Final Report

Stormwater Master Plan

Village of Anmore, BC
September 19, 2018

Project ID: 2017-051-ANM

Prepared for:

Village of Anmore, BC
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Anmore, BC V3H 5G9

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September 19, 2018

Village of Anmore, BC
2697 Sunnyside Road
Anmore, BC V3H 5G9

Attention: Ms. Juli Halliwell

Re: Final Report for the Village of Anmore Stormwater Master Plan

Dear Ms. Halliwell,

GeoAdvice Engineering Inc. is pleased to submit to the Village of Anmore one (1) digital copy of our final report for the Village of Anmore Stormwater Master Plan.

If you have any questions, or require clarification on any point made herein, please contact me. It has been a pleasure to work with the Village, and I look forward to continue working with the Village in the future.

Yours truly,

GeoAdvice Engineering Inc.

Werner de Schaetzen, Ph.D., P.Eng.
Project Manager

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Document History and Version Control

Revision No.	Date	Document Description	Revised By	Reviewed By
R0	April 30, 2018	Draft Submission	Jonathan Hung	Werner de Schaetzen
R1	Sept 14, 2018	Final Draft Submission	Chuck Linders	Werner de Schaetzen
R2	Sept 19, 2018	Final Submission	Chuck Linders	Werner de Schaetzen

Contents

List of Figures

List of Tables

1. Executive Summary

The Village of Anmore (Village) retained GeoAdvice Engineering Inc. (GeoAdvice) to develop a Stormwater Master Plan (SMP) that will help direct the orderly expansion and improvement of the Village's stormwater system to meet current and future needs. The key components of the Village's existing stormwater system are summarized in **Table 1.1.**

Table 1.1: Village of Anmore Stormwater System Key Component Summary

Item	Quantity
Count and length of culverts	476 (7.0 km)
Count and length of storm mains	240 (7.7 km)
Count of manholes	158
Count of control manholes	17
Count of detention facilities	20
Current number of residents	2,210 (2016)
Future number of residents	4,000 (2041)

GeoAdvice developed a model of the current stormwater system using PCSWMM (CHI Water Software). The primary data used to develop the hydraulic network included information collected in the field by Urban Systems Ltd. (USL), ground reconnaissance work completed by GeoAdvice, and available asbuilt drawings. The model was calibrated to stream flow monitoring data recorded during the 2018 wet weather season. Once calibrated, a future scenario model was defined based on the land use zoning information from the Village Official Community Plan (OCP) and from additional information provided by ISL Engineering and Land Services Ltd. (ISL).

The data collection and culvert condition assessment were performed throughout a 3-week period from January 15, 2018 to February 2, 2018. USL was tasked to assess all culverts in the Village. **Table 1.2** summarizes the culvert condition rating categories and results.

Table 1.2: Village of Anmore Culvert Condition Ratings

Condition Rating	Number of Culverts
1 - Very Good	184
2 - Good	164
3 - Fair	57
4 - Poor	**37**
5 - Critical	**1**

The flow monitoring program consisted of four (4) flow monitoring sites and one (1) rain gauge, for a period of record of about two months from January 2, 2018 to March 7, 2018.

As agreed with the Village, the drainage model consisted of all pipes, plus the open-channel ditch and creek systems. In addition, some of the larger detention facilities were included; however the on-lot detention facilities, catch basins and swales were excluded from the Village model.

Rather than simulating individual storm events for model calibration, a continuous simulation from January 2, 2018 to March 7, 2018 was run. The model parameters were adjusted in an iterative manner until model results achieved an acceptable correlation with the measured flow data for the storm events identified. Overall, the model shows an acceptable agreement with the measured flows at the four flow stations.

Design storms were then simulated to assess the hydraulic capacity of the existing conveyance system of culverts and storm mains under existing and future OCP land use conditions. Each asset was assessed using a capacity Likelihood of Failure (LoF) rating system. A LoF rating of '1' means it is unlikely to fail, while a LoF of '5' is highly likely to fail. **Table 1.3** and **Table 1.4** summarize the capacity LoF rating results.

