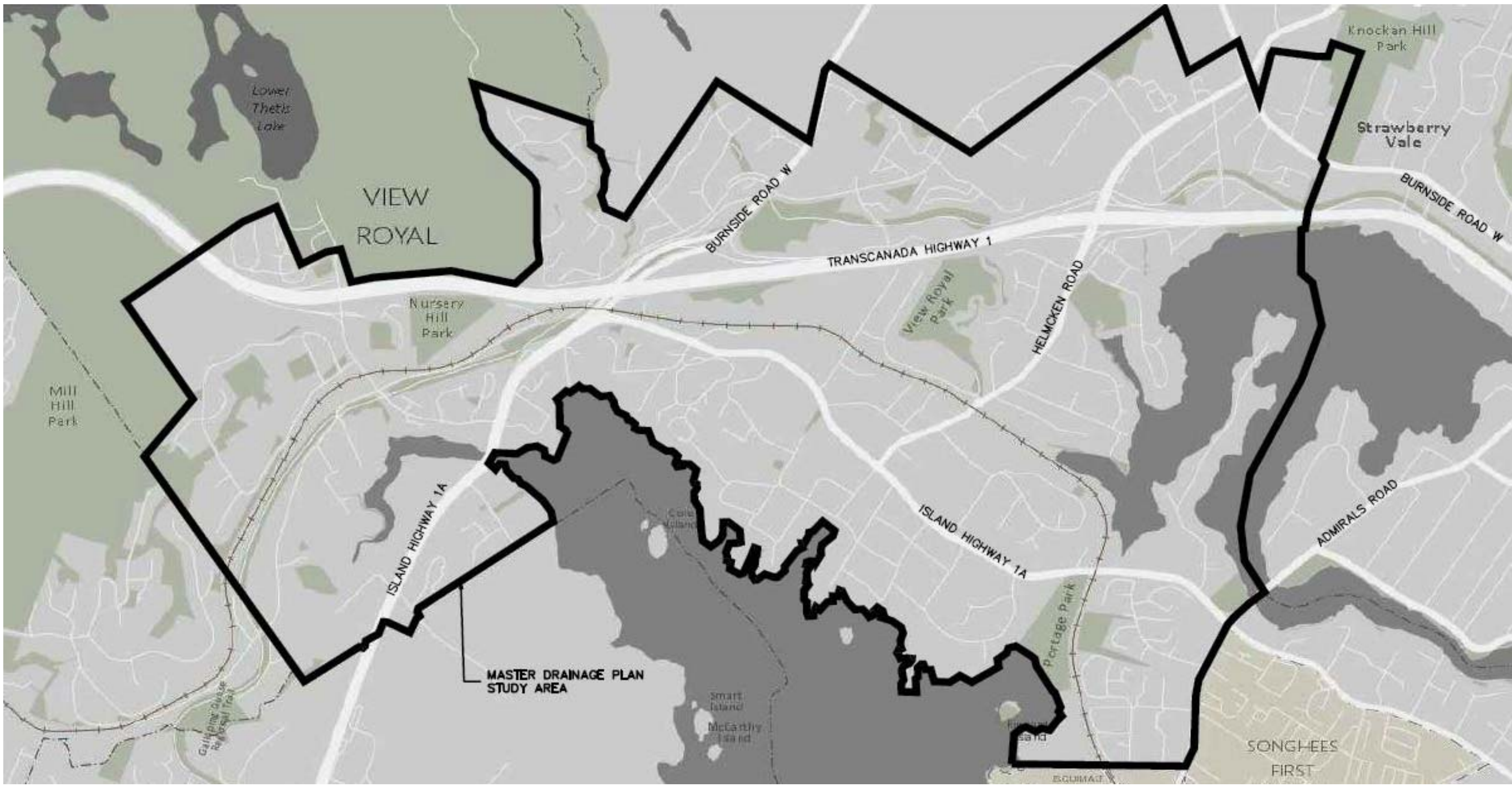

TOWN OF VIEW ROYAL

MASTER DRAINAGE PLAN UPDATE 2017

Project No. 16-282
October 11, 2017
Aplin & Martin Consultants Ltd.

APLIN MARTIN
ENGINEERING ARCHITECTURE PLANNING SURVEYING

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EXECUTIVE SUMMARY

In 2017, the Town of View Royal (Town) retained Aplin & Martin Consultants Ltd. (Aplin Martin) to update its Master Drainage Plan (MDP) and to provide a 20-year capital plan that addresses current and future drainage infrastructure needs. The 2017 MDP provides an update to View Royal's most recent MDP prepared by Kerr Wood Leidal Associates Ltd in 2008. The update incorporates changes in the Town's drainage system, developments completed after the previous MDP, as well as revisions to the Town's ultimate land use concept. The following tasks were performed in this study:

- Reviewed the existing drainage GIS database and provided an update to include new drainage projects and developments completed since the previous MDP update;
- Developed a hydrological and hydraulic model in PCSWMM using the existing model, GIS database, and latest land use plans;
- Performed a hydrotechnical assessment on the drainage system for the 10-year and 25-year event to identify system deficiencies, and the 100-year event to review overland flow routes;
- Evaluated drainage upgrade requirements and prepared a 20-year phased implementation plan with cost estimates

The analysis result identified 76 storm drains or culverts that are deficient due to poor condition or capacity issues. In addition, 17 storm drains or culverts require further investigation to assess replacement needs. Based on the analysis results and information gathered during the study, the following are recommendations provide for the Town with respect to drainage infrastructure planning and asset management:

- The Town shall establish long-term budgets for infrastructure upgrades as outlined in Section 6.1;
- The Town shall conduct a comprehensive update to the drainage GIS database. The scope of the update includes the collection of missing information, storm drain condition assessment, and a review of the accuracy of the existing information;
- The Town shall develop a maintenance program to inspect and maintain its drainage infrastructure on a regular basis;
- The Town shall review its overland flow paths for major storm drainage to identify and eliminate potential flood hazards;
- The Town may consider conducting additional studies to assess stormwater quality, flood risk at the low-lying coastal areas, potential climate change impacts, and develop appropriate remediation or control measures; and
- An Integrated Stormwater Management Plan (ISMP) may be prepared in place of the MDP Update within 10 years of this update. The ISMP is proposed to include the assessment of watershed health in addition to the hydrotechnical review that is carried out in a MDP study.

1.0 INTRODUCTION

The latest Master Drainage Plan (MDP) and the hydrological/hydraulic model of the stormwater drainage system for the Town of View Royal (Town) was developed in 2008 by Kerr Wood Leidal Associates Ltd. Although extensive development has not occurred, there have been several significant changes to the Town's drainage system since the 2008 MDP study. In 2017, The Town retained Aplin Martin Consultants Ltd. (Aplin Martin) for the preparation of a new MDP. The new MDP study included an assessment of the current drainage infrastructure in the urban area of the Town, identified system deficiencies, recommended improvements required to satisfy current and future needs and provided a 20-year capital plan that addresses current and future drainage infrastructure needs.

This report provides details of the updated MDP, with consideration of the changes subsequent to the previous study in 2008. It illustrates the tasks performed to update the MDP and details the methodology and design information utilized in the analysis. The results of the analysis and recommendations for upgrades are also included in this report.

1.1 Background

In 1990, the Town initiated the first MDP to assess the state of its drainage infrastructures and to formulate programs for future engineering works and services. The MDP identifies system deficiencies by simulating the performance of the infrastructure system under various design storm events using hydrological and hydraulic modelling. Based on the analysis results, recommendations for upgrades are provided in support of the Town's capital plan development. Since its implementation, the Town has updated the MDP several times to reflect land use changes and modifications to the drainage system. Table 1 shows the timeline and the respective consultants commissioned for the various iterations of the MDP.

Table 1 - Master Drainage Plan Timeline

MDP Timeline	Consultant
1990 Master Drainage Plan	Ker Priestman & Associated Ltd. (KPA)
2000 Master Drainage Plan Update	Reid Crowther & Partners Ltd. (Reid Crowther)
2008 Master Drainage Plan Update	Kerr Wood Leidal Associates Ltd. (KWL)
2017 Master Drainage Plan Update	Aplin & Martin Consultants Ltd. (Aplin Martin)

A GIS database containing the Town's key drainage infrastructures and a hydrological/hydraulic model was developed as part of the 2008 MDP. Aplin Martin was tasked to augment the GIS database and hydrological/hydraulic model to include the changes since the 2008 study.

The following materials were referenced in the preparation of this report:

- Master Drainage Plan 2008 Update – Draft Report, by KWL, dated March 2008;
- Modelling information, analysis data and digital files from KWL's 2008 MDP Update;
- Latest GIS drainage database, provided by the Town;
- As-constructed drawings for all developments and capital projects completed after 2008, provided by the Town;

- Light Detection and Ranging (LiDAR) data, provided by Capital Regional District (CRD)

1.2 Work Program

Table 2 outlines the tasks performed for the 2017 MDP study.

Table 2 - Work Program

Task	Task Description
Activity 1 - Project Initiation	
1.1. Data Collection and Review	• Review past MDP reports prepared for The Town of View Royal. • Review the existing GIS database, as-constructed drainage information for the new developments and re-developments since 2008 to identify changes required to update the existing drainage network • Identify missing data required for analysis. • Collect and review soil maps, LiDAR and contour data, air photos, zoning maps, and other community plan maps and documentation related to the study area.
1.2. Site Visit & Project Initiation	• Conduct a site visit with the Town staff to examine major stormwater infrastructure • Meet with Town staff to review project goals and objectives, verify project scope, work plan, schedule, and confirm drainage design criteria and existing drainage information
Activity 2 - Drainage Inventory Review	
2.1. GIS Database Update for the Drainage Network	• Review the GIS database developed for the 2008 MDP Study and evaluate the state of the information. • Update the GIS database to include as-built information that has not yet been incorporated, where information is available.
2.2. Adjust Catchment Delineation and Develop Existing and Future Land Use Maps	• Review the catchment delineation in the 2008 MDP and adjust catchment boundaries to account for the latest catchment and storm infrastructure information. • Review the 2008 land use map developed in the 2008 MDP, update it with the Town's most up to date zoning maps, orthophotos and development information to generate an existing land-use plan for 2017. • Update the future land-use map used in the 2008 MDP based on the updated View Royal Growth Strategy, OCP, and Neighbourhood Plans.

Task	Task Description
Activity 3 - Hydrologic/Hydraulic Modeling	
3.1. Design Storms and PCSWMM Model Set Up	• Develop design storms. • Determine future hydrologic parameters for each sub-catchment • Develop a PCSWMM model using the 2008 XPSWMM model and GIS database. • Verify the quality of data inputs.
3.2. Drainage System Assessment	• Conduct condition assessment of existing drainage infrastructure. • Perform model runs for design storm events under existing land-use conditions and future land-use conditions with existing drainage infrastructure. • Identify areas of surcharge, flooding, and other system deficiencies and determine their impacts • Identify the need for hydraulic upgrades and size required upgrades
Activity 4 - Master Drainage Plan Development	
4.1. Development of the Plan	• Summarize drainage upgrades identified and develop options to address drainage system deficiencies. • Develop Class C capital cost estimates for the selected upgrade options; • Evaluate drainage upgrade options based on effectiveness to providing flood protection, the Town's annual budget for drainage works, land acquisition requirements, and acceptability by The Town, community groups, and public. • Prioritize the need of the upgrades and develop a 20 Year Capital Plan for the Town using a phased approach
Activity 5 - Master Drainage Plan Report & Council Presentation	
5.1. Draft Report Preparation	• Prepare a draft MDP Report • Submit and review the draft report with The Town.
5.2. Council Presentation	• Prepare a PowerPoint presentation summarizing key findings of the study and recommended implementation plans of the Master Drainage Plan. • Present the findings and recommendations to Council;
5.3 Final Report and Deliverables	• Submit the final MDP Report and associated digital data

2.0 DRAINAGE INVENTORY

The Town of View Royal is divided into two major land-use areas:

- Land-use to the south of Thetis Lake Regional Park and the District of Saanich is typically urban.
- Land-use in the area north of Thetis Lake Regional Park is primarily rural.

This study is limited to the mapping and modelling of drainage infrastructure in the urban areas of View Royal. Examination of the natural channels and creeks north of Thetis Lake are outside the scope of this study.

The total catchment area for the urban portion of View Royal is 715 hectares. The drainage system in this portion consists of a large numbers of storm drains, ditches, and culverts that discharge to four major receiving water bodies through 73 outfalls. These bodies of water include Esquimalt Harbour, Portage Inlet, Craigflower Creek, and Millstream Creek.

2.1 GIS Database

A GIS database was constructed as part of the 2008 MDP study for the Town's drainage infrastructure system. It contains detailed information such as pipe sizes, inverts, materials, slopes, ditch cross-sections and manhole rim elevations. The database was compiled with as-constructed information available at the time and supplemented with survey data collected using a handheld GPS device and simple field measurements. Since its development, Town staff has occasionally updated the database to include new developments and infrastructure revisions. The database was utilized to setup the infrastructure network for the 2008 hydrologic and hydraulic model.

As part of this study, Aplin Martin was tasked to examine the state of the GIS database and update it with available as-built information provided by the Town for the drainage capital works and new developments designed and constructed since 2008. The review of the current database showed a considerable amount of data gaps. In some instances, discrepancies were identified between the existing data and the as-built information. Examples of the missing or inaccurate data include the following:

- Missing infrastructure (pipes, manholes, culverts, ditches, etc);
- Missing or erroneous infrastructure attributes (sizing, invert elevations, material, etc);
- Infrastructure shown at the incorrect locations; and
- Sizes or elevations of infrastructure shown differently in the existing GIS and the as-built data

Aplin Martin inserted a number of infrastructure designed and constructed after the previous MDP update into the database. Also, some of the discorded information was scrutinized and amended where digital as-constructed information is available. A log of the GIS updates conducted in this study is shown in Appendix A.

It is outside the scope of this study to conduct a detailed review and amendment of the database. A comprehensive review and update to the Town's drainage GIS database is recommended in the implementation plan of the 2017 MDP.

3.0 HYDROLOGIC AND HYDRAULIC MODELLING

To prepare each of the Town's MDP, hydrologic and hydraulic modelling has been performed to assess the drainage system under different design event conditions. In the 2008 MDP, a XP-SWMM model was constructed based on the GIS database at the time.

In this study, PCSWMM is utilized for the hydrologic and hydraulic modelling analysis. PCSWMM is a computer program developed by Computational Hydraulics International (CHI), based in Guelph, Ontario. It utilizes the EPA SWMM 5.0 modelling engine to perform hydrologic and hydraulic routings. PCSWMM contains a complete GIS system tailored to urban drainage modelling.

When the previous XP-SWMM model was built in 2008, various assumptions were made to develop a complete drainage network system for the Town due to a number of missing information in the database. Accordingly, it is not feasible to build a new model in PCSWMM using the incomplete GIS database within the scope of this study. The 2008 XP-SWMM model was imported into PCSWMM and updated to incorporate changes to the infrastructure system and land use plan since 2008.

Although data gaps are present and assumptions were made to construct the model, it should be noted that the majority of the main drainage system is included and the analysis results are considered to provide sufficient level of accuracy for the purpose of master planning.

The following sections illustrate details of the PCSWMM model development.

3.1 HYDROLOGIC MODEL SET-UP

3.1.1 Model Catchments & Coverage

The catchment plan for the 2008 MDP was delineated using contour map, orthophotos, and available drainage information at the time. This plan was updated in our 2017 study with a number of catchments/subcatchments adjusted and redelineated to reflect changes in the drainage characteristics due to new developments and infrastructure revisions. The model encompasses areas within the Town's Urban Growth Boundary (UGB), as well as areas outside of the UGB that drain towards the Town's drainage infrastructure system. Areas that are adjacent and drains to main waterbodies were excluded from the model as the runoffs are not collected by the Town's infrastructure system.

In total, 59 major catchments and 425 subcatchments were delineated. A major catchment differentiates the area that drains to a common discharge point. Each major catchment is further segmented into subcatchments which define the areas draining to localized storm drainage systems. For the purpose of master planning, all of the Town's lands within the study boundaries are assumed to drain to the municipal drainage network. The delineation of subcatchments was conducted based on known connection points to the drainage system or general site gradient as observed on contour maps. Figure 1 shows the catchment plan for the Town's latest drainage model.

