	0.623	1.27	95.942	95.818	0.548
411	414	94.185	94.113	1050	72.0	0.1	0.013	98.170	98.060	0.997	0.864	1.09	1.3	0.583	1.27	95.818	95.698	0.552
414	417	93.963	93.895	1200	68.0	0.1	0.013	98.060	97.960	1.090	1.233	1.34	1.1	0.535	1.23	95.698	95.611	0.562
417	420	93.875	93.803	1200	72.0	0.1	0.013	97.960	97.850	1.090	1.233	1.57	1.3	0.536	1.23	95.611	95.489	0.549
420	431	93.653	93.580	1350	73.0	0.1	0.013	97.850	97.740	1.179	1.688	1.81	1.1	0.486	1.23	95.489	95.402	0.561
431	432	93.560	93.473	1350	79.0	0.1	0.013	97.740	97.620	1.237	1.770	2.45	1.4	0.492	1.27	95.402	95.230	0.538
432	444	93.443	93.347	1350	87.5	0.1	0.013	97.620	97.500	1.237	1.770	2.59	1.5	0.437	1.27	95.230	94.824	0.590
444	445	93.197	93.132	1500	64.5	0.1	0.013	97.500	96.710	1.265	2.235	3.22	1.4	0.127	1.25	94.824	94.712	0.876
445	446	93.102	93.078	1500	23.5	0.1	0.013	96.710	96.710	1.265	2.235	3.26	1.5	0.110	1.25	94.712	94.675	0.198
446	447	93.048	93.006	1500	38.0	0.1	0.013	96.710	95.500	1.327	2.344	3.73	1.6	0.127	1.23	94.675	94.620	0.235
447	448	92.976	92.927	1500	44.5	0.1	0.013	95.500	95.500	1.327	2.344	3.72	1.6	0.144	1.23	94.620	94.515	N/A
448	449	92.867	92.847	1500	18.0	0.1	0.013	95.500	95.500	1.327	2.344	3.70	1.6	0.148	1.23	94.515	94.515	N/A
449	Pond2	92.817	92.800	1500	15.5	0.1	0.013	95.500	95.500	1.327	2.344	3.68	1.6	0.198	1.23	94.515	94.515	N/A
Pond2	Out	N/A	N/A	N/A	N/A	N/A	N/A	95.500	95.500	N/A	N/A	2.09	N/A	N/A	3.42	94.515	93.200	N/A

Note: (1) A negative surcharge implies that the pipe is not flowing full

Table B-1D: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [1] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [2] (m)

[2] Freeboard between upstream hydraulic gradeline elevation and upstream manhole cover elevation for 200 and 300 series trunk sewers. Freeboard between upstream hydraulic gradeline and estimated underside of footing elevation (1.8 m below upstream manhole cover elevation) for 400 series trunk sewers.

[3] Ponding allowed above manholes in undetailed future development areas to represent road surface storage above catchbasins.

Table B-1E: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [(1)] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [(2)] (m)
204	205	94.098	93.943	600	111.0	0.1	0.013	96.300	96.130	0.813	0.230	0.47	2.0	1.620	12.27	96.318	96.143	-0.018
205	207	93.868	93.790	675	65.0	0.1	0.013	96.130	96.030	0.814	0.291	0.67	2.3	1.600	12.18	96.143	96.040	-0.013
207	209	93.715	93.669	750	41.5	0.1	0.013	96.030	95.960	0.836	0.369	0.83	2.2	1.575	12.15	96.040	95.971	-0.010
209	211	93.594	93.516	825	78.0	0.1	0.013	95.960	95.840	0.849	0.454	0.92	2.0	1.552	12.13	95.971	95.862	-0.011
211	219	93.291	93.221	1050	70.0	0.1	0.013	95.840	95.730	0.997	0.864	1.60	1.9	1.521	12.12	95.862	95.690	-0.022
219	222	93.071	93.005	1200	66.0	0.1	0.013	95.730	95.630	1.090	1.233	2.28	1.9	1.419	11.92	95.690	95.484	0.040
222	224	92.985	92.868	1200	78.0	0.2	0.013	95.630	95.510	1.335	1.510	2.98	2.0	1.299	11.95	95.484	94.707	0.146
224	225	92.808	92.755	1200	37.5	0.1	0.013	95.510	95.510	1.290	1.459	2.98	2.0	0.699	11.95	94.707	94.707	0.803
225	Pond2	92.725	92.700	1200	17.5	0.1	0.013	95.510	95.500	1.290	1.459	2.97	2.0	0.781	11.95	94.706	94.705	N/A
301	302	94.230	94.016	1500	119.0	0.2	0.013	97.230	97.160	1.697	2.999	1.61	0.5	-0.099	13.63	95.631	95.581	1.599
302	303	93.996	93.803	1500	96.5	0.2	0.013	97.160	97.060	1.789	3.161	2.59	0.8	0.085	14.03	95.581	95.460	1.579
303	304	93.783	93.580	1500	96.5	0.2	0.013	97.060	96.970	1.833	3.239	2.60	0.8	0.177	14.03	95.460	95.339	1.600
304	307	93.560	93.348	1500	96.5	0.2	0.013	96.970	96.800	1.876	3.316	2.60	0.8	0.279	14.05	95.339	95.099	1.631
307	308	92.922	92.810	1650	70.0	0.2	0.013	96.800	96.330	1.705	3.646	2.61	0.7	0.527	14.05	95.099	94.953	1.701
308	311	92.660	92.585	1800	74.5	0.1	0.013	96.330	96.200	1.428	3.635	2.62	0.7	0.493	14.03	94.953	94.915	1.377
311	312	92.565	92.495	1800	70.0	0.1	0.013	96.200	96.110	1.428	3.635	2.62	0.7	0.550	14.03	94.915	94.810	1.285
312	314	92.435	92.396	1800	38.5	0.1	0.013	96.110	96.060	1.428	3.635	2.62	0.7	0.574	14.05	94.809	94.723	1.301
314	Pond2	92.336	92.300	1800	32.5	0.1	0.013	96.060	95.500	1.498	3.812	2.62	0.7	0.588	14.03	94.724	94.705	1.336
401	402	95.318	95.191	600	90.5	0.1	0.013	98.970	98.860	0.813	0.230	0.14	0.6	0.567	12.12	96.485	96.401	0.685
402	403	95.116	95.010	675	88.5	0.1	0.013	98.860	98.730	0.814	0.291	0.23	0.8	0.610	12.12	96.401	96.333	0.659
403	404	94.990	94.872	675	78.5	0.2	0.013	98.730	98.620	0.910	0.326	0.32	1.0	0.668	12.12	96.333	96.184	0.597
404	405	94.797	94.748	750	44.5	0.1	0.013	98.620	98.550	0.836	0.369	0.34	0.9	0.637	12.12	96.184	96.133	0.636
405	406	94.673	94.622	825	51.0	0.1	0.013	98.550	98.480	0.849	0.454	0.40	0.9	0.635	12.12	96.133	96.084	0.617
406	407	94.547	94.419	900	127.5	0.1	0.013	98.480	98.290	0.900	0.572	0.54	0.9	0.637	12.12	96.084	95.957	0.596
407	411	94.344	94.260	975	83.5	0.1	0.013	98.290	98.170	0.949	0.709	0.63	0.9	0.638	12.12	95.957	95.837	0.533
411	414	94.185	94.113	1050	72.0	0.1	0.013	98.170	98.060	0.997	0.864	1.05	1.2	0.602	12.12	95.837	95.722	0.533
414	417	93.963	93.895	1200	68.0	0.1	0.013	98.060	97.960	1.090	1.233	1.29	1.0	0.559	12.12	95.722	95.640	0.538
417	420	93.875	93.803	1200	72.0	0.1	0.013	97.960	97.850	1.090	1.233	1.51	1.2	0.565	12.12	95.640	95.523	0.520
420	431	93.653	93.580	1350	73.0	0.1	0.013	97.850	97.740	1.179	1.688	1.74	1.0	0.521	12.12	95.524	95.439	0.526
431	432	93.560	93.473	1350	79.0	0.1	0.013	97.740	97.620	1.237	1.770	2.36	1.3	0.529	12.12	95.439	95.283	0.501
432	444	93.443	93.347	1350	87.5	0.1	0.013	97.620	97.500	1.237	1.770	2.49	1.4	0.490	12.12	95.283	94.979	0.537
444	445	93.197	93.132	1500	64.5	0.1	0.013	97.500	96.710	1.265	2.235	3.05	1.4	0.282	12.13	94.979	94.888	0.721
445	446	93.102	93.078	1500	23.5	0.1	0.013	96.710	96.710	1.265	2.235	3.05	1.4	0.286	12.13	94.888	94.852	0.022
446	447	93.048	93.006	1500	38.0	0.1	0.013	96.710	95.500	1.327	2.344	3.18	1.4	0.304	12.13	94.852	94.800	0.058
447	448	92.976	92.927	1500	44.5	0.1	0.013	95.500	95.500	1.327	2.344	3.18	1.4	0.324	12.13	94.800	94.707	N/A
448	449	92.867	92.847	1500	18.0	0.1	0.013	95.500	95.500	1.327	2.344	3.17	1.4	0.340	12.13	94.707	94.707	N/A
449	Pond2	92.817	92.800	1500	15.5	0.1	0.013	95.500	95.500	1.327	2.344	3.17	1.4	0.390	12.13	94.707	94.705	N/A
Pond2	Out	N/A	N/A	N/A	N/A	N/A	N/A	95.500	95.500	N/A	N/A	2.73	N/A	N/A	14.70	94.705	93.200	N/A

Note: [(1)] A negative surcharge implies that the pipe is not flowing full

Table B-1E: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [(1)] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [(2)] (m)

[(2)] Freeboard between upstream hydraulic gradeline elevation and upstream manhole cover elevation for 200 and 300 series trunk sewers. Freeboard between upstream hydraulic gradeline and estimated underside of footing elevation (1.8 m below upstream manhole cover elevation) for 400 series trunk sewers.

[(3)] Ponding allowed above manholes in undetailed future development areas to represent road surface storage above catchbasins.

ATTACHMENT

C

Pond 1 Hydraulic Gradeline Results

JFSA Water Resources and Environmental Consultants

Table C-1A: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
1	2	93.328	93.172	300	44.5	0.4	0.013	95.566	95.449	0.809	0.057	-0.06	-1.0	0.858	0.99	94.486	94.465	1.080
2	2a	93.134	92.925	375	69.6	0.3	0.013	95.449	95.449	0.869	0.096	-0.07	-0.7	0.956	0.98	94.465	94.413	0.984
2a	3	92.925	92.857	375	22.9	0.3	0.013	95.449	95.220	0.869	0.096	0.12	1.3	1.113	1.01	94.413	94.287	N/A
3	4	92.827	92.787	375	13.5	0.3	0.013	95.220	95.300	0.869	0.096	0.12	1.2	1.085	1.02	94.287	94.211	0.933
4	7	92.757	92.561	375	65.5	0.3	0.013	95.300	95.174	0.869	0.096	0.12	1.2	1.079	1.09	94.211	93.935	1.089
5	5a	92.986	92.957	300	8.3	0.4	0.013	95.298	95.378	0.809	0.057	-0.02	-0.4	1.033	0.98	94.319	94.318	0.979
5a	6	92.957	92.797	300	45.7	0.4	0.013	95.378	95.378	0.809	0.057	0.09	1.5	1.061	0.99	94.318	94.065	N/A
6	6a	92.609	92.499	675	73.5	0.2	0.013	95.378	95.378	0.910	0.326	0.09	0.3	0.781	0.99	94.065	94.056	1.313
6a	7	92.499	92.448	675	34.0	0.2	0.013	95.378	95.174	0.910	0.326	0.39	1.2	0.882	0.98	94.056	93.935	N/A
7	7a	92.373	92.313	750	54.4	0.1	0.013	95.174	95.174	0.836	0.369	0.49	1.3	0.812	1.07	93.935	93.844	1.239
7a	8	92.313	92.300	750	11.6	0.1	0.013	95.174	95.040	0.836	0.369	0.60	1.6	0.781	1.04	93.844	93.776	N/A
8	8a	92.225	92.211	900	13.1	0.1	0.013	95.040	95.199	0.944	0.600	0.72	1.2	0.651	1.03	93.776	93.776	1.264
8a	11	92.211	92.144	900	60.4	0.1	0.013	95.199	95.199	0.944	0.600	0.84	1.4	0.665	1.03	93.776	93.776	N/A
9	10	92.912	92.614	300	59.5	0.5	0.013	95.652	94.963	0.967	0.068	0.03	0.4	0.707	1.04	93.919	93.865	1.733
10	10a	92.501	92.486	525	6.1	0.3	0.013	94.963	95.199	0.993	0.215	0.03	0.1	0.839	1.04	93.865	93.864	1.098
10a	11	92.486	92.331	525	61.9	0.3	0.013	95.199	95.199	0.993	0.215	0.27	1.3	0.853	1.07	93.864	93.776	N/A
11	11a	92.106	92.040	975	59.6	0.1	0.013	95.199	95.199	0.996	0.743	1.11	1.5	0.695	1.03	93.776	93.776	1.423
11a	12	92.040	92.036	975	4.4	0.1	0.013	95.199	94.782	0.996	0.743	1.20	1.6	0.761	1.03	93.776	93.776	N/A
12	12a	92.006	91.963	975	39.2	0.1	0.013	94.782	94.964	0.996	0.743	1.20	1.6	0.795	1.03	93.776	93.775	1.006
12a	15	91.963	91.924	975	35.9	0.1	0.013	94.964	94.964	0.996	0.743	1.25	1.7	0.837	1.03	93.775	93.775	N/A
13	13a	92.160	92.156	825	3.3	0.1	0.013	95.250	95.201	0.891	0.476	0.44	0.9	0.790	1.02	93.775	93.775	1.475
13a	13b	92.156	92.069	825	79.1	0.1	0.013	95.201	95.201	0.891	0.476	0.47	1.0	0.794	1.02	93.775	93.775	N/A
13b	14	92.069	92.046	825	21.1	0.1	0.013	95.201	94.902	0.891	0.476	0.66	1.4	0.881	1.02	93.775	93.775	N/A
14	15	92.016	91.999	825	15.5	0.1	0.013	94.902	94.964	0.891	0.476	0.66	1.4	0.934	1.02	93.775	93.775	1.127
15	104b	91.810	91.793	1200	15.5	0.1	0.013	94.964	94.500	1.143	1.293	1.89	1.5	0.765	1.03	93.775	93.775	1.189
16	17	92.602	92.499	600	68.5	0.2	0.013	94.979	95.298	0.841	0.238	0.29	1.2	1.198	1.00	94.400	94.250	0.579
17	17a	92.461	92.373	675	58.7	0.2	0.013	95.298	95.298	0.910	0.326	0.29	0.9	1.114	1.05	94.250	94.181	1.048
17a	18	92.373	92.363	675	6.4	0.2	0.013	95.298	95.030	0.910	0.326	0.44	1.3	1.133	1.04	94.181	94.136	N/A
18	19	92.333	92.317	675	10.5	0.2	0.013	95.030	95.094	0.910	0.326	0.44	1.3	1.128	1.04	94.136	94.094	0.894
19	23	92.287	92.205	675	55.0	0.2	0.013	95.094	95.383	0.910	0.326	0.43	1.3	1.132	1.04	94.094	93.917	1.000
20	20a	92.442	92.427	675	10.1	0.2	0.013	95.562	95.562	0.910	0.326	0.45	1.4	1.236	1.13	94.353	94.326	1.209
20	20b	93.147	92.935	300	53.0	0.4	0.013	95.562	95.562	0.865	0.061	0.02	0.3	0.906	0.97	94.353	94.356	1.209
20a	21	92.427	92.327	675	66.9	0.2	0.013	95.562	95.128	0.910	0.326	0.47	1.4	1.224	1.13	94.326	94.139	N/A
20b	24	92.935	92.755	300	45.0	0.4	0.013	95.562	95.243	0.865	0.061	0.08	1.2	1.121	0.98	94.356	94.115	N/A
21	21a	92.252	92.228	825	22.2	0.1	0.013	95.128	95.198	0.891	0.476	0.47	1.0	1.063	1.13	94.140	94.118	0.988
21a	22	92.228	92.181	825	42.3	0.1	0.013	95.198	95.198	0.891	0.476	0.63	1.3	1.065	1.12	94.118	94.009	N/A
22	23	92.151	92.130	825	19.5	0.1	0.013	95.198	95.383	0.891	0.476	0.63	1.3	1.033	1.12	94.009	93.917	1.189
23	105b	92.092	92.059	900	26.5	0.1	0.013	95.383	94.500	0.944	0.600	1.04	1.7	0.925	1.05	93.917	93.776	1.466
24	24a	92.605	92.572	600	22.2	0.2	0.013	95.243	95.320	0.841	0.238	0.07	0.3	0.910	1.03	94.115	94.112	1.128