Table 1.3: Existing Land Use Capacity LoF Rating Results

Capacity LoF	Number of Storm Mains	Number of Minor System Culverts	Number of Major System Culverts
1	221	398	44
2	27	1	1
3	5	13	1
4	**6**	**0**	**0**
5	**4**	**11**	**7**

Table 1.4: Future Land Use Capacity LoF Rating Results

Capacity LoF	Number of Storm Mains	Number of Minor System Culverts	Number of Major System Culverts
1	210	394	44
2	34	1	1
3	8	14	1
4	**7**	**0**	**0**
5	**4**	**14**	**7**

To assess the risk associated with each culvert and storm main should the asset fail, condition and capacity LoF ratings were analyzed together with its corresponding consequence of failure to develop an overall risk score. A consequence of failure rating of '1' represents the least impact, while a consequence of failure rating of '3' represents the greatest impact.
Table 1.5 summarizes the consequence of failure ratings statistics.

Table 1.5: Village of Anmore Consequence of Failure Rating Results

Consequence of Failure	Number of Storm Mains	Number of Culverts
1	68	14
2	152	356
3	**43**	**106**

Matrices of the relationship between an asset's condition and capacity LoF ratings and its consequence of failure ratings were used to evaluate risks. A risk score of '1' represents the lowest risk while a risk score of '3' represents the highest risk. **Table 1.6** below summarizes the condition and capacity risk score results.

Table 1.6: Condition and Capacity Risk Results

	Condition		Existing Land use - Capacity			Future Land use - Capacity		
Risk Score	Storm Main	Culvert	Storm Main	Minor System Culvert	Major System Culvert	Storm Main	Minor System Culvert	Major System Culvert
1	42	389	253	410	45	251	407	45
2	220	75	9	2	1	11	2	1
3	**1**	**12**	**1**	**11**	**7**	**1**	**14**	**7**

A benefit of developing risk scores for the Village's drainage assets is that it provides a decision-making process for near-term and long-term capital planning. Priority ratings were assigned to each asset based on the asset's condition and capacity risk scores. The overall priority rating combines the condition, capacity and consequence failure risk assessments into a single 1 to 5 priority rating. A rating of '1' represents the highest priority and a rating of '5' represents the lowest priority.

Only culverts and storm mains with a condition or capacity risk score of '3' were considered critical and were considered for improvement. **Table 1.7** summarizes the priority rating results.

Table 1.7: Culverts and Storm Mains Priority Rating Results

Priority	Number of Storm Mains	Number of Minor System Culverts	Number of Major System Culverts
1	**0**	**0**	**2**
2	0	2	3
3	1	9	2
4	0	0	0
5	1	12	1

Recommended improvements were sized to convey the flows simulated under the future land use scenario with consideration of impacts from climate change. **Table 1.8** lists the culvert and storm main improvements triggered by capacity and condition risks. The recommended improvements were grouped into projects based on physical location and flow path. The project ID indicates the priority for each project. A full list of projects with prioritization is provided in **Table 7.1**.

Table 1.8: List of Culvert and Storm Main Improvements

Project ID	Location	Length (m)	Existing Diameter (mm)	Upgrade Diameter (mm)	Conduit Type	Cost Estimate ($)
1	Sunnyside Rd	60	450 – 800	450 – 1,200 x 2,400	Culvert/Storm	$109,000
2	East Rd/Creek	112	450 – 900	1,200 – 1,500	Culvert	$360,000
3	Alpine Dr	47	450	600 – 675	Culvert	$53,000
4	Sunnyside Rd	28	300 - 650	450 – 675	Culvert	$22,000
5	East Rd	164	250 – 900	450 – 1,200	Culvert	$223,000
6	East Rd	59	300 – 900	450 – 1,200	Culvert	$48,000
7	Spence Way	25	300	450	Culvert	$10,000
8	Ravenswood Dr	115	300	450 – 600	Culvert/Storm	$82,000
9	Fern Dr	54	300	450	Culvert	$23,000
	Total	**664**			**Total**	**$930,000**

2. Introduction

The Village of Anmore (Village) retained GeoAdvice Engineering Inc. (GeoAdvice) to develop a Stormwater Master Plan (SMP) that will help direct the orderly expansion and improvement of the Village's stormwater system to meet current and future needs.