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MASTER DRAINAGE PLAN
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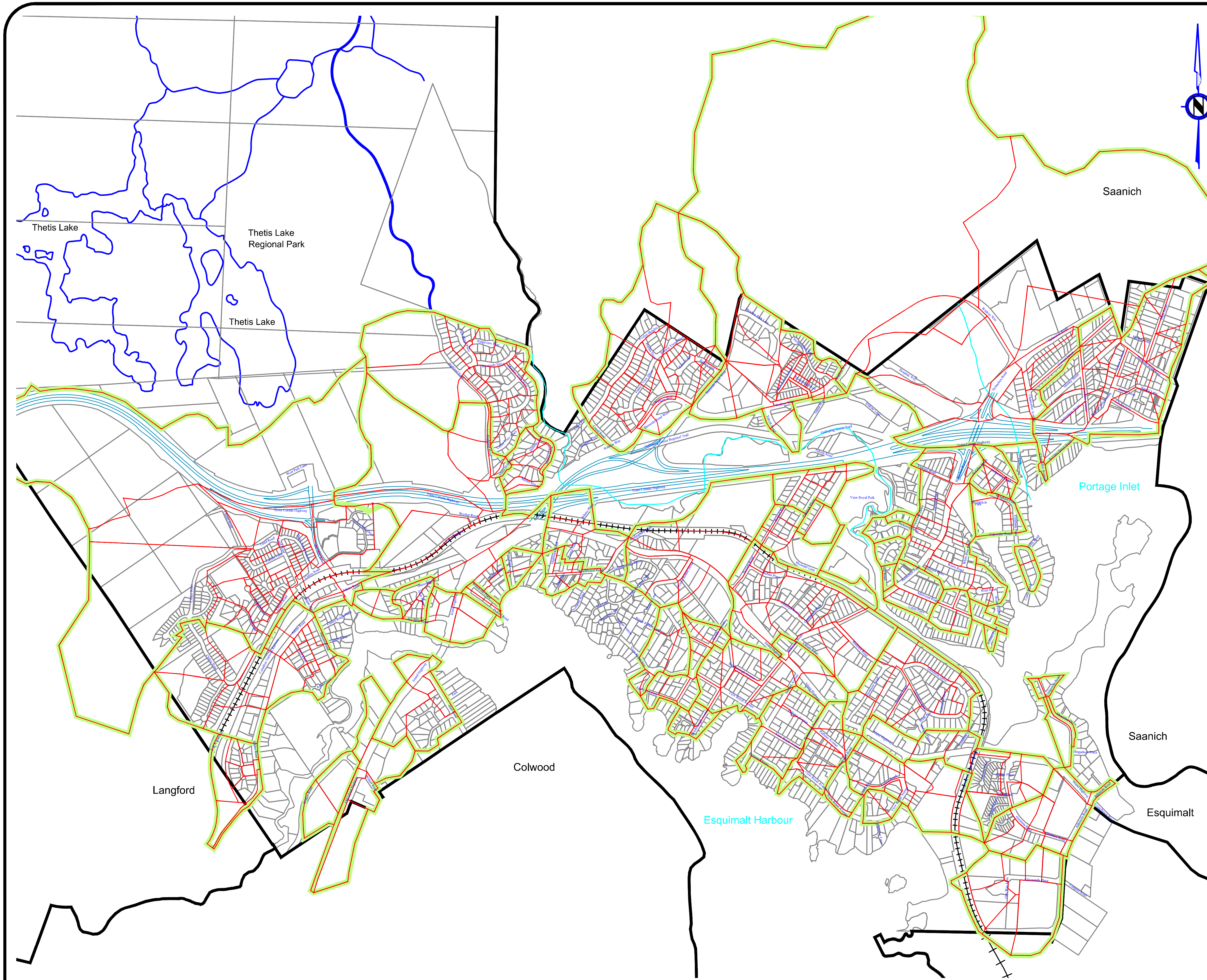
CATCHMENT PLAN



LEGEND

- SUB-CATCHMENT BOUNDARY
- MAJOR-CATCHMENT BOUNDARY
- MUNICIPAL BOUNDARY
- RAILROAD
- STREAM

0 150 1:15,000 750m

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Figure 1

M:\2016\16-282\ENGINEERING\DWG\OFFSITE\PRODUCTION DWGS\16-282 FIGURE 1 Catchment Plan.dwg

3.1.2 Land Use Plans and Imperviousness Values

Percent of imperviousness values were determined for each catchment based on land uses to properly simulate the corresponding land coverage. For the existing condition, the Town's zoning map and latest orthophotos were referenced to develop the existing land-use map. For the future condition, the land use designations illustrated in the Town's Official Community Plan (OCP) were adopted. The existing and future land-use maps developed for the study area can be referenced in Figure 2 and Figure 3.

The imperviousness for each catchment was determined by reviewing its land use composition and typical values assigned for various land use types. Typical imperviousness values were developed from a review of the Town's zoning bylaw and airphotos showing land coverage composition for various land uses. For catchments with multiple land use designations, the imperviousness values were calculated by pro-rating the area fraction of each land use within the catchment. Table 3 shows the typical imperviousness values assigned to various land use types.

Table 3 - Typical Imperviousness Values

Land Use Designations	Imperviousness
Commercial (C)	85%
Intensive Mixed Use (IMU)	80%
Mixed Residential (M-R)	80%
Neighbourhood Mixed Use (NMU)	80%
Community Facility (CF)	75%
Road	70%
Residential (R)	60%
Large Lot Residential (R-L)	25%
Rural (RU)	10%
Park, Open Space, Recreation (P)	10%

Based on the values in Table 3, we have estimated has an overall imperviousness of 39.7% under the existing land use condition and 41.7% under the future land use condition. A list of the modelled catchments and their basic parameters can be referenced in Appendix B.

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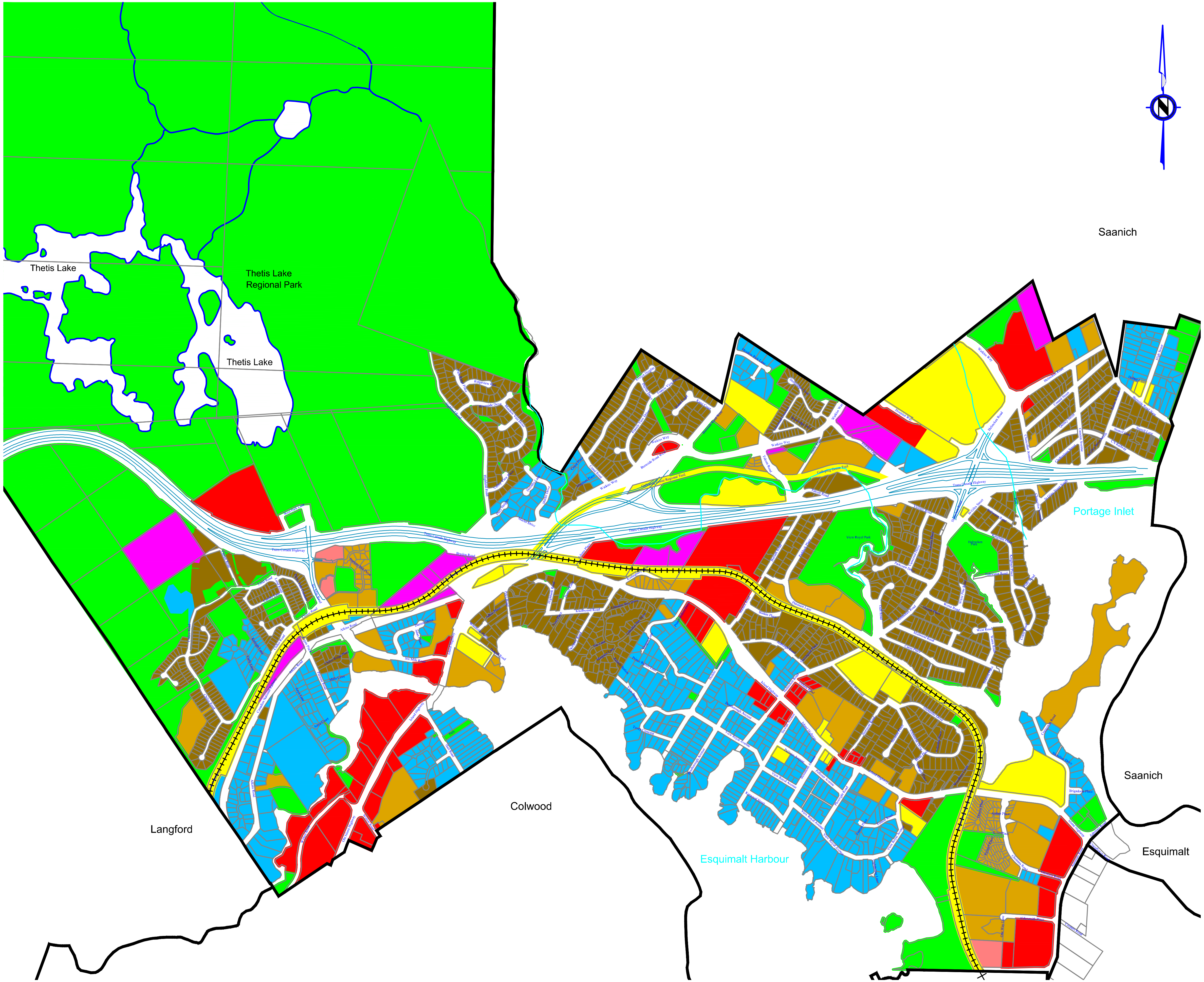
EXISTING LAND USE MAP



LEGEND

- COMMERCIAL
- COMMUNITY FACILITY
- MIXED RESIDENTIAL
- NEIGHBORHOOD MIXED-USE
- PARK, OPEN SPACE
- RESIDENTIAL
- LARGE LOT RESIDENTIAL
- RURAL
- MUNICIPAL BOUNDARY
- RAILROAD
- STREAM

0 150 1:15,000 750m

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Figure
2

M:\2016\16-282\ENGINEERING\DWG\OFFSITE\PRODUCTION DWGS\16-282 FIGURE 2 EX. LAND USE.dwg

TOWN OF VIEW ROYAL
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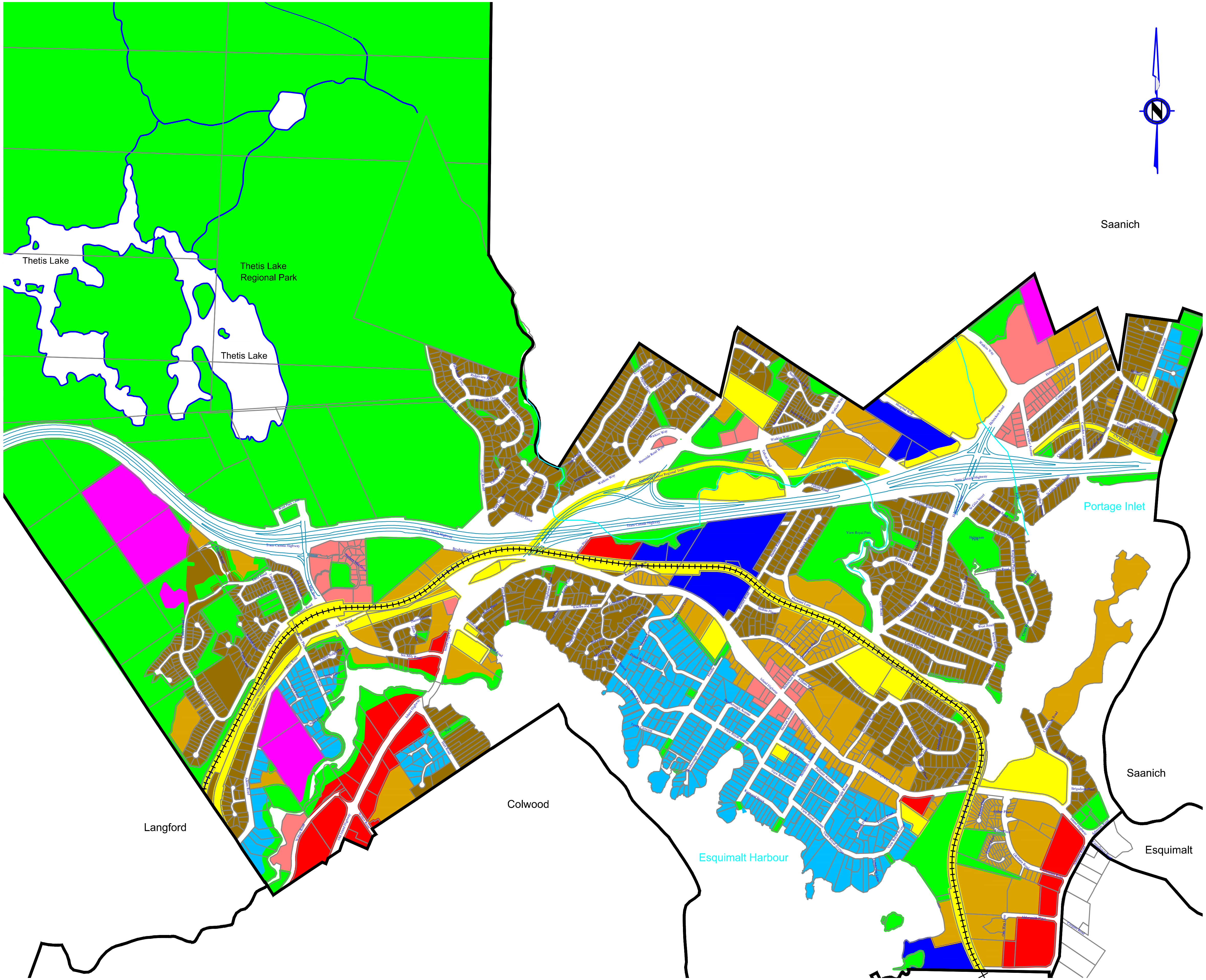
FUTURE LAND USE MAP



LEGEND

- COMMERCIAL
- COMMUNITY FACILITY
- MIXED RESIDENTIAL
- NEIGHBORHOOD MIXED-USE
- PARK, OPEN SPACE
- RESIDENTIAL
- LARGE LOT RESIDENTIAL
- RURAL
- INTENSIVE MIXED-USE
- MUNICIPAL BOUNDARY
- RAILROAD
- STREAM

0 150 1:15,000 750m

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Figure 3

M:\2016\16-282\ENGINEERING\DWG\OFFSITE\PRODUCTION DWGS\16-282 FIGURE 3 OCP_LU Map UTM83-11.dwg

3.1.3 Soil Conditions

The 2000 Quaternary Geological Map of Greater Victoria, prepared by the Geological Survey Branch of the Ministry of Energy and Mines of BC, was used to classify the soil conditions of the study area. This map provides a comprehensive presentation of the surficial geology of the area. The following geological classifications are noted within the study area:

- R1 - Bedrock;
- R1/2 - Outcrop and thin soil cover; and
- R2 - Thin soil cover with bedrock outcrop.
- C2 - Thick soft clay;
- C1 - Intermediate between R2 and C2, shallow to thick clay cover, scattered bedrock outcrop;

The study area is predominated by Clay soils or shallow soils over an impervious layer. Based on the above, the overall area is considered to have a very low infiltration rate with a permanently high water table.

3.1.4 Hydrological Parameters

The hydrologic model considers surface/subsurface storage, runoff, infiltration and subsurface flows in the computation. Parameters for hydrological modelling were selected from a database of calibrated model parameters with respect to the soil types in the study area based on our past modelling experience. Table 4 shows the infiltration and groundwater parameters used in the hydrological model.

Table 4 - Infiltration & Groundwater Modelling Parameters

Global Data	Depression Storage (mm)	
	- Impervious	2
	- Pervious (Lawn)	7.5
	Manning's n	
	- Impervious	0.015
	- Pervious	0.4
Green-Ampt Infiltration Parameters	Average Capillary Suction (mm) (Wet)	292.2
	Initial Moisture Deficit (Wet)	0.9
	Saturated Hydraulic Conductivity (mm/hr)	0.21
Aquifer Parameters	Porosity, fraction	0.479
	Wilting Point, fraction	0.26
	Field Capacity, fraction	0.41
	Conductivity, mm/hr	0.9
	Conduct. Slope	14.5
	Tension Slope, mm	500
	Upper ET Fraction, fraction	1
	Lower ET Depth, m	0.6
	Lower GW Loss Rate, mm/hr	0.01
	Bottom Elevation, m	Assumed to be 1.6m from the surface
	Water Table Elevation, m	Assumed to be 1.6m from the surface
	Unsaturated Zone Moisture, fraction (Wet)	0.26
Groundwater Interflow Parameters	Surface Elevation, m	Variable
	GW Flow Coefficient (A1)	0.5
	GW Flow Exponent (B1)	1
	SW Flow Coefficient (A2)	0
	SW Flow Exponent (B2)	0
	SW-GW Interaction (A3)	0
	Fixed SW Depth, m	0
	Threshold Elev. M	-99

3.2 HYDRAULIC MODEL SET-UP

3.2.1 Model Network

The drainage model includes the majority of the drainage features within the Town's Urban Growth Boundary. It contains the Town's main storm drains, culverts, ditches, storage ponds, manholes and outfalls that are documented in the GIS database. For the purpose of master planning, the smaller infrastructure such as catch basins, service connections, cleanouts, and small ditches were omitted from the model. Assumptions were made for information that are missing from the GIS database.

In total, the following components of the Town's drainage system is included in the latest drainage model:

- 34.7 km of storm drains and culverts;
- 12.2 km of ditches;
- 599 manholes, catch basins and lawn basins;
- 4 detention facilities; and
- 73 outfalls

Figure 4 shows a plan of the Town's drainage network included in the model developed for the study.