Table C-1A: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
24a	25	92.572	92.459	600	74.8	0.2	0.013	95.320	95.330	0.841	0.238	0.26	1.1	0.940	0.98	94.112	93.938	N/A
25	25a	92.234	92.230	1050	3.2	0.1	0.013	95.330	95.320	1.046	0.906	1.11	1.2	0.654	1.03	93.938	93.931	1.392
25a	26	92.230	92.152	1050	71.8	0.1	0.013	95.320	95.212	1.046	0.906	1.23	1.4	0.651	1.03	93.931	93.789	N/A
26	26a	92.077	92.032	1200	41.3	0.1	0.013	95.212	95.352	1.143	1.293	1.37	1.1	0.512	1.03	93.789	93.776	1.423
26a	26b	92.032	92.007	1200	22.9	0.1	0.013	95.352	95.352	1.143	1.293	1.39	1.1	0.544	1.03	93.776	93.776	N/A
26b	27	92.007	91.988	1200	16.8	0.1	0.013	95.352	95.352	1.143	1.293	1.56	1.2	0.569	1.04	93.776	93.776	N/A
27	27a	92.856	92.796	300	17.1	0.4	0.013	95.352	95.352	0.809	0.057	-0.10	-1.8	0.620	0.95	93.776	93.776	1.576
27	27b	91.928	91.910	1200	16.8	0.1	0.013	95.352	95.352	1.143	1.293	1.56	1.2	0.648	1.03	93.776	93.776	1.576
27a	29	92.796	92.623	300	49.4	0.4	0.013	95.352	95.352	0.809	0.057	0.08	1.5	0.680	1.08	93.776	93.775	N/A
27b	107b	91.910	91.846	1200	58.2	0.1	0.013	95.352	95.232	1.143	1.293	1.66	1.3	0.666	1.03	93.776	93.776	N/A
29	111b	91.588	91.542	1650	41.5	0.1	0.013	95.352	95.502	1.414	3.023	6.61	2.2	0.537	0.96	93.775	93.774	1.577
30	30a	92.746	92.561	450	74.2	0.3	0.013	95.372	95.372	0.896	0.143	-0.08	-0.6	0.670	1.00	93.866	93.919	1.506
30	31	92.662	92.542	300	12.0	1.0	0.013	95.372	95.212	1.368	0.097	0.08	0.8	0.904	1.02	93.866	93.776	1.506
30a	26	92.561	92.542	450	43.3	0.3	0.013	95.372	95.212	0.896	0.143	0.18	1.2	0.908	0.97	93.919	93.789	N/A
31	31a	92.429	92.327	525	51.0	0.2	0.013	95.212	95.212	0.888	0.192	0.08	0.4	0.822	1.01	93.776	93.776	1.436
31a	32	92.327	92.301	525	13.0	0.2	0.013	95.212	94.974	0.888	0.192	0.30	1.6	0.924	1.01	93.776	93.776	N/A
32	33	92.271	92.246	525	12.5	0.2	0.013	94.974	95.049	0.888	0.192	0.30	1.6	0.980	1.04	93.776	93.776	1.198
33	330	92.216	92.146	525	35.0	0.2	0.013	95.049	95.230	0.888	0.192	0.30	1.6	1.035	1.04	93.776	93.776	1.273
104b	Pond1	91.763	91.700	1200	57.5	0.1	0.013	94.500	95.500	1.143	1.293	1.89	1.5	0.812	1.03	93.775	93.774	0.725
105b	106b	92.029	91.960	900	62.5	0.1	0.013	94.500	94.500	0.944	0.600	1.04	1.7	0.847	1.05	93.776	93.776	0.724
106b	108b	91.930	91.854	900	69.5	0.1	0.013	94.500	94.218	0.944	0.600	1.04	1.7	0.946	1.05	93.776	93.775	0.724
107b	1070b	91.786	91.778	1200	7.0	0.1	0.013	95.232	95.055	1.143	1.293	1.66	1.3	0.790	1.03	93.776	93.775	1.456
108b	109b	91.629	91.617	1350	10.5	0.1	0.013	94.218	94.500	1.237	1.770	2.99	1.7	0.796	1.04	93.775	93.775	0.443
109b	Pond1	91.557	91.550	1350	6.0	0.1	0.013	94.500	95.500	1.237	1.770	2.98	1.7	0.868	1.04	93.775	93.774	0.725
111b	Pond1	91.522	91.450	1650	38.0	0.2	0.013	95.502	95.500	1.858	3.973	6.85	1.7	0.602	0.95	93.774	93.774	1.728
200	201	93.286	93.180	300	12.5	0.9	0.013	95.389	95.314	1.261	0.089	-0.06	-0.7	0.303	1.00	93.889	93.887	1.500
200	202	93.289	93.084	300	58.5	0.4	0.013	95.389	95.259	0.809	0.057	-0.02	-0.3	0.300	1.27	93.889	93.904	1.500
201	201a	93.030	92.900	450	29.6	0.4	0.013	95.314	95.314	1.189	0.189	-0.07	-0.3	0.407	0.99	93.887	93.885	1.427
201a	8	92.900	92.500	450	90.9	0.4	0.013	95.314	95.040	1.189	0.189	0.13	0.7	0.535	1.02	93.885	93.776	N/A
202	202a	93.054	93.050	300	1.2	0.4	0.013	95.259	95.296	0.809	0.057	-0.03	-0.5	0.550	1.00	93.904	93.904	1.355
202a	203	93.050	93.012	300	10.8	0.4	0.013	95.296	95.296	0.809	0.057	0.11	1.8	0.554	1.03	93.904	93.777	N/A
203	204	92.862	92.677	450	92.5	0.2	0.013	95.296	95.110	0.802	0.128	0.11	0.8	0.465	1.03	93.777	93.776	1.519
204	204a	92.511	92.463	600	21.9	0.2	0.013	95.110	95.250	1.019	0.288	0.11	0.4	0.665	1.02	93.776	93.776	1.334
204a	204b	92.463	92.324	600	63.0	0.2	0.013	95.250	95.250	1.019	0.288	0.40	1.4	0.713	1.02	93.776	93.776	N/A
204b	13	92.324	92.290	600	15.6	0.2	0.013	95.250	95.250	1.019	0.288	0.44	1.5	0.852	1.02	93.776	93.775	N/A
205	210	93.210	93.060	450	75.0	0.2	0.013	95.493	95.671	0.802	0.128	0.12	0.9	1.225	0.95	94.885	94.812	0.608
206	206a	93.320	93.316	375	1.5	0.3	0.013	95.468	95.493	0.869	0.096	-0.07	-0.8	1.226	0.97	94.921	94.921	0.547
206a	205	93.316	93.285	375	10.0	0.3	0.013	95.493	95.493	0.869	0.096	0.13	1.4	1.230	0.96	94.921	94.885	N/A
207	206	93.598	93.395	300	58.0	0.4	0.013	95.923	95.468	0.809	0.057	-0.06	-1.0	0.994	0.98	94.892	94.921	1.031

Table C-1A: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
208	207	93.700	93.658	300	12.0	0.4	0.013	95.851	95.923	0.809	0.057	-0.04	-0.7	0.884	0.98	94.884	94.892	0.967
208	208a	93.672	93.294	375	44.5	0.9	0.013	95.851	95.851	1.464	0.162	-0.08	-0.5	0.837	0.98	94.884	94.883	0.967
208a	209	93.294	92.949	375	40.5	0.9	0.013	95.851	95.614	1.464	0.162	0.16	1.0	1.214	0.95	94.883	94.671	N/A
209	212	92.724	92.639	600	56.5	0.2	0.013	95.614	95.238	0.841	0.238	0.33	1.4	1.347	1.01	94.671	94.524	0.943
210	211	93.030	93.007	450	11.5	0.2	0.013	95.671	95.601	0.802	0.128	0.10	0.8	1.332	1.01	94.812	94.796	0.859
211	211a	92.932	92.871	525	30.3	0.2	0.013	95.601	95.614	0.888	0.192	0.09	0.5	1.339	1.12	94.796	94.785	0.805
211a	209	92.871	92.799	525	36.2	0.2	0.013	95.614	95.614	0.888	0.192	0.19	1.0	1.389	1.03	94.785	94.671	N/A
212	212a	92.564	92.553	675	7.3	0.2	0.013	95.238	95.550	0.910	0.326	0.33	1.0	1.285	1.13	94.524	94.514	0.714
212a	20	92.553	92.460	675	62.2	0.2	0.013	95.550	95.562	0.910	0.326	0.44	1.4	1.286	1.13	94.514	94.353	N/A
213	214	93.791	93.638	300	30.5	0.5	0.013	96.071	95.908	0.967	0.068	0.08	1.1	1.178	0.93	95.269	95.168	0.802
214	214a	93.338	93.284	600	36.3	0.2	0.013	95.908	95.918	0.841	0.238	0.11	0.5	1.230	1.01	95.168	95.157	0.740
214a	215	93.284	93.232	600	34.2	0.2	0.013	95.918	95.849	0.841	0.238	0.26	1.1	1.273	0.97	95.157	95.110	N/A
215	215a	93.212	93.138	600	49.2	0.2	0.013	95.849	95.849	0.841	0.238	0.25	1.0	1.298	0.98	95.110	95.042	0.739
215a	220	93.138	93.120	600	11.8	0.2	0.013	95.849	95.723	0.841	0.238	0.32	1.3	1.304	1.04	95.042	94.936	N/A
216	216a	93.869	93.679	300	54.4	0.4	0.013	95.972	95.972	0.809	0.057	-0.03	-0.5	1.053	0.97	95.222	95.219	0.750
216	217	93.870	93.726	300	12.0	1.2	0.013	95.972	95.900	1.499	0.106	-0.07	-0.6	1.052	0.96	95.222	95.217	0.750
216a	214	93.679	93.638	300	11.6	0.4	0.013	95.972	95.908	0.809	0.057	0.05	0.9	1.240	1.01	95.219	95.168	N/A
217	217a	93.576	93.494	450	40.9	0.2	0.013	95.900	95.900	0.802	0.128	-0.08	-0.7	1.191	0.96	95.217	95.207	0.683
217a	218	93.494	93.345	450	74.6	0.2	0.013	95.900	95.677	0.802	0.128	0.14	1.1	1.263	0.97	95.207	95.096	N/A
218	219	93.315	93.292	450	11.5	0.2	0.013	95.677	95.594	0.802	0.128	0.12	1.0	1.331	0.98	95.096	95.068	0.581
219	219a	93.254	93.217	525	18.4	0.2	0.013	95.594	95.733	0.888	0.192	0.12	0.6	1.289	1.03	95.068	95.050	0.526
219a	220	93.217	93.121	525	48.1	0.2	0.013	95.733	95.723	0.888	0.192	0.23	1.2	1.308	0.98	95.050	94.936	N/A
220	220a	93.045	92.918	675	63.4	0.2	0.013	95.723	95.733	1.051	0.376	0.51	1.4	1.216	1.03	94.936	94.707	0.787
220a	221	92.918	92.913	675	2.6	0.2	0.013	95.733	95.466	1.051	0.376	0.52	1.4	1.114	1.03	94.707	94.571	N/A
221	221a	92.838	92.772	750	33.1	0.2	0.013	95.466	95.515	1.127	0.498	0.58	1.2	0.983	1.03	94.571	94.489	0.895
221a	222	92.772	92.600	750	85.9	0.2	0.013	95.515	95.515	1.127	0.498	0.73	1.5	0.967	0.98	94.489	94.125	N/A
222	223	92.525	92.505	825	13.5	0.2	0.013	95.515	95.409	1.040	0.556	0.70	1.3	0.774	1.02	94.124	94.063	1.391
223	223a	92.430	92.369	900	32.0	0.2	0.013	95.409	95.409	1.240	0.789	0.71	0.9	0.733	0.99	94.063	94.017	1.346
223a	223b	92.369	92.316	900	27.8	0.2	0.013	95.409	95.409	1.240	0.789	0.88	1.1	0.748	0.99	94.017	93.958	N/A
223b	25	92.316	92.300	900	8.7	0.2	0.013	95.409	95.330	1.240	0.789	0.88	1.1	0.742	0.99	93.958	93.938	N/A
224	221	93.432	93.288	300	41.0	0.4	0.013	95.273	95.466	0.809	0.057	0.07	1.2	0.997	0.97	94.729	94.571	0.544
330	1070b	92.116	92.096	525	10.0	0.2	0.014	95.230	95.055	0.825	0.179	0.30	1.7	1.135	1.04	93.776	93.775	1.454
1070b	108b	91.758	91.709	1200	44.5	0.1	0.014	95.055	94.218	1.062	1.201	1.95	1.6	0.817	1.04	93.775	93.775	1.280
1600	1600a	92.658	92.635	600	15.5	0.2	0.013	95.090	95.090	0.841	0.238	0.20	0.8	1.163	0.92	94.421	94.412	0.669
1600a	16	92.635	92.622	600	8.5	0.2	0.013	95.090	94.979	0.841	0.238	0.23	1.0	1.177	1.00	94.412	94.400	N/A
Pond1	Out	N/A	N/A	N/A	N/A	N/A	N/A	95.500	94.500	N/A	N/A	3.24	N/A	N/A	3.05	93.774	92.350	1.726
250	252	93.433	93.270	300	46.5	0.4	0.013	95.380	95.390	0.809	0.057	0.07	1.2	1.456	1.33	95.189	95.107	0.191
251	251a	93.563	93.356	300	46.1	0.5	0.013	95.530	95.530	0.918	0.065	-0.08	-1.2	1.388	1.32	95.251	95.267	0.279
251	251b	93.320	93.079	300	48.2	0.5	0.013	95.530	95.500	0.967	0.068	-0.06	-0.9	1.631	0.93	95.251	95.163	0.279

Table C-1A: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [1] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [2] (m)
251	251c	93.625	93.607	375	6.0	0.3	0.013	95.530	95.530	0.869	0.096	0.10	1.0	1.251	1.28	95.251	95.259	0.279
251a	252	93.356	93.270	300	18.9	0.5	0.013	95.530	95.390	0.918	0.065	0.08	1.3	1.611	0.92	95.267	95.107	N/A
251b	255	93.079	92.980	300	19.8	0.5	0.013	95.500	95.330	0.967	0.068	0.10	1.5	1.783	1.24	95.162	94.988	N/A
251c	251d	93.607	93.526	375	26.9	0.3	0.013	95.530	95.530	0.869	0.096	0.11	1.1	1.277	1.28	95.259	95.280	N/A
251e	263	93.450	93.421	375	9.7	0.3	0.013	95.530	95.630	0.869	0.096	-0.21	-2.2	1.469	0.93	95.294	95.327	N/A
252	252a	93.045	92.914	525	52.2	0.3	0.013	95.390	95.390	0.993	0.215	-0.16	-0.7	1.537	0.93	95.107	95.080	0.283
252a	253	92.914	92.872	525	16.8	0.3	0.013	95.390	95.180	0.993	0.215	0.22	1.0	1.641	1.29	95.080	95.053	N/A
253	253a	92.797	92.693	600	69.3	0.2	0.013	95.180	95.180	0.841	0.238	0.22	0.9	1.656	1.31	95.053	95.003	0.127
253a	254	92.693	92.675	600	11.7	0.2	0.013	95.180	95.180	0.841	0.238	0.29	1.2	1.710	1.31	95.003	94.954	N/A
254	254a	92.615	92.568	600	31.4	0.2	0.013	95.180	95.230	0.841	0.238	0.37	1.6	1.739	1.31	94.954	94.923	0.226
254	254c	93.239	93.106	300	29.5	0.5	0.013	95.180	95.180	0.918	0.065	-0.14	-2.2	1.415	0.92	94.954	94.945	0.226
254a	257	92.568	92.562	600	4.1	0.2	0.013	95.230	95.230	0.841	0.238	0.40	1.7	1.755	1.31	94.923	94.917	N/A
259a	257	93.017	92.977	300	7.9	0.5	0.013	95.280	95.230	0.967	0.068	0.08	1.1	1.672	1.27	94.989	94.917	N/A
254c	273	93.106	92.964	300	31.5	0.5	0.013	95.180	95.140	0.918	0.065	-0.11	-1.6	1.539	1.52	94.945	94.761	N/A
255	255a	92.830	92.701	450	64.5	0.2	0.013	95.330	95.330	0.802	0.128	0.11	0.9	1.708	1.23	94.988	94.897	0.342
255a	256	92.701	92.667	450	17.0	0.2	0.013	95.330	95.260	0.802	0.128	0.17	1.3	1.746	1.23	94.897	94.857	N/A
256	256a	92.422	92.402	675	13.0	0.2	0.013	95.260	95.260	0.910	0.326	0.58	1.8	1.760	1.28	94.857	94.825	0.403
256a	261	92.402	92.372	675	20.0	0.2	0.013	95.260	95.250	0.910	0.326	0.59	1.8	1.748	1.28	94.825	94.772	N/A
251d	251e	93.526	93.450	375	25.4	0.3	0.013	95.530	95.530	0.869	0.096	-0.12	-1.3	1.379	0.94	95.280	95.294	N/A
258	258a	93.104	92.887	300	54.2	0.4	0.013	95.450	95.450	0.865	0.061	-0.06	-0.9	1.555	0.92	94.959	94.943	0.491
258a	261	92.887	92.840	300	11.8	0.4	0.013	95.450	95.250	0.865	0.061	0.09	1.4	1.756	1.01	94.943	94.772	N/A
259	259a	93.152	93.017	300	27.1	0.5	0.013	95.280	95.280	0.967	0.068	0.06	0.8	1.577	0.98	95.029	94.989	0.251
257	256	92.542	92.497	600	30.0	0.2	0.013	95.230	95.260	0.841	0.238	0.45	1.9	1.775	1.28	94.917	94.857	0.313
260	260a	92.954	92.866	375	25.1	0.4	0.013	95.320	95.320	0.939	0.104	-0.04	-0.4	1.517	0.91	94.846	94.846	0.474
260a	261	92.866	92.840	300	7.4	0.4	0.013	95.320	95.250	0.809	0.057	0.07	1.2	1.680	1.23	94.846	94.772	N/A
261	265	92.297	92.262	825	35.0	0.1	0.013	95.250	95.550	0.849	0.454	0.71	1.6	1.650	1.23	94.772	94.667	0.478
263	263a	92.209	92.176	1500	22.2	0.2	0.013	95.630	95.630	1.549	2.738	4.53	1.7	1.618	1.00	95.327	95.230	0.303
263a	264	92.176	92.096	1500	52.8	0.2	0.013	95.630	95.530	1.549	2.738	4.58	1.7	1.554	1.00	95.230	95.004	N/A
264	264a	92.076	92.033	1500	28.5	0.2	0.013	95.530	95.530	1.549	2.738	4.58	1.7	1.428	1.00	95.004	94.879	0.526
264a	265	92.033	91.963	1500	46.5	0.2	0.013	95.530	95.550	1.549	2.738	4.72	1.7	1.347	1.00	94.880	94.667	N/A
265	265a	91.924	91.816	1500	53.8	0.2	0.013	95.550	95.550	1.789	3.161	5.24	1.7	1.243	1.00	94.667	94.366	0.883
265a	266	91.816	91.778	1500	19.2	0.2	0.013	95.550	95.540	1.789	3.161	5.31	1.7	1.050	1.00	94.366	93.799	N/A
266	266a	91.568	91.509	1500	29.7	0.2	0.013	95.540	95.550	1.789	3.161	5.31	1.7	0.732	1.00	93.800	93.776	1.740
266a	267	91.509	91.429	1500	39.8	0.2	0.013	95.550	95.630	1.789	3.161	5.34	1.7	0.767	1.01	93.776	93.775	N/A
267	Pond1	91.429	91.350	1500	39.5	0.2	0.013	95.630	95.500	1.789	3.161	5.33	1.7	0.846	1.01	93.775	93.774	1.855
270	270a	92.828	92.710	900	59.1	0.2	0.013	95.500	95.500	1.273	0.810	1.56	1.9	1.868	0.91	95.596	95.298	-0.096
270a	271	92.710	92.665	900	22.4	0.2	0.013	95.500	95.320	1.273	0.810	1.58	2.0	1.688	0.91	95.298	95.179	N/A
271	271a	92.643	92.503	900	46.6	0.3	0.013	95.320	95.320	1.559	0.992	1.57	1.6	1.636	0.91	95.179	94.937	0.141
271a	273	92.503	92.416	900	28.9	0.3	0.013	95.320	95.140	1.559	0.992	1.57	1.6	1.534	0.91	94.937	94.761	N/A