The project was managed on behalf of the Village by ISL Engineering and Land Services Ltd. (ISL).

Urban Systems Ltd. (USL) developed the culvert inventory component of the SMP. USL completed the culvert surveys that provided the necessary information to develop a hydraulic model of the Village stormwater system. Furthermore, USL completed the culvert condition assessments that were used to determine and prioritize culvert upgrades.

GeoAdvice developed a model of the current stormwater system using PCSWMM (CHI Water Software). The primary data used to develop the hydraulic network included information collected in the field by USL, ground reconnaissance work completed by GeoAdvice, and available asbuilt drawings. The model was calibrated using flow monitoring data recorded during the 2018 wet weather season. Once calibrated, a future scenario was modeled based on the land use zoning information from the Village Official Community Plan (OCP) and from additional information provided by the Village.

2.1. Background

The Village is bounded by Belcarra to the West, Port Moody to the South, Coquitlam to the East, and Electoral Area A to the North. The study area includes all land within the municipal boundary as well as all major creeks that enter and/or exit the Village, which ultimately discharge into the Burrard Inlet and Buntzen Lake. Minor drainage ditches, seeps and overland flow were not incorporated into the hydraulic model, but rather were characterized in the software's hydrology model. The major creeks that flow through the Village municipal boundary include Anmore, Mossom, and Schoolhouse Creeks.

Much of the Village's land area is dedicated as Park or Watershed land use and is currently undeveloped and forested. The local topography consists of steep slopes, mature forests, creeks and wildlife habitat. The stormwater system that services the developed areas consists of a network of culverts, stormwater conduits, ditches and swales. This system currently services a population of about 2,210 (2016) residents. According to the latest OCP, the Village has been experiencing steady growth and is expected to serve about 4,000 residents by 2041.

The key components of the Village's stormwater system are summarized in **Table 2.1** and shown in **Figure 2.1.**

Table 2.1: Village of Anmore Stormwater System Key Component Summary

Item	Quantity
Count and length of culverts	476 (7.0 km)
Count and length of storm mains	240 (7.7 km)
Count of manholes	158
Count of control manholes	17
Count of detention facilities	20
Current number of residents	2,210 (2016)
Future number of residents	4,000 (2041)

GeoAdvice Engineering Inc.

Legend

- Outfall
- Culvert
- Storm Main
- Creek
- Ditch
- Detention Main
- Village of Anmore Boundary

Village of Anmore Stormwater System

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N S E W

Figure 2.1

2.2. Objectives

The primary objective of this project was to create a Stormwater Master Plan (SMP) that provides a roadmap to direct the orderly expansion and improvement of the Village stormwater system. To meet this objective, a hydrologic and hydraulic model of the Village stormwater system was created using PCSWMM.

The intent of this project was to provide the Village with:

- A hydrologic/hydraulic model of the Village's stormwater system (ditches/culverts and conduits/stormwater structures);
- A culvert inventory suitable for incorporation into the Village's GIS and Asset Management systems; and,
- A Stormwater Master Plan report that:
    - describes the hydraulic condition of the existing stormwater system;
    - describes the physical condition of the existing culvert infrastructure; and
    - provides improvement recommendations to accommodate existing and future development, complete with preliminary costing for budgeting purposes.

2.3. Project Participants

The SMP was developed through the combined effort of personnel from the Village, ISL, GeoAdvice, USL, and Bot Corp. Key team members are:

Village of Anmore, BC
Juli Halliwell – Chief Administrative Officer
Luke Guerin – Operations Superintendent
Lorne Iveson – Maintenance & Utility Worker II
Lance Fortier – Maintenance & Utility Worker II

ISL Engineering and Land Services Ltd.
Chris Boit, P.Eng. – Project Manager for the Village

GeoAdvice Engineering Inc.
Sean Geyer, EIT – Hydraulic & Hydrologic Modeler, Project Engineer
Jonathan Hung, P.Eng. – Water Resources Engineer
Chuck Linders – Stormwater Modeling Expert, Senior Review
Werner de Schaetzen, Ph.D., P.Eng. – Project Manager
Renaud Dufays – Junior Modeler