3.2.2 Infrastructure Data

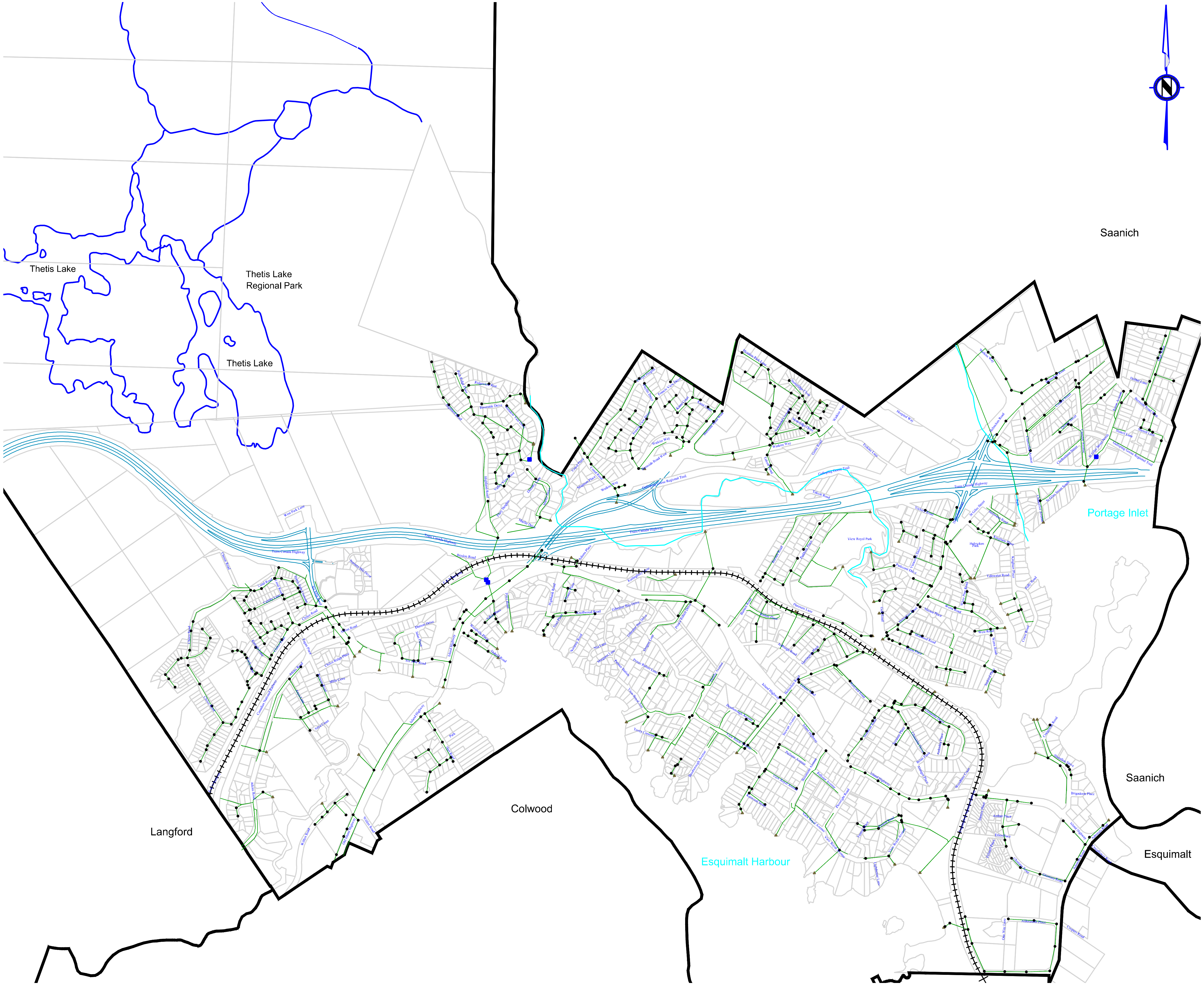
The physical data for all the infrastructure included in the model was taken from the GIS database which has been updated based on available as-built information. Assumptions were made to fill the data gaps in the GIS database for missing information or information noted with discrepancies. Ditch cross-sections determined by field measurements conducted during the 2008 MDP Update were continuously used in the latest model developed for the 2017 MDP Update.

Manning's roughness coefficient values were assigned to the modelled storm drains and ditches based on their respective material and channel composition. Table 5 lists the typical values adopted in the model.

Table 5 - Typical Manning's Roughness Coefficients

Pipe Material/Channel	Manning's n value
PVC	0.011
Concrete	0.013
Corrugated Steel Pipe	0.024
Open Channel/Ditches	0.030

For a number of storm drains where the pipe material is unknown, parameters from the 2008 model was taken for this study.



TOWN OF VIEW ROYAL
MASTER DRAINAGE PLAN
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MODEL NETWORK

LEGEND

- • **JUNCTION**
- ▪ **STORAGE**
- △ **OUTFALL**
- **CONDUIT**
- **MUNICIPAL BOUNDARY**
- **RAILROAD**
- **STREAM**

0 150 1:15,000 750

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10/10/2017

Figure **4**

M:\2016\16-282\ENGINEERING\DWG\OFFSITE\PRODUCTION DWGS\16-282 FIGURE 4_5_6 MODEL NETWORK.dwg

3.2.3 Downstream Boundary Conditions

A number of the Town's drainage features are situated near sea level and may be impacted by high tide events. To account for this phenomenon, an extreme high tide level of 1.77m-geodetic was assigned as the constant boundary water level to outfalls. The extreme high tide elevation was taken from the 2017 Canadian Tide and Current Table, Vol 5 at the Esquimalt Harbour Secondary Port, with reference to the historically highest tide level recorded at Victoria Reference Port, compiled by Canadian Hydrographic Services.

A separate scenario assuming a free outflow boundary condition for all outfalls was also performed in the model. This is to assess the Town's storm drain system to ensure it has sufficient capacity to drain the system under a low tide condition without restriction caused by undersized pipes in the tidal impacted back water zone.

3.2.4 Model Calibration

Model calibration was not performed in this study as no monitoring data is available within the project limits. However, the model parameters assigned were determined based on our past experience with the calibrated models for watersheds with similar hydrologic and hydraulic conditions. The model developed for this study is deemed to provide a reasonable representation of the Town's drainage system for the purpose of master planning.

4.0 HYDROTECHNICAL ASSESSMENT

Using the hydrologic and hydraulic model developed for this study, a hydrotechnical assessment was conducted to evaluate the existing drainage system under both the existing and future land use conditions to identify deficient infrastructure that requires immediate attention and provide recommendations for upgrades to minimize flood risks and plan for future growth.

The Town's Land Use Bylaw, 1990, No.35, stipulates the following criteria for drainage infrastructure sizing:

- Storm drains up to and including 900mm diameter to be designed for the 10-year return period for flood protection; and
- Storm drains greater than 900mm diameter to be designed for the 25-year return period for flood protection.

The hydrotechnical assessment performed in this study focuses mainly on meeting the Town's storm drain criteria and include:

- Conduct a review of the capacities of the existing drainage system to convey the 10-year, 25-year, and 100-year peak flows under existing and future land use conditions.
- Provide recommendations for storm drain and culvert upgrades for the conveyance of the 10-year and 25-year peak flows under existing and future land use conditions
- Prioritize upgrade requirements and prepare a 20-year capital plan for drainage improvement

The following sections provide details of the methodology, evaluation criteria, and results of the assessment.

4.1 Design Storms

The following design storms are simulated for modelling the Town's drainage system:

- 10-year return period, 1-hour, 2-hour, 6-hour, 12-hour and 24-hour design events;
- 25-year return period, 1-hour, 2-hour, 6-hour, 12-hour and 24-hour design events; and
- 100-year return period, 1-hour, 2-hour, 6-hour, 12-hour and 24-hour design events

Since the Town does not contain any long-term rainfall record, data from various regional Environment Canada climate stations were extracted to observe local rainfall patterns and develop design storms for analysis. Based on a review of the climate stations in the region, the Esquimalt Harbour station is found to be the closest in distance.

Only daily data has been recorded and Intensity-Duration-Frequency (IDF) curves are not available at the Esquimalt Harbour station. Historical daily rainfall data from the Esquimalt Harbour station was collected and filtered to derive a series of annual maximum daily rainfall values. Using Gumbel's method, a frequency analysis was performed to estimate peak daily rainfall values for the 10-year, 25-year, and 100-year return period.

For design storms with less than 24 hours durations, the IDF data from 4 other regional climate stations at Gonzales Heights, Camosun College, the University of Victoria, and the Victoria International Airport were utilized to develop IDF curves for the Esquimalt Harbour station. Table 6 presents the total peak daily rainfall at the aforementioned climate stations.

Table 6 - Peak Daily Rainfall at Neighbouring Climate Stations

Station #	Station Name	Period of Available Record	Total Peak Daily Rainfall (mm)		
			1:10-Year	1:25-Year	1:100-Year
1018610	Victoria Gonzales	1925 - 1988	75.3	90.6	113.2
1018FF6	Victoria UVic	1965 - 1985	74.1	87.5	107.4
1016941	Saanich Camosun College	1964 - 1975	78.6	92.7	113.7
1018621	Victoria Int'l A	1965 - 2013	82.3	96.6	117.7
1012710	Esquimalt Harbour	1957 - 2016	78.9	91.4	109.8

For each climate station, the ratio of total rainfall value for each duration to the total daily rainfall value was calculated for each return period. The average of these ratios was then applied to the estimated peak daily rainfall values to determine the total rainfall values for the 1-hour, 2-hour, 6-hour, and 12-hour events at the Esquimalt Station. Table 7 summarizes the estimated total peak design rainfall values for all durations at the Esquimalt Station.

Table 7 - Estimate Peak Design Rainfall Values at the Esquimalt Station

Duration	Peak Accumulative Rainfall (mm)		
	1:10-year	1:25-year	1:100-year
1-hour	12.6	14.5	17.2
2-hour	19.1	21.7	25.7
6-hour	37.5	42.1	49.1
12-hour	56.6	64.2	75.8
24-hour	78.9	91.4	109.8

With the IDF data, design storm hyetographs are generated using the AES distribution curves. Based on rainfall analysis previously performed for the Capital Regional District area (e.g. for the recent City of Victoria and District of Saanich drainage studies), the AES 30% distribution is recommended for short durations up to 6-hours and the AES 50% distribution is recommended for long durations. The design storm hyetographs prepared for the model can be referenced in Appendix C.

4.2 Drainage System Analysis

Using the View Royal's storm drain design criteria, the Town's existing drainage system was assessed to determine its capability to convey the 10-year and 25-year design events under 4 different scenarios listed in Table 8:

Table 8 - Model Simulations

Scenario	Simulation Objective
1) Existing land use with the extreme high tide elevation of 1.77m-geodetic as the boundary condition for all outfalls	Assess impact of backwater effect from high tide elevations
2) Future land use with the extreme high tide elevation of 1.77m-geodetic as the boundary condition for all outfalls	
3) Existing land use with free discharge at all outfalls	Assess system capacity to convey runoff
4) Future land use with free discharge at all outfalls	

A comparison of the analysis results between the scenarios of existing land use and future land use conditions shows negligible differences in terms of the quantity and locations for system deficiency. This can be attributed to the minor differences in land coverage between the existing and future land use plan. Since the differences are minimal, the proposed infrastructure upgrades and implementation plan are developed for the future ultimate land use servicing needs.

Storm drains and culverts are denoted as conduits in the model. Manholes and junctions that are flooded or surcharged, and conduits that are surcharged are noted and requirements for potential upgrades are reviewed. Junctions are classified as surcharged when one or more of the connecting drains are under capacity but the flood water remains under the ground surface. Junctions are classified as flooded when the flood water breaches the ground surface elevation. For a conduit to be categorized as undersized, it must be surcharged for longer than 2 minutes. The model is setup to contain all flows in the system to ensure that every conduit is modelled with its maximum potential inflow regardless of any upstream surcharge or flood conditions.

Under the future land use conditions, 112 modelled conduits which are made up of approximately 4090m of storm drains and culverts, were found to be undersized under the 10-year design storm conditions. There are only limited number of storm drains found being greater than 900mm diameter and no surcharging was noted for these storm drains both the 10-year and 25-year storm conditions. This is reasonable as the Town of View Royal has a significant amount of land fronting the ocean or major waterbodies near the ocean with highly variable terrain. Contributing catchment area to each outfall is small, which minimizes the need for large storm drains. Figure 5 and Figure 6 present the results of the analysis and highlight the undersized storm drains during the 10-year and 25-year event, respectively.

To assess the upgrade requirements, all conduits that are deemed to be undersized are upsized in the model to eliminate surcharging in the system. While the simulations identify the impacts from a high tide condition, infrastructure that are flooded from tidal influences are excluded from the replacement plan. It is a pre-existing condition and most of them do not have practical options for an overhaul due to natural topography. Therefore, the replacement recommendations and implementation plan is customized to address infrastructure needs under the future land use plan with a free outflow condition.

4.3 Major Storm Drainage & Overland Flow Path Assessment

As discussed in the previous section, the Town's design criteria specify new storm drains to be designed for the 10-year and 25-year event depending on pipe sizes. The storm drainage system is not required to convey runoff generated by greater storm events and runoff is expected to flow overland to an outfall. In this study, a simulation for the 100-year event was performed to pinpoint the locations where storm flows exceed the capacity of the storm drainage system and breach the surface. At these locations, a safe overland flow route is required to prevent surface flooding and eliminate flood hazard to private properties. Using LiDAR data provided by the CRD, we determined the overland flow routes from these locations and they are presented on Figure 7.

The following remarks were made upon a review of the flow routes:

- The majority of the locations with potential flooding have overland flow routes to convey surface flows to an outfall along the road right-of-ways or park areas;
- Several of the overland flow routes traverse through private properties. Further review of site topography is recommended for these overland flow routes to ensure that all properties are safeguarded from major storm overland flows.
- One location with potential flooding on Island Highway, west of Adams Place, is a localized low point and it does not have an outlet for flood water. At this location, the storm drainage system must be sized to convey the 100-year flow. The required upsizing to provide safe conveyance for major flows will be included in the infrastructure upgrade plan.

Please note the assessment performed in this study is only able to provide an estimation of the flow paths as the level of accuracy is bounded by the accuracy of the LiDAR data. A more thorough assessment using detailed topographic survey is required for the design of new developments.

4.4 Infrastructure Condition Assessment

Field investigation was not performed for this study. However, 23 storm drains and culverts with a total length of approximately 300m were identified with structural deficiency and/or risk of failure from the 2008 MDP study and previous condition assessment by Town staff. These conduits are proposed to be rehabilitated as part of the capital plan in this study.

NOTICE TO CONTRACTOR

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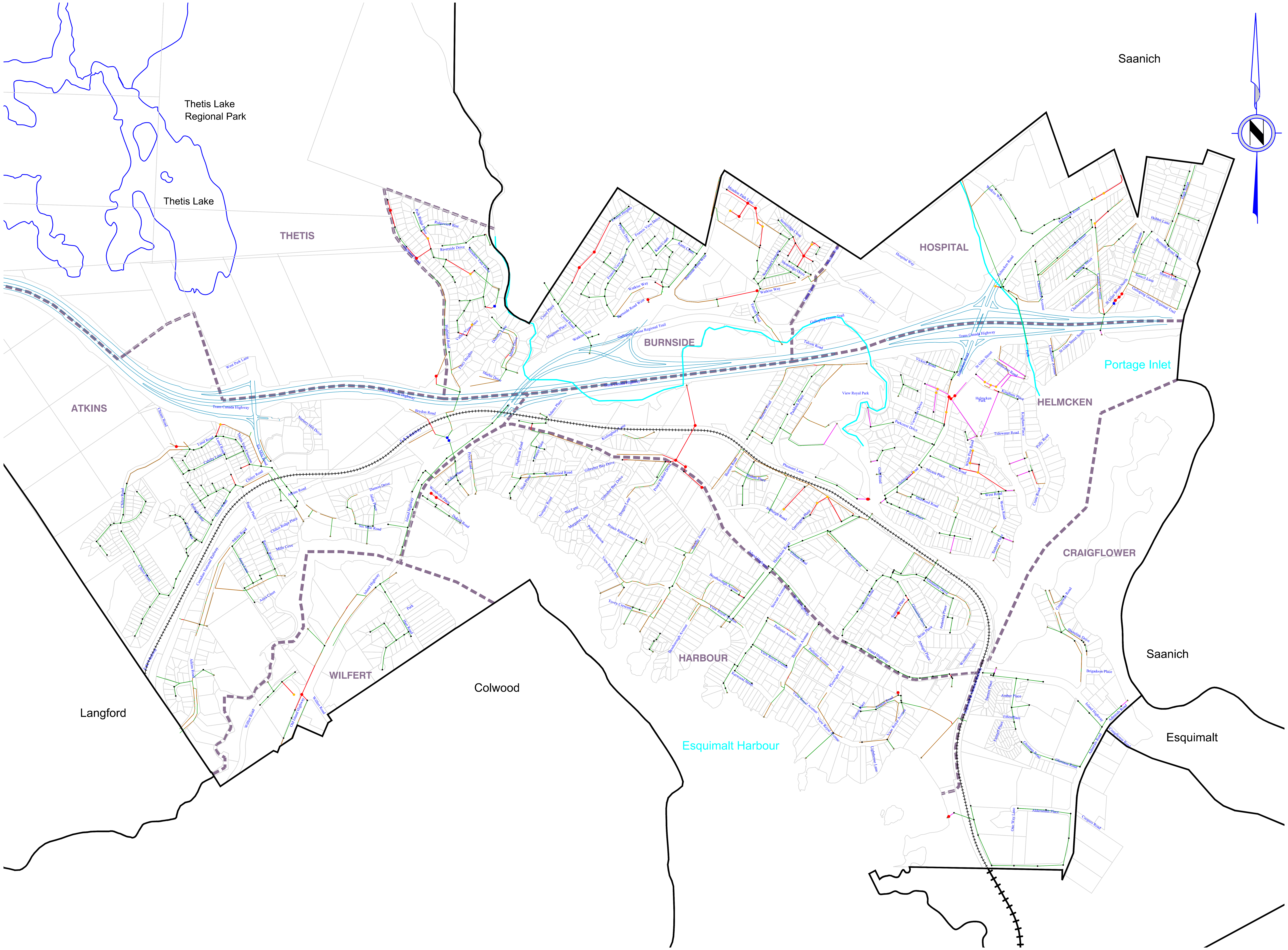

LEGEND

- 10 YEAR STORM FLOODED MANHOLE
- 10 YEAR STORM SURCHARGED MANHOLE
- MANHOLE
- STORAGE
- OUTFALL
- STORM SEWERS & CULVERTS
- DITCH
- 10 YEAR STORM SURCHARGED PIPE
- SURCHARGED PIPES UNDER HIGH TIDE BOUNDARY CONDITION
- LEGAL LINES
- MUNICIPAL BOUNDARY
- TRANS CANADA HWY
- STREAM
- RAILWAY
- NEIGHBOURHOOD BOUNDARY

LEGAL DESCRIPTION:

B.M. MONUMENT NO. ELEVATION:
LOCATED AT:

REV. NO.	DESCRIPTION	DR	CH	DATE	APP
1	FOR REVIEW	JS	VL	14/07/2017	WY
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CLIENT: **TOWN OF VIEW ROYAL**
45 VIEW ROYAL AVENUE, VICTORIA, BC V9B 1A6

PROJECT: **TOWN OF VIEW ROYAL**
MASTER DRAINAGE PLAN 2016-2017

The location of existing underground utilities are shown in an approximate way only & have not been independently verified by the owner or its representative. The contractor shall determine the exact location of all existing utilities before commencing work, and agrees to be fully responsible for any and all damages which might be occasioned by the contractor's failure to exactly locate and preserve any and all underground utilities.