Table C-1A: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
273	273a	92.364	92.313	900	25.5	0.2	0.013	95.140	95.140	1.273	0.810	1.52	1.9	1.497	0.96	94.761	94.600	0.379
273a	275	92.313	92.298	900	7.6	0.2	0.013	95.140	95.200	1.273	0.810	1.58	1.9	1.387	0.96	94.600	94.537	N/A
275	276	92.268	92.209	900	29.5	0.2	0.013	95.200	95.620	1.273	0.810	1.57	1.9	1.369	0.96	94.537	94.252	0.663
276	277	92.179	92.148	900	15.5	0.2	0.013	95.620	95.500	1.273	0.810	1.57	1.9	1.173	0.96	94.252	94.095	1.368
277	277a	92.067	91.964	975	51.7	0.2	0.013	95.500	95.630	1.342	1.002	1.70	1.7	1.053	0.96	94.095	93.926	1.405
277a	277b	91.964	91.869	975	47.5	0.2	0.013	95.630	95.630	1.342	1.002	1.75	1.7	0.987	0.96	93.926	93.776	N/A
277b	278	91.869	91.842	975	13.3	0.2	0.013	95.630	95.630	1.342	1.002	1.79	1.8	0.932	1.00	93.776	93.775	N/A
278	279	91.782	91.775	975	3.5	0.2	0.013	95.630	95.630	1.342	1.002	1.79	1.8	1.018	1.00	93.775	93.775	1.855
279	Pond1	91.715	91.650	975	32.5	0.2	0.013	95.630	95.500	1.342	1.002	1.79	1.8	1.085	1.00	93.775	93.774	1.855
280	280a	91.825	91.714	1650	73.8	0.2	0.013	95.450	95.510	1.651	3.530	2.60	0.7	0.478	3.09	93.953	93.892	1.497
280a	281	91.714	91.657	1650	38.2	0.2	0.013	95.510	95.510	1.651	3.530	2.60	0.7	0.528	3.09	93.892	93.860	N/A
281	Pond1	91.657	91.600	1650	38.0	0.2	0.013	95.510	95.500	1.651	3.530	2.60	0.7	0.553	3.09	93.860	93.774	1.650
328	263	92.425	92.359	1350	65.5	0.1	0.013	95.700	95.630	1.179	1.688	2.94	1.7	1.762	1.00	95.537	95.327	0.163
329	329a	92.534	92.465	1050	27.4	0.3	0.013	95.700	95.700	1.577	1.365	2.16	1.6	2.153	1.22	95.737	95.619	-0.037
329a	263	92.465	92.434	1050	12.6	0.3	0.013	95.700	95.630	1.577	1.365	2.19	1.6	2.104	1.22	95.619	95.327	N/A
101	102	94.092	93.958	600	95.5	0.1	0.013	97.120	97.010	0.813	0.230	0.69	3.0	2.477	1.54	97.169	97.032	-0.049
102	103	93.883	93.783	675	83.5	0.1	0.013	97.010	96.880	0.814	0.291	0.93	3.2	2.474	1.53	97.032	96.889	-0.022
103	106	93.708	93.664	750	40.0	0.1	0.013	96.880	96.820	0.836	0.369	1.16	3.1	2.431	1.47	96.889	96.859	-0.009
106	109	93.589	93.544	825	45.0	0.1	0.013	96.820	96.750	0.849	0.454	1.41	3.1	2.445	1.46	96.859	96.792	-0.039
109	111	93.469	93.391	900	78.0	0.1	0.013	96.750	96.640	0.900	0.572	1.65	2.9	2.438	1.42	96.807	96.670	-0.057
111	112	93.241	93.142	1050	98.5	0.1	0.013	96.640	96.500	0.997	0.864	2.13	2.5	2.372	1.39	96.663	96.552	-0.023
112	113	92.992	92.863	1200	129.0	0.1	0.013	96.500	96.310	1.090	1.233	2.63	2.1	2.360	1.37	96.552	96.353	-0.052
113	114	92.833	92.754	1200	78.5	0.1	0.013	96.310	96.190	1.090	1.233	2.85	2.3	2.320	1.33	96.353	96.240	-0.043
114	122	92.604	92.524	1350	80.0	0.1	0.013	96.190	96.070	1.179	1.688	3.36	2.0	2.286	1.25	96.240	96.110	-0.050
122	126	92.494	92.287	1350	122.0	0.2	0.013	96.070	95.770	1.537	2.201	3.80	1.7	2.266	1.27	96.110	95.799	-0.040
126	127	92.212	92.111	1500	91.5	0.1	0.013	95.770	95.630	1.327	2.344	4.62	2.0	2.085	0.94	95.797	95.645	-0.027
127	130	92.081	91.980	1500	91.5	0.1	0.013	95.630	95.490	1.327	2.344	5.01	2.1	2.066	0.94	95.647	94.902	-0.017
130	138	91.905	91.840	1650	64.5	0.1	0.013	95.490	95.140	1.348	2.882	5.52	1.9	1.347	0.96	94.902	94.245	0.588
138	139	91.780	91.730	1650	50.0	0.1	0.013	95.140	95.400	1.348	2.882	6.45	2.2	0.815	0.96	94.245	93.775	0.895
139	140	91.670	91.656	1650	14.0	0.1	0.013	95.400	95.400	1.348	2.882	6.49	2.2	0.455	0.96	93.775	93.775	1.625
140	29	91.651	91.608	1650	43.4	0.1	0.013	95.400	95.352	1.348	2.882	6.56	2.3	0.474	0.96	93.775	93.775	1.625

Note: (1) A negative surcharge implies that the pipe is not flowing full

(2) Freeboard between upstream hydraulic gradeline elevation and upstream manhole cover elevation.

(3) Ponding allowed above manholes in undetailed future development areas to represent road surface storage above catchbasins.

Table C-1B: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
1	2	93.328	93.172	300	44.5	0.4	0.013	95.566	95.449	0.809	0.057	-0.05	-0.8	0.949	11.89	94.577	94.568	0.989
2	2a	93.134	92.925	375	69.6	0.3	0.013	95.449	95.449	0.869	0.096	-0.07	-0.7	1.059	11.88	94.568	94.550	0.881
2a	3	92.925	92.857	375	22.9	0.3	0.013	95.449	95.220	0.869	0.096	0.11	1.2	1.250	11.96	94.550	94.447	N/A
3	4	92.827	92.787	375	13.5	0.3	0.013	95.220	95.300	0.869	0.096	0.11	1.2	1.245	11.96	94.447	94.380	0.773
4	7	92.757	92.561	375	65.5	0.3	0.013	95.300	95.174	0.869	0.096	0.11	1.1	1.248	11.96	94.380	94.169	0.920
5	5a	92.986	92.957	300	8.3	0.4	0.013	95.298	95.378	0.809	0.057	-0.01	-0.2	1.191	11.87	94.477	94.476	0.821
5a	6	92.957	92.797	300	45.7	0.4	0.013	95.378	95.378	0.809	0.057	0.07	1.2	1.219	11.94	94.476	94.273	N/A
6	6a	92.609	92.499	675	73.5	0.2	0.013	95.378	95.378	0.910	0.326	0.07	0.2	0.989	11.97	94.273	94.268	1.105
6a	7	92.499	92.448	675	34.0	0.2	0.013	95.378	95.174	0.910	0.326	0.33	1.0	1.094	11.99	94.268	94.169	N/A
7	7a	92.373	92.313	750	54.4	0.1	0.013	95.174	95.174	0.836	0.369	0.44	1.2	1.046	12.00	94.169	94.094	1.005
7a	8	92.313	92.300	750	11.6	0.1	0.013	95.174	95.040	0.836	0.369	0.54	1.5	1.031	11.98	94.094	93.984	N/A
8	8a	92.225	92.211	900	13.1	0.1	0.013	95.040	95.199	0.944	0.600	0.64	1.1	0.859	11.96	93.984	93.969	1.056
8a	11	92.211	92.144	900	60.4	0.1	0.013	95.199	95.199	0.944	0.600	0.74	1.2	0.858	11.96	93.969	93.882	N/A
9	10	92.912	92.614	300	59.5	0.5	0.013	95.652	94.963	0.967	0.068	0.03	0.4	0.954	12.20	94.166	94.122	1.486
10	10a	92.501	92.486	525	6.1	0.3	0.013	94.963	95.199	0.993	0.215	0.03	0.2	1.096	12.20	94.122	94.122	0.841
10a	11	92.486	92.331	525	61.9	0.3	0.013	95.199	95.199	0.993	0.215	0.24	1.1	1.111	11.99	94.122	93.882	N/A
11	11a	92.106	92.040	975	59.6	0.1	0.013	95.199	95.199	0.996	0.743	0.97	1.3	0.801	11.97	93.882	93.797	1.317
11a	12	92.040	92.036	975	4.4	0.1	0.013	95.199	94.782	0.996	0.743	1.05	1.4	0.782	11.97	93.797	93.796	N/A
12	12a	92.006	91.963	975	39.2	0.1	0.013	94.782	94.964	0.996	0.743	1.05	1.4	0.815	11.97	93.796	93.795	0.986
12a	15	91.963	91.924	975	35.9	0.1	0.013	94.964	94.964	0.996	0.743	1.10	1.5	0.857	11.97	93.795	93.794	N/A
13	13a	92.160	92.156	825	3.3	0.1	0.013	95.250	95.201	0.891	0.476	0.39	0.8	0.811	11.97	93.796	93.796	1.454
13a	13b	92.156	92.069	825	79.1	0.1	0.013	95.201	95.201	0.891	0.476	0.42	0.9	0.815	11.98	93.796	93.795	N/A
13b	14	92.069	92.046	825	21.1	0.1	0.013	95.201	94.902	0.891	0.476	0.58	1.2	0.901	11.98	93.795	93.795	N/A
14	15	92.016	91.999	825	15.5	0.1	0.013	94.902	94.964	0.891	0.476	0.58	1.2	0.954	11.98	93.795	93.794	1.107
15	104b	91.810	91.793	1200	15.5	0.1	0.013	94.964	94.500	1.143	1.293	1.67	1.3	0.784	11.97	93.794	93.794	1.170
16	17	92.602	92.499	600	68.5	0.2	0.013	94.979	95.298	0.841	0.238	0.33	1.4	1.431	11.95	94.633	94.492	0.346
17	17a	92.461	92.373	675	58.7	0.2	0.013	95.298	95.298	0.910	0.326	0.32	1.0	1.356	11.95	94.492	94.430	0.806
17a	18	92.373	92.363	675	6.4	0.2	0.013	95.298	95.030	0.910	0.326	0.42	1.3	1.382	11.97	94.430	94.392	N/A
18	19	92.333	92.317	675	10.5	0.2	0.013	95.030	95.094	0.910	0.326	0.42	1.3	1.384	11.97	94.392	94.355	0.638
19	23	92.287	92.205	675	55.0	0.2	0.013	95.094	95.383	0.910	0.326	0.42	1.3	1.393	11.97	94.355	94.196	0.739
20	20a	92.442	92.427	675	10.1	0.2	0.013	95.562	95.562	0.910	0.326	0.41	1.2	1.438	12.00	94.555	94.533	1.007
20	20b	93.147	92.935	300	53.0	0.4	0.013	95.562	95.562	0.865	0.061	0.02	0.3	1.108	11.92	94.555	94.558	1.007
20a	21	92.427	92.327	675	66.9	0.2	0.013	95.562	95.128	0.910	0.326	0.42	1.3	1.431	12.00	94.533	94.380	N/A
20b	24	92.935	92.755	300	45.0	0.4	0.013	95.562	95.243	0.865	0.061	0.07	1.1	1.323	12.01	94.558	94.348	N/A
21	21a	92.252	92.228	825	22.2	0.1	0.013	95.128	95.198	0.891	0.476	0.42	0.9	1.303	12.00	94.380	94.363	0.748
21a	22	92.228	92.181	825	42.3	0.1	0.013	95.198	95.198	0.891	0.476	0.58	1.2	1.310	12.00	94.363	94.273	N/A
22	23	92.151	92.130	825	19.5	0.1	0.013	95.198	95.383	0.891	0.476	0.58	1.2	1.297	12.00	94.273	94.196	0.925
23	105b	92.092	92.059	900	26.5	0.1	0.013	95.383	94.500	0.944	0.600	0.98	1.6	1.204	11.97	94.196	94.026	1.187
24	24a	92.605	92.572	600	22.2	0.2	0.013	95.243	95.320	0.841	0.238	0.07	0.3	1.143	12.01	94.348	94.344	0.895

Table C-1B: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
24a	25	92.572	92.459	600	74.8	0.2	0.013	95.320	95.330	0.841	0.238	0.24	1.0	1.172	12.01	94.344	94.194	N/A
25	25a	92.234	92.230	1050	3.2	0.1	0.013	95.330	95.320	1.046	0.906	1.03	1.1	0.910	12.01	94.194	94.188	1.136
25a	26	92.230	92.152	1050	71.8	0.1	0.013	95.320	95.212	1.046	0.906	1.15	1.3	0.908	12.01	94.188	94.072	N/A
26	26a	92.077	92.032	1200	41.3	0.1	0.013	95.212	95.352	1.143	1.293	1.25	1.0	0.795	12.01	94.072	94.037	1.140
26a	26b	92.032	92.007	1200	22.9	0.1	0.013	95.352	95.352	1.143	1.293	1.28	1.0	0.805	12.01	94.037	94.018	N/A
26b	27	92.007	91.988	1200	16.8	0.1	0.013	95.352	95.352	1.143	1.293	1.43	1.1	0.811	11.98	94.018	93.911	N/A
27	27a	92.856	92.796	300	17.1	0.4	0.013	95.352	95.352	0.809	0.057	-0.04	-0.7	0.755	12.26	93.911	93.954	1.441
27	27b	91.928	91.910	1200	16.8	0.1	0.013	95.352	95.352	1.143	1.293	1.43	1.1	0.783	11.98	93.911	93.891	1.441
27a	29	92.796	92.623	300	49.4	0.4	0.013	95.352	95.352	0.809	0.057	0.08	1.3	0.858	11.98	93.954	94.083	N/A
27b	107b	91.910	91.846	1200	58.2	0.1	0.013	95.352	95.232	1.143	1.293	1.51	1.2	0.781	11.98	93.891	93.797	N/A
29	111b	91.588	91.542	1650	41.5	0.1	0.013	95.352	95.502	1.414	3.023	5.32	1.8	0.845	12.00	94.083	93.901	1.269
30	30a	92.746	92.561	450	74.2	0.3	0.013	95.372	95.372	0.896	0.143	-0.08	-0.5	0.923	11.97	94.119	94.163	1.253
30	31	92.662	92.542	300	12.0	1.0	0.013	95.372	95.212	1.368	0.097	0.08	0.8	1.157	11.97	94.119	94.050	1.253
30a	26	92.561	92.542	450	43.3	0.3	0.013	95.372	95.212	0.896	0.143	0.14	0.9	1.152	11.97	94.163	94.072	N/A
31	31a	92.429	92.327	525	51.0	0.2	0.013	95.212	95.212	0.888	0.192	0.08	0.4	1.096	11.98	94.050	94.040	1.162
31a	32	92.327	92.301	525	13.0	0.2	0.013	95.212	94.974	0.888	0.192	0.28	1.4	1.188	11.97	94.040	93.971	N/A
32	33	92.271	92.246	525	12.5	0.2	0.013	94.974	95.049	0.888	0.192	0.28	1.4	1.175	11.97	93.971	93.904	1.003
33	330	92.216	92.146	525	35.0	0.2	0.013	95.049	95.230	0.888	0.192	0.28	1.4	1.163	11.97	93.904	93.798	1.145
104b	Pond1	91.763	91.700	1200	57.5	0.1	0.013	94.500	95.500	1.143	1.293	1.67	1.3	0.831	11.97	93.794	93.793	0.706
105b	106b	92.029	91.960	900	62.5	0.1	0.013	94.500	94.500	0.944	0.600	0.98	1.6	1.097	11.97	94.026	93.863	0.474
106b	108b	91.930	91.854	900	69.5	0.1	0.013	94.500	94.218	0.944	0.600	0.98	1.6	1.033	11.97	93.863	93.796	0.637
107b	1070b	91.786	91.778	1200	7.0	0.1	0.013	95.232	95.055	1.143	1.293	1.51	1.2	0.811	11.98	93.797	93.797	1.435
108b	109b	91.629	91.617	1350	10.5	0.1	0.013	94.218	94.500	1.237	1.770	2.76	1.6	0.817	11.97	93.796	93.793	0.422
109b	Pond1	91.557	91.550	1350	6.0	0.1	0.013	94.500	95.500	1.237	1.770	2.76	1.6	0.886	11.97	93.793	93.793	0.707
111b	Pond1	91.522	91.450	1650	38.0	0.2	0.013	95.502	95.500	1.858	3.973	5.40	1.4	0.729	11.90	93.901	93.793	1.601
200	201	93.286	93.180	300	12.5	0.9	0.013	95.389	95.314	1.261	0.089	-0.05	-0.5	0.493	11.89	94.079	94.080	1.310
200	202	93.289	93.084	300	58.5	0.4	0.013	95.389	95.259	0.809	0.057	-0.03	-0.4	0.490	12.25	94.079	94.080	1.310
201	201a	93.030	92.900	450	29.6	0.4	0.013	95.314	95.314	1.189	0.189	-0.05	-0.3	0.600	11.89	94.080	94.080	1.234
201a	8	92.900	92.500	450	90.9	0.4	0.013	95.314	95.040	1.189	0.189	0.12	0.6	0.730	11.96	94.080	93.984	N/A
202	202a	93.054	93.050	300	1.2	0.4	0.013	95.259	95.296	0.809	0.057	-0.04	-0.6	0.726	11.88	94.080	94.081	1.179
202a	203	93.050	93.012	300	10.8	0.4	0.013	95.296	95.296	0.809	0.057	0.09	1.6	0.731	11.97	94.081	93.962	N/A
203	204	92.862	92.677	450	92.5	0.2	0.013	95.296	95.110	0.802	0.128	0.09	0.7	0.650	11.97	93.962	93.887	1.334
204	204a	92.511	92.463	600	21.9	0.2	0.013	95.110	95.250	1.019	0.288	0.09	0.3	0.776	11.97	93.887	93.884	1.223
204a	204b	92.463	92.324	600	63.0	0.2	0.013	95.250	95.250	1.019	0.288	0.36	1.2	0.821	11.97	93.884	93.796	N/A
204b	13	92.324	92.290	600	15.6	0.2	0.013	95.250	95.250	1.019	0.288	0.39	1.3	0.872	11.97	93.796	93.796	N/A
205	210	93.210	93.060	450	75.0	0.2	0.013	95.493	95.671	0.802	0.128	0.09	0.7	1.355	12.01	95.015	94.953	0.478
206	206a	93.320	93.316	375	1.5	0.3	0.013	95.468	95.493	0.869	0.096	-0.13	-1.3	1.352	11.87	95.047	95.047	0.421
206a	205	93.316	93.285	375	10.0	0.3	0.013	95.493	95.493	0.869	0.096	0.09	1.0	1.356	11.86	95.047	95.015	N/A
207	206	93.598	93.395	300	58.0	0.4	0.013	95.923	95.468	0.809	0.057	-0.06	-1.0	1.141	11.88	95.039	95.047	0.884