Urban Systems Ltd.
Ricky Banga, BGIS – GIS Analyst and Field Team Member
Cory Sivell – Asset Management Consultant
Wade Turner, GISP – Condition Assessment and Field Survey Coordinator
Glen Shkurhan, P.Eng. – Master Planning Advisor, Senior Review Engineer

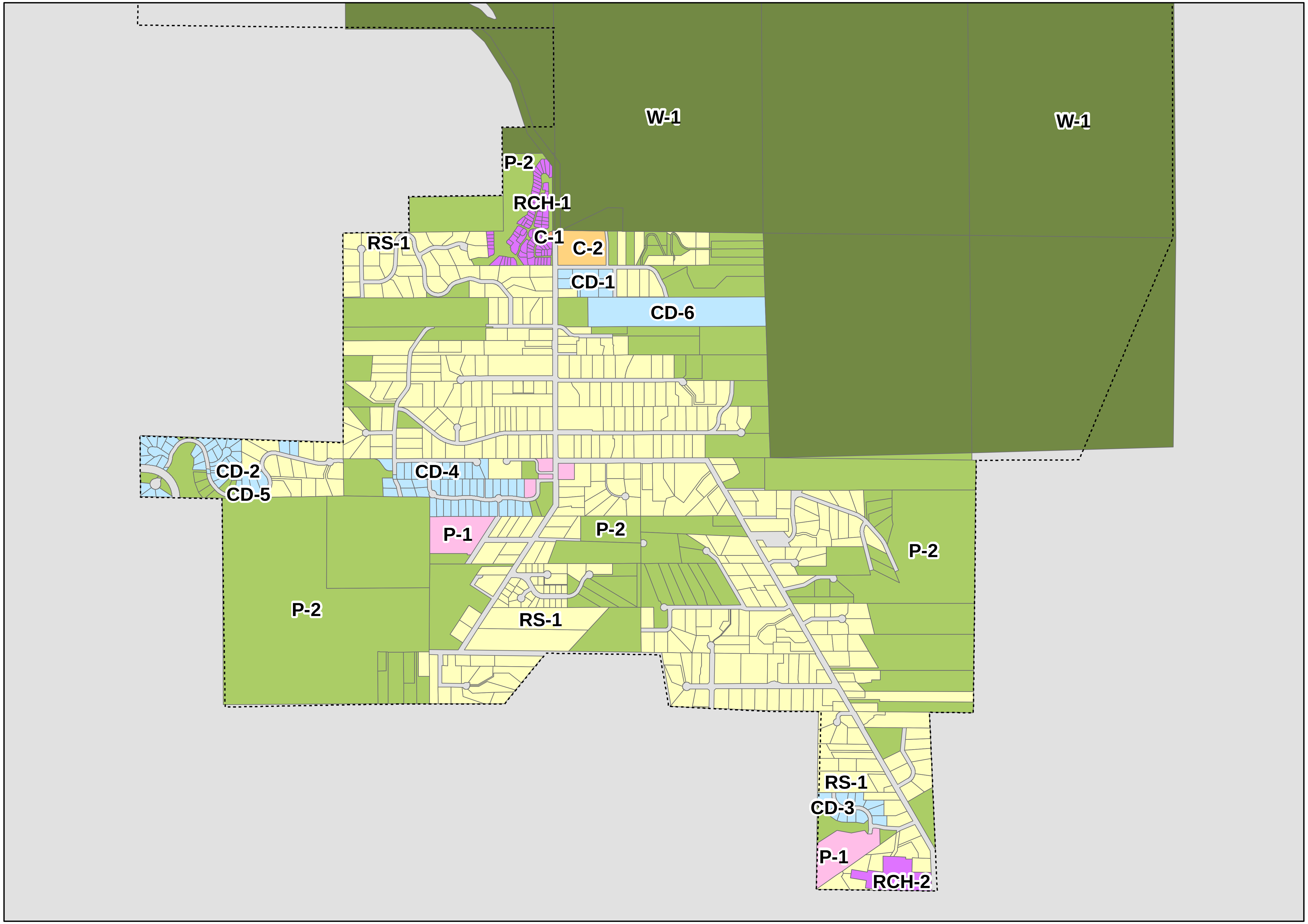
Bot Corp Environmental Monitoring
Brian Bot – River, Stream and Sewer Flow Monitoring Specialist

3. Land Use and Zoning

Existing and future land uses were based on the Village of Anmore Official Community Plan (OCP)[1]. In consultation with the Village, a land use map showing the existing land use was created as shown in **Figure 3.1**.