TITLE:
10 YEAR EVENT FUTURE LAND USE STORM SEWER ASSESSMENT

DESIGN: VL CHECK: VL
DRAWN: JS APPR: WY

A & M FILE: **16-282**

PROJECT NO. **16-282**

SCALE : HORZ. 1:7,500 VERT.

DRAWING DATE: **JULY2017**

DRAWING NO.

A & M DRAWING NO. **FIGURE 5**

FIGURE NO. **05 OF 08**

REV. **2**

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Oct 06 2017 – 8:57am M:\2016\16-282\ENGINEERING\DWG\OFFSITE\PRODUCTION DWGS\16-282 FIGURE 4_5_6 MODEL NETWORK.dwg/05 FIGURE 5 10 Yrs STORM SEWER JSHI

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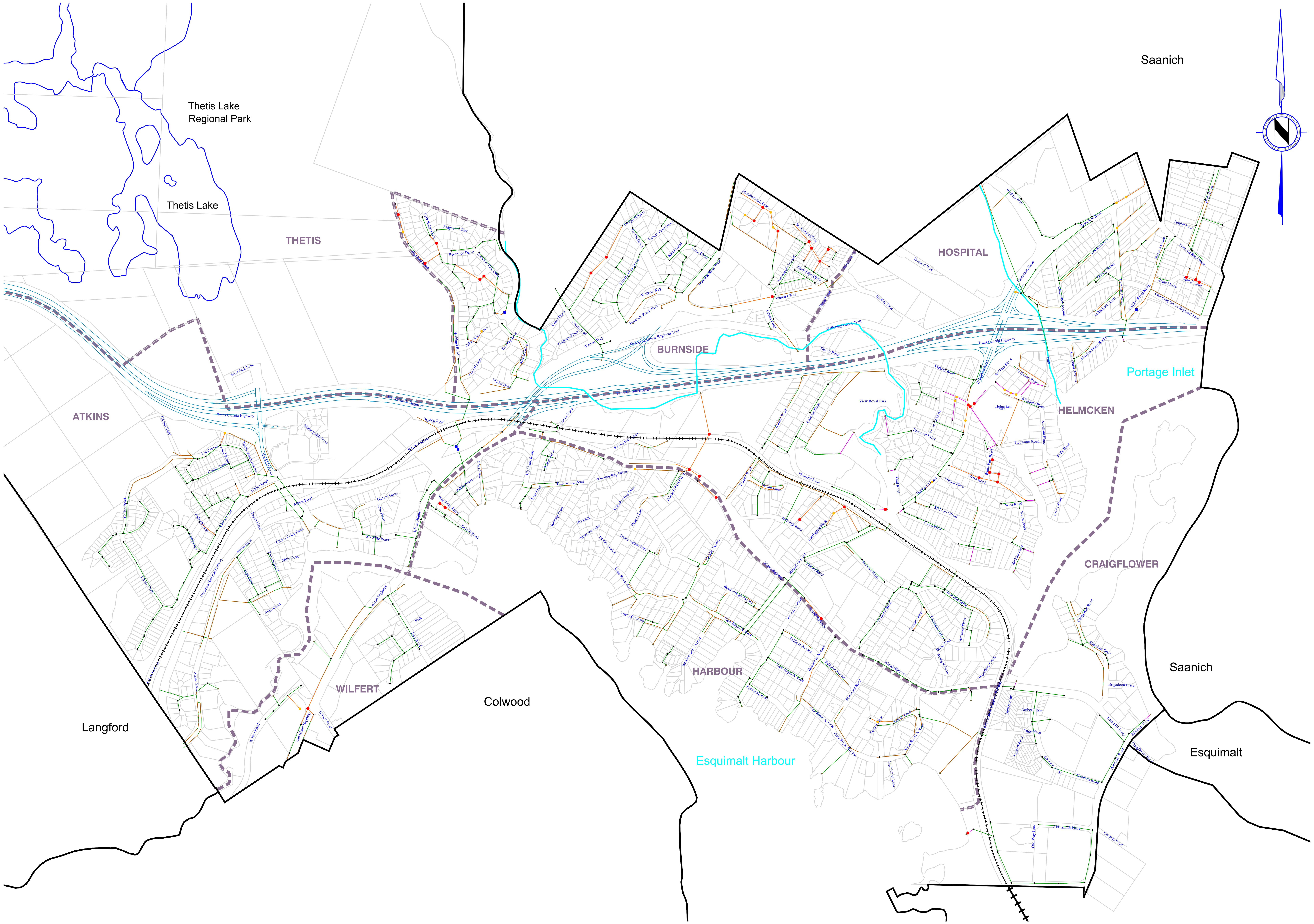

LEGEND

- 25 YEAR STORM FLOODED MANHOLE
- 25 YEAR STORM SURCHARGED MANHOLE
- MANHOLE
- STORAGE
- OUTFALL
- STORM SEWERS & CULVERTS
- DITCH
- 25 YEAR STORM SURCHARGED PIPE (>900mm)
- 25 YEAR STORM SURCHARGED PIPE (≤900mm DIA.)
- SURCHARGED PIPES UNDER HIGH TIDE BOUNDARY CONDITION
- LEGAL LINES
- MUNICIPAL BOUNDARY
- TRANS CANADA HWY
- STREAM
- RAILWAY
- NEIGHBOURHOOD BOUNDARY

LEGAL DESCRIPTION:

B.M. MONUMENT NO. ELEVATION:
LOCATED AT:

REV. NO.	DESCRIPTION	DR	CH	DATE	APP
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2	FINAL SUBMISSION	JS	VL	10/10/2017	WY

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CLIENT: **TOWN OF VIEW ROYAL**
45 VIEW ROYAL AVENUE, VICTORIA, BC V9B 1A6

PROJECT: **TOWN OF VIEW ROYAL MASTER DRAINAGE PLAN 2016-2017**

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TITLE: **25 YEAR EVENT FUTURE LAND USE STORM SEWER ASSESSMENT**

DESIGN: VL CHECK: VL
DRAWN: JS APPR: WY
A & M FILE: **16-282**

PROJECT NO. **16-282**
SCALE : HORZ. 1:7,500 VERT. N/A
DRAWING DATE: **JULY 2017**

DRAWING NO.
A & M DRAWING NO. **FIGURE 6**
FIGURE NO. **06 OF 08**
REV. **2**

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NOTICE TO CONTRACTOR

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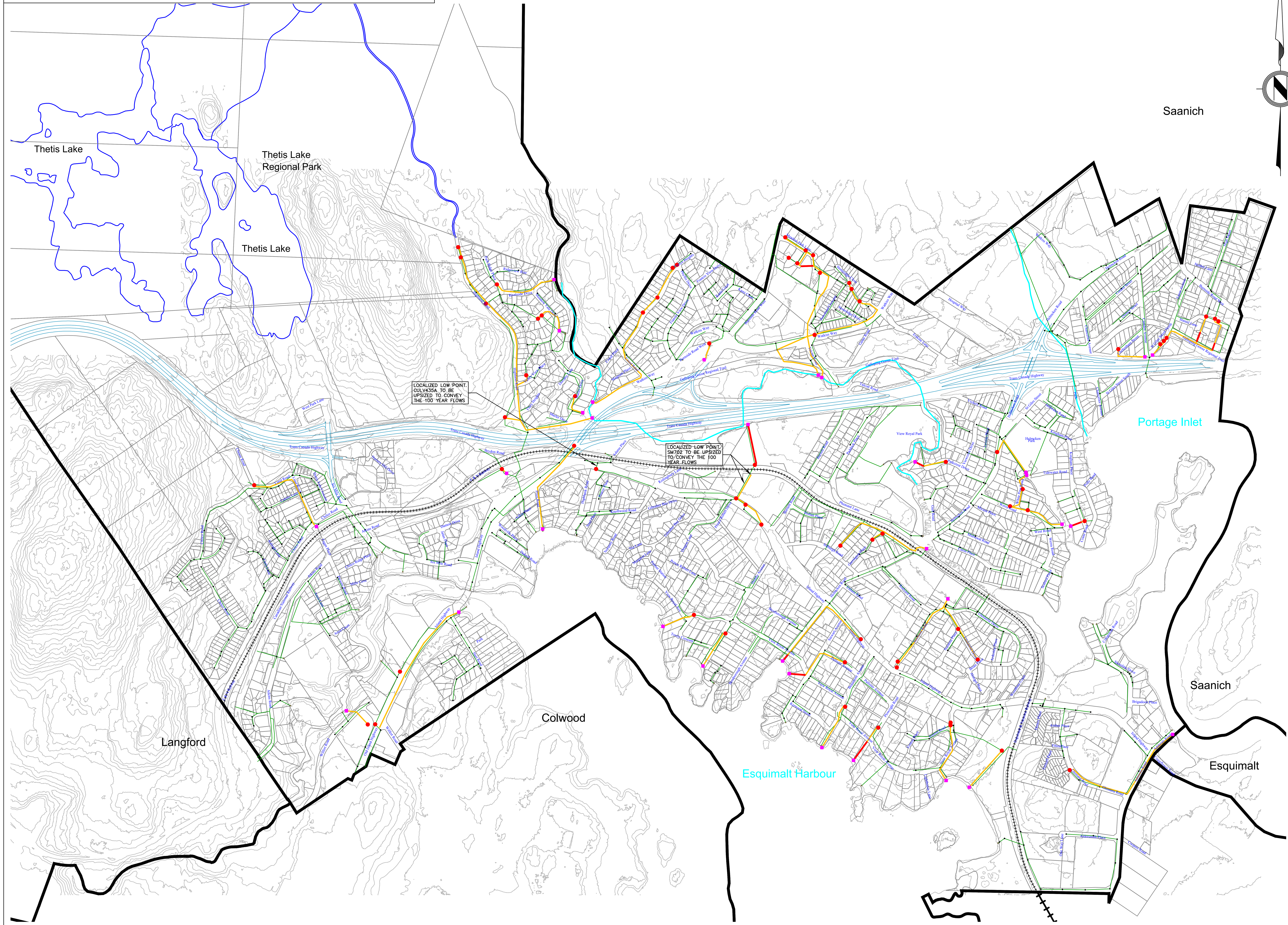

LEGEND

- STORM DRAINAGE SYSTEM
- FLOODED MANHOLE UNDER 100 YEAR CONDITION
- MAJOR OVERLAND FLOW PATH
- MAJOR OVERLAND FLOW PATH THROUGH PRIVATE PROPERTY
- MAJOR OVERLAND FLOW OUTFALL
- RAILROAD
- STREAM

LEGAL DESCRIPTION:

B.M. MONUMENT NO. ELEVATION:
LOCATED AT:

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PROJECT: **TOWN OF VIEW ROYAL MASTER DRAINAGE PLAN 2016-2017**

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TITLE: **OVERLAND FLOW PATH**

DESIGN: VL CHECK: VL
DRAWN: JS APPR: WY
A & M FILE: **16-282**

PROJECT NO. **16-282**

SCALE : HORZ. 1:7,500 VERT. N/A

DRAWING DATE: **JUNE 2017**

DRAWING NO.

A & M DRAWING NO. **FIGURE 7**

SHEET NO. **07 OF 08**

REV. **2**

Oct 06 2017 - 12:06pm M:\2016\16-282\ENGINEERING\DWG\OFFSITE\PRODUCTION DWGS\16-282 FIGURE 7 OVERLAND FLOW PATHS.dwg/07 FIGURE 7 FULL SIZE JShi

5.0 INFRASTRUCTURE UPGRADE PLAN

This section of the report discusses the recommendations and respective rationale for infrastructure upgrades, and provide cost estimates for the proposed works.

5.1 Evaluation Criteria

Due to the sheer number of infrastructure that requires attention, careful considerations were needed to prioritize the upgrades. In total, 134 deficient conduits were noted: 112 conduits were surcharged based on modelling results, 22 conduits have condition issues and 1 conduit is both surcharged and noted to be in poor condition. A thorough review of the conduits that are undersized or in poor condition was conducted to establish the recommendations for infrastructure upgrades and replacement. The deficient conduits are further categorized as follows:

- 53 conduits were identified to require upsizing due to capacity issues;
- 22 conduits were identified to require replacement due to poor condition;
- 1 conduit was identified to require replacement due to both capacity issues and poor condition;
- 17 conduits were identified to require additional investigation. Data for these storm drains is incomplete and/or questionable, therefore more detailed survey and review are recommended to confirm their upgrade requirements.; and
- 41 conduits were deemed to be acceptable as the surcharging conditions were designed deliberately and would not cause flooding issues, or the surcharge conditions are removed from the proposed upgrades for pipes downstream.

For the conduits that require replacement, a phased implementation strategy was developed based on the following criteria:

- Condition of the infrastructure;
- Effectiveness to provide flood protection;
- Annual Town budget for drainage works; and
- Proximity to other deficient infrastructure with potential for a combined replacement project.

5.2 Infrastructure Upgrade Plan & Cost Estimate

Based on the evaluation criteria as described above, an infrastructure upgrade implementation plan was developed as shown in Figure 8. Table 9, Table 10, and Table 11 list the recommended short, medium, and long-term implementation plan and associated cost estimate for the proposed upgrades.

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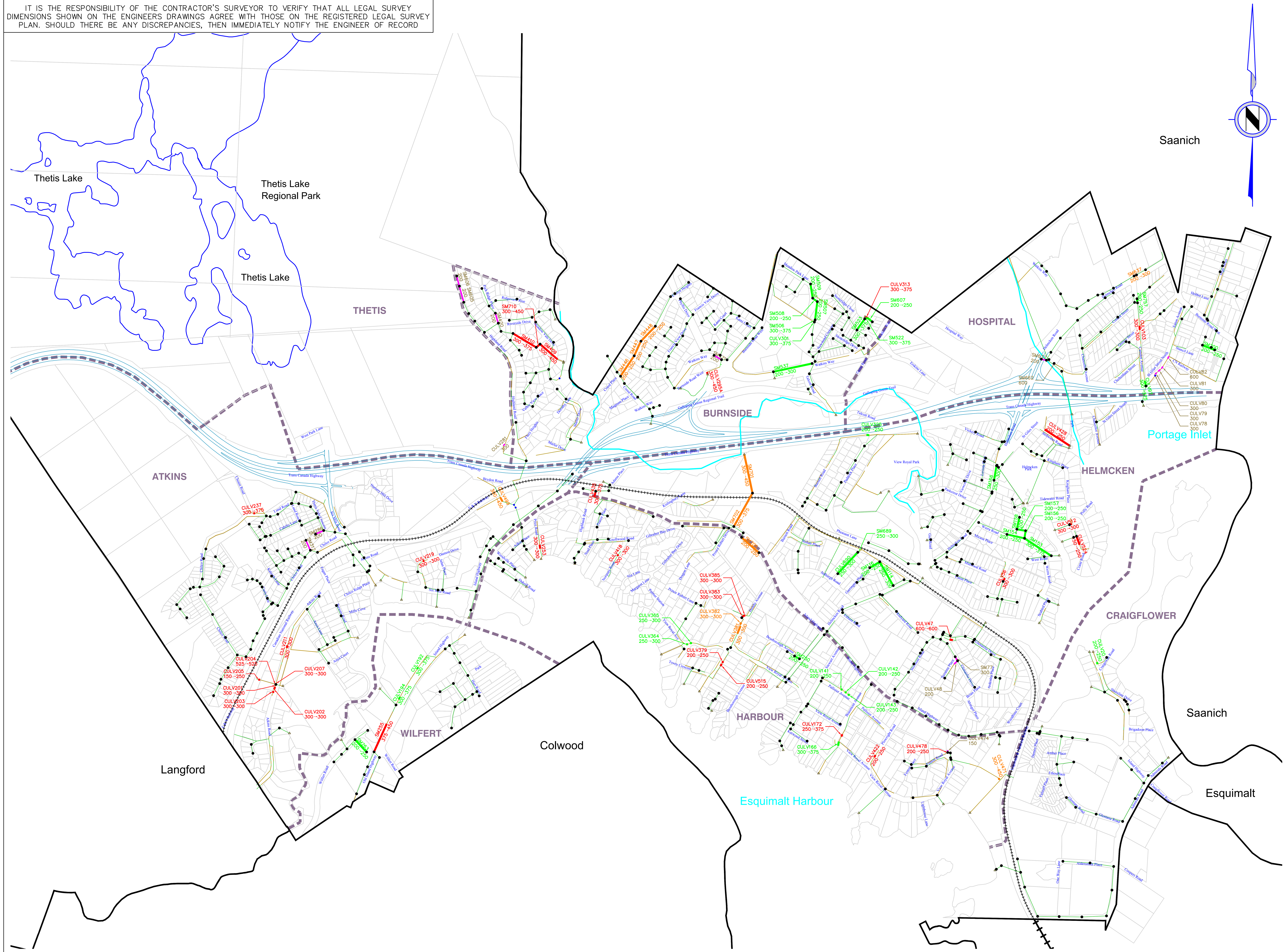

LEGEND

- JUNCTION
- STORAGE
- OUTFALL
- STORM SEWERS & CULVERTS
- DITCH
- SEWERS TO BE REPLACED - HIGH PRIORITY
- SEWERS TO BE REPLACED - MEDIUM PRIORITY
- SEWERS TO BE REPLACED - LOW PRIORITY
- SEWERS TO BE INVESTIGATED
- LEGAL LINES
- MUNICIPAL BOUNDARY
- TRANS CANADA HWY
- STREAM
- RAILWAY
- NEIGHBOURHOOD BOUNDARY

LEGAL DESCRIPTION:

B.M. MONUMENT NO. ELEVATION:
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45 VIEW ROYAL AVENUE, VICTORIA, BC V9B 1A6

PROJECT: **TOWN OF VIEW ROYAL MASTER DRAINAGE PLAN 2016-2017**

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TITLE: **PROPOSED INFRASTRUCTURE UPGRADES**

PROJECT NO. **16-282**

SCALE : HORZ. 1:7,500 VERT. N/A

DRAWING NO.