Table C-1B: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
208	207	93.700	93.658	300	12.0	0.4	0.013	95.851	95.923	0.809	0.057	-0.06	-1.0	1.033	11.89	95.033	95.039	0.818
208	208a	93.672	93.294	375	44.5	0.9	0.013	95.851	95.851	1.464	0.162	-0.05	-0.3	0.986	11.88	95.033	95.027	0.818
208a	209	93.294	92.949	375	40.5	0.9	0.013	95.851	95.614	1.464	0.162	0.14	0.8	1.358	12.01	95.027	94.829	N/A
209	212	92.724	92.639	600	56.5	0.2	0.013	95.614	95.238	0.841	0.238	0.31	1.3	1.505	11.95	94.829	94.700	0.785
210	211	93.030	93.007	450	11.5	0.2	0.013	95.671	95.601	0.802	0.128	0.09	0.7	1.473	12.01	94.953	94.939	0.718
211	211a	92.932	92.871	525	30.3	0.2	0.013	95.601	95.614	0.888	0.192	0.09	0.5	1.482	12.02	94.939	94.929	0.662
211a	209	92.871	92.799	525	36.2	0.2	0.013	95.614	95.614	0.888	0.192	0.18	1.0	1.533	11.98	94.929	94.829	N/A
212	212a	92.564	92.553	675	7.3	0.2	0.013	95.238	95.550	0.910	0.326	0.31	0.9	1.461	11.95	94.700	94.691	0.538
212a	20	92.553	92.460	675	62.2	0.2	0.013	95.550	95.562	0.910	0.326	0.41	1.3	1.463	11.95	94.691	94.555	N/A
213	214	93.791	93.638	300	30.5	0.5	0.013	96.071	95.908	0.967	0.068	0.07	1.0	1.262	11.91	95.353	95.256	0.718
214	214a	93.338	93.284	600	36.3	0.2	0.013	95.908	95.918	0.841	0.238	0.11	0.5	1.318	11.97	95.256	95.244	0.652
214a	215	93.284	93.232	600	34.2	0.2	0.013	95.918	95.849	0.841	0.238	0.23	0.9	1.360	11.94	95.244	95.208	N/A
215	215a	93.212	93.138	600	49.2	0.2	0.013	95.849	95.849	0.841	0.238	0.22	0.9	1.396	11.94	95.208	95.155	0.641
215a	220	93.138	93.120	600	11.8	0.2	0.013	95.849	95.723	0.841	0.238	0.29	1.2	1.417	11.97	95.155	95.063	N/A
216	216a	93.869	93.679	300	54.4	0.4	0.013	95.972	95.972	0.809	0.057	-0.06	-1.0	1.112	11.91	95.281	95.298	0.691
216	217	93.870	93.726	300	12.0	1.2	0.013	95.972	95.900	1.499	0.106	-0.09	-0.8	1.111	11.91	95.281	95.274	0.691
216a	214	93.679	93.638	300	11.6	0.4	0.013	95.972	95.908	0.809	0.057	-0.08	-1.3	1.319	11.90	95.298	95.256	N/A
217	217a	93.576	93.494	450	40.9	0.2	0.013	95.900	95.900	0.802	0.128	-0.12	-1.0	1.248	11.90	95.274	95.267	0.626
217a	218	93.494	93.345	450	74.6	0.2	0.013	95.900	95.677	0.802	0.128	0.10	0.8	1.323	11.98	95.267	95.178	N/A
218	219	93.315	93.292	450	11.5	0.2	0.013	95.677	95.594	0.802	0.128	0.11	0.8	1.413	12.01	95.178	95.159	0.499
219	219a	93.254	93.217	525	18.4	0.2	0.013	95.594	95.733	0.888	0.192	0.11	0.6	1.380	12.00	95.159	95.152	0.435
219a	220	93.217	93.121	525	48.1	0.2	0.013	95.733	95.723	0.888	0.192	0.20	1.1	1.410	12.00	95.152	95.063	N/A
220	220a	93.045	92.918	675	63.4	0.2	0.013	95.723	95.733	1.051	0.376	0.48	1.3	1.343	11.97	95.063	94.869	0.660
220a	221	92.918	92.913	675	2.6	0.2	0.013	95.733	95.466	1.051	0.376	0.49	1.3	1.276	11.97	94.869	94.742	N/A
221	221a	92.838	92.772	750	33.1	0.2	0.013	95.466	95.515	1.127	0.498	0.54	1.1	1.154	11.97	94.742	94.674	0.724
221a	222	92.772	92.600	750	85.9	0.2	0.013	95.515	95.515	1.127	0.498	0.65	1.3	1.152	11.96	94.674	94.354	N/A
222	223	92.525	92.505	825	13.5	0.2	0.013	95.515	95.409	1.040	0.556	0.65	1.2	1.004	11.96	94.354	94.300	1.161
223	223a	92.430	92.369	900	32.0	0.2	0.013	95.409	95.409	1.240	0.789	0.65	0.8	0.970	11.96	94.300	94.261	1.109
223a	223b	92.369	92.316	900	27.8	0.2	0.013	95.409	95.409	1.240	0.789	0.79	1.0	0.992	11.96	94.261	94.211	N/A
223b	25	92.316	92.300	900	8.7	0.2	0.013	95.409	95.330	1.240	0.789	0.80	1.0	0.995	11.96	94.211	94.194	N/A
224	221	93.432	93.288	300	41.0	0.4	0.013	95.273	95.466	0.809	0.057	0.06	1.0	1.114	12.17	94.846	94.742	0.427
330	1070b	92.116	92.096	525	10.0	0.2	0.014	95.230	95.055	0.825	0.179	0.28	1.5	1.157	11.98	93.798	93.797	1.432
1070b	108b	91.758	91.709	1200	44.5	0.1	0.014	95.055	94.218	1.062	1.201	1.79	1.5	0.839	11.98	93.797	93.796	1.258
1600	1600a	92.658	92.635	600	15.5	0.2	0.013	95.090	95.090	0.841	0.238	0.20	0.8	1.411	11.92	94.669	94.651	0.421
1600a	16	92.635	92.622	600	8.5	0.2	0.013	95.090	94.979	0.841	0.238	0.27	1.1	1.416	11.97	94.651	94.633	N/A
Pond1	Out	N/A	N/A	N/A	N/A	N/A	N/A	95.500	94.500	N/A	N/A	4.15	N/A	N/A	13.03	93.793	92.350	1.707
250	252	93.433	93.270	300	46.5	0.4	0.013	95.380	95.390	0.809	0.057	0.07	1.1	1.484	12.27	95.217	95.147	0.163
251	251a	93.563	93.356	300	46.1	0.5	0.013	95.530	95.530	0.918	0.065	-0.07	-1.1	1.426	12.25	95.289	95.315	0.241
251	251b	93.320	93.079	300	48.2	0.5	0.013	95.530	95.500	0.967	0.068	0.05	0.7	1.669	11.93	95.289	95.187	0.241

Table C-1B: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
251	251c	93.625	93.607	375	6.0	0.3	0.013	95.530	95.530	0.869	0.096	0.08	0.8	1.289	12.24	95.289	95.291	0.241
251a	252	93.356	93.270	300	18.9	0.5	0.013	95.530	95.390	0.918	0.065	0.07	1.1	1.659	12.01	95.315	95.147	N/A
251b	255	93.079	92.980	300	19.8	0.5	0.013	95.500	95.330	0.967	0.068	0.09	1.4	1.808	11.90	95.187	95.050	N/A
251c	251d	93.607	93.526	375	26.9	0.3	0.013	95.530	95.530	0.869	0.096	0.09	0.9	1.309	12.22	95.291	95.304	N/A
251e	263	93.450	93.421	375	9.7	0.3	0.013	95.530	95.630	0.869	0.096	0.14	1.5	1.503	12.22	95.328	95.365	N/A
252	252a	93.045	92.914	525	52.2	0.3	0.013	95.390	95.390	0.993	0.215	0.10	0.5	1.577	11.93	95.147	95.118	0.243
252a	253	92.914	92.872	525	16.8	0.3	0.013	95.390	95.180	0.993	0.215	0.20	0.9	1.679	12.23	95.118	95.096	N/A
253	253a	92.797	92.693	600	69.3	0.2	0.013	95.180	95.180	0.841	0.238	0.20	0.8	1.699	12.23	95.096	95.053	0.084
253a	254	92.693	92.675	600	11.7	0.2	0.013	95.180	95.180	0.841	0.238	0.26	1.1	1.760	12.25	95.053	95.018	N/A
254	254a	92.615	92.568	600	31.4	0.2	0.013	95.180	95.230	0.841	0.238	0.34	1.4	1.803	12.25	95.018	94.996	0.162
254	254c	93.239	93.106	300	29.5	0.5	0.013	95.180	95.180	0.918	0.065	-0.13	-2.1	1.479	12.36	95.018	95.008	0.162
254a	257	92.568	92.562	600	4.1	0.2	0.013	95.230	95.230	0.841	0.238	0.36	1.5	1.828	12.25	94.996	94.992	N/A
259a	257	93.017	92.977	300	7.9	0.5	0.013	95.280	95.230	0.967	0.068	0.06	0.9	1.709	12.22	95.026	94.992	N/A
254c	273	93.106	92.964	300	31.5	0.5	0.013	95.180	95.140	0.918	0.065	-0.10	-1.5	1.602	12.38	95.008	94.862	N/A
255	255a	92.830	92.701	450	64.5	0.2	0.013	95.330	95.330	0.802	0.128	0.10	0.7	1.770	12.15	95.050	94.979	0.280
255a	256	92.701	92.667	450	17.0	0.2	0.013	95.330	95.260	0.802	0.128	0.15	1.2	1.828	12.18	94.979	94.952	N/A
256	256a	92.422	92.402	675	13.0	0.2	0.013	95.260	95.260	0.910	0.326	0.54	1.6	1.855	12.20	94.952	94.930	0.308
256a	261	92.402	92.372	675	20.0	0.2	0.013	95.260	95.250	0.910	0.326	0.56	1.7	1.853	12.20	94.930	94.900	N/A
251d	251e	93.526	93.450	375	25.4	0.3	0.013	95.530	95.530	0.869	0.096	0.12	1.2	1.403	12.22	95.304	95.328	N/A
258	258a	93.104	92.887	300	54.2	0.4	0.013	95.450	95.450	0.865	0.061	0.03	0.4	1.634	12.15	95.038	95.010	0.412
258a	261	92.887	92.840	300	11.8	0.4	0.013	95.450	95.250	0.865	0.061	0.07	1.2	1.823	11.96	95.010	94.900	N/A
259	259a	93.152	93.017	300	27.1	0.5	0.013	95.280	95.280	0.967	0.068	0.05	0.7	1.583	11.94	95.035	95.026	0.245
257	256	92.542	92.497	600	30.0	0.2	0.013	95.230	95.260	0.841	0.238	0.40	1.7	1.850	12.24	94.992	94.952	0.238
260	260a	92.954	92.866	375	25.1	0.4	0.013	95.320	95.320	0.939	0.104	-0.03	-0.3	1.587	11.87	94.916	94.918	0.404
260a	261	92.866	92.840	300	7.4	0.4	0.013	95.320	95.250	0.809	0.057	0.07	1.3	1.752	12.14	94.918	94.900	N/A
261	265	92.297	92.262	825	35.0	0.1	0.013	95.250	95.550	0.849	0.454	0.65	1.4	1.778	12.20	94.900	94.831	0.350
263	263a	92.209	92.176	1500	22.2	0.2	0.013	95.630	95.630	1.549	2.738	4.09	1.5	1.657	12.00	95.366	95.286	0.264
263a	264	92.176	92.096	1500	52.8	0.2	0.013	95.630	95.530	1.549	2.738	4.13	1.5	1.610	12.00	95.286	95.104	N/A
264	264a	92.076	92.033	1500	28.5	0.2	0.013	95.530	95.530	1.549	2.738	4.13	1.5	1.528	12.00	95.104	95.003	0.426
264a	265	92.033	91.963	1500	46.5	0.2	0.013	95.530	95.550	1.549	2.738	4.27	1.6	1.470	12.00	95.003	94.831	N/A
265	265a	91.924	91.816	1500	53.8	0.2	0.013	95.550	95.550	1.789	3.161	4.70	1.5	1.407	11.94	94.831	94.592	0.719
265a	266	91.816	91.778	1500	19.2	0.2	0.013	95.550	95.540	1.789	3.161	4.76	1.5	1.276	11.95	94.592	94.151	N/A
266	266a	91.568	91.509	1500	29.7	0.2	0.013	95.540	95.550	1.789	3.161	4.76	1.5	1.083	11.95	94.151	93.985	1.389
266a	267	91.509	91.429	1500	39.8	0.2	0.013	95.550	95.630	1.789	3.161	4.79	1.5	0.976	11.97	93.985	93.835	N/A
267	Pond1	91.429	91.350	1500	39.5	0.2	0.013	95.630	95.500	1.789	3.161	4.79	1.5	0.906	11.97	93.835	93.793	1.795
270	270a	92.828	92.710	900	59.1	0.2	0.013	95.500	95.500	1.273	0.810	1.36	1.7	1.843	11.87	95.571	95.315	-0.071
270a	271	92.710	92.665	900	22.4	0.2	0.013	95.500	95.320	1.273	0.810	1.40	1.7	1.705	11.87	95.315	95.215	N/A
271	271a	92.643	92.503	900	46.6	0.3	0.013	95.320	95.320	1.559	0.992	1.39	1.4	1.672	11.87	95.215	95.010	0.105
271a	273	92.503	92.416	900	28.9	0.3	0.013	95.320	95.140	1.559	0.992	1.40	1.4	1.607	11.87	95.010	94.862	N/A

Table C-1B: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
273	273a	92.364	92.313	900	25.5	0.2	0.013	95.140	95.140	1.273	0.810	1.37	1.7	1.598	12.01	94.862	94.726	0.278
273a	275	92.313	92.298	900	7.6	0.2	0.013	95.140	95.200	1.273	0.810	1.41	1.7	1.513	11.91	94.726	94.672	N/A
275	276	92.268	92.209	900	29.5	0.2	0.013	95.200	95.620	1.273	0.810	1.41	1.7	1.504	11.91	94.672	94.441	0.528
276	277	92.179	92.148	900	15.5	0.2	0.013	95.620	95.500	1.273	0.810	1.41	1.7	1.362	11.91	94.441	94.305	1.179
277	277a	92.067	91.964	975	51.7	0.2	0.013	95.500	95.630	1.342	1.002	1.52	1.5	1.263	11.92	94.305	94.155	1.195
277a	277b	91.964	91.869	975	47.5	0.2	0.013	95.630	95.630	1.342	1.002	1.58	1.6	1.216	11.92	94.155	94.016	N/A
277b	278	91.869	91.842	975	13.3	0.2	0.013	95.630	95.630	1.342	1.002	1.62	1.6	1.172	11.95	94.016	93.891	N/A
278	279	91.782	91.775	975	3.5	0.2	0.013	95.630	95.630	1.342	1.002	1.62	1.6	1.134	11.95	93.891	93.823	1.739
279	Pond1	91.715	91.650	975	32.5	0.2	0.013	95.630	95.500	1.342	1.002	1.62	1.6	1.133	11.97	93.823	93.793	1.807
280	280a	91.825	91.714	1650	73.8	0.2	0.013	95.450	95.510	1.651	3.530	3.24	0.9	0.594	13.75	94.069	93.974	1.381
280a	281	91.714	91.657	1650	38.2	0.2	0.013	95.510	95.510	1.651	3.530	3.24	0.9	0.610	13.75	93.974	93.924	N/A
281	Pond1	91.657	91.600	1650	38.0	0.2	0.013	95.510	95.500	1.651	3.530	3.24	0.9	0.617	13.75	93.924	93.793	1.586
328	263	92.425	92.359	1350	65.5	0.1	0.013	95.700	95.630	1.179	1.688	2.59	1.5	1.750	12.00	95.525	95.366	0.175
329	329a	92.534	92.465	1050	27.4	0.3	0.013	95.700	95.700	1.577	1.365	1.98	1.5	2.141	12.13	95.725	95.631	-0.025
329a	263	92.465	92.434	1050	12.6	0.3	0.013	95.700	95.630	1.577	1.365	2.00	1.5	2.116	12.13	95.631	95.366	N/A
101	102	94.092	93.958	600	95.5	0.1	0.013	97.120	97.010	0.813	0.230	0.69	3.0	2.500	12.42	97.192	97.035	-0.072
102	103	93.883	93.783	675	83.5	0.1	0.013	97.010	96.880	0.814	0.291	0.91	3.1	2.477	12.32	97.035	96.887	-0.025
103	106	93.708	93.664	750	40.0	0.1	0.013	96.880	96.820	0.836	0.369	0.92	2.5	2.428	12.33	96.886	96.846	-0.006
106	109	93.589	93.544	825	45.0	0.1	0.013	96.820	96.750	0.849	0.454	1.31	2.9	2.432	12.28	96.846	96.755	-0.026
109	111	93.469	93.391	900	78.0	0.1	0.013	96.750	96.640	0.900	0.572	1.33	2.3	2.385	12.30	96.754	96.652	-0.004
111	112	93.241	93.142	1050	98.5	0.1	0.013	96.640	96.500	0.997	0.864	1.39	1.6	2.357	12.31	96.648	96.524	-0.008
112	113	92.992	92.863	1200	129.0	0.1	0.013	96.500	96.310	1.090	1.233	2.19	1.8	2.332	12.26	96.524	96.326	-0.024
113	114	92.833	92.754	1200	78.5	0.1	0.013	96.310	96.190	1.090	1.233	2.67	2.2	2.293	12.17	96.326	96.211	-0.016
114	122	92.604	92.524	1350	80.0	0.1	0.013	96.190	96.070	1.179	1.688	2.95	1.7	2.257	12.19	96.211	96.090	-0.021
122	126	92.494	92.287	1350	122.0	0.2	0.013	96.070	95.770	1.537	2.201	3.57	1.6	2.244	12.09	96.088	95.785	-0.018
126	127	92.212	92.111	1500	91.5	0.1	0.013	95.770	95.630	1.327	2.344	4.28	1.8	2.074	12.14	95.786	95.631	-0.016
127	130	92.081	91.980	1500	91.5	0.1	0.013	95.630	95.490	1.327	2.344	4.35	1.9	2.048	12.14	95.629	95.043	0.001
130	138	91.905	91.840	1650	64.5	0.1	0.013	95.490	95.140	1.348	2.882	4.56	1.6	1.488	11.92	95.043	94.641	0.447
138	139	91.780	91.730	1650	50.0	0.1	0.013	95.140	95.400	1.348	2.882	5.26	1.8	1.211	12.00	94.641	94.402	0.499
139	140	91.670	91.656	1650	14.0	0.1	0.013	95.400	95.400	1.348	2.882	5.26	1.8	1.082	12.00	94.402	94.308	0.998
140	29	91.651	91.608	1650	43.4	0.1	0.013	95.400	95.352	1.348	2.882	5.25	1.8	1.007	12.00	94.308	94.083	1.092

Note: (1) A negative surcharge implies that the pipe is not flowing full

(2) Freeboard between upstream hydraulic gradeline elevation and upstream manhole cover elevation.

(3) Ponding allowed above manholes in undetailed future development areas to represent road surface storage above catchbasins.