The Village OCP identifies future development to predominantly occur on currently undeveloped lands, with some infill or redevelopment in existing residential areas. The OCP further stipulates that the average density for new subdivisions will remain at one lot per one acre, consistent with the existing RS-1 zoning. However, in consultation with the Village, some of the future development areas currently designated as RS-1 were changed to comprehensive development (CD) for modeling purposes. This modification reflects more densified future developments (i.e. reflects a more conservative analysis of stormwater runoff) and is consistent with current development trends in the Village. The future land use plan assumed for this project is shown in **Figure 3.2**.

[1] Village of Anmore Official Community Plan Bylaw No. 532, 2014



GeoAdvice Engineering Inc.

Legend

- Village of Anmore Boundary

Land Use Zoning Code

- Local Commercial (C-1)
- Campground Commercial (C-2)
- Equestrian Commercial (C-3)
- Comprehensive Development (CD-1, CD-2, CD-3, CD-4, CD-5, CD-6)
- Civic Institutional (P-1)
- Park (P-2)
- Compact Housing(RCH-1, RCH-2)
- Residential 1 (RS-1)
- Watershed (W-1)

Existing Landuse Zoning

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

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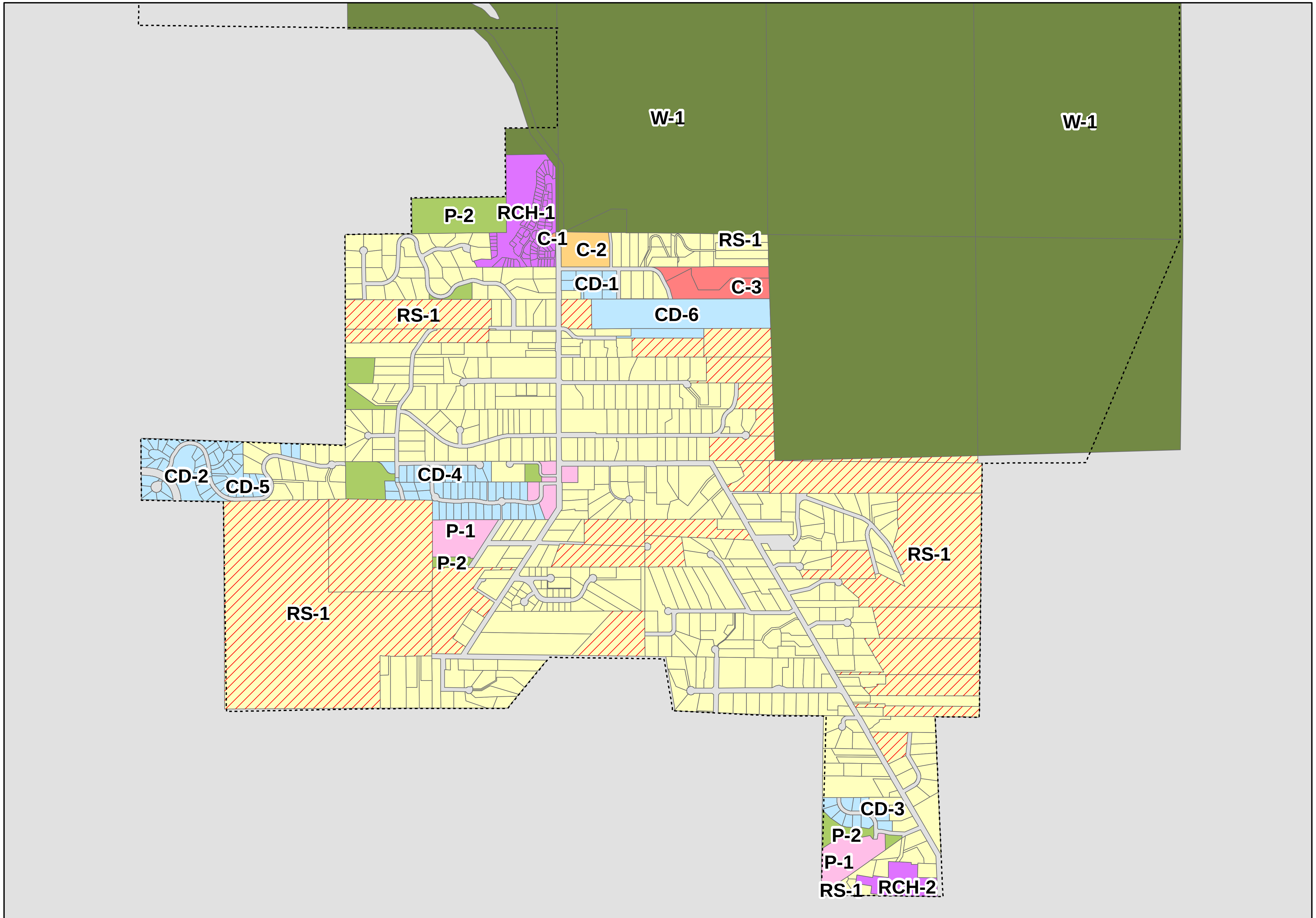
Figure 3.1