A & M DRAWING NO. **FIGURE 8**

DESIGN: VL CHECK: VL
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A & M FILE: **16-282**

DRAWING DATE: **JUNE 2017**

FIGURE NO. **08 OF 08**

REV. **2**

Table 9: Storm Drains Replacement Plan - Short Term (1-5 Years)

Replacement Priority: High(1)-Low(5)	Proposed Timeline	Conduit	Location	Reason for Replacement	Burial Depth (m)	Existing Diameter (mm)	Proposed Diameter (mm)	Replacement Pipe Material	Length (m)	Cost
1	Short Term (1-5 Years)	CULV435A	371 Island Highway	Surcharged	1 - 2	300	375	PVC	23	$ 13,430
1	Short Term (1-5 Years)	CULV172	304 Beaumont Avenue	Surcharged	< 1	250	375	Concrete	8.6	$ 5,000
1	Short Term (1-5 Years)	SM255	1680 Island Highway	Surcharged	1 - 2	375	450	Concrete	114.4	$ 70,710
1	Short Term (1-5 Years)	CULV295A	2311 Burnside Road West	Surcharged	< 1	300	450	Concrete	9.1	$ 5,600
1	Short Term (1-5 Years)	CULV237	Cheam Road & Lund Road	Surcharged	< 1	300	375	Concrete	6.2	$ 3,630
1	Short Term (1-5 Years)	CULV103	31 Camden Avenue	Condition Issue	1 - 2	500	525	Concrete	13.9	$ 9,420
1	Short Term (1-5 Years)	CULV313	205 Stoneridge Place	Surcharged	1 - 2	300	375	PVC	11.1	$ 6,480
1	Short Term (1-5 Years)	CULV524	77 Kingham Place	Surcharged	< 1	150	250	Concrete	33.5	$ 18,570
1	Short Term (1-5 Years)	CULV512	70 Kingham Place	Condition Issue	< 1	300	300	Concrete	9.5	$ 5,420
1	Short Term (1-5 Years)	CULV47	340 Glenairlie Drive	Condition Issue	1 - 2	600	600	Concrete	12.2	$ 9,220
4	Short Term (1-5 Years)	CULV205	170 Atkins Road	Surcharged	< 1	150	250	Concrete	6.2	$ 3,410
1	Short Term (1-5 Years)	CULV204	170 Atkins Road	Condition Issue	1 - 2	500	525	Concrete	3	$ 2,030
1	Short Term (1-5 Years)	CULV203	174 Atkins Road	Condition Issue	< 1	300	300	Concrete	6.2	$ 3,510
1	Short Term (1-5 Years)	CULV202	172 Atkins Road	Condition Issue	< 1	300	300	Concrete	10.1	$ 5,730
1	Short Term (1-5 Years)	CULV201	170 Atkins Road	Condition Issue	1 - 2	300	300	PVC	3.7	$ 2,120
1	Short Term (1-5 Years)	CULV207	170 Atkins Road	Condition Issue	1 - 2	300	300	PVC	3.8	$ 2,170
1	Short Term (1-5 Years)	CULV211	148 Heddle Avenue	Condition Issue	< 1	300	300	Concrete	9.8	$ 5,550
1	Short Term (1-5 Years)	CULV383	515 Prince Robert Drive	Condition Issue	< 1	300	300	Concrete	10.4	$ 5,930
1	Short Term (1-5 Years)	CULV385	500 Prince Robert Drive	Condition Issue	1 - 2	300	300	PVC	6.4	$ 3,660
1	Short Term (1-5 Years)	CULV422	277 Plowright Road	Condition Issue	< 1	200	250	Concrete	9.2	$ 5,110
1	Short Term (1-5 Years)	CULV418	74 Norquay Road	Condition Issue	1 - 2	300	300	PVC	6.7	$ 3,810
1	Short Term (1-5 Years)	CULV56	22 Midwood Road	Condition Issue	1 - 2	500	525	Concrete	13.9	$ 9,430
1	Short Term (1-5 Years)	CULV219	325 Damon Drive	Condition Issue	< 1	300	300	Concrete	5.8	$ 3,320
1	Short Term (1-5 Years)	CULV478	45 View Royal Avenue	Condition Issue	< 1	200	250	Concrete	2	$ 1,110
1	Short Term (1-5 Years)	CULV253	12 Prince Road	Condition Issue	1 - 2	300	300	PVC	14.6	$ 8,280
1	Short Term (1-5 Years)	SM409	1969 Chalmers Court	Surcharged	2 - 3	300	450	Concrete	86.3	$ 65,160
1	Short Term (1-5 Years)	SM410	1969 Chalmers Court	Surcharged	2 - 3	300	375	PVC	101.2	$ 68,670
1	Short Term (1-5 Years)	SM710	1969 Chalmers Court	Surcharged	2 - 3	300	450	Concrete	18.5	$ 13,990
1	Short Term (1-5 Years)	CULV428	10 Stillwater Road	Condition Issue	< 1	200	250	Concrete	110.8	$ 61,510
1	Short Term (1-5 Years)	CULV515	13 Heddle Avenue	Condition Issue	< 1	200	250	Concrete	3.5	$ 1,930
1	Short Term (1-5 Years)	CULV379	9 Heddle Avenue	Condition Issue	< 1	300	300	Concrete	6.5	$ 3,680
									Short Term (1-5) Implementation Plan Total	**$ 427,590**

Table 10: Storm Drains Replacement Plan - Medium Term (6-10 Years)

Replacement Priority: High(1)-Low(5)	Proposed Timeline	Conduit	Location	Reason for Replacement	Burial Depth (m)	Existing Diameter (mm)	Proposed Diameter (mm)	Replacement Pipe Material	Length (m)	Cost
1	Medium Term (6-10 Years)	CULV381	252 Heddle Avenue	Condition Issue	1 - 2	300	300	PVC	30.3	$ 17,260
1	Medium Term (6-10 Years)	CULV382	245 Heddle Avenue	Condition Issue	< 1	300	300	Concrete	8	$ 4,520
2	Medium Term (6-10 Years)	CULV471	45 View Royal Avenue	Surcharged	< 1	300	450	Concrete	6.2	$ 3,810
4	Medium Term (6-10 Years)	SM702	340 Island Highway	Surcharged	1 - 2	300	375	PVC	142.4	$ 82,990
3	Medium Term (6-10 Years)	SM701	340 Island Highway	Surcharged	1 - 2	300	450	Concrete	147.3	$ 90,990
4	Medium Term (6-10 Years)	SM705	341 Island Highway	Surcharged	< 1	200	250	Concrete	86.2	$ 47,840
2	Medium Term (6-10 Years)	SM446	2336 Evelyn Heights	Surcharged	2 - 3	200	250	PVC	91.2	$ 57,620
2	Medium Term (6-10 Years)	SM447	2332 Evelyn Heights	Surcharged	2 - 3	200	250	PVC	59.9	$ 37,850
2	Medium Term (6-10 Years)	SM448	2326 Evelyn Heights	Surcharged	2 - 3	200	250	PVC	77.1	$ 48,710
3	Medium Term (6-10 Years)	CULV499	Atkins Road	Surcharged	< 1	300	450	Concrete	17.8	$ 11,000
3	Medium Term (6-10 Years)	SM637	5 Helmcken Road	Surcharged	2 - 3	200	300	PVC	10	$ 6,570
									Medium Term (5-10) Implementation Plan Total	**$ 409,160**

Table 11: Storm Drains Replacement Plan - Long Term (11-20 Years)

Replacement Priority: High(1)-Low(5)	Proposed Timeline	Conduit	Location	Reason for Replacement	Burial Depth (m)	Existing Diameter (mm)	Proposed Diameter (mm)	Replacement Pipe Material	Length (m)	Cost
3	Long Term (11-20 Years)	CULV364	548 View Royal Avenue	Surcharged	< 1	250	300	Concrete	6.2	$ 3,520
3	Long Term (11-20 Years)	CULV365	548 View Royal Avenue	Surcharged	< 1	250	300	Concrete	6.6	$ 3,780
3	Long Term (11-20 Years)	SM166	152 Helmcken Road	Surcharged	1 - 2	250	300	PVC	55.2	$ 31,400
3	Long Term (11-20 Years)	SM263	1700 Wilfert Road	Surcharged	3 - 4	200	250	PVC	63.1	$ 55,550
3	Long Term (11-20 Years)	CULV192	1636 Island Highway	Surcharged & Condition Issue	< 1	300	375	Concrete	8	$ 4,670
4	Long Term (11-20 Years)	CULV194	1658 Island Highway	Surcharged	< 1	300	375	Concrete	10.5	$ 6,090
3	Long Term (11-20 Years)	SM507	140 Meadow Park Lane	Surcharged	2 - 3	200	250	PVC	68	$ 42,950
3	Long Term (11-20 Years)	SM508	140 Meadow Park Lane	Surcharged	2 - 3	200	250	PVC	21.6	$ 13,650
3	Long Term (11-20 Years)	SM509	140 Meadow Park Lane	Surcharged	2 - 3	200	250	PVC	53.2	$ 33,600
3	Long Term (11-20 Years)	SM506	140 Meadow Park Lane	Surcharged	2 - 3	300	375	PVC	8.9	$ 6,010
4	Long Term (11-20 Years)	CULV301	140 Meadow Park Lane	Surcharged	2 - 3	300	375	PVC	2.8	$ 1,890
3	Long Term (11-20 Years)	SM537	1900 Watkiss Way	Surcharged	1 - 2	200	300	PVC	147.1	$ 83,680
4	Long Term (11-20 Years)	CULV97	48 Camden Avenue	Surcharged	2 - 3	300	375	PVC	20.5	$ 13,920
4	Long Term (11-20 Years)	CULV141	286 Pallsier Avenue	Surcharged	< 1	200	250	Concrete	6.3	$ 3,500
4	Long Term (11-20 Years)	CULV142	284 Pallisier Avenue	Surcharged	1 - 2	200	250	PVC	6.1	$ 3,370
4	Long Term (11-20 Years)	CULV143	282 Pallisier Avenue	Surcharged	1 - 2	200	250	PVC	7.5	$ 4,160
4	Long Term (11-20 Years)	SM250	277 Bessborough Avenue	Surcharged	1 - 2	200	250	PVC	21.2	$ 11,760
4	Long Term (11-20 Years)	CULV20	2815 Shoreline Drive	Surcharged	< 1	200	250	Concrete	7.4	$ 4,110
4	Long Term (11-20 Years)	CULV166	305 Beaumont Avenue	Surcharged	1 - 2	300	375	PVC	15.5	$ 9,050
4	Long Term (11-20 Years)	SM757	8 CONARD STREET	Surcharged	2 - 3	200	250	PVC	15.5	$ 9,810
4	Long Term (11-20 Years)	SM153	141 Werra Road	Surcharged	2 - 3	300	375	PVC	118.8	$ 80,600
4	Long Term (11-20 Years)	SM154	129 Werra Road	Surcharged	3 - 4	200	250	PVC	67.1	$ 59,060
4	Long Term (11-20 Years)	SM156	184 Werra Road	Surcharged	1 - 2	200	250	PVC	28.3	$ 15,720
4	Long Term (11-20 Years)	SM157	184 Werra Road	Surcharged	1 - 2	200	250	PVC	33.1	$ 18,380
4	Long Term (11-20 Years)	SM158	176 White Pine Road	Surcharged	1 - 2	200	250	PVC	45.7	$ 25,360
4	Long Term (11-20 Years)	SM200	1270 Stancil Lane	Surcharged	< 1	200	250	Concrete	48.7	$ 27,030
4	Long Term (11-20 Years)	SM522	205 Stoneridge Place	Surcharged	1 - 2	300	375	PVC	12	$ 7,000
4	Long Term (11-20 Years)	SM523	205 Stoneridge Place	Surcharged	1 - 2	300	375	PVC	50.2	$ 29,280
4	Long Term (11-20 Years)	SM607	205 Stoneridge Place	Surcharged	1 - 2	200	250	PVC	22	$ 12,210
4	Long Term (11-20 Years)	CULV325	101 Trans Canada Highway	Surcharged	1 - 2	200	250	PVC	10	$ 5,560
4	Long Term (11-20 Years)	SM116	222 Garrington Place	Surcharged	2 - 3	200	250	PVC	43.3	$ 27,330
4	Long Term (11-20 Years)	SM114	222 Garrington Place	Surcharged	2 - 3	250	300	PVC	101.5	$ 66,510
5	Long Term (11-20 Years)	SM689	112 Jedburgh Place	Surcharged	1 - 2	250	300	PVC	5.1	$ 2,900
5	Long Term (11-20 Years)	SM690	102 Jedburgh Place	Surcharged	3 - 4	250	300	PVC	108.9	$ 97,400
									Long Term (11-20) Implementation Plan Total	**$ 820,810**

The cost estimate is classified as “Class C estimates”, based on unit costs in 2017 dollars, taken from Aplin Martin’s construction database. Class C cost estimate is a preliminary estimate prepared with little or no specific site information. It provides indicative costs that aids the prioritization of required upgrades. Aplin Martin’s construction database was developed from a compilation of many past projects and provides a reasonable baseline for cost estimation.

Please note that a number of storm drains were indicated to be undersized in the analysis, but due to uncertainty with the data accuracy, further investigation is recommended to confirm replacement requirements. Replacing these storm drains is not included in the base infrastructure upgrade plan, but as contingencies. Table 12 shows the list of these storm drains and their respective remediation cost if required.

Table 12: Storm Drains requiring additional investigation

Investigation Priority: High(1)-Low(3)	Proposed Timeline	Conduit	Location	Burial Depth (m)	Existing Diameter (mm)	Replacement Pipe Material	Length (m)	Note	Order of Magnitude Cost*
1	Short Term (1-5 Years)	CULV78	71 St. Giles Street	1 - 2	300	PVC	3.7	Confirm U/S catchment area and connecting ditch cross sections	$ 2,130
1	Short Term (1-5 Years)	CULV79	71 St. Giles Street	< 1	300	Concrete	7.4	Confirm U/S catchment area and connecting ditch cross sections	$ 4,210
1	Short Term (1-5 Years)	CULV80	69St. Giles Street	< 1	300	Concrete	9.9	Confirm U/S catchment area and connecting ditch cross sections	$ 5,600
1	Short Term (1-5 Years)	CULV81	65 St. Giles Street	< 1	300	Concrete	9	Confirm U/S catchment area and connecting ditch cross sections	$ 5,100
1	Short Term (1-5 Years)	CULV82	27 Eaton Avenue	< 1	600	Concrete	9.6	Confirm U/S catchment area and connecting ditch cross sections	$ 7,230
2	Short Term (1-5 Years)	SM605	2463 Highland Road	1 - 2	200	PVC	61.9	Confirm upstream catchment area	$ 32,350
2	Short Term (1-5 Years)	SM606	2481 Highland Road	1 - 2	200	PVC	38.9	Confirm upstream catchment area	$ 20,320
								Short Term (1-5) Replacement Plan Total	**$ 76,940**
3	Medium Term (6-10 Years)	CULV474	45 View Royal Avenue	< 1	150	Concrete	8.9	Confirm upstream catchment area & culvert location/properties	$ 4,910
3	Medium Term (6-10 Years)	SM286	103 Thetis Vale Crescent	2 - 3	200	PVC	33.3	Review connection to downstream storm drain	$ 19,860
3	Medium Term (6-10 Years)	CULV281	59 Flury Heights	< 1	300	Concrete	7.6	Confirm culvert location/properties and connecting ditch cross sections	$ 4,340
3	Medium Term (6-10 Years)	SM312	2454 Lund Road	2 - 3	200	PVC	40.5	Review connection to downstream storm drain	$ 24,200
3	Medium Term (6-10 Years)	SM420	2302 Park Ridge Place	1 - 2	200	PVC	38.4	Confirm U/S catchment area (minor surcharging in the 10 Year event)	$ 20,060
3	Medium Term (6-10 Years)	SM471	2306 Watkiss Way	2 - 3	200	PVC	31.9	Review connection to downstream storm drain	$ 19,040
3	Medium Term (6-10 Years)	SM662	50 Helmcken Road	3 - 4	600	Concrete	5	Confirm outlet location and properties	$ 5,750
3	Medium Term (6-10 Years)	CULV48	204 Suzanne Place	1 - 2	200	PVC	17.6	D/S pipe has a very mild slope (SM77 @ 0.16%)	$ 9,740
3	Medium Term (6-10 Years)	SM632	50 Helmcken Road	3 - 4	200	PVC	19.6	Confirm inlet location and properties	$ 16,890
3	Medium Term (6-10 Years)	SM77	238 Glenairlie Drive	1 - 2	300	PVC	17.7	Confirm pipe properties. (0.16% slope)	$ 10,060
								Medium Term (6-10) Replacement Plan Total	**$ 134,850**

Note:
1) Remediation cost for drains that require additional investigation is included as contingencies in the capital budget
2) Cost are shown for future capital planning purposes, based on replacement of the same size only

6.0 MASTER DRAINAGE PLAN

6.1 Infrastructure Replacement and Upgrades

The analysis performed in this study identified a number of infrastructure that requires replacement or upgrades to adequately service the Town. It is recommended that the Town set long-term budgets for drainage infrastructure works as outlined in Table 13. The projected capital amounts, in 2017 dollars are as follows:

Table 13 - Proposed Capital Budget for Infrastructure Upgrades

Replacement Phasing	Conduits with Condition Issues		Conduits with Insufficient Capacity		20 Year Drainage Capital Plan			
	# of Conduits Replaced	Cost Estimate	# of Conduits Replaced	Cost Estimate	# of Conduits Replaced	Contingency	Total Length of Replacement	Infrastructure Replacement Budget (2017 Dollars)
Short Term (1-5 Years)	20	$152,940	11	$274,650	31	$76,940	680 m	$504,530
Medium Term (6-10 Years)	2	$21,780	9	$387,380	11	$134,850	676 m	$544,010
Long Term (11-20 Years)	1	-	34	$820,810	34	-	1246 m	$820,810
Total	23	$174,720	54	$1,482,840	76		2602 m	$1,869,350

Note: Contingency is built into the budget for potential replacement projects for drains that were identified to require additional investigation as discussed in Section 5.2

It is recommended that visual inspection be conducted for all infrastructure labelled with condition issues. If required, CCTV inspection shall be performed to confirm the deficiency prior to remediation works.