Table C-1C: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [(1)] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [(2)] (m)
1	2	93.328	93.172	300	44.5	0.4	0.013	95.566	95.449	0.809	0.057	-0.07	-1.2	0.976	0.96	94.604	94.602	0.962
2	2a	93.134	92.925	375	69.6	0.3	0.013	95.449	95.449	0.869	0.096	-0.09	-0.9	1.093	0.95	94.602	94.592	0.847
2a	3	92.925	92.857	375	22.9	0.3	0.013	95.449	95.220	0.869	0.096	0.12	1.3	1.292	1.02	94.592	94.474	N/A
3	4	92.827	92.787	375	13.5	0.3	0.013	95.220	95.300	0.869	0.096	0.12	1.2	1.272	1.02	94.474	94.395	0.746
4	7	92.757	92.561	375	65.5	0.3	0.013	95.300	95.174	0.869	0.096	0.12	1.2	1.263	1.11	94.395	94.125	0.905
5	5a	92.986	92.957	300	8.3	0.4	0.013	95.298	95.378	0.809	0.057	-0.02	-0.4	1.203	0.94	94.489	94.485	0.809
5a	6	92.957	92.797	300	45.7	0.4	0.013	95.378	95.378	0.809	0.057	0.08	1.5	1.228	0.95	94.485	94.261	N/A
6	6a	92.609	92.499	675	73.5	0.2	0.013	95.378	95.378	0.910	0.326	0.08	0.2	0.977	1.01	94.261	94.254	1.117
6a	7	92.499	92.448	675	34.0	0.2	0.013	95.378	95.174	0.910	0.326	0.41	1.3	1.080	0.95	94.254	94.125	N/A
7	7a	92.373	92.313	750	54.4	0.1	0.013	95.174	95.174	0.836	0.369	0.49	1.3	1.002	1.10	94.125	94.022	1.049
7a	8	92.313	92.300	750	11.6	0.1	0.013	95.174	95.040	0.836	0.369	0.61	1.6	0.959	1.00	94.022	93.865	N/A
8	8a	92.225	92.211	900	13.1	0.1	0.013	95.040	95.199	0.944	0.600	0.77	1.3	0.740	0.99	93.865	93.843	1.175
8a	11	92.211	92.144	900	60.4	0.1	0.013	95.199	95.199	0.944	0.600	0.90	1.5	0.732	1.00	93.843	93.804	N/A
9	10	92.912	92.614	300	59.5	0.5	0.013	95.652	94.963	0.967	0.068	0.04	0.5	0.923	1.01	94.135	94.076	1.517
10	10a	92.501	92.486	525	6.1	0.3	0.013	94.963	95.199	0.993	0.215	0.04	0.2	1.050	1.09	94.076	94.076	0.887
10a	11	92.486	92.331	525	61.9	0.3	0.013	95.199	95.199	0.993	0.215	0.28	1.3	1.064	1.10	94.075	93.804	N/A
11	11a	92.106	92.040	975	59.6	0.1	0.013	95.199	95.199	0.996	0.743	1.16	1.6	0.723	1.00	93.804	93.803	1.395
11a	12	92.040	92.036	975	4.4	0.1	0.013	95.199	94.782	0.996	0.743	1.28	1.7	0.788	1.00	93.803	93.802	N/A
12	12a	92.006	91.963	975	39.2	0.1	0.013	94.782	94.964	0.996	0.743	1.28	1.7	0.821	1.00	93.802	93.801	0.980
12a	15	91.963	91.924	975	35.9	0.1	0.013	94.964	94.964	0.996	0.743	1.34	1.8	0.863	1.00	93.801	93.799	N/A
13	13a	92.160	92.156	825	3.3	0.1	0.013	95.250	95.201	0.891	0.476	0.47	1.0	0.817	0.99	93.802	93.802	1.448
13a	13b	92.156	92.069	825	79.1	0.1	0.013	95.201	95.201	0.891	0.476	0.51	1.1	0.820	0.99	93.801	93.801	N/A
13b	14	92.069	92.046	825	21.1	0.1	0.013	95.201	94.902	0.891	0.476	0.72	1.5	0.907	0.99	93.801	93.800	N/A
14	15	92.016	91.999	825	15.5	0.1	0.013	94.902	94.964	0.891	0.476	0.72	1.5	0.959	0.99	93.800	93.799	1.102
15	104b	91.810	91.793	1200	15.5	0.1	0.013	94.964	94.500	1.143	1.293	2.05	1.6	0.789	0.99	93.799	93.798	1.165
16	17	92.602	92.499	600	68.5	0.2	0.013	94.979	95.298	0.841	0.238	0.36	1.5	1.499	0.97	94.701	94.499	0.278
17	17a	92.461	92.373	675	58.7	0.2	0.013	95.298	95.298	0.910	0.326	0.35	1.1	1.362	0.97	94.498	94.413	0.800
17a	18	92.373	92.363	675	6.4	0.2	0.013	95.298	95.030	0.910	0.326	0.49	1.5	1.366	0.97	94.414	94.362	N/A
18	19	92.333	92.317	675	10.5	0.2	0.013	95.030	95.094	0.910	0.326	0.49	1.5	1.354	0.98	94.362	94.312	0.668
19	23	92.287	92.205	675	55.0	0.2	0.013	95.094	95.383	0.910	0.326	0.49	1.5	1.350	1.01	94.312	94.114	0.782
20	20a	92.442	92.427	675	10.1	0.2	0.013	95.562	95.562	0.910	0.326	0.46	1.4	1.469	1.05	94.586	94.556	0.976
20	20b	93.147	92.935	300	53.0	0.4	0.013	95.562	95.562	0.865	0.061	0.03	0.4	1.139	0.94	94.586	94.603	0.976
20a	21	92.427	92.327	675	66.9	0.2	0.013	95.562	95.128	0.910	0.326	0.48	1.5	1.454	1.05	94.556	94.351	N/A
20b	24	92.935	92.755	300	45.0	0.4	0.013	95.562	95.243	0.865	0.061	0.09	1.4	1.368	0.95	94.603	94.334	N/A
21	21a	92.252	92.228	825	22.2	0.1	0.013	95.128	95.198	0.891	0.476	0.48	1.0	1.274	1.05	94.351	94.327	0.777
21a	22	92.228	92.181	825	42.3	0.1	0.013	95.198	95.198	0.891	0.476	0.65	1.4	1.274	1.04	94.327	94.211	N/A
22	23	92.151	92.130	825	19.5	0.1	0.013	95.198	95.383	0.891	0.476	0.64	1.4	1.235	1.04	94.211	94.114	0.987
23	105b	92.092	92.059	900	26.5	0.1	0.013	95.383	94.500	0.944	0.600	1.11	1.9	1.122	1.01	94.114	93.908	1.269
24	24a	92.605	92.572	600	22.2	0.2	0.013	95.243	95.320	0.841	0.238	0.09	0.4	1.129	0.95	94.334	94.330	0.909

Table C-1C: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
24a	25	92.572	92.459	600	74.8	0.2	0.013	95.320	95.330	0.841	0.238	0.29	1.2	1.158	0.95	94.330	94.156	N/A
25	25a	92.234	92.230	1050	3.2	0.1	0.013	95.330	95.320	1.046	0.906	1.17	1.3	0.872	1.08	94.156	94.148	1.174
25a	26	92.230	92.152	1050	71.8	0.1	0.013	95.320	95.212	1.046	0.906	1.29	1.4	0.868	1.11	94.148	93.993	N/A
26	26a	92.077	92.032	1200	41.3	0.1	0.013	95.212	95.352	1.143	1.293	1.42	1.1	0.716	1.01	93.993	93.941	1.219
26a	26b	92.032	92.007	1200	22.9	0.1	0.013	95.352	95.352	1.143	1.293	1.47	1.1	0.709	1.01	93.941	93.911	N/A
26b	27	92.007	91.988	1200	16.8	0.1	0.013	95.352	95.352	1.143	1.293	1.66	1.3	0.704	1.01	93.911	93.807	N/A
27	27a	92.856	92.796	300	17.1	0.4	0.013	95.352	95.352	0.809	0.057	-0.11	-1.9	0.651	0.93	93.807	93.806	1.545
27	27b	91.928	91.910	1200	16.8	0.1	0.013	95.352	95.352	1.143	1.293	1.67	1.3	0.679	1.00	93.807	93.807	1.545
27a	29	92.796	92.623	300	49.4	0.4	0.013	95.352	95.352	0.809	0.057	0.09	1.6	0.710	1.00	93.806	93.959	N/A
27b	107b	91.910	91.846	1200	58.2	0.1	0.013	95.352	95.232	1.143	1.293	1.80	1.4	0.697	1.01	93.807	93.803	N/A
29	111b	91.588	91.542	1650	41.5	0.1	0.013	95.352	95.502	1.414	3.023	6.74	2.2	0.721	0.94	93.959	93.826	1.393
30	30a	92.746	92.561	450	74.2	0.3	0.013	95.372	95.372	0.896	0.143	-0.10	-0.7	0.854	1.02	94.050	94.116	1.322
30	31	92.662	92.542	300	12.0	1.0	0.013	95.372	95.212	1.368	0.097	0.10	1.0	1.088	1.02	94.050	93.938	1.322
30a	26	92.561	92.542	450	43.3	0.3	0.013	95.372	95.212	0.896	0.143	0.21	1.5	1.105	0.94	94.116	93.993	N/A
31	31a	92.429	92.327	525	51.0	0.2	0.013	95.212	95.212	0.888	0.192	0.10	0.5	0.984	1.01	93.938	93.922	1.274
31a	32	92.327	92.301	525	13.0	0.2	0.013	95.212	94.974	0.888	0.192	0.32	1.7	1.070	1.00	93.922	93.828	N/A
32	33	92.271	92.246	525	12.5	0.2	0.013	94.974	95.049	0.888	0.192	0.32	1.7	1.032	1.00	93.828	93.807	1.146
33	330	92.216	92.146	525	35.0	0.2	0.013	95.049	95.230	0.888	0.192	0.32	1.7	1.066	1.01	93.807	93.804	1.242
104b	Pond1	91.763	91.700	1200	57.5	0.1	0.013	94.500	95.500	1.143	1.293	2.05	1.6	0.835	0.99	93.798	93.798	0.702
105b	106b	92.029	91.960	900	62.5	0.1	0.013	94.500	94.500	0.944	0.600	1.11	1.9	0.979	1.01	93.908	93.807	0.592
106b	108b	91.930	91.854	900	69.5	0.1	0.013	94.500	94.218	0.944	0.600	1.11	1.9	0.977	1.01	93.807	93.801	0.693
107b	1070b	91.786	91.778	1200	7.0	0.1	0.013	95.232	95.055	1.143	1.293	1.80	1.4	0.817	1.01	93.803	93.803	1.429
108b	109b	91.629	91.617	1350	10.5	0.1	0.013	94.218	94.500	1.237	1.770	3.22	1.8	0.822	1.01	93.801	93.798	0.417
109b	Pond1	91.557	91.550	1350	6.0	0.1	0.013	94.500	95.500	1.237	1.770	3.22	1.8	0.891	1.01	93.798	93.798	0.702
111b	Pond1	91.522	91.450	1650	38.0	0.2	0.013	95.502	95.500	1.858	3.973	7.10	1.8	0.654	0.93	93.826	93.798	1.676
200	201	93.286	93.180	300	12.5	0.9	0.013	95.389	95.314	1.261	0.089	-0.08	-0.9	0.565	0.96	94.151	94.154	1.238
200	202	93.289	93.084	300	58.5	0.4	0.013	95.389	95.259	0.809	0.057	-0.03	-0.4	0.562	1.01	94.151	94.142	1.238
201	201a	93.030	92.900	450	29.6	0.4	0.013	95.314	95.314	1.189	0.189	-0.08	-0.4	0.674	0.96	94.154	94.153	1.160
201a	8	92.900	92.500	450	90.9	0.4	0.013	95.314	95.040	1.189	0.189	0.17	0.9	0.803	0.99	94.153	93.865	N/A
202	202a	93.054	93.050	300	1.2	0.4	0.013	95.259	95.296	0.809	0.057	-0.04	-0.6	0.789	0.96	94.143	94.143	1.116
202a	203	93.050	93.012	300	10.8	0.4	0.013	95.296	95.296	0.809	0.057	0.13	2.2	0.793	1.00	94.143	93.940	N/A
203	204	92.862	92.677	450	92.5	0.2	0.013	95.296	95.110	0.802	0.128	0.12	1.0	0.628	0.99	93.940	93.805	1.356
204	204a	92.511	92.463	600	21.9	0.2	0.013	95.110	95.250	1.019	0.288	0.12	0.4	0.694	0.99	93.805	93.805	1.305
204a	204b	92.463	92.324	600	63.0	0.2	0.013	95.250	95.250	1.019	0.288	0.42	1.5	0.742	0.99	93.805	93.802	N/A
204b	13	92.324	92.290	600	15.6	0.2	0.013	95.250	95.250	1.019	0.288	0.46	1.6	0.878	0.99	93.802	93.802	N/A
205	210	93.210	93.060	450	75.0	0.2	0.013	95.493	95.671	0.802	0.128	0.12	0.9	1.460	0.92	95.120	95.052	0.373
206	206a	93.320	93.316	375	1.5	0.3	0.013	95.468	95.493	0.869	0.096	-0.08	-0.8	1.460	0.94	95.155	95.154	0.313
206a	205	93.316	93.285	375	10.0	0.3	0.013	95.493	95.493	0.869	0.096	0.13	1.4	1.463	0.93	95.154	95.120	N/A
207	206	93.598	93.395	300	58.0	0.4	0.013	95.923	95.468	0.809	0.057	-0.06	-1.0	1.246	0.95	95.144	95.155	0.779

Table C-1C: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
208	207	93.700	93.658	300	12.0	0.4	0.013	95.851	95.923	0.809	0.057	0.03	0.5	1.144	0.95	95.144	95.144	0.707
208	208a	93.672	93.294	375	44.5	0.9	0.013	95.851	95.851	1.464	0.162	-0.09	-0.5	1.097	0.95	95.144	95.141	0.707
208a	209	93.294	92.949	375	40.5	0.9	0.013	95.851	95.614	1.464	0.162	0.16	1.0	1.472	0.92	95.141	94.909	N/A
209	212	92.724	92.639	600	56.5	0.2	0.013	95.614	95.238	0.841	0.238	0.33	1.4	1.585	0.97	94.909	94.762	0.705
210	211	93.030	93.007	450	11.5	0.2	0.013	95.671	95.601	0.802	0.128	0.10	0.8	1.572	1.20	95.052	95.039	0.619
211	211a	92.932	92.871	525	30.3	0.2	0.013	95.601	95.614	0.888	0.192	0.10	0.5	1.582	1.23	95.039	95.029	0.562
211a	209	92.871	92.799	525	36.2	0.2	0.013	95.614	95.614	0.888	0.192	0.20	1.0	1.633	0.97	95.029	94.909	N/A
212	212a	92.564	92.553	675	7.3	0.2	0.013	95.238	95.550	0.910	0.326	0.33	1.0	1.523	1.04	94.762	94.751	0.476
212a	20	92.553	92.460	675	62.2	0.2	0.013	95.550	95.562	0.910	0.326	0.44	1.4	1.523	0.97	94.751	94.586	N/A
213	214	93.791	93.638	300	30.5	0.5	0.013	96.071	95.908	0.967	0.068	0.10	1.4	1.485	0.92	95.576	95.386	0.495
214	214a	93.338	93.284	600	36.3	0.2	0.013	95.908	95.918	0.841	0.238	0.12	0.5	1.448	0.99	95.386	95.372	0.522
214a	215	93.284	93.232	600	34.2	0.2	0.013	95.918	95.849	0.841	0.238	0.28	1.2	1.488	0.95	95.372	95.322	N/A
215	215a	93.212	93.138	600	49.2	0.2	0.013	95.849	95.849	0.841	0.238	0.27	1.1	1.510	0.94	95.322	95.255	0.527
215a	220	93.138	93.120	600	11.8	0.2	0.013	95.849	95.723	0.841	0.238	0.32	1.4	1.517	0.95	95.255	95.158	N/A
216	216a	93.869	93.679	300	54.4	0.4	0.013	95.972	95.972	0.809	0.057	-0.05	-0.9	1.249	0.94	95.418	95.437	0.554
216	217	93.870	93.726	300	12.0	1.2	0.013	95.972	95.900	1.499	0.106	-0.06	-0.6	1.248	0.94	95.418	95.411	0.554
216a	214	93.679	93.638	300	11.6	0.4	0.013	95.972	95.908	0.809	0.057	0.05	0.8	1.458	1.07	95.437	95.386	N/A
217	217a	93.576	93.494	450	40.9	0.2	0.013	95.900	95.900	0.802	0.128	-0.09	-0.7	1.385	0.93	95.411	95.412	0.489
217a	218	93.494	93.345	450	74.6	0.2	0.013	95.900	95.677	0.802	0.128	0.14	1.1	1.468	0.94	95.412	95.292	N/A
218	219	93.315	93.292	450	11.5	0.2	0.013	95.677	95.594	0.802	0.128	0.12	1.0	1.527	0.95	95.292	95.267	0.385
219	219a	93.254	93.217	525	18.4	0.2	0.013	95.594	95.733	0.888	0.192	0.12	0.6	1.488	0.95	95.267	95.255	0.327
219a	220	93.217	93.121	525	48.1	0.2	0.013	95.733	95.723	0.888	0.192	0.22	1.2	1.513	0.95	95.255	95.158	N/A
220	220a	93.045	92.918	675	63.4	0.2	0.013	95.723	95.733	1.051	0.376	0.53	1.4	1.438	0.95	95.158	94.949	0.565
220a	221	92.918	92.913	675	2.6	0.2	0.013	95.733	95.466	1.051	0.376	0.52	1.4	1.356	0.95	94.949	94.813	N/A
221	221a	92.838	92.772	750	33.1	0.2	0.013	95.466	95.515	1.127	0.498	0.58	1.2	1.225	0.95	94.813	94.732	0.653
221a	222	92.772	92.600	750	85.9	0.2	0.013	95.515	95.515	1.127	0.498	0.76	1.5	1.210	0.95	94.732	94.359	N/A
222	223	92.525	92.505	825	13.5	0.2	0.013	95.515	95.409	1.040	0.556	0.71	1.3	1.009	1.03	94.359	94.288	1.156
223	223a	92.430	92.369	900	32.0	0.2	0.013	95.409	95.409	1.240	0.789	0.72	0.9	0.958	0.95	94.288	94.259	1.121
223a	223b	92.369	92.316	900	27.8	0.2	0.013	95.409	95.409	1.240	0.789	0.90	1.1	0.990	0.95	94.259	94.179	N/A
223b	25	92.316	92.300	900	8.7	0.2	0.013	95.409	95.330	1.240	0.789	0.90	1.1	0.963	1.10	94.179	94.156	N/A
224	221	93.432	93.288	300	41.0	0.4	0.013	95.273	95.466	0.809	0.057	0.07	1.3	1.238	0.95	94.970	94.813	0.303
330	1070b	92.116	92.096	525	10.0	0.2	0.014	95.230	95.055	0.825	0.179	0.32	1.8	1.163	1.01	93.804	93.803	1.426
1070b	108b	91.758	91.709	1200	44.5	0.1	0.014	95.055	94.218	1.062	1.201	2.11	1.8	0.845	1.01	93.803	93.801	1.252
1600	1600a	92.658	92.635	600	15.5	0.2	0.013	95.090	95.090	0.841	0.238	0.26	1.1	1.483	0.93	94.741	94.721	0.349
1600a	16	92.635	92.622	600	8.5	0.2	0.013	95.090	94.979	0.841	0.238	0.32	1.3	1.486	0.98	94.721	94.701	N/A
Pond1	Out	N/A	N/A	N/A	N/A	N/A	N/A	95.500	94.500	N/A	N/A	4.38	N/A	N/A	2.84	93.798	92.350	1.702
250	252	93.433	93.270	300	46.5	0.4	0.013	95.380	95.390	0.809	0.057	0.06	1.1	1.607	1.53	95.340	95.240	0.040
251	251a	93.563	93.356	300	46.1	0.5	0.013	95.530	95.530	0.918	0.065	-0.09	-1.4	1.560	1.55	95.423	95.454	0.107
251	251b	93.320	93.079	300	48.2	0.5	0.013	95.530	95.500	0.967	0.068	-0.07	-1.1	1.803	0.91	95.423	95.300	0.107