GeoAdvice Engineering Inc.

Legend

Village of Anmore Boundary

Land Use Zoning Code

- Local Commercial (C-1)
- Campground Commercial (C-2)
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- Civic Institutional (P-1)
- Park (P-2)
- Compact Housing(RCH-1, RCH-2)
- Residential 1 (RS-1)
- Watershed (W-1)
- Future development areas designated as RS-1 in the OCP were changed to comprehensive development (CD) for modeling purposes

Future Landuse Zoning

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

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Figure 3.2

4. Drainage Design Criteria

4.1. Minor and Major Systems

The Village stormwater system consists of "minor" and "major" drainage systems. The following are excerpts from the Village of Anmore Design Criteria and provide a general description of each system.

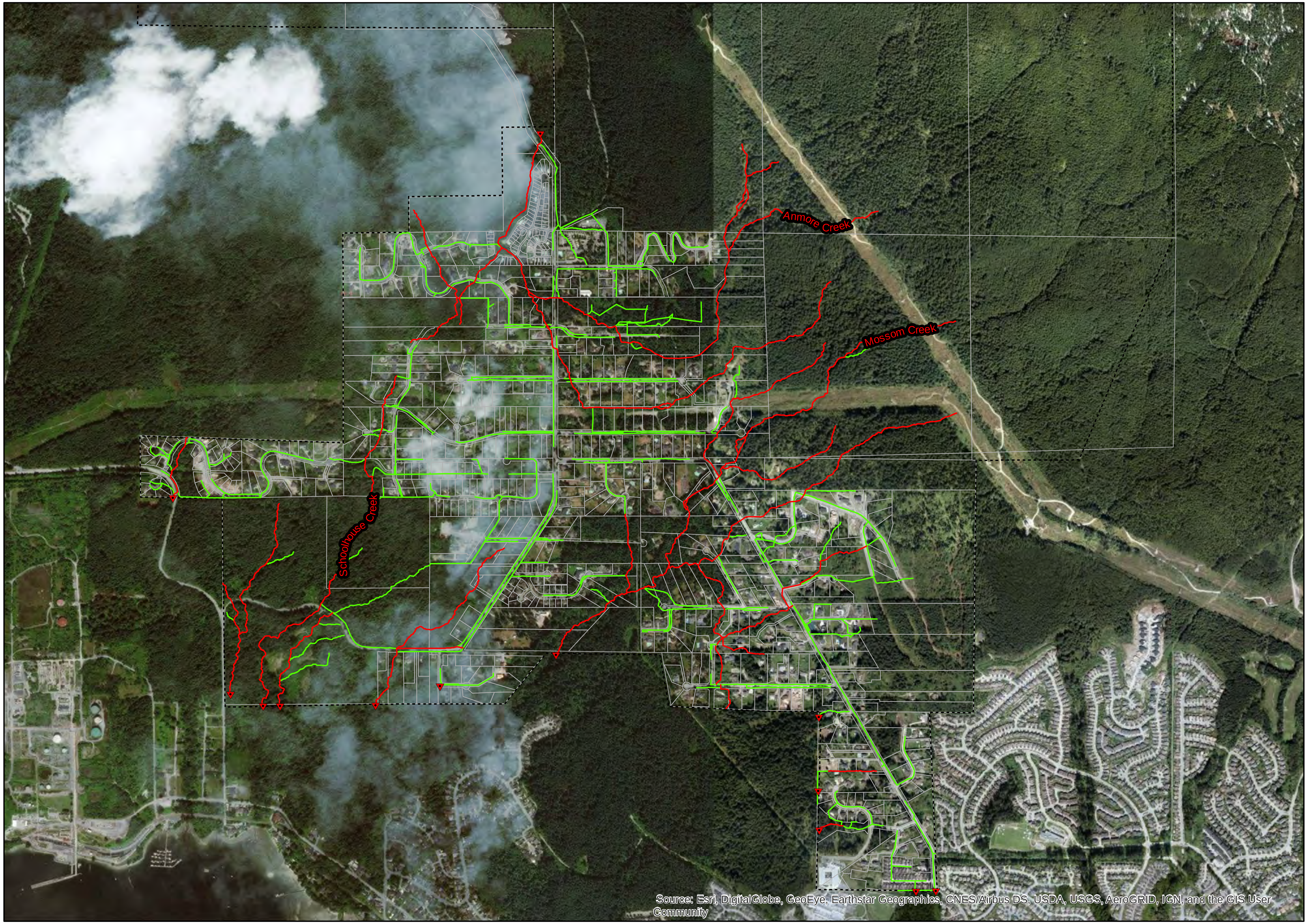
Minor System
The "minor system" consists of underground conduits, open channels and watercourses to convey a 5-year return flow.