6.2 GIS Database Update and Maintenance

Although great efforts were put forth to assemble, manage, and update the GIS database, it remains to be incomplete as discussed in Section 2.1. A thorough review and enhancement of the data is recommended to procure a comprehensive database that is suitable for future infrastructure planning applications. A list of advantages in having a comprehensive GIS database include:

- Easy access to infrastructure information;
- Quick overview of infrastructure inventory;
- Promotes better management of the infrastructure system; and
- Simplifies the process for future master drainage planning.

The following tasks are recommended to supplement the existing database: Review available record drawings and validate all existing data;

- Perform field survey to collect missing information;
- Conduct preliminary assessment to the condition for all drainage infrastructure, prioritized by the extent of their service limits; and
- Revise the database upon completion of all land development and capital projects.

An order of magnitude budget for the Town to assemble a comprehensive GIS database is estimated to be $50,000. This task is recommended to be fitted into the Town's short-term (1-5 year) plan.

Once it is established, it is recommended that the GIS database to be maintain and updated along with the Town's capital works and development plans. The estimated cost to maintain and update the GIS database is $2,000 per year.

6.3 Storm Drain Condition Assessment

Up to this time, only a small percentage of the Town's infrastructure have received condition assessments. It should be noted that the age and condition for the majority of the infrastructure are unknown. As the Town augments the GIS database, additional data will allow a more thorough review of the age and condition of the infrastructure system. For infrastructure that are nearing the end of its estimated service life or observed to be deficient, a CCTV and field inspection is recommended to assess the actual physical conditions. An inspection will allow for the determination of whether the questionable infrastructure can be kept, or need to be cleaned or replaced.

6.4 Outfall Review

As the Town possesses a variable terrain and contains many steep sections of storm drains, high flow velocities are expected in the majority of the Town's drainage system with potential erosion and scouring to the receiving waterbody or watercourse. Inspection to all of the storm drain outfall areas by qualified professional(s) is recommended.

Erosion may not be a serious issue for every instance. The areas that are away from property and do not appear to cause potential infrastructure failure may not warrant repair as these sites pose low to no risk of damage. Nevertheless, these sites should be monitored as part of the drainage infrastructure maintenance efforts.

In areas where erosion is severe and there is an imminent threat to impact infrastructure or property, embankment repair and structural protection should be designed and implemented.

Possible embankment repair project would involve:

- Accessing the sites with equipment;
- Reconstruction the bank where required; and
- Stabilizing the embankments with bio-engineering (if possible) and/or protection structures (e.g. stone riprap, lock-block wall, concrete, energy dissipater, etc.).

6.5 Maintenance Program

The level of maintenance provided directly affects the efficiency of a storm drainage system. The development of a drainage infrastructure maintenance plan is recommended to ensure the following items be executed on a scheduled interval:

- Inspect manhole/catch basin sumps and inlet/outlet structures;
- Remove accumulated sediments and garbage from manhole/catch basin sumps;

- Inspect detention facilities and remove accumulated sediments and garbage from these facilities;
- Inspect and maintain storm drain outfall structures; and
- Remove overgrown vegetation and channel obstructions along drainage ditches;

In particular, the detention facility at Stoneridge Drive has created upstream flooding problems due to sediment accumulation in the past. It is recommended to annually inspect the facility and administer dredging when required.

Street and parking lots should be cleaned on a regular basis. The effects of regular street cleaning will reduce the frequency of required maintenance and extend the life (reduction of abrasive grit) of the storm drainage infrastructure and reduce the pollutant load being transported by the storm drains.

6.6 Stormwater Management Policy Update

The Town of View Royal's Land Use Bylaw, 1990, No. 35, is currently the key document used by the Town for planning and design of their storm drainage infrastructure system. It provides the Town's design criteria for their storm drainage system and very basic guidelines on storm drain and service connection design and installation. This document is considered being out of date and does not include details and requirements on onsite stormwater management source control facilities.

Besides, the Town's existing OCP (2011) stipulates a few policy clauses for stormwater management. As specified in the OCP, the Town has established an aggressive stormwater quality and quantify control program, which includes major investments in bio-swales and treatment wetlands associated with road improvement projects and the requirement of stormwater management plans for all new developments to include the design of on- and off-site stormwater source control facilities, such as rain gardens, infiltration systems, roadside bio-swales and constructed wetlands. This program should be maintained and continued. However, the OCP provides only directions but not design guidelines on the stormwater quality and quantity control measures.

It is recommended that a more comprehensive stormwater management design and policy document be developed for the Town, either as an updated section in the Land Use Bylaw or as a standalone document. It is to ensure that future land developments and capital works would not cause any negative impacts on the Town's storm drain system, but will improve the overall ecological health of the receiving environment.

Benefits of such a document include:

- Ensure consistency of stormwater design approaches throughout development projects in the Town;
- Reduce the effort required to revise designs by having designers use approved design methodologies by the Town; and
- Provide guidance to designers to ensure acceptable minimum level of design quality and performance are achieved for all projects.

Suggested contents of the document include:

- Design criteria for the Town's minor and major systems;
- Accepted methodologies for calculating peak flows for storm sewer sizing according to catchment size.
- Specifications for rainfall data that should be used in stormwater calculations;
- Specifications for design to address climate change, including projected sea levels impacts on infrastructure and rainfall data adjusted to accommodate projected climate change;

The document can be developed based on the Stormwater Management section of the MMCD Design Guidelines 2014. The MMCD Design Guidelines 2014 is a manual to provide a standardized set of guidelines that can be adopted by municipalities and other agencies involved with design and construction of municipal infrastructures and has been used by various municipalities to tailor into their own infrastructure design manuals.

6.7 Water Quality Monitoring

Increased development in the Town will affect the quality of runoff reaching the stormwater pipes and eventually the marine environment. This will increase the risk to residents interacting with water near the outfalls, either at beaches or in the water during recreational activities.

The Capital Regional District (CRD) has been monitoring water quality at the storm drain outfalls in the CRD area since the early 1980s. The CRD monitoring program covers the sampling of a selection of outfalls in View Royal. In 2016, CRD staff sampled 16 of View Royal's stormwater discharges; 9 locations were noted with elevated E.coli levels. Based on the results, CRD staff assigned a moderate public health concern rating to 7 stations and a low rating to the remaining 9 stations. No discharges are rated of high public health concern in View Royal. Since the scope of this project is only to review and update the storm drain system, the review of water quality issues associated with the Town's storm drain system was not conducted in the study.

It is recommended that the CRD's sampling program and historical water quality sampling data for the View Royal's outfalls be further reviewed to identify potential water quality issues in the Town. This will also allow for an assessment of additional sampling requirements to monitor and guide water quality control for the Town's stormwater management.

6.8 Flood Protection in the Low-Lying Coastal Areas

Majority of the Town of View Royal's lands are in high ground outside the tidal impacted zones and the Town's storm drains typically have high gradient and are not influenced by the ocean high tidal levels. However, there are a few pockets of the ocean-front lands, such as the areas near Helmcken Centennial Park. These lands have low ground elevations and storm drains installed in these areas are also below the winter high tide levels. Surge of storm drains and land flooding have been frequently observed in these lands during high tide and storm surge conditions. Our modelling results based on the extreme high tide boundary conditions indicated surged and flooded manholes at a few low-lying coastal areas (see Figures 5 and 6).

It is not in the scope of this study to investigate the flooding issues due to high tide and identify flood protection solutions. It is recommended that further investigation be conducted to assess the extent and potential damage from the flooding and identify mitigation measures.

6.9 Flood Protection under Major Storm Events

The Town's current design criteria for storm drainage systems does not contain stipulations for major storm flows. While it is customary for land development engineers to provide safe overland routes or sufficient detention and controls for the major storm events, the methodology and requirements for the analysis are not clearly stated. It is recommended that the Town append their criteria to specify and standardize the requirements for overland flow path review and downstream impact assessment.

Based on the 100-year storm simulation performed in this study, a number of overland flow routes currently passes through private properties as noted on Figure 7. It is recommended that these particular routes be thoroughly reviewed to identify any potential flood hazard to private properties. In the event where the overland flow paths cannot be redirected, the storm drainage system must be upsized to accommodate the major flows.

6.10 Climate Change Impacts

Potential climate change could also affect pipe performance as more rain could fall during frequently occurring storms. Sea level rise predictions would also put the Town's storm drain system at risk of experiencing increased coastal flood hazard in the low-lying areas.

Alteration to the existing Land Use and design of infrastructure projects should consider significant changes in sea level as predicted by numerous comprehensive studies. A 1.0m sea level rise by 2100 has been recommended for coastal community plans in BC. Sea level rise could affect stormwater outfall infrastructure. Rising sea level could flood these systems and they may no longer be fully functional. Rising sea level could also reduce the capacity of storm sewer conveyance systems that are currently near sea level. Planning for sea level rise should be incorporated into the design of any new stormwater infrastructure near the current sea level elevation.

It is not in the scope of this project to review the impacts of climate change on the Town's storm drain infrastructures. It is recommended that climate change impacts be reviewed and risks and adaptation measures be identified in a separate study in the near future. This study can be used to guide the Town's future development and infrastructure projects near the coastal areas.

6.11 Master Drainage Plan Update/Integrated Stormwater Management Plan

Due to the budget and schedule constrains, the 2017 MDP Update can only provide a review of the hydraulic capacity of the Town's existing storm drain system and an infrastructure improvement plan that can fit into the Town's limited capital budget to address existing deficiencies. Although considerable effort has been made by the Town to enforce stormwater management best practices for bothcapital and land development projects, the Town's storm drain system design is mainly driven by its efficiency for transporting runoff.

This can and often does have negative impacts on the receiving watercourses in the form of channel erosion, habitat degradation, reduced baseflow and reduced water quality.

The concepts and techniques for municipal stormwater management have constantly evolved with research and development and increased awareness of sustainability. In recent years, more emphasis has been placed on the protection of watercourse health and stability while also providing flood conveyance. In order for the Town's storm drain system to meet the current stormwater management standards, it is recommended that a more comprehensive study with integrated review of system capacity and watershed health be carried out for the next update to the Town's stormwater management study. In addition to providing a hydrotechnical review of the Town's storm drain system, water quantity, flooding and erosion, water quality, and aquatic and terrestrial habitat review should also be conducted in the study. The overall watershed health under the existing and proposed future conditions should be assessed and mitigation measures are to be recommended to ensure an overall watershed health be maintained with new developments. Climate change impacts should also be addressed in the next study to ensure risks resulted from the potential climate change impacts are well understood and mitigation measures be evaluated and planned for the Town to be prepared for these potential impacts.

We recommend that an Integrated Stormwater Management Plan (ISMP) be conducted as the next Master Drainage Plan Update for the Town within 10 years from this 2017 MDP Update. Prior to this study, the proposed update to the GIS system should be completed.

6.12 Drainage Capital Budget Summary

Further to the sections above, Table 14 provides a budget summary for all the tasks recommended for the Town's drainage infrastructure. It is recommended that the Town set capital budgets and implement the proposed plan to maintain and enhance the long-term health of its drainage infrastructure.

Table 14 – 20 Year Capital Budget for Drainage Works

Phased Implementation Plan	Drainage Infrastructure Replacement (with Contingency)	GIS Update & Maintenance	Total Capital Budget (2017 Dollars)
Short Term (1-5 Yrs)	$ 504,530	$ 50,000	$ 554,530
Medium Term (6-10 Yrs)	$ 544,010	$ 2,000/Year	$ 554,010
Long Term (11-20 Yrs)	$ 820,810	$ 2,000/Year	$ 840,810
		Total	$ 1,949,350

CLOSURE

We trust that the information presented in this report is sufficient for your current needs.

Please contact the undersigned should you have any questions or require additional information.

Yours truly,

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Enclosure

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APPENDIX A

Drainage GIS Database

Update Log

Table A1: 2017 GIS Update Log

Development Projects As-builts	
Location	Infrastructure Added to GIS/Notes*
13 Vickery	DMH491, SM718, SM719
15 Quincy	* Infrastructure information not available
22 Fenton	SM724, SM731, CULV540
85 Norquay	CULV415, CULV416, CULV417, CULV541
86-94 Atkins Road	* Infrastructure information not available
102 Atkins Rd	* Missing digital CAD information
170 Nursery Hill Drv (Six Mile Rd)	* Missing digital CAD information
210 Stormont Rd	* Missing digital CAD information
218 Hart Rd	* Private sewer to the outlet, not added to GIS
235 Island Highway	SM778, DMH504, DMH505
333 Island Highway (Public Safety Building)	SM747, DMH506, DMH492
1511 Admirals (Glentana)	* Private system not added to GIS
1652 Island Highway	* Missing CAD as-builts
1701 Island Highway	DMH507, DMH494, DMH508, DMH509, DMH510, DMH493, SM750, SM752, SM751, SM779, SM749
2311 Watkiss Way	SM753, CB691
Atkins Drainage Improvements	* Missing digital CAD information
Burnside Rd West	SM780, SM754, SM755
Camden Green (Camden - Conard)	SM757, SM756, SM760, SM761, SM762, SM758
Eagle Creek (Helmcken - Watkiss)	SM781, DMH511, DMH512, DMH513, DMH514, DMH515, DMH516, SM782, SM783, SM784, SM785, SM786, DMH517, SM787, SM788
Lloyd Place	SM765, SN766, DMH496, DMH497
Lloyd Place (Hart Road 207)	DCO111, DMH498, SM768, SM767
Meadow Park Lane	* Pipes have been added to GIS previously
Price Bay Lane	* Minor private system not added to GIS
Seahaven Terrace	DMH499, DMH500, SM769, SM763
Stancil Lane 1255-1259	DCO112, DMH501, SM771
Thetis Vale Phase 4	SM343, SM342, SM341, SM348, SM345, SM344, SM597, SM764, SM789, SM791, SM790
Thetis Vale Phase 5	SM792, SM793, SM794, SM795, SM796, SM797, SM798, SM799, SM800, SM801, SM802, SM803, SM804
Thetis Vale Phase 6	SM805, SM806, SM807, SM808, SM809, SM810, SM811, SM812, SM813, SM814, SM815, SM816, SM817, SM818, SM819, SM820, SM821, OF56, OF57, OF58, DMH518, DMH519, DMH520, DMH521, DMH522, DMH523, DMH524, DMH525, DMH526, DMH527, DMH528, DMH529, DMH530, DMH531, DMH532
Viewcrest Subdivision	DCO113, DCO114, DCO115, DMH503, DMH491, DMH502, OF59, OF60, SM776, SM777, SM718, SM719, SM773, SM775, SM774
White Pine	SM822, SM823, DMH534, DMH533, OF61
14 Jedburgh Road	DCO116, DCO117, DCO118, DMH543, DMH544, DMH545, DMH546, DMH547, DMH548, DMH549, SM836, SM837, SM838, SM839, SM840, SM841, SM842, SM843, SM844, *Revised SM551.
Capital Projects As-builts	
Location	Infrastructure Added to GIS/Notes*
Bessborough Avenue	* Infrastructure information not available
Chancellor Avenue	DMH434, SM720, DMH436, SM759, DMH437
Eltham Road	DMH536, DMH537, SM831
Island Highway (IHIP)	DMH452, DMH451, DMH450, DMH535, DMH449, DMH448, DMH447, DMH446, DMH443, DMH444, DMH445, OF62, DMH248, DMH24, DMH481, DMH480, SM720, SM759, SM739, SM740, SM741, SM824, SM742, SM743, SM744, SM745, SM825, SM826, SM827, SM828, SM31, SM829, SM830
Island Highway 287	DMH538, DMH539, DMH540, DMH541, DMH542, SM832, SM833, SM834, SM835
Island Highway Improvement Project Phase 1 (IHIP)	* Missing digital CAD information
Jedburgh Storm Drain Extension	* Missing digital CAD information
Stillwater Road	* Infrastructure information not available
View Royal Ave 157	* Infrastructure information not available

APPENDIX B

Town of View Royal Drainage Model

Design Storms

Synthetic Hyetographs for Design Storms used for modelling of the View Royal Drainage System