Table C-1C: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
251	251c	93.625	93.607	375	6.0	0.3	0.013	95.530	95.530	0.869	0.096	0.12	1.2	1.423	1.49	95.423	95.435	0.107
251a	252	93.356	93.270	300	18.9	0.5	0.013	95.530	95.390	0.918	0.065	0.10	1.5	1.798	0.90	95.454	95.240	N/A
251b	255	93.079	92.980	300	19.8	0.5	0.013	95.500	95.330	0.967	0.068	0.10	1.4	1.921	1.46	95.300	95.166	N/A
251c	251d	93.607	93.526	375	26.9	0.3	0.013	95.530	95.530	0.869	0.096	-0.15	-1.6	1.453	0.91	95.435	95.481	N/A
251e	263	93.450	93.421	375	9.7	0.3	0.013	95.530	95.630	0.869	0.096	-0.28	-3.0	1.671	0.91	95.496	95.516	N/A
252	252a	93.045	92.914	525	52.2	0.3	0.013	95.390	95.390	0.993	0.215	-0.13	-0.6	1.670	0.90	95.240	95.206	0.150
252a	253	92.914	92.872	525	16.8	0.3	0.013	95.390	95.180	0.993	0.215	0.20	0.9	1.767	0.89	95.206	95.180	N/A
253	253a	92.797	92.693	600	69.3	0.2	0.013	95.180	95.180	0.841	0.238	0.20	0.8	1.783	1.50	95.180	95.160	0.000
253a	254	92.693	92.675	600	11.7	0.2	0.013	95.180	95.180	0.841	0.238	0.29	1.2	1.867	1.50	95.160	95.131	N/A
254	254a	92.615	92.568	600	31.4	0.2	0.013	95.180	95.230	0.841	0.238	0.39	1.7	1.916	1.54	95.131	95.117	0.049
254	254c	93.239	93.106	300	29.5	0.5	0.013	95.180	95.180	0.918	0.065	-0.15	-2.3	1.592	0.89	95.131	95.114	0.049
254a	257	92.568	92.562	600	4.1	0.2	0.013	95.230	95.230	0.841	0.238	0.42	1.8	1.949	1.54	95.117	95.115	N/A
259a	257	93.017	92.977	300	7.9	0.5	0.013	95.280	95.230	0.967	0.068	0.08	1.1	1.824	1.49	95.141	95.115	N/A
254c	273	93.106	92.964	300	31.5	0.5	0.013	95.180	95.140	0.918	0.065	-0.10	-1.6	1.708	1.78	95.114	94.897	N/A
255	255a	92.830	92.701	450	64.5	0.2	0.013	95.330	95.330	0.802	0.128	0.11	0.8	1.886	1.46	95.166	95.111	0.164
255a	256	92.701	92.667	450	17.0	0.2	0.013	95.330	95.260	0.802	0.128	0.18	1.4	1.960	1.46	95.111	95.088	N/A
256	256a	92.422	92.402	675	13.0	0.2	0.013	95.260	95.260	0.910	0.326	0.63	1.9	1.991	1.46	95.088	95.073	0.172
256a	261	92.402	92.372	675	20.0	0.2	0.013	95.260	95.250	0.910	0.326	0.65	2.0	1.996	1.46	95.073	95.068	N/A
251d	251e	93.526	93.450	375	25.4	0.3	0.013	95.530	95.530	0.869	0.096	-0.21	-2.2	1.580	0.91	95.481	95.496	N/A
258	258a	93.104	92.887	300	54.2	0.4	0.013	95.450	95.450	0.865	0.061	-0.06	-1.0	1.722	0.92	95.126	95.123	0.324
258a	261	92.887	92.840	300	11.8	0.4	0.013	95.450	95.250	0.865	0.061	0.09	1.4	1.936	1.20	95.123	95.068	N/A
259	259a	93.152	93.017	300	27.1	0.5	0.013	95.280	95.280	0.967	0.068	0.06	0.9	1.712	0.96	95.164	95.141	0.116
257	256	92.542	92.497	600	30.0	0.2	0.013	95.230	95.260	0.841	0.238	0.48	2.0	1.973	1.49	95.115	95.088	0.115
260	260a	92.954	92.866	375	25.1	0.4	0.013	95.320	95.320	0.939	0.104	-0.07	-0.6	1.711	0.91	95.040	95.019	0.280
260a	261	92.866	92.840	300	7.4	0.4	0.013	95.320	95.250	0.809	0.057	-0.10	-1.8	1.853	0.91	95.019	95.068	N/A
261	265	92.297	92.262	825	35.0	0.1	0.013	95.250	95.550	0.849	0.454	0.81	1.8	1.946	1.45	95.068	95.051	0.182
263	263a	92.209	92.176	1500	22.2	0.2	0.013	95.630	95.630	1.549	2.738	5.09	1.9	1.807	0.92	95.516	95.458	0.114
263a	264	92.176	92.096	1500	52.8	0.2	0.013	95.630	95.530	1.549	2.738	5.09	1.9	1.782	0.92	95.458	95.305	N/A
264	264a	92.076	92.033	1500	28.5	0.2	0.013	95.530	95.530	1.549	2.738	5.08	1.9	1.729	0.92	95.305	95.216	0.225
264a	265	92.033	91.963	1500	46.5	0.2	0.013	95.530	95.550	1.549	2.738	5.21	1.9	1.683	0.92	95.216	95.051	N/A
265	265a	91.924	91.816	1500	53.8	0.2	0.013	95.550	95.550	1.789	3.161	5.40	1.7	1.627	0.93	95.051	94.844	0.499
265a	266	91.816	91.778	1500	19.2	0.2	0.013	95.550	95.540	1.789	3.161	5.46	1.7	1.528	0.93	94.844	94.399	N/A
266	266a	91.568	91.509	1500	29.7	0.2	0.013	95.540	95.550	1.789	3.161	5.46	1.7	1.331	0.93	94.399	94.158	1.141
266a	267	91.509	91.429	1500	39.8	0.2	0.013	95.550	95.630	1.789	3.161	5.49	1.7	1.149	0.98	94.158	94.039	N/A
267	Pond1	91.429	91.350	1500	39.5	0.2	0.013	95.630	95.500	1.789	3.161	5.49	1.7	1.110	0.98	94.039	93.798	1.591
270	270a	92.828	92.710	900	59.1	0.2	0.013	95.500	95.500	1.273	0.810	1.61	2.0	1.970	0.89	95.698	95.386	-0.198
270a	271	92.710	92.665	900	22.4	0.2	0.013	95.500	95.320	1.273	0.810	1.63	2.0	1.776	0.89	95.386	95.275	N/A
271	271a	92.643	92.503	900	46.6	0.3	0.013	95.320	95.320	1.559	0.992	1.61	1.6	1.732	0.89	95.275	95.050	0.045
271a	273	92.503	92.416	900	28.9	0.3	0.013	95.320	95.140	1.559	0.992	1.59	1.6	1.647	0.89	95.050	94.897	N/A

Table C-1C: Pipe Data and Hydraulic Simulation Results for the 100-Year, 3-Hour Chicago Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [1] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [2] (m)
273	273a	92.364	92.313	900	25.5	0.2	0.013	95.140	95.140	1.273	0.810	1.51	1.9	1.633	0.92	94.897	94.760	0.243
273a	275	92.313	92.298	900	7.6	0.2	0.013	95.140	95.200	1.273	0.810	1.57	1.9	1.547	0.97	94.760	94.708	N/A
275	276	92.268	92.209	900	29.5	0.2	0.013	95.200	95.620	1.273	0.810	1.57	1.9	1.540	0.97	94.708	94.480	0.492
276	277	92.179	92.148	900	15.5	0.2	0.013	95.620	95.500	1.273	0.810	1.57	1.9	1.401	0.97	94.480	94.341	1.140
277	277a	92.067	91.964	975	51.7	0.2	0.013	95.500	95.630	1.342	1.002	1.73	1.7	1.299	0.93	94.341	94.193	1.159
277a	277b	91.964	91.869	975	47.5	0.2	0.013	95.630	95.630	1.342	1.002	1.80	1.8	1.254	0.96	94.193	94.059	N/A
277b	278	91.869	91.842	975	13.3	0.2	0.013	95.630	95.630	1.342	1.002	1.85	1.8	1.215	0.97	94.059	93.944	N/A
278	279	91.782	91.775	975	3.5	0.2	0.013	95.630	95.630	1.342	1.002	1.85	1.8	1.187	0.97	93.944	93.891	1.686
279	Pond1	91.715	91.650	975	32.5	0.2	0.013	95.630	95.500	1.342	1.002	1.85	1.8	1.201	0.97	93.891	93.798	1.739
280	280a	91.825	91.714	1650	73.8	0.2	0.013	95.450	95.510	1.651	3.530	3.43	1.0	0.634	3.09	94.109	94.002	1.341
280a	281	91.714	91.657	1650	38.2	0.2	0.013	95.510	95.510	1.651	3.530	3.43	1.0	0.638	3.09	94.002	93.946	N/A
281	Pond1	91.657	91.600	1650	38.0	0.2	0.013	95.510	95.500	1.651	3.530	3.43	1.0	0.639	3.09	93.946	93.798	1.564
328	263	92.425	92.359	1350	65.5	0.1	0.013	95.700	95.630	1.179	1.688	3.75	2.2	1.968	0.92	95.743	95.516	-0.043
329	329a	92.534	92.465	1050	27.4	0.3	0.013	95.700	95.700	1.577	1.365	2.26	1.7	2.274	1.43	95.858	95.700	-0.158
329a	263	92.465	92.434	1050	12.6	0.3	0.013	95.700	95.630	1.577	1.365	2.29	1.7	2.185	1.44	95.700	95.516	N/A
101	102	94.092	93.958	600	95.5	0.1	0.013	97.120	97.010	0.813	0.230	0.72	3.1	2.478	1.79	97.170	97.046	-0.050
102	103	93.883	93.783	675	83.5	0.1	0.013	97.010	96.880	0.814	0.291	0.94	3.2	2.488	1.70	97.046	96.903	-0.036
103	106	93.708	93.664	750	40.0	0.1	0.013	96.880	96.820	0.836	0.369	1.24	3.4	2.445	1.66	96.903	96.870	-0.023
106	109	93.589	93.544	825	45.0	0.1	0.013	96.820	96.750	0.849	0.454	1.42	3.1	2.456	1.58	96.870	96.778	-0.050
109	111	93.469	93.391	900	78.0	0.1	0.013	96.750	96.640	0.900	0.572	1.63	2.9	2.409	1.56	96.778	96.669	-0.028
111	112	93.241	93.142	1050	98.5	0.1	0.013	96.640	96.500	0.997	0.864	2.00	2.3	2.378	1.54	96.669	96.594	-0.029
112	113	92.992	92.863	1200	129.0	0.1	0.013	96.500	96.310	1.090	1.233	2.57	2.1	2.402	1.52	96.594	96.384	-0.094
113	114	92.833	92.754	1200	78.5	0.1	0.013	96.310	96.190	1.090	1.233	2.82	2.3	2.351	1.47	96.384	96.272	-0.074
114	122	92.604	92.524	1350	80.0	0.1	0.013	96.190	96.070	1.179	1.688	3.15	1.9	2.318	1.30	96.272	96.157	-0.082
122	126	92.494	92.287	1350	122.0	0.2	0.013	96.070	95.770	1.537	2.201	3.69	1.7	2.313	1.25	96.157	95.785	-0.087
126	127	92.212	92.111	1500	91.5	0.1	0.013	95.770	95.630	1.327	2.344	4.48	1.9	2.071	0.92	95.783	95.648	-0.013
127	130	92.081	91.980	1500	91.5	0.1	0.013	95.630	95.490	1.327	2.344	4.93	2.1	2.073	0.92	95.654	95.056	-0.024
130	138	91.905	91.840	1650	64.5	0.1	0.013	95.490	95.140	1.348	2.882	5.53	1.9	1.502	0.92	95.057	94.364	0.433
138	139	91.780	91.730	1650	50.0	0.1	0.013	95.140	95.400	1.348	2.882	6.59	2.3	0.934	0.94	94.364	94.153	0.776
139	140	91.670	91.656	1650	14.0	0.1	0.013	95.400	95.400	1.348	2.882	6.62	2.3	0.833	0.94	94.153	94.070	1.247
140	29	91.651	91.608	1650	43.4	0.1	0.013	95.400	95.352	1.348	2.882	6.71	2.3	0.769	0.94	94.070	93.959	1.330

Note: [1] A negative surcharge implies that the pipe is not flowing full

[2] Freeboard between upstream hydraulic gradeline elevation and upstream manhole cover elevation.

[3] Ponding allowed above manholes in undetailed future development areas to represent road surface storage above catchbasins.

Table C-1D: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
1	2	93.328	93.172	300	44.5	0.4	0.013	95.566	95.449	0.809	0.057	-0.05	-0.8	1.170	11.83	94.798	94.777	0.768
2	2a	93.134	92.925	375	69.6	0.3	0.013	95.449	95.449	0.869	0.096	-0.07	-0.7	1.268	11.82	94.777	94.770	0.672
2a	3	92.925	92.857	375	22.9	0.3	0.013	95.449	95.220	0.869	0.096	0.11	1.2	1.470	11.90	94.770	94.679	N/A
3	4	92.827	92.787	375	13.5	0.3	0.013	95.220	95.300	0.869	0.096	0.11	1.2	1.477	11.90	94.679	94.626	0.541
4	7	92.757	92.561	375	65.5	0.3	0.013	95.300	95.174	0.869	0.096	0.11	1.1	1.493	11.90	94.625	94.409	0.675
5	5a	92.986	92.957	300	8.3	0.4	0.013	95.298	95.378	0.809	0.057	-0.01	-0.2	1.410	11.81	94.696	94.696	0.602
5a	6	92.957	92.797	300	45.7	0.4	0.013	95.378	95.378	0.809	0.057	0.07	1.2	1.439	11.87	94.696	94.505	N/A
6	6a	92.609	92.499	675	73.5	0.2	0.013	95.378	95.378	0.910	0.326	0.07	0.2	1.221	11.93	94.505	94.500	0.873
6a	7	92.499	92.448	675	34.0	0.2	0.013	95.378	95.174	0.910	0.326	0.33	1.0	1.326	12.11	94.500	94.409	N/A
7	7a	92.373	92.313	750	54.4	0.1	0.013	95.174	95.174	0.836	0.369	0.43	1.2	1.286	12.04	94.409	94.337	0.765
7a	8	92.313	92.300	750	11.6	0.1	0.013	95.174	95.040	0.836	0.369	0.54	1.4	1.274	11.92	94.337	94.222	N/A
8	8a	92.225	92.211	900	13.1	0.1	0.013	95.040	95.199	0.944	0.600	0.66	1.1	1.097	11.92	94.222	94.206	0.818
8a	11	92.211	92.144	900	60.4	0.1	0.013	95.199	95.199	0.944	0.600	0.77	1.3	1.095	11.98	94.206	94.107	N/A
9	10	92.912	92.614	300	59.5	0.5	0.013	95.652	94.963	0.967	0.068	0.04	0.5	1.212	12.01	94.424	94.358	1.228
10	10a	92.501	92.486	525	6.1	0.3	0.013	94.963	95.199	0.993	0.215	0.03	0.2	1.332	12.01	94.358	94.357	0.605
10a	11	92.486	92.331	525	61.9	0.3	0.013	95.199	95.199	0.993	0.215	0.24	1.1	1.346	12.04	94.357	94.107	N/A
11	11a	92.106	92.040	975	59.6	0.1	0.013	95.199	95.199	0.996	0.743	0.99	1.3	1.026	11.98	94.107	93.998	1.092
11a	12	92.040	92.036	975	4.4	0.1	0.013	95.199	94.782	0.996	0.743	1.10	1.5	0.983	11.97	93.998	93.958	N/A
12	12a	92.006	91.963	975	39.2	0.1	0.013	94.782	94.964	0.996	0.743	1.10	1.5	0.977	11.97	93.958	93.916	0.824
12a	15	91.963	91.924	975	35.9	0.1	0.013	94.964	94.964	0.996	0.743	1.16	1.6	0.978	11.97	93.916	93.890	N/A
13	13a	92.160	92.156	825	3.3	0.1	0.013	95.250	95.201	0.891	0.476	0.40	0.8	0.957	11.97	93.942	93.941	1.308
13a	13b	92.156	92.069	825	79.1	0.1	0.013	95.201	95.201	0.891	0.476	0.45	0.9	0.960	11.97	93.941	93.926	N/A
13b	14	92.069	92.046	825	21.1	0.1	0.013	95.201	94.902	0.891	0.476	0.62	1.3	1.032	11.96	93.926	93.906	N/A
14	15	92.016	91.999	825	15.5	0.1	0.013	94.902	94.964	0.891	0.476	0.61	1.3	1.065	11.96	93.906	93.890	0.996
15	104b	91.810	91.793	1200	15.5	0.1	0.013	94.964	94.500	1.143	1.293	1.76	1.4	0.880	11.96	93.890	93.880	1.074
16	17	92.602	92.499	600	68.5	0.2	0.013	94.979	95.298	0.841	0.238	0.32	1.4	1.659	11.92	94.861	94.709	0.118
17	17a	92.461	92.373	675	58.7	0.2	0.013	95.298	95.298	0.910	0.326	0.32	1.0	1.573	11.92	94.709	94.646	0.589
17a	18	92.373	92.363	675	6.4	0.2	0.013	95.298	95.030	0.910	0.326	0.44	1.3	1.598	11.92	94.646	94.608	N/A
18	19	92.333	92.317	675	10.5	0.2	0.013	95.030	95.094	0.910	0.326	0.44	1.3	1.600	11.92	94.608	94.572	0.422
19	23	92.287	92.205	675	55.0	0.2	0.013	95.094	95.383	0.910	0.326	0.43	1.3	1.610	11.92	94.572	94.418	0.522
20	20a	92.442	92.427	675	10.1	0.2	0.013	95.562	95.562	0.910	0.326	0.41	1.3	1.656	11.96	94.773	94.751	0.789
20	20b	93.147	92.935	300	53.0	0.4	0.013	95.562	95.562	0.865	0.061	0.02	0.3	1.326	12.21	94.773	94.782	0.789
20a	21	92.427	92.327	675	66.9	0.2	0.013	95.562	95.128	0.910	0.326	0.43	1.3	1.649	11.96	94.751	94.596	N/A
20b	24	92.935	92.755	300	45.0	0.4	0.013	95.562	95.243	0.865	0.061	0.07	1.2	1.547	11.96	94.782	94.586	N/A
21	21a	92.252	92.228	825	22.2	0.1	0.013	95.128	95.198	0.891	0.476	0.43	0.9	1.519	11.96	94.596	94.578	0.532
21a	22	92.228	92.181	825	42.3	0.1	0.013	95.198	95.198	0.891	0.476	0.57	1.2	1.525	11.96	94.578	94.491	N/A
22	23	92.151	92.130	825	19.5	0.1	0.013	95.198	95.383	0.891	0.476	0.57	1.2	1.515	11.95	94.491	94.418	0.707
23	105b	92.092	92.059	900	26.5	0.1	0.013	95.383	94.500	0.944	0.600	0.99	1.6	1.426	11.93	94.418	94.266	0.965
24	24a	92.605	92.572	600	22.2	0.2	0.013	95.243	95.320	0.841	0.238	0.07	0.3	1.381	11.96	94.586	94.584	0.657