Major System
The "major system" consists of surface flood paths, roadways and watercourses to convey the 100-year return flow. In special conditions where surface flood paths cannot be established, pipes and culverts of the minor system may be enlarged to accommodate the major system flow.

The Village design criteria also state the following:

- Culverts crossing all roads shall be designed to accommodate the "major flows" with either by inlet or outlet control.
- Driveway culverts shall be designed to accommodate the "minor flows" unless otherwise indicated.

In summary, the conveyance features that form the Village stormwater system were classified, in consultation with the Village, as minor or major systems as shown in **Figure 4.1**.



GeoAdvice Engineering Inc.

Legend

- Village of Anmore Boundary
- Parcels
- Outfall
- Major System
- Minor System

Minor and Major Systems

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

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Kilometers

N W E S

Figure 4.1

4.2. Design Criteria

Table 4.1 summarizes the stormwater criteria consolidated from the Village design criteria and past Village reports.

Table 4.1: Village's Stormwater Criteria

Stormwater System	Stormwater Criteria
Culvert	Driveway culverts: safe conveyance of 5-year peak flows. Road crossing culverts: safe conveyance of 100-year peak flows. Driveway culverts shall be minimum 450 mm in diameter.
Storm sewer	Safe conveyance of 5-year peak flows in minor system. Safe conveyance of 100-year peak flows in major system. The minimum storm sewer pipe diameter shall be 200 mm in diameter, except where ditches discharge directly into a storm main where the minimum shall be 300 mm.
Ditch	Maximum velocity in an unlined ditch shall be 1 m/s.
Detention Requirement	5-year peak flows detained to 5-year pre-development peak flows.

Source: Anmore Works and Services Bylaw No. 242-1998

4.3. Design Storms

The Intensity-Duration-Frequency (IDF) curve data used to create the design storms are tabulated in **Table 4.2**. The IDF curve data were extracted from Metro Vancouver rain gauge QT57 – Westwood Plateau, and are based on recorded rain gauge data for the period of 1997-2014 (17 years).