Table B1 - 10 Year Storm Hyetograph

AES Type 1, 1-hour 30% Distribution						AES BC Coast, 12-hour 50% Distribution							
Time (min)	1 Hour Storm (mm/hr)	Time (min)	2 Hour Storm (mm/hr)	Time (min)	6 Hour Storm (mm/hr)	Time (min)	12 Hour Storm (mm/hr)	Time (min)	12 Hour Storm Continued (mm/hr)	Time (min)	24 Hour Storm (mm/hr)	Time (min)	24 Hour Storm Continued (mm/hr)
5	4.03	5	3.06	10	8.00	10	2.65	370	13.06	20	7.39	740	36.37
10	5.22	10	3.06	20	8.00	20	2.65	380	13.06	40	7.39	760	36.37
15	4.53	15	3.96	30	8.00	30	2.65	390	13.06	60	7.39	780	36.37
20	6.65	20	3.96	40	10.36	40	2.65	400	13.06	80	7.39	800	36.37
25	8.26	25	3.44	50	10.36	50	2.65	410	13.06	100	7.39	820	36.37
30	7.01	30	3.44	60	10.36	60	2.65	420	13.06	120	7.39	840	36.37
35	4.07	35	5.04	70	9.00	70	6.32	430	8.47	140	17.62	860	23.60
40	6.63	40	5.04	80	9.00	80	6.32	440	8.47	160	17.62	880	23.60
45	4.56	45	6.27	90	9.00	90	6.32	450	8.47	180	17.62	900	23.60
50	6.89	50	6.27	100	13.19	100	6.32	460	8.47	200	17.62	920	23.60
55	3.58	55	5.32	110	13.19	110	6.32	470	8.47	220	17.62	940	23.60
60	1.50	60	5.32	120	13.19	120	6.32	480	8.47	240	17.62	960	23.60
		65	3.09	130	16.40	130	6.62	490	10.59	260	18.43	980	29.49
		70	3.09	140	16.40	140	6.62	500	10.59	280	18.43	1000	29.49
		75	5.03	150	16.40	150	6.62	510	10.59	300	18.43	1020	29.49
		80	5.03	160	13.91	160	6.62	520	10.59	320	18.43	1040	29.49
		85	3.46	170	13.91	170	6.62	530	10.59	340	18.43	1060	29.49
		90	3.46	180	13.91	180	6.62	540	10.59	360	18.43	1080	29.49
		95	5.23	190	8.08	190	7.80	550	8.04	380	21.72	1100	22.39
		100	5.23	200	8.08	200	7.80	560	8.04	400	21.72	1120	22.39
		105	2.71	210	8.08	210	7.80	570	8.04	420	21.72	1140	22.39
		110	2.71	220	13.15	220	7.80	580	8.04	440	21.72	1160	22.39
		115	1.14	230	13.15	230	7.80	590	8.04	460	21.72	1180	22.39
		120	1.14	240	13.15	240	7.80	600	8.04	480	21.72	1200	22.39
				250	9.06	250	8.84	610	8.09	500	24.63	1220	22.53
				260	9.06	260	8.84	620	8.09	520	24.63	1240	22.53
				270	9.06	270	8.84	630	8.09	540	24.63	1260	22.53
				280	13.68	280	8.84	640	8.09	560	24.63	1280	22.53
				290	13.68	290	8.84	650	8.09	580	24.63	1300	22.53
				300	13.68	300	8.84	660	8.09	600	24.63	1320	22.53
				310	7.10	310	8.30	670	5.62	620	23.12	1340	15.65
				320	7.10	320	8.30	680	5.62	640	23.12	1360	15.65
				330	7.10	330	8.30	690	5.62	660	23.12	1380	15.65
				340	2.98	340	8.30	700	5.62	680	23.12	1400	15.65
				350	2.98	350	8.30	710	5.62	700	23.12	1420	15.65
				360	2.98	360	8.30	720	5.62	720	23.12	1440	15.65

Table B2 - 25 Year Storm Hyetograph

AES Type 1, 1-hour 30% Distribution						AES BC Coast, 12-hour 50% Distribution							
Time (min)	1 Hour Storm (mm/hr)	Time (min)	2 Hour Storm (mm/hr)	Time (min)	6 Hour Storm (mm/hr)	Time (min)	12 Hour Storm (mm/hr)	Time (min)	12 Hour Storm Continued (mm/hr)	Time (min)	24 Hour Storm (mm/hr)	Time (min)	24 Hour Storm Continued (mm/hr)
5	4.63	5	3.48	10	8.99	10	3.01	370	14.80	20	8.56	740	42.13
10	6.00	10	3.48	20	8.99	20	3.01	380	14.80	40	8.56	760	42.13
15	5.21	15	4.51	30	8.99	30	3.01	390	14.80	60	8.56	780	42.13
20	7.64	20	4.51	40	11.65	40	3.01	400	14.80	80	8.56	800	42.13
25	9.50	25	3.91	50	11.65	50	3.01	410	14.80	100	8.56	820	42.13
30	8.06	30	3.91	60	11.65	60	3.01	420	14.80	120	8.56	840	42.13
35	4.68	35	5.73	70	10.12	70	7.17	430	9.61	140	20.40	860	27.34
40	7.62	40	5.73	80	10.12	80	7.17	440	9.61	160	20.40	880	27.34
45	5.25	45	7.13	90	10.12	90	7.17	450	9.61	180	20.40	900	27.34
50	7.93	50	7.13	100	14.83	100	7.17	460	9.61	200	20.40	920	27.34
55	4.11	55	6.05	110	14.83	110	7.17	470	9.61	220	20.40	940	27.34
60	1.73	60	6.05	120	14.83	120	7.17	480	9.61	240	20.40	960	27.34
		65	3.51	130	18.44	130	7.50	490	12.00	260	21.35	980	34.16
		70	3.51	140	18.44	140	7.50	500	12.00	280	21.35	1000	34.16
		75	5.72	150	18.44	150	7.50	510	12.00	300	21.35	1020	34.16
		80	5.72	160	15.64	160	7.50	520	12.00	320	21.35	1040	34.16
		85	3.94	170	15.64	170	7.50	530	12.00	340	21.35	1060	34.16
		90	3.94	180	15.64	180	7.50	540	12.00	360	21.35	1080	34.16
		95	5.95	190	9.08	190	8.84	550	9.11	380	25.15	1100	25.93
		100	5.95	200	9.08	200	8.84	560	9.11	400	25.15	1120	25.93
		105	3.09	210	9.08	210	8.84	570	9.11	420	25.15	1140	25.93
		110	3.09	220	14.78	220	8.84	580	9.11	440	25.15	1160	25.93
		115	1.30	230	14.78	230	8.84	590	9.11	460	25.15	1180	25.93
		120	1.30	240	14.78	240	8.84	600	9.11	480	25.15	1200	25.93
				250	10.18	250	10.02	610	9.17	500	28.53	1220	26.09
				260	10.18	260	10.02	620	9.17	520	28.53	1240	26.09
				270	10.18	270	10.02	630	9.17	540	28.53	1260	26.09
				280	15.38	280	10.02	640	9.17	560	28.53	1280	26.09
				290	15.38	290	10.02	650	9.17	580	28.53	1300	26.09
				300	15.38	300	10.02	660	9.17	600	28.53	1320	26.09
				310	7.98	310	9.41	670	6.37	620	26.78	1340	18.13
				320	7.98	320	9.41	680	6.37	640	26.78	1360	18.13
				330	7.98	330	9.41	690	6.37	660	26.78	1380	18.13
				340	3.35	340	9.41	700	6.37	680	26.78	1400	18.13
				350	3.35	350	9.41	710	6.37	700	26.78	1420	18.13
				360	3.35	360	9.41	720	6.37	720	26.78	1440	18.13

Table B3 - 100 Year Storm Hyetograph

AES Type 1, 1-hour 30% Distribution						AES BC Coast, 12-hour 50% Distribution							
Time (min)	1 Hour Storm (mm/hr)	Time (min)	2 Hour Storm (mm/hr)	Time (min)	6 Hour Storm (mm/hr)	Time (min)	12 Hour Storm (mm/hr)	Time (min)	12 Hour Storm Continued (mm/hr)	Time (min)	24 Hour Storm (mm/hr)	Time (min)	24 Hour Storm Continued (mm/hr)
5	5.52	5	4.11	10	10.48	10	3.55	370	17.48	20	10.29	740	50.64
10	7.15	10	4.11	20	10.48	20	3.55	380	17.48	40	10.29	760	50.64
15	6.21	15	5.32	30	10.48	30	3.55	390	17.48	60	10.29	780	50.64
20	9.10	20	5.32	40	13.58	40	3.55	400	17.48	80	10.29	800	50.64
25	11.32	25	4.62	50	13.58	50	3.55	410	17.48	100	10.29	820	50.64
30	9.60	30	4.62	60	13.58	60	3.55	420	17.48	120	10.29	840	50.64
35	5.57	35	6.77	70	11.80	70	8.47	430	11.35	140	24.53	860	32.87
40	9.08	40	6.77	80	11.80	80	8.47	440	11.35	160	24.53	880	32.87
45	6.25	45	8.42	90	11.80	90	8.47	450	11.35	180	24.53	900	32.87
50	9.44	50	8.42	100	17.29	100	8.47	460	11.35	200	24.53	920	32.87
55	4.90	55	7.15	110	17.29	110	8.47	470	11.35	220	24.53	940	32.87
60	2.06	60	7.15	120	17.29	120	8.47	480	11.35	240	24.53	960	32.87
		65	4.15	130	21.50	130	8.86	490	14.18	260	25.66	980	41.06
		70	4.15	140	21.50	140	8.86	500	14.18	280	25.66	1000	41.06
		75	6.75	150	21.50	150	8.86	510	14.18	300	25.66	1020	41.06
		80	6.75	160	18.24	160	8.86	520	14.18	320	25.66	1040	41.06
		85	4.65	170	18.24	170	8.86	530	14.18	340	25.66	1060	41.06
		90	4.65	180	18.24	180	8.86	540	14.18	360	25.66	1080	41.06
		95	7.02	190	10.59	190	10.44	550	10.76	380	30.24	1100	31.17
		100	7.02	200	10.59	200	10.44	560	10.76	400	30.24	1120	31.17
		105	3.64	210	10.59	210	10.44	570	10.76	420	30.24	1140	31.17
		110	3.64	220	17.24	220	10.44	580	10.76	440	30.24	1160	31.17
		115	1.53	230	17.24	230	10.44	590	10.76	460	30.24	1180	31.17
		120	1.53	240	17.24	240	10.44	600	10.76	480	30.24	1200	31.17
				250	11.87	250	11.84	610	10.83	500	34.30	1220	31.37
				260	11.87	260	11.84	620	10.83	520	34.30	1240	31.37
				270	11.87	270	11.84	630	10.83	540	34.30	1260	31.37
				280	17.93	280	11.84	640	10.83	560	34.30	1280	31.37
				290	17.93	290	11.84	650	10.83	580	34.30	1300	31.37
				300	17.93	300	11.84	660	10.83	600	34.30	1320	31.37
				310	9.31	310	11.11	670	7.52	620	32.19	1340	21.79
				320	9.31	320	11.11	680	7.52	640	32.19	1360	21.79
				330	9.31	330	11.11	690	7.52	660	32.19	1380	21.79
				340	3.91	340	11.11	700	7.52	680	32.19	1400	21.79
				350	3.91	350	11.11	710	7.52	700	32.19	1420	21.79
				360	3.91	360	11.11	720	7.52	720	32.19	1440	21.79

APPENDIX C

Town of View Royal
Drainage Model

Basic Catchment Parameters

Table C1 - View Royal Future Land Use Catchment Parameters

Catchment ID	Outlet Node	Total Area (ha)	Catchment Travel Length (m)	% Impervious	Slope
C1_S1	DMH456	29.066	300	17%	0.4
C1_S2	TN1009	9.476	400	26%	0.4
C1_S3	TN1000	52.800	50	24%	0.3
C1_S4	TN1006	1.171	50	64%	0.2
C1_S5	TN1002	1.816	50	67%	0.08
C1_S6	TN996	0.960	150	68%	0.15
C1_S7	TN995	3.637	150	66%	0.13
C1_S8	DMH151	2.671	100	37%	0.12
C1_S9	DCO30	0.954	50	39%	0.2
C1_S10	DMH192	0.686	50	60%	0.25
C1_S11	DMH186	0.373	50	79%	0.25
C1_S12	DMH187	0.529	50	55%	0.15
C1_S13	DMH195	0.541	50	57%	0.2
C1_S14	CB321	0.476	50	73%	0.2
C1_S15	DMH148	0.309	50	31%	0.15
C1_S16	DMH150	0.799	100	28%	0.15
C1_S17	TN969	1.112	50	45%	0.15
C1_S18	TN971	0.745	50	40%	0.15
C1_S19	TN994	0.771	50	27%	0.2
C1_S20	DMH163	0.814	50	77%	0.02
C1_S21	DMH157	0.984	80	49%	0.02
C1_S22	DMH167	1.217	50	54%	0.2
C1_S23	DCO26	0.575	30	78%	0.07
C1_S24	DCO27	0.214	30	74%	0.1
C1_S25	DMH181	0.153	50	71%	0.1
C1_S26	DCO28	0.465	50	78%	0.05
C1_S27	DMH178	0.255	150	80%	0.2
C1_S28	DMH180	1.250	150	27%	0.3
C1_S29	CB244	1.123	50	20%	0.3
C1_S30	DMH179	0.365	50	79%	0.1
C1_S31	DMH175	0.515	50	70%	0.1
C1_S32	DMH172	0.364	50	52%	0.02
C1_S33	DMH154	0.177	50	80%	0.02
C1_S34	DMH153	0.397	50	78%	0.02
C1_S35	DMH183	0.311	50	51%	0.2
C1_S36	DMH170	0.288	200	33%	0.2
C2_S1	DCO31	3.613	200	10%	0.3
C2_S2	DCO95	3.352	100	46%	0.3
C2_S3	TN977	1.543	100	54%	0.25
C2_S4	DMH200	0.968	80	31%	0.25
C2_S5	TN948	0.834	80	10%	0.3
C2_S6	TN943	2.552	80	33%	0.3
C2_S7	TN953	0.400	50	56%	0.3
C2_S8	TN958	2.016	100	32%	0.3
C2_S9	TN960	0.745	50	24%	0.2
C2_S10	DMH214	1.207	50	24%	0.1
C2_S11	TN965	1.633	120	13%	0.1

Catchment ID	Outlet Node	Total Area (ha)	Catchment Travel Length (m)	% Impervious	Slope
C2_S12	DMH213	0.390	50	54%	0.1
C2_S13	DMH213	0.246	30	53%	0.1
C2_S14	DMH213	0.135	20	60%	0.1
C2_S15	DMH213	0.304	50	60%	0.1
C2_S16	DMH213	0.162	30	60%	0.1
C2_S17	DMH215	0.744	80	61%	0.06
C2_S18	DMH216	0.408	50	64%	0.1
C2_S19	DMH211	1.033	100	46%	0.06
C2_S20	TN961	0.260	50	66%	0.08
C3_S1	TN925	0.972	100	39%	0.3
C3_S2	TN936	1.638	60	31%	0.3
C3_S3	TN934	0.399	80	70%	0.15
C3_S4	TN920	0.776	50	77%	0.2
C3_S5	LB63	0.472	50	62%	0.3
C3_S6	TN935	0.500	50	59%	0.25
C3_S7	TN916	0.196	50	80%	0.05
C3_S8	TN914	0.104	20	70%	0.05
C3_S9	TN912	0.560	50	63%	0.2
C4_S1	DCO80	6.102	260	19%	0.25
C4_S2	DCO47	1.024	50	80%	0.15
C4_S3	DCO48	0.771	50	80%	0.25
C4_S4	DMH246	0.437	50	80%	0.2
C4_S5	DMH241	0.152	20	80%	0.2
C4_S6	TN870	0.697	60	22%	0.4
C4_S7	DMH239	0.241	30	80%	0.3
C4_S8	DMH238	0.280	30	45%	0.25
C4_S9	DCO46	1.029	50	80%	0.3
C4_S10	DCO40	0.363	30	80%	0.3
C4_S11	DMH237	1.447	50	60%	0.15
C4_S12	DCO43	0.229	50	80%	0.15
C4_S13	TN1141	0.166	40	80%	0.15
C4_S14	DMH250	0.267	40	80%	0.2
C4_S15	DMH235	0.346	50	80%	0.15
C4_S16	DCO39	0.445	50	80%	0.3
C4_S17	DMH233	0.791	50	80%	0.1
C4_S18	DMH346	0.455	50	80%	0.25
C4_S19	DCO79	0.977	50	80%	0.1
C4_S20	DMH232	0.543	50	80%	0.15
C4_S21	DMH243	6.726	300	16%	0.25
C5_S1	TN859	12.733	400	18%	0.25
C5_S2	TN846	4.313	50	37%	0.15
C5_S3	TN845	4.755	150	42%	0.2
C5_S4	TN840	5.722	100	73%	0.06
C5_S5	TN868	1.784	100	16%	0.3
C5_S6	TN864	2.289	100	15%	0.25
C5_S7	TN851	1.043	50	62%	0.1
C5_S8	DMH226	0.569	50	76%	0.15
C5_S9	TN853	0.248	50	60%	0.15
C5_S10	DMH392	1.836	50	74%	0.06

Catchment ID	Outlet Node	Total Area (ha)	Catchment Travel Length (m)	% Impervious	Slope
C5_S11	DMH224	0.448	50	60%	0.05
C5_S12	DMH222	0.752	50	60%	0.1
C5_S13	DMH225	0.166	30	60%	0.1
C5_S14	DMH392	2.373	100	64%	0.08
C6_S1	TN1014	0.710	50	66%	0.15
C6_S2	TN1016	0.945	80	69%	0.15
C7_S1	TN1032	0.756	50	64%	0.15
C7_S2	TN1024	0.225	50	64%	0.25
C7_S3	CB231	0.414	50	62%	0.25
C7_S4	TN1033	0.417	50	61%	0.2
C8_S1	CB509	0.383	50	66%	0.2
C8_S2	DMH219	1.571	50	79%	0.05
C8_S3	DMH388	0.178	30	70%	0.05
C8_S4	DMH220	1.195	100	77%	0.03
C8_S5	DMH220	0.921	100	83%	0.03
C9_S1	CB339	0.366	50	70%	0.05
C9_S2	CB339	0.418	50	70%	0.05
C10_S1	TN744	0.251	100	66%	0.2
C10_S2	TN745	0.363	50	70%	0.2
C10_S3	TN741	0.841	50	60%	0.15
C10_S4	TN737	0.800	50	60%	0.15
C10_S5	TN759	0.784	50	64%	0.2
C10_S6	DCO36	0.117	30	68%	0.1
C10_S7	TN754	0.052	20	60%	0.1
C10_S8	TN740	0.239	50	60%	0.1
C11_S1	TN836	0.982	50	61%	0.2
C11_S2	TN833	0.418	50	62%	0.2
C12_S1	DMH256	1.936	50	71%	0.15
C12_S2	DMH261	1.485	50	74%	0.2
C12_S3	DMH267	0.501	50	79%	0.15
C12_S4	DMH273	1.260	50	80%	0.15
C12_S5	DCO55	0.555	50	80%	0.15
C12_S6	DMH262	1.648	50	60%	0.15
C12_S7	DCO54	4.170	150	28%	0.15
C12_S8	DMH290	9.106	300	10%	0.15
C12_S9	DCO56	0.479	60	80%	0.15
C12_S10	DCO57	0.776	60	62%	0.15
C12_S11	DMH277	0.858	50	59%	0.15
C12_S12	CB387	0.747	50	77%	0.25
C12_S13	TN724	0.237	20	70%	0.25
C12_S14	TN722	0.320	50	24%	0.2
C12_S15	DMH279	1.154	100	72%	0.2
C12_S16	DCO58	0.511	50	28%	0.25
C12_S17	DCO77	0.153	50	80%	0.25
C12_S18	DCO61	0.290	50	80%	0.25
C12_S19	DCO63	0.471	50	80%	0.2
C12_S20	DMH286	1.699	50	79%	0.2
C12_S21	DMH289	0.316	50	80%	0.15
C12_S22	DMH293	0.383	50	75%	0.2