Table C-1D: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
24a	25	92.572	92.459	600	74.8	0.2	0.013	95.320	95.330	0.841	0.238	0.24	1.0	1.412	11.92	94.584	94.460	N/A
25	25a	92.234	92.230	1050	3.2	0.1	0.013	95.330	95.320	1.046	0.906	1.03	1.1	1.176	12.02	94.460	94.454	0.870
25a	26	92.230	92.152	1050	71.8	0.1	0.013	95.320	95.212	1.046	0.906	1.14	1.3	1.174	12.08	94.454	94.331	N/A
26	26a	92.077	92.032	1200	41.3	0.1	0.013	95.212	95.352	1.143	1.293	1.26	1.0	1.054	11.94	94.331	94.290	0.881
26a	26b	92.032	92.007	1200	22.9	0.1	0.013	95.352	95.352	1.143	1.293	1.29	1.0	1.058	11.94	94.290	94.266	N/A
26b	27	92.007	91.988	1200	16.8	0.1	0.013	95.352	95.352	1.143	1.293	1.46	1.1	1.059	11.94	94.266	94.144	N/A
27	27a	92.856	92.796	300	17.1	0.4	0.013	95.352	95.352	0.809	0.057	0.04	0.6	0.988	12.18	94.144	94.136	1.208
27	27b	91.928	91.910	1200	16.8	0.1	0.013	95.352	95.352	1.143	1.293	1.48	1.1	1.016	11.95	94.144	94.127	1.208
27a	29	92.796	92.623	300	49.4	0.4	0.013	95.352	95.352	0.809	0.057	0.08	1.5	1.040	11.95	94.136	94.279	N/A
27b	107b	91.910	91.846	1200	58.2	0.1	0.013	95.352	95.232	1.143	1.293	1.59	1.2	1.017	11.95	94.127	93.999	N/A
29	111b	91.588	91.542	1650	41.5	0.1	0.013	95.352	95.502	1.414	3.023	5.51	1.8	1.042	12.00	94.280	94.088	1.072
30	30a	92.746	92.561	450	74.2	0.3	0.013	95.372	95.372	0.896	0.143	-0.09	-0.6	1.182	11.96	94.378	94.413	0.994
30	31	92.662	92.542	300	12.0	1.0	0.013	95.372	95.212	1.368	0.097	0.09	0.9	1.416	11.95	94.378	94.307	0.994
30a	26	92.561	92.542	450	43.3	0.3	0.013	95.372	95.212	0.896	0.143	0.13	0.9	1.402	11.87	94.413	94.331	N/A
31	31a	92.429	92.327	525	51.0	0.2	0.013	95.212	95.212	0.888	0.192	0.09	0.5	1.353	11.95	94.307	94.296	0.905
31a	32	92.327	92.301	525	13.0	0.2	0.013	95.212	94.974	0.888	0.192	0.28	1.5	1.444	11.94	94.296	94.221	N/A
32	33	92.271	92.246	525	12.5	0.2	0.013	94.974	95.049	0.888	0.192	0.28	1.5	1.425	11.94	94.221	94.147	0.753
33	330	92.216	92.146	525	35.0	0.2	0.013	95.049	95.230	0.888	0.192	0.28	1.5	1.406	11.94	94.147	94.035	0.902
104b	Pond1	91.763	91.700	1200	57.5	0.1	0.013	94.500	95.500	1.143	1.293	1.76	1.4	0.917	11.96	93.880	93.873	0.620
105b	106b	92.029	91.960	900	62.5	0.1	0.013	94.500	94.500	0.944	0.600	0.99	1.6	1.337	11.96	94.266	94.118	0.234
106b	108b	91.930	91.854	900	69.5	0.1	0.013	94.500	94.218	0.944	0.600	0.99	1.6	1.288	11.96	94.118	93.934	0.382
107b	1070b	91.786	91.778	1200	7.0	0.1	0.013	95.232	95.055	1.143	1.293	1.58	1.2	1.013	11.95	93.999	93.992	1.233
108b	109b	91.629	91.617	1350	10.5	0.1	0.013	94.218	94.500	1.237	1.770	2.84	1.6	0.955	11.95	93.934	93.874	0.284
109b	Pond1	91.557	91.550	1350	6.0	0.1	0.013	94.500	95.500	1.237	1.770	2.83	1.6	0.967	11.95	93.874	93.873	0.626
111b	Pond1	91.522	91.450	1650	38.0	0.2	0.013	95.502	95.500	1.858	3.973	5.51	1.4	0.917	12.00	94.089	93.873	1.413
200	201	93.286	93.180	300	12.5	0.9	0.013	95.389	95.314	1.261	0.089	-0.04	-0.5	0.829	11.82	94.415	94.418	0.974
200	202	93.289	93.084	300	58.5	0.4	0.013	95.389	95.259	0.809	0.057	-0.02	-0.3	0.826	11.82	94.415	94.418	0.974
201	201a	93.030	92.900	450	29.6	0.4	0.013	95.314	95.314	1.189	0.189	-0.05	-0.2	0.938	11.82	94.418	94.419	0.896
201a	8	92.900	92.500	450	90.9	0.4	0.013	95.314	95.040	1.189	0.189	0.14	0.8	1.069	11.94	94.419	94.222	N/A
202	202a	93.054	93.050	300	1.2	0.4	0.013	95.259	95.296	0.809	0.057	-0.04	-0.7	1.064	11.80	94.418	94.418	0.841
202a	203	93.050	93.012	300	10.8	0.4	0.013	95.296	95.296	0.809	0.057	0.11	1.9	1.068	11.95	94.418	94.263	N/A
203	204	92.862	92.677	450	92.5	0.2	0.013	95.296	95.110	0.802	0.128	0.11	0.8	0.951	11.94	94.263	94.146	1.033
204	204a	92.511	92.463	600	21.9	0.2	0.013	95.110	95.250	1.019	0.288	0.11	0.4	1.035	11.94	94.146	94.140	0.964
204a	204b	92.463	92.324	600	63.0	0.2	0.013	95.250	95.250	1.019	0.288	0.37	1.3	1.077	11.94	94.140	93.976	N/A
204b	13	92.324	92.290	600	15.6	0.2	0.013	95.250	95.250	1.019	0.288	0.40	1.4	1.052	11.97	93.976	93.942	N/A
205	210	93.210	93.060	450	75.0	0.2	0.013	95.493	95.671	0.802	0.128	0.09	0.7	1.557	11.86	95.217	95.148	0.276
206	206a	93.320	93.316	375	1.5	0.3	0.013	95.468	95.493	0.869	0.096	-0.10	-1.0	1.551	11.81	95.246	95.245	0.222
206a	205	93.316	93.285	375	10.0	0.3	0.013	95.493	95.493	0.869	0.096	0.09	1.0	1.554	11.86	95.245	95.217	N/A
207	206	93.598	93.395	300	58.0	0.4	0.013	95.923	95.468	0.809	0.057	-0.05	-0.9	1.333	11.83	95.231	95.246	0.692

Table C-1D: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
208	207	93.700	93.658	300	12.0	0.4	0.013	95.851	95.923	0.809	0.057	-0.05	-0.8	1.232	11.83	95.232	95.231	0.619
208	208a	93.672	93.294	375	44.5	0.9	0.013	95.851	95.851	1.464	0.162	-0.06	-0.4	1.185	11.83	95.232	95.230	0.619
208a	209	93.294	92.949	375	40.5	0.9	0.013	95.851	95.614	1.464	0.162	0.13	0.8	1.561	11.93	95.230	95.030	N/A
209	212	92.724	92.639	600	56.5	0.2	0.013	95.614	95.238	0.841	0.238	0.30	1.3	1.706	11.91	95.030	94.907	0.584
210	211	93.030	93.007	450	11.5	0.2	0.013	95.671	95.601	0.802	0.128	0.09	0.7	1.668	12.21	95.148	95.134	0.523
211	211a	92.932	92.871	525	30.3	0.2	0.013	95.601	95.614	0.888	0.192	0.09	0.5	1.677	12.21	95.134	95.124	0.467
211a	209	92.871	92.799	525	36.2	0.2	0.013	95.614	95.614	0.888	0.192	0.18	0.9	1.728	11.91	95.124	95.030	N/A
212	212a	92.564	92.553	675	7.3	0.2	0.013	95.238	95.550	0.910	0.326	0.30	0.9	1.668	11.96	94.907	94.898	0.331
212a	20	92.553	92.460	675	62.2	0.2	0.013	95.550	95.562	0.910	0.326	0.41	1.2	1.670	11.92	94.898	94.773	N/A
213	214	93.791	93.638	300	30.5	0.5	0.013	96.071	95.908	0.967	0.068	0.10	1.4	1.557	11.92	95.648	95.456	0.423
214	214a	93.338	93.284	600	36.3	0.2	0.013	95.908	95.918	0.841	0.238	0.13	0.5	1.518	11.94	95.456	95.446	0.452
214a	215	93.284	93.232	600	34.2	0.2	0.013	95.918	95.849	0.841	0.238	0.23	1.0	1.562	11.92	95.446	95.403	N/A
215	215a	93.212	93.138	600	49.2	0.2	0.013	95.849	95.849	0.841	0.238	0.23	1.0	1.591	11.92	95.403	95.341	0.446
215a	220	93.138	93.120	600	11.8	0.2	0.013	95.849	95.723	0.841	0.238	0.29	1.2	1.603	11.91	95.341	95.253	N/A
216	216a	93.869	93.679	300	54.4	0.4	0.013	95.972	95.972	0.809	0.057	-0.06	-1.0	1.311	11.85	95.480	95.493	0.492
216	217	93.870	93.726	300	12.0	1.2	0.013	95.972	95.900	1.499	0.106	-0.10	-0.9	1.310	11.85	95.480	95.469	0.492
216a	214	93.679	93.638	300	11.6	0.4	0.013	95.972	95.908	0.809	0.057	-0.08	-1.5	1.514	11.85	95.493	95.456	N/A
217	217a	93.576	93.494	450	40.9	0.2	0.013	95.900	95.900	0.802	0.128	-0.13	-1.1	1.443	11.85	95.469	95.468	0.431
217a	218	93.494	93.345	450	74.6	0.2	0.013	95.900	95.677	0.802	0.128	0.11	0.9	1.524	11.92	95.468	95.365	N/A
218	219	93.315	93.292	450	11.5	0.2	0.013	95.677	95.594	0.802	0.128	0.11	0.9	1.600	11.92	95.365	95.343	0.312
219	219a	93.254	93.217	525	18.4	0.2	0.013	95.594	95.733	0.888	0.192	0.11	0.6	1.564	11.92	95.343	95.333	0.251
219a	220	93.217	93.121	525	48.1	0.2	0.013	95.733	95.723	0.888	0.192	0.19	1.0	1.591	12.20	95.333	95.253	N/A
220	220a	93.045	92.918	675	63.4	0.2	0.013	95.723	95.733	1.051	0.376	0.46	1.2	1.533	11.91	95.253	95.080	0.470
220a	221	92.918	92.913	675	2.6	0.2	0.013	95.733	95.466	1.051	0.376	0.48	1.3	1.487	11.91	95.080	94.970	N/A
221	221a	92.838	92.772	750	33.1	0.2	0.013	95.466	95.515	1.127	0.498	0.51	1.0	1.382	11.91	94.970	94.910	0.496
221a	222	92.772	92.600	750	85.9	0.2	0.013	95.515	95.515	1.127	0.498	0.64	1.3	1.388	11.91	94.910	94.611	N/A
222	223	92.525	92.505	825	13.5	0.2	0.013	95.515	95.409	1.040	0.556	0.64	1.1	1.261	11.91	94.611	94.562	0.904
223	223a	92.430	92.369	900	32.0	0.2	0.013	95.409	95.409	1.240	0.789	0.64	0.8	1.232	11.95	94.562	94.526	0.847
223a	223b	92.369	92.316	900	27.8	0.2	0.013	95.409	95.409	1.240	0.789	0.79	1.0	1.257	11.94	94.526	94.478	N/A
223b	25	92.316	92.300	900	8.7	0.2	0.013	95.409	95.330	1.240	0.789	0.80	1.0	1.262	12.08	94.478	94.460	N/A
224	221	93.432	93.288	300	41.0	0.4	0.013	95.273	95.466	0.809	0.057	0.06	1.0	1.342	12.34	95.074	94.970	0.199
330	1070b	92.116	92.096	525	10.0	0.2	0.014	95.230	95.055	0.825	0.179	0.28	1.6	1.394	11.95	94.035	93.992	1.195
1070b	108b	91.758	91.709	1200	44.5	0.1	0.014	95.055	94.218	1.062	1.201	1.85	1.5	1.034	11.95	93.992	93.934	1.063
1600	1600a	92.658	92.635	600	15.5	0.2	0.013	95.090	95.090	0.841	0.238	0.26	1.1	1.638	11.92	94.896	94.876	0.194
1600a	16	92.635	92.622	600	8.5	0.2	0.013	95.090	94.979	0.841	0.238	0.30	1.3	1.641	11.91	94.876	94.861	N/A
Pond1	Out	N/A	N/A	N/A	N/A	N/A	N/A	95.500	94.500	N/A	N/A	9.15	N/A	N/A	12.47	93.873	92.350	1.627
250	252	93.433	93.270	300	46.5	0.4	0.013	95.380	95.390	0.809	0.057	0.05	0.9	1.628	12.48	95.361	95.241	0.019
251	251a	93.563	93.356	300	46.1	0.5	0.013	95.530	95.530	0.918	0.065	-0.07	-1.1	1.561	12.48	95.424	95.403	0.106
251	251b	93.320	93.079	300	48.2	0.5	0.013	95.530	95.500	0.967	0.068	0.05	0.8	1.804	11.87	95.424	95.318	0.106

Table C-1D: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S (1) (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard (2) (m)
251	251c	93.625	93.607	375	6.0	0.3	0.013	95.530	95.530	0.869	0.096	0.10	1.0	1.424	12.43	95.424	95.436	0.106
251a	252	93.356	93.270	300	18.9	0.5	0.013	95.530	95.390	0.918	0.065	0.08	1.2	1.747	11.94	95.403	95.241	N/A
251b	255	93.079	92.980	300	19.8	0.5	0.013	95.500	95.330	0.967	0.068	0.09	1.3	1.939	11.85	95.318	95.210	N/A
251c	251d	93.607	93.526	375	26.9	0.3	0.013	95.530	95.530	0.869	0.096	0.12	1.2	1.454	12.35	95.436	95.481	N/A
251e	263	93.450	93.421	375	9.7	0.3	0.013	95.530	95.630	0.869	0.096	0.22	2.3	1.687	12.34	95.512	95.604	N/A
252	252a	93.045	92.914	525	52.2	0.3	0.013	95.390	95.390	0.993	0.215	0.11	0.5	1.671	12.01	95.241	95.205	0.149
252a	253	92.914	92.872	525	16.8	0.3	0.013	95.390	95.180	0.993	0.215	0.18	0.8	1.766	12.44	95.205	95.180	N/A
253	253a	92.797	92.693	600	69.3	0.2	0.013	95.180	95.180	0.841	0.238	0.18	0.7	1.783	12.44	95.180	95.171	0.000
253a	254	92.693	92.675	600	11.7	0.2	0.013	95.180	95.180	0.841	0.238	0.26	1.1	1.878	12.45	95.171	95.156	N/A
254	254a	92.615	92.568	600	31.4	0.2	0.013	95.180	95.230	0.841	0.238	0.36	1.5	1.941	12.48	95.156	95.151	0.024
254	254c	93.239	93.106	300	29.5	0.5	0.013	95.180	95.180	0.918	0.065	-0.14	-2.2	1.617	12.59	95.156	95.146	0.024
254a	257	92.568	92.562	600	4.1	0.2	0.013	95.230	95.230	0.841	0.238	0.37	1.6	1.983	12.46	95.151	95.149	N/A
259a	257	93.017	92.977	300	7.9	0.5	0.013	95.280	95.230	0.967	0.068	0.07	1.0	1.853	12.37	95.170	95.149	N/A
254c	273	93.106	92.964	300	31.5	0.5	0.013	95.180	95.140	0.918	0.065	-0.08	-1.2	1.740	11.74	95.146	94.977	N/A
255	255a	92.830	92.701	450	64.5	0.2	0.013	95.330	95.330	0.802	0.128	0.10	0.8	1.930	12.34	95.210	95.152	0.120
255a	256	92.701	92.667	450	17.0	0.2	0.013	95.330	95.260	0.802	0.128	0.16	1.3	2.001	12.34	95.152	95.129	N/A
256	256a	92.422	92.402	675	13.0	0.2	0.013	95.260	95.260	0.910	0.326	0.55	1.7	2.032	12.42	95.129	95.115	0.131
256a	261	92.402	92.372	675	20.0	0.2	0.013	95.260	95.250	0.910	0.326	0.60	1.8	2.038	12.40	95.115	95.094	N/A
251d	251e	93.526	93.450	375	25.4	0.3	0.013	95.530	95.530	0.869	0.096	0.15	1.6	1.580	12.34	95.481	95.512	N/A
258	258a	93.104	92.887	300	54.2	0.4	0.013	95.450	95.450	0.865	0.061	0.03	0.5	1.754	12.35	95.158	95.151	0.292
258a	261	92.887	92.840	300	11.8	0.4	0.013	95.450	95.250	0.865	0.061	0.09	1.4	1.964	12.34	95.151	95.094	N/A
259	259a	93.152	93.017	300	27.1	0.5	0.013	95.280	95.280	0.967	0.068	0.05	0.7	1.733	11.89	95.185	95.170	0.095
257	256	92.542	92.497	600	30.0	0.2	0.013	95.230	95.260	0.841	0.238	0.42	1.8	2.007	12.45	95.149	95.129	0.081
260	260a	92.954	92.866	375	25.1	0.4	0.013	95.320	95.320	0.939	0.104	0.03	0.3	1.782	12.34	95.111	95.106	0.209
260a	261	92.866	92.840	300	7.4	0.4	0.013	95.320	95.250	0.809	0.057	0.09	1.6	1.940	12.34	95.106	95.094	N/A
261	265	92.297	92.262	825	35.0	0.1	0.013	95.250	95.550	0.849	0.454	0.75	1.7	1.972	12.34	95.094	95.051	0.156
263	263a	92.209	92.176	1500	22.2	0.2	0.013	95.630	95.630	1.549	2.738	4.14	1.5	1.895	11.95	95.604	95.515	0.026
263a	264	92.176	92.096	1500	52.8	0.2	0.013	95.630	95.530	1.549	2.738	4.17	1.5	1.838	11.96	95.514	95.399	N/A
264	264a	92.076	92.033	1500	28.5	0.2	0.013	95.530	95.530	1.549	2.738	4.17	1.5	1.823	11.96	95.399	95.225	0.131
264a	265	92.033	91.963	1500	46.5	0.2	0.013	95.530	95.550	1.549	2.738	4.31	1.6	1.692	11.94	95.225	95.051	N/A
265	265a	91.924	91.816	1500	53.8	0.2	0.013	95.550	95.550	1.789	3.161	4.69	1.5	1.627	11.94	95.051	94.847	0.499
265a	266	91.816	91.778	1500	19.2	0.2	0.013	95.550	95.540	1.789	3.161	4.76	1.5	1.531	11.96	94.847	94.515	N/A
266	266a	91.568	91.509	1500	29.7	0.2	0.013	95.540	95.550	1.789	3.161	4.76	1.5	1.447	11.96	94.515	94.278	1.025
266a	267	91.509	91.429	1500	39.8	0.2	0.013	95.550	95.630	1.789	3.161	4.81	1.5	1.269	11.96	94.278	94.162	N/A
267	Pond1	91.429	91.350	1500	39.5	0.2	0.013	95.630	95.500	1.789	3.161	4.80	1.5	1.233	11.96	94.162	93.873	1.468
270	270a	92.828	92.710	900	59.1	0.2	0.013	95.500	95.500	1.273	0.810	1.35	1.7	1.912	11.82	95.640	95.381	-0.140
270a	271	92.710	92.665	900	22.4	0.2	0.013	95.500	95.320	1.273	0.810	1.35	1.7	1.771	11.82	95.381	95.289	N/A
271	271a	92.643	92.503	900	46.6	0.3	0.013	95.320	95.320	1.559	0.992	1.35	1.4	1.746	11.82	95.289	95.105	0.031
271a	273	92.503	92.416	900	28.9	0.3	0.013	95.320	95.140	1.559	0.992	1.38	1.4	1.702	11.81	95.105	94.977	N/A