Table 4.2: Intensity-Duration-Frequency Rainfall Intensity Values (QT57)

	Rainfall Intensity (mm/hr)					
Return Period / Duration	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
5-min	43.0	61.3	73.4	88.6	100.0	111.2
15-min	26.3	37.6	45.1	54.6	61.7	68.7
30-min	19.8	25.7	29.6	34.6	38.3	41.9
1-hour	13.6	17.7	20.4	23.8	26.4	28.9
2-hour	10.5	13.8	16.0	18.8	20.8	22.8
6-hour	7.7	10.6	12.5	14.9	16.7	18.4
12-hour	5.6	8.0	9.6	11.7	13.2	14.7
24-hour	4.0	5.8	7.0	8.5	9.6	10.7
48-hour	2.7	4.2	5.1	6.3	7.2	8.1
72-hour	2.1	3.2	3.9	4.8	5.5	6.1

Source: Metro Vancouver Rain Gauge QT57 - Westwood Plateau (1997-2014)

The synthetic "all duration" method was used to develop the design storm events. **Table 4.3** below presents total rainfall depths of the design events used to assess the drainage system.

Table 4.3: Design Storm Total Rainfall Depths

Storm Duration	1:5-year Total Depth (mm)	1:100-year Total Depth (mm)	Design Storm Shape
24 Hour	139.5	257.8	All Duration

Figures 4.2 and **4.3** show the design storm hyetographs used in the model.

Figure 4.2: 5-Year Design Storm ("All Duration")

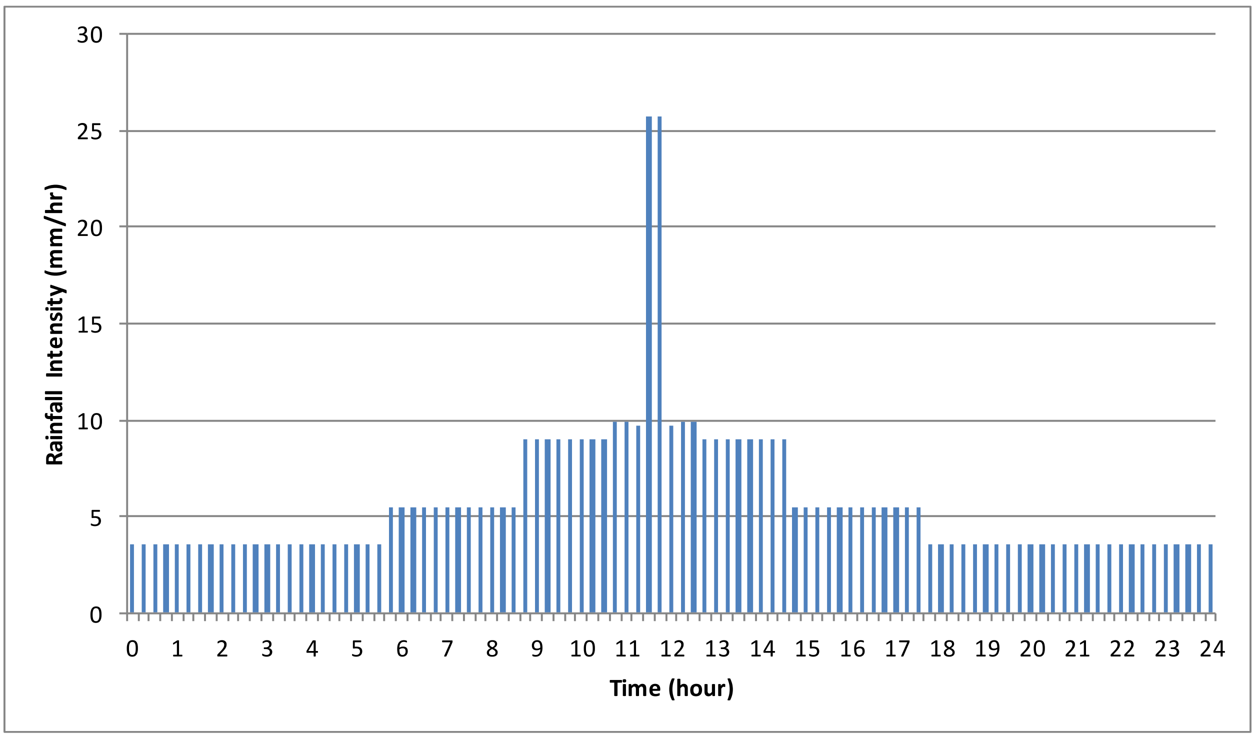