Catchment ID	Outlet Node	Total Area (ha)	Catchment Travel Length (m)	% Impervious	Slope
C12_S23	DCO64	0.225	50	77%	0.2
C12_S24	TN720	0.401	50	75%	0.2
C12_S25	DCO62	0.289	50	67%	0.2
C13_S1	CB475	1.826	50	49%	0.05
C13_S2	CB532	0.475	50	50%	0.1
C13_S3	CB476	0.296	50	38%	0.1
C13_S4	TN1083	0.998	50	58%	0.25
C13_S5	DCO83	0.417	50	52%	0.25
C13_S6	TN1088	2.085	50	59%	0.1
C13_S7	CB486	0.871	50	61%	0.2
C14_S1	TN826	0.386	50	60%	0.25
C14_S2	TN822	0.459	50	60%	0.1
C14_S3	TN823	0.152	50	60%	0.1
C14_S4	DMH338	0.600	50	60%	0.2
C14_S5	TN815	0.367	50	60%	0.15
C14_S6	CB463	0.498	50	60%	0.15
C15_S1	TN788	1.699	50	51%	0.1
C15_S2	TN764	0.710	50	70%	0.06
C15_S3	LB51	2.422	50	65%	0.2
C15_S4	LB50	0.156	20	77%	0.15
C15_S5	TN774	1.066	50	39%	0.25
C15_S6	CB457	1.169	75	63%	0.2
C15_S7	CB456	3.159	100	56%	0.2
C15_S8	DMH329	3.279	100	78%	0.05
C15_S9	DMH328	6.222	150	79%	0.07
C16_S1	TN234	0.407	50	60%	0.15
C16_S2	TN236	0.445	50	60%	0.1
C16_S3	TN237	0.746	50	60%	0.1
C16_S4	TN241	0.677	50	60%	0.1
C16_S5	TN257	0.417	50	44%	0.15
C16_S6	LB55	0.350	50	60%	0.15
C16_S7	TN270	0.409	50	34%	0.15
C16_S8	TN275	0.516	50	25%	0.15
C16_S9	TN280	0.331	50	60%	0.15
C17_S1	TN599	121.995	500	10%	0.05
C17_S2	TN599	4.163	100	38%	0.05
C17_S3	TN1135	1.748	75	84%	0.1
C17_S4	TN598	11.850	100	74%	0.1
C17_S5	CB530	3.768	100	78%	0.07
C17_S6	DMH359	0.427	50	70%	0.05
C17_S7	DMH357	4.861	100	61%	0.05
C17_S8	CB584	1.677	75	77%	0.08
C17_S9	DMH436	0.606	50	76%	0.05
C17_S10	DMH361	0.852	50	70%	0.05
C17_S11	TN596	0.264	30	74%	0.02
C17_S12	TN574	0.463	20	80%	0.05
C17_S13	DMH321	1.561	50	78%	0.07
C17_S14	CB566	0.932	30	74%	0.05
C17_S15	TN604	6.111	150	57%	0.06

Catchment ID	Outlet Node	Total Area (ha)	Catchment Travel Length (m)	% Impervious	Slope
C17_S16	TN600	49.329	300	16%	0.15
C18_S1	TN653	1.106	50	77%	0.2
C18_S2	DMH297	0.695	50	75%	0.15
C18_S3	TN706	2.304	150	46%	0.1
C18_S4	DCO85	1.827	150	66%	0.1
C18_S5	DMH305	1.123	100	84%	0.05
C18_S6	DMH306	0.513	50	81%	0.15
C18_S7	TN712	0.238	30	70%	0.1
C18_S8	DMH313	0.512	50	80%	0.1
C18_S9	DCO67	0.316	50	80%	0.15
C18_S10	DCO69	0.129	30	70%	0.1
C18_S11	DCO70	0.155	40	80%	0.1
C18_S12	DMH317	0.219	40	80%	0.1
C18_S13	TN699	0.100	30	70%	0.05
C18_S14	TN700	0.079	30	71%	0.05
C18_S15	TN703	0.409	50	74%	0.1
C18_S16	DCO72	0.493	50	78%	0.1
C18_S17	DCO71	0.750	50	80%	0.1
C18_S18	DCO73	0.208	40	80%	0.15
C18_S19	DCO74	0.153	40	80%	0.15
C18_S20	TN681	0.461	50	32%	0.1
C18_S21	DCO75	1.816	50	73%	0.15
C18_S22	TN656	1.661	50	74%	0.06
C18_S23	DCO66	2.590	50	56%	0.08
C18_S24	TN665	6.487	200	13%	0.1
C19_S1	TN627	1.237	50	78%	0.1
C19_S2	DCO84	0.980	50	63%	0.15
C19_S3	DMH323	0.387	50	78%	0.15
C19_S4	TN617	0.212	40	50%	0.1
C19_S5	TN614	0.110	30	38%	0.2
C19_S6	TN613	0.911	50	39%	0.1
C19_S7	TN606	0.522	80	16%	0.12
C20_S1	TN639	2.254	50	73%	0.1
C20_S2	TN641	0.483	50	71%	0.1
C20_S3	CB448	0.220	50	80%	0.1
C20_S4	DMH324	0.576	50	78%	0.1
C20_S5	TN648	0.397	50	80%	0.15
C20_S6	DMH327	0.538	50	78%	0.15
C21_S1	CB449	2.043	50	72%	0.3
C21_S2	TN1046	0.297	50	69%	0.1
C21_S3	TN1046	0.759	50	70%	0.05
C21_S4	CB449	1.302	50	70%	0.1
C21_S5	TN1073	1.069	50	62%	0.1
C21_S6	TN1051	0.522	50	65%	0.05
C21_S7	TN1063	0.815	50	61%	0.05
C21_S8	TN1042	0.376	50	65%	0.05
C21_S9	TN1129	1.600	50	78%	0.2
C21_S10	DCO89	1.972	50	79%	0.1
C21_S11	TN1041	0.774	50	71%	0.2

Catchment ID	Outlet Node	Total Area (ha)	Catchment Travel Length (m)	% Impervious	Slope
C21_S12	DMH35	1.113	80	75%	0.1
C21_S13	DMH32	1.078	50	79%	0.15
C21_S14	DCO6	0.934	50	80%	0.15
C21_S15	DMH62	1.138	50	79%	0.2
C21_S16	DMH57	2.329	100	71%	0.2
C21_S17	DMH59	2.520	100	74%	0.15
C22_S1	TN90	0.708	50	60%	0.1
C22_S2	TN81	0.269	50	60%	0.1
C22_S3	TN77	1.550	50	35%	0.07
C22_S4	TN119	0.502	50	38%	0.15
C22_S5	TN122	0.627	50	34%	0.2
C22_S6	DMH124	0.578	50	78%	0.15
C22_S7	TN120	0.792	50	71%	0.1
C22_S8	TN111	1.309	50	44%	0.15
C22_S9	TN108	0.618	50	60%	0.2
C22_S10	TN103	1.045	50	60%	0.2
C22_S11	DMH126	0.503	50	72%	0.2
C22_S12	DMH127	0.309	50	69%	0.1
C22_S13	TN121	1.078	50	81%	0.1
C22_S14	DMH128	1.675	50	78%	0.1
C23_S1	DMH115	0.311	50	42%	0.1
C23_S2	DMH117	0.582	50	60%	0.1
C23_S3	DMH119	1.583	50	60%	0.08
C23_S4	LB32	1.995	50	44%	0.12
C23_S5	TN233	1.423	50	55%	0.1
C23_S6	LB33	0.295	50	60%	0.1
C24_S1	TN172	0.427	50	36%	0.15
C24_S2	TN183	0.189	40	60%	0.05
C24_S3	TN189	1.043	50	60%	0.2
C24_S4	TN193	1.212	50	60%	0.2
C24_S5	TN194	0.335	50	60%	0.2
C24_S6	TN204	0.638	50	61%	0.15
C24_S7	TN205	0.448	50	60%	0.1
C24_S8	CB219	0.997	50	70%	0.15
C25	CB506	0.416	50	60%	0.15
C26	CB506	1.248	50	63%	0.1
C27	DCO10	1.017	50	60%	0.15
C28	CB163	0.427	50	60%	0.25
C29	DMH69	1.166	50	69%	0.1
C30_S1	TN374	1.180	50	60%	0.15
C30_S2	DMH73	0.144	30	70%	0.1
C30_S3	DMH75	1.970	50	61%	0.15
C31_S1	CB116	1.512	50	68%	0.1
C31_S2	CB112	1.137	50	60%	0.15
C31_S3	CB108	0.356	50	61%	0.25
C31_S4	TN339	1.039	50	74%	0.15
C31_S5	DMH50	1.519	50	60%	0.15
C31_S6	LB2	0.952	50	60%	0.15
C31_S7	CB96	2.093	50	60%	0.2

Catchment ID	Outlet Node	Total Area (ha)	Catchment Travel Length (m)	% Impervious	Slope
C31_S8	DMH38	1.356	50	62%	0.05
C31_S9	DMH52	2.180	50	62%	0.1
C31_S10	DMH43	0.705	50	60%	0.1
C31_S11	TN318	0.779	50	60%	0.15
C31_S12	TN310	0.218	50	68%	0.2
C32_S1	DMH451	2.032	50	77%	0.08
C32_S2	DMH448	1.493	50	62%	0.15
C32_S3	DMH248	1.455	50	51%	0.12
C32_S4	DMH480	0.287	30	70%	0.1
C32_S5	DMH24	1.848	50	79%	0.12
C32_S6	DMH25	0.916	50	78%	0.15
C32_S7	CB50	1.403	50	78%	0.15
C32_S8	DMH29	0.339	50	80%	0.1
C32_S9	DMH27	0.483	50	79%	0.1
C32_S10	DCO2	1.605	50	48%	0.25
C33_S1	TN127	1.070	100	31%	0.25
C33_S2	TN126	0.844	50	63%	0.1
C33_S3	TN124	2.273	120	17%	0.15
C33_S4	TN132	1.400	100	29%	0.15
C33_S5	CB495	0.794	50	60%	0.05
C33_S6	TN157	0.339	50	60%	0.12
C33_S7	TN137	0.671	50	78%	0.12
C33_S8	TN136	0.519	60	84%	0.1
C33_S9	LB37	1.813	50	60%	0.1
C33_S10	TN148	1.052	50	66%	0.1
C34_S1	CB464	0.249	30	60%	0.12
C34_S2	TN170	1.411	70	60%	0.25
C35_S1	TN164	0.835	50	36%	0.25
C35_S2	TN160	0.669	50	34%	0.25
C36_S1	TN411	0.408	50	63%	0.1
C36_S2	TN419	0.707	50	65%	0.1
C36_S3	TN520	1.345	50	74%	0.1
C36_S4	TN550	1.317	50	70%	0.1
C36_S5	TN423	2.542	50	67%	0.2
C36_S6	TN468	0.496	50	80%	0.12
C36_S7	TN431	0.794	50	80%	0.2
C36_S8	TN433	1.301	50	63%	0.15
C36_S9	CB185	0.271	50	60%	0.15
C36_S10	TN475	0.751	50	80%	0.2
C36_S11	TN457	0.524	50	75%	0.2
C36_S12	DCO12	0.534	50	61%	0.15
C36_S13	DMH103	0.662	50	61%	0.1
C36_S14	TN481	0.268	50	80%	0.2
C36_S15	LB24	0.504	50	80%	0.1
C36_S16	CB192	0.643	50	77%	0.12
C36_S17	DMH107	0.625	50	80%	0.15
C36_S18	TN485	0.417	50	80%	0.1
C36_S19	TN501	0.742	50	79%	0.15
C36_S20	TN502	0.810	50	80%	0.15

Catchment ID	Outlet Node	Total Area (ha)	Catchment Travel Length (m)	% Impervious	Slope
C36_S21	CB193	0.830	50	65%	0.2
C36_S22	TN449	1.202	50	63%	0.15
C36_S23	LB23	0.781	50	62%	0.15
C36_S24	TN436	0.682	50	62%	0.2
C36_S25	TN438	0.640	50	49%	0.17
C36_S26	DCO13	0.419	50	60%	0.2
C36_S27	TN445	2.380	50	31%	0.25
C36_S28	TN409	0.147	30	60%	0.1
C36_S29	TN528	1.757	50	80%	0.1
C38_S1	LB60	0.534	50	63%	0.1
C38_S2	LB57	0.393	50	60%	0.1
C38_S3	TN61	0.284	50	60%	0.1
C38_S4	TN62	0.156	50	60%	0.1
C38_S5	TN71	0.105	30	65%	0.1
C38_S6	TN408	0.996	50	66%	0.1
C39_S1	CB499	1.956	100	26%	0.03
C39_S2	LB62	0.560	50	60%	0.12
C39_S3	TN60	0.335	30	19%	0.03
C40_S1	DCO8	0.484	50	60%	0.15
C40_S2	DMH80	1.125	50	60%	0.15
C40_S3	DMH82	1.580	50	63%	0.2
C40_S4	DMH94	0.972	50	62%	0.06
C40_S5	DCO9	1.298	50	60%	0.1
C40_S6	DMH96	0.571	50	62%	0.05
C40_S7	CB179	0.722	50	62%	0.1
C40_S8	DMH86	1.781	70	34%	0.05
C40_S9	DCO113	0.965	50	62%	0.12
C40_S10	DMH482	1.116	50	60%	0.08
C40_S11	CB168	0.375	50	70%	0.05
C40_S12	LB16	1.218	50	47%	0.12
C40_S13	DMH99	1.154	50	69%	0.1
C40_S14	TN405	0.521	50	69%	0.1
C41_S1	TN46	0.619	50	60%	0.1
C41_S2	TN52	0.420	50	60%	0.1
C42_S1	DCO97	0.808	50	60%	0.2
C42_S2	DCO7	0.554	50	60%	0.2
C42_S3	TN386	0.423	50	60%	0.2
C42_S4	TN378	0.455	50	60%	0.2
C43	TN395	0.753	50	60%	0.15
C44	TN393	0.375	50	60%	0.06
C45_S1	TN26	0.252	50	60%	0.1
C45_S2	LB65	0.429	50	68%	0.13
C46_S1	TN12	1.228	50	71%	0.07
C46_S2	TN45	0.308	30	60%	0.1
C47_S1	DMH23	0.753	50	69%	0.2
C47_S2	DMH23	0.996	50	72%	0.2
C47_S3	DMH20	0.927	50	79%	0.15
C47_S4	DMH19	0.484	50	78%	0.1
C47_S5	DMH18	0.158	30	70%	0.05

Catchment ID	Outlet Node	Total Area (ha)	Catchment Travel Length (m)	% Impervious	Slope
C47_S6	DMH23	0.830	50	78%	0.1
C47_S7	DMH20	0.723	50	79%	0.2
C47_S8	DMH15	2.989	100	82%	0.02
C47_S9	CB33	0.570	40	73%	0.1
C47_S10	DMH14	0.281	30	70%	0.05
C48_S1	DMH2	0.875	50	76%	0.1
C48_S2	DMH7	1.718	70	77%	0.15
C48_S3	DMH9	4.344	100	79%	0.07
C48_S4	DMH5	1.711	100	80%	0.12
C48_S5	DMH4	1.554	100	80%	0.15
C48_S6	DMH13	1.002	60	78%	0.15
C48_S7	DMH12	0.793	50	79%	0.2
C48_S8	DMH11	0.964	60	81%	0.03
C49_S1	TN281	0.319	50	60%	0.12
C49_S2	TN283	0.224	50	60%	0.1
C49_S3	TN295	1.314	100	59%	0.2
C49_S4	TN289	1.574	100	34%	0.2
C49_S5	TN301	1.034	50	49%	0.16
C50_S1	TN636	0.559	50	66%	0.1
C50_S2	TN632	1.330	100	10%	0.05
C51_S1	LB77	0.697	50	60%	0.1
C51_S2	LB77	0.420	50	60%	0.05
C51_S3	LB77	0.454	50	60%	0.2
C52_S1	DMH139	1.819	50	83%	0.05
C52_S2	DCO88	2.052	50	80%	0.06
C53_S1	DMH132	2.536	100	80%	0.2
C53_S2	TN907	1.081	100	81%	0.2
C53_S3	TN910	3.123	100	10%	0.2
C53_S4	TN906	0.840	100	70%	0.2
C54	TN905	2.004	50	79%	0.05
C55	TN903	2.433	50	74%	0.05
C56	DMH496	2.612	100	37%	0.2
C57	DMH385	0.728	100	49%	0.2
C58	TN882	0.937	50	76%	0.03
C59	TN886	0.705	50	85%	0.02

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