Table C-1D: Pipe Data and Hydraulic Simulation Results for the 100-Year, 24-Hour SCS Type II Storm + 20%

U/S MH	D/S MH	U/S Invert (m)	D/S Invert (m)	Pipe Dia. / Height (mm)	Pipe Length (m)	Pipe Slope (%)	n	U/S MH Cover Elev. (m)	D/S MH Cover Elev. (m)	Design Vel. (m/s)	Design Flow (m^3/s)	Peak Pipe Flow (m^3/s)	Peak / Design Flow	Surcharge U/S [1] (m)	Time to Peak (h)	Max. U/S HGL (m)	Max. D/S HGL (m)	Freeboard [2] (m)
273	273a	92.364	92.313	900	25.5	0.2	0.013	95.140	95.140	1.273	0.810	1.34	1.7	1.713	11.84	94.977	94.861	0.163
273a	275	92.313	92.298	900	7.6	0.2	0.013	95.140	95.200	1.273	0.810	1.38	1.7	1.648	11.85	94.861	94.817	N/A
275	276	92.268	92.209	900	29.5	0.2	0.013	95.200	95.620	1.273	0.810	1.38	1.7	1.649	11.85	94.817	94.615	0.383
276	277	92.179	92.148	900	15.5	0.2	0.013	95.620	95.500	1.273	0.810	1.38	1.7	1.536	11.85	94.615	94.477	1.005
277	277a	92.067	91.964	975	51.7	0.2	0.013	95.500	95.630	1.342	1.002	1.50	1.5	1.435	11.91	94.477	94.323	1.023
277a	277b	91.964	91.869	975	47.5	0.2	0.013	95.630	95.630	1.342	1.002	1.57	1.6	1.384	11.92	94.323	94.178	N/A
277b	278	91.869	91.842	975	13.3	0.2	0.013	95.630	95.630	1.342	1.002	1.63	1.6	1.334	11.92	94.178	94.048	N/A
278	279	91.782	91.775	975	3.5	0.2	0.013	95.630	95.630	1.342	1.002	1.63	1.6	1.291	11.92	94.048	93.972	1.582
279	Pond1	91.715	91.650	975	32.5	0.2	0.013	95.630	95.500	1.342	1.002	1.63	1.6	1.282	11.92	93.972	93.873	1.658
280	280a	91.825	91.714	1650	73.8	0.2	0.013	95.450	95.510	1.651	3.530	4.19	1.2	0.802	13.75	94.277	94.118	1.173
280a	281	91.714	91.657	1650	38.2	0.2	0.013	95.510	95.510	1.651	3.530	4.20	1.2	0.754	13.75	94.118	94.033	N/A
281	Pond1	91.657	91.600	1650	38.0	0.2	0.013	95.510	95.500	1.651	3.530	4.20	1.2	0.726	13.75	94.033	93.873	1.477
328	263	92.425	92.359	1350	65.5	0.1	0.013	95.700	95.630	1.179	1.688	2.93	1.7	1.952	11.96	95.727	95.604	-0.027
329	329a	92.534	92.465	1050	27.4	0.3	0.013	95.700	95.700	1.577	1.365	2.02	1.5	2.224	12.33	95.808	95.700	-0.108
329a	263	92.465	92.434	1050	12.6	0.3	0.013	95.700	95.630	1.577	1.365	2.04	1.5	2.185	12.33	95.700	95.604	N/A
101	102	94.092	93.958	600	95.5	0.1	0.013	97.120	97.010	0.813	0.230	0.70	3.1	2.490	12.59	97.182	97.060	-0.062
102	103	93.883	93.783	675	83.5	0.1	0.013	97.010	96.880	0.814	0.291	0.89	3.1	2.502	12.55	97.060	96.890	-0.050
103	106	93.708	93.664	750	40.0	0.1	0.013	96.880	96.820	0.836	0.369	1.15	3.1	2.432	12.46	96.890	96.855	-0.010
106	109	93.589	93.544	825	45.0	0.1	0.013	96.820	96.750	0.849	0.454	1.29	2.8	2.441	12.41	96.855	96.760	-0.035
109	111	93.469	93.391	900	78.0	0.1	0.013	96.750	96.640	0.900	0.572	1.31	2.3	2.391	12.44	96.760	96.655	-0.010
111	112	93.241	93.142	1050	98.5	0.1	0.013	96.640	96.500	0.997	0.864	1.72	2.0	2.359	12.39	96.650	96.552	-0.010
112	113	92.992	92.863	1200	129.0	0.1	0.013	96.500	96.310	1.090	1.233	2.43	2.0	2.360	12.38	96.552	96.347	-0.052
113	114	92.833	92.754	1200	78.5	0.1	0.013	96.310	96.190	1.090	1.233	2.64	2.1	2.314	12.35	96.347	96.236	-0.037
114	122	92.604	92.524	1350	80.0	0.1	0.013	96.190	96.070	1.179	1.688	2.97	1.8	2.282	12.30	96.236	96.120	-0.046
122	126	92.494	92.287	1350	122.0	0.2	0.013	96.070	95.770	1.537	2.201	3.37	1.5	2.276	12.17	96.120	95.625	-0.050
126	127	92.212	92.111	1500	91.5	0.1	0.013	95.770	95.630	1.327	2.344	3.88	1.7	1.914	11.86	95.626	95.455	0.144
127	130	92.081	91.980	1500	91.5	0.1	0.013	95.630	95.490	1.327	2.344	4.05	1.7	1.875	11.87	95.456	94.959	0.174
130	138	91.905	91.840	1650	64.5	0.1	0.013	95.490	95.140	1.348	2.882	4.53	1.6	1.404	11.92	94.959	94.722	0.531
138	139	91.780	91.730	1650	50.0	0.1	0.013	95.140	95.400	1.348	2.882	5.43	1.9	1.292	12.00	94.722	94.505	0.418
139	140	91.670	91.656	1650	14.0	0.1	0.013	95.400	95.400	1.348	2.882	5.43	1.9	1.183	12.00	94.503	94.457	0.897
140	29	91.651	91.608	1650	43.4	0.1	0.013	95.400	95.352	1.348	2.882	5.43	1.9	1.156	12.00	94.457	94.280	0.943

Note: [1] A negative surcharge implies that the pipe is not flowing full

[2] Freeboard between upstream hydraulic gradeline elevation and upstream manhole cover elevation.

[3] Ponding allowed above manholes in undetailed future development areas to represent road surface storage above catchbasins.

APPENDIX J

JFSA Water Balance

J.F. Sabourin and Associates Inc.
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS

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October 31, 2013

David Schaeffer Engineering Ltd.
120 Iber Road, Unit 203
Ottawa, Ontario K2S 1E9

Attention: **Kevin Murphy, P.Eng.**

Subject: **Richmond Village (South) Limited Subdivision / Water Balance Analysis** *our file: 922-11*

As requested by your office, we have evaluated, based on the provided information as described below, the average annual infiltration volumes for the subject site under existing and proposed conditions.

As per the October 2013 *Richmond Village (South) Limited Subdivision / Preliminary Stormwater Management Analysis*, the proposed Richmond Village (South) development consists of a 126.81 ha drainage area to be treated by two Stormwater Management (SWM) facilities; SWM Facility 1 (91.82 ha at 51% imperviousness) discharging to Van Gaal Drain, and SWM Facility 2 (34.99 ha at 51% imperviousness) discharging to the Jock River. Note that, on the assumption that approximately half of each proposed building roof will be serviced by roof leaders directed onto grassed areas, the directly connected imperviousness of the proposed subdivision is approximately 45% for the drainage area to SWM Facility 1, and 46% for the drainage area to SWM Facility 2.

Existing drainage characteristics of the subject site are as per the *Floodplain Mapping Report for the Van Gaal and Arbuckle Municipal Drains in the Village of Richmond* (November 2009, JFSA). Refer to the October 2013 *Richmond Village (South) Limited Subdivision / Preliminary Stormwater Management Plan* memo for existing and proposed drainage plans and further details.

Under existing and proposed conditions, by means of 36 years of continuous hydrologic simulations using hourly rainfall data from the Ottawa International Airport from 1967 to 2003 (excluding missing 2001 rainfall data), the average annual runoff volumes from the subject site were computed and compared. Continuous modelling parameters were set as follows for both existing and proposed conditions:

APII=[50], APIK=[0.90]/day; used to compute the Antecedent Precipitation Index during the continuous simulation. Without model calibration these are the default values.

IaREC=[6](hrs); the time that it takes for the Initial Abstraction over pervious areas to recover during a dry period in undeveloped areas.

SMIN=[-1], SMAX=[-1](mm); the negative values indicate that the storage volume in the SCS procedure will vary between the "S" determined for AMC I and AMC III conditions of the entered CN value in undeveloped and urban areas.

SK=[0.03]/(mm); a calibration coefficient that can typically vary from 0.01 to 0.3 for undeveloped and urban areas. The higher the value, the more runoff generated. To set the baseline for existing conditions, we decided to take a value in the low range.

InitGWResVol=[100](mm), GWResK=[0.9](mm/day/mm), VhydCond=[1](mm/hr);
parameters that are used to simulate both the groundwater storage and discharge to surface watercourses from undeveloped areas. Without

adequate field measurements, these parameters were selected based on previous experience.

IaRECper=[3](hrs); the time that it takes for the Initial Abstraction over pervious areas to recover during a dry period in urban areas.

IaRECimp=[2](hrs); the time that it takes for the Initial Abstraction over impervious areas to recover during a dry period in urban areas.

InterEventTime=[12](hrs); the continuous dry time required to reset the parameters in the SCS procedure to their initial values.

Note that the subject site has a relatively high Curve Number (CN) of 88 under existing conditions as per the November 2009 *Floodplain Mapping Report*. In order to best represent the slow infiltration rates of the existing soils, and to provide a consistent comparison between existing and proposed conditions, the SCS procedure was used to simulate infiltration over the subject site for both existing and proposed conditions. Continuous hydrologic simulations were also performed with a CN of 99.99, in order to simulate the runoff from the subject site if no infiltration takes place. The difference between the runoff simulated with the actual CN of 88, and the runoff simulated with the CN of 99.99, is equal to the infiltrated volume over the subject site.

Based on the existing and proposed continuous simulations, the average annual infiltration over the subject site is approximately 58.4% less under proposed conditions (89,007 m^3) than under existing conditions (214,079 m^3).

A summary of the water balance analysis results may be found in Attachment A. Digital SWMHYMO modelling input and output files are also attached.

Yours truly,
J.F. Sabourin and Associates Inc.

Laura Pipkins, P.Eng.

cc: J.F. Sabourin, M.Eng, P.Eng.
Director of Water Resources Projects

Attachment A: Simulated Annual Infiltration Volumes for the Richmond Village (South) Limited Subdivision Site

ATTACHMENT

A

Simulated Annual Infiltration Volumes for the Richmond Village (South) Limited Subdivision Site

JFSA Water Resources and Environmental Consultants

Table 1: Richmond Village (South) Limited Subdivision Infiltration Volumes Under Existing Conditions [(1)]

Year	Total Rainfall		Runoff (No Infiltration)		Runoff (With Infiltration)		Infiltration	
	(mm)	(m^3)	(mm)	(m^3)	(mm)	(m^3)	(mm)	(m^3)
1967	386.9	490628	253.96	322047	148.87	188782	105.09	133265
1968	592.8	751730	338.04	428669	163.51	207347	174.53	221321
1969	569.8	722563	312.40	396154	147.21	186677	165.19	209477
1970	558.9	708741	306.76	389002	143.44	181896	163.32	207106
1971	522.1	662075	258.93	328349	113.48	143904	145.45	184445
1972	784.3	994571	484.87	614864	263.87	334614	221.00	280250
1973	744.9	944608	433.84	550153	212.13	269002	221.71	281150
1974	386.2	489740	184.15	233521	78.73	99838	105.42	133683
1975	535.5	679068	301.57	382421	140.55	178231	161.02	204189
1976	492.4	624412	238.57	302531	105.76	134114	132.81	168416
1977	677.6	859265	369.37	468398	169.93	215488	199.44	252910
1978	638.8	810062	345.64	438306	142.15	180260	203.49	258046
1979	866.5	1098809	540.45	685345	281.15	356526	259.30	328818
1980	622.0	788758	328.88	417053	147.69	187286	181.19	229767
1981	936.4	1187449	562.73	713598	318.35	403700	244.38	309898
1982	596.1	755914	300.13	380595	123.91	157130	176.22	223465
1983	587.3	744755	288.49	365834	129.88	164701	158.61	201133
1984	459.4	582565	268.94	341043	128.13	162482	140.81	178561
1985	559.9	710009	316.74	401658	127.56	161759	189.18	239899
1986	849.4	1077124	509.26	645793	282.46	358188	226.80	287605
1987	639.9	811457	321.75	408011	157.93	200271	163.82	207740
1988	643.2	815642	336.59	426830	161.03	204202	175.56	222628
1989	522.5	662582	260.01	329719	112.97	143257	147.04	186461
1990	727.8	922923	392.68	497958	190.63	241738	202.05	256220
1991	555.8	704810	264.10	334905	118.36	150092	145.74	184813
1992	730.2	925967	398.37	505173	197.92	250982	200.45	254191
1993	721.1	914427	373.67	473851	168.11	213180	205.56	260671
1994	527.0	668289	306.73	388964	150.72	191128	156.01	197836
1995	321.6	407821	216.31	274303	130.16	165056	86.15	109247
1996	512.2	649521	277.39	351758	129.99	164840	147.40	186918
1997	433.2	549341	232.72	295112	92.08	116767	140.64	178346
1998	440.3	558344	231.72	293844	100.94	128002	130.78	165842
1999	424.4	538182	243.43	308694	104.27	132225	139.16	176469
2000	535.9	679575	293.17	371769	144.61	183380	148.56	188389
2002	551.5	699357	367.64	466204	205.93	261140	161.71	205064
2003	554.6	703288	326.84	414466	174.96	221867	151.88	192599
Average		747066		415191		201113		214079
Minimum		407821		233521		99838		109247
Maximum		1187449		713598		403700		328818

[(1)] For a 126.81 ha drainage area as per the October 2013 *Preliminary Stormwater Management Plan* memo.

Note: Average Annual Percentage Infiltration = 28.7%.

Table 2: Richmond Village (South) Limited Subdivision Infiltration Volumes Under Proposed Conditions [(1)]

Year	Total Rainfall		Runoff (No Infiltration)		Runoff (With Infiltration)		Infiltration	
	(mm)	(m^3)	(mm)	(m^3)	(mm)	(m^3)	(mm)	(m^3)
1967	386.9	490628	242.82	307920	196.76	249511	46.06	58409
1968	592.8	751730	347.65	440855	274.34	347891	73.31	92964
1969	569.8	722563	318.26	403586	248.93	315668	69.33	87917
1970	558.9	708741	310.40	393618	242.19	307121	68.21	86497
1971	522.1	662075	273.24	346496	213.62	270892	59.62	75604
1972	784.3	994571	487.38	618047	393.59	499111	93.79	118935
1973	744.9	944608	445.68	565167	348.72	442212	96.96	122955
1974	386.2	489740	190.32	241345	149.25	189264	41.07	52081
1975	535.5	679068	307.41	389827	240.13	304509	67.28	85318
1976	492.4	624412	242.87	307983	192.04	243526	50.83	64458
1977	677.6	859265	385.52	488878	301.73	382624	83.79	106254
1978	638.8	810062	366.36	464581	278.14	352709	88.22	111872
1979	866.5	1098809	550.21	697721	437.19	554401	113.02	143321
1980	622.0	788758	340.46	431737	264.71	335679	75.75	96059
1981	936.4	1187449	571.16	724288	469.71	595639	101.45	128649
1982	596.1	755914	323.51	410243	252.13	319726	71.38	90517
1983	587.3	744755	301.25	382015	239.28	303431	61.97	78584
1984	459.4	582565	267.20	338836	207.17	262712	60.03	76124
1985	559.9	710009	335.03	424852	250.23	317317	84.80	107535
1986	849.4	1077124	507.20	643180	412.94	523649	94.26	119531
1987	639.9	811457	325.93	413312	263.69	334385	62.24	78927
1988	643.2	815642	345.53	438167	275.46	349311	70.07	88856
1989	522.5	662582	272.43	345468	212.29	269205	60.14	76264
1990	727.8	922923	403.48	511653	320.38	406274	83.10	105379
1991	555.8	704810	278.48	353140	223.39	283281	55.09	69860
1992	730.2	925967	404.60	513073	325.65	412957	78.95	100116
1993	721.1	914427	395.96	502117	313.49	397537	82.47	104580
1994	527.0	668289	307.63	390106	243.13	308313	64.50	81792
1995	321.6	407821	211.03	267607	173.42	219914	37.61	47693
1996	512.2	649521	284.57	360863	224.69	284929	59.88	75934
1997	433.2	549341	242.73	307806	184.03	233368	58.70	74437
1998	440.3	558344	235.46	298587	181.14	229704	54.32	68883
1999	424.4	538182	244.78	310406	185.49	235220	59.29	75186
2000	535.9	679575	299.89	380291	236.95	300476	62.94	79814
2002	551.5	699357	367.44	465951	296.52	376017	70.92	89934
2003	554.6	703288	333.96	423495	268.51	340498	65.45	82997
Average		747066		425089		336083		89007
Minimum		407821		241345		189264		47693
Maximum		1187449		724288		595639		143321

[(1)] For a 126.81 ha drainage area as per the October 2013 *Preliminary Stormwater Management Plan* memo.

Note: Average Annual Percentage Infiltration = 11.9%;

Proposed conditions average annual infiltration volume = 58.4% less than existing conditions volume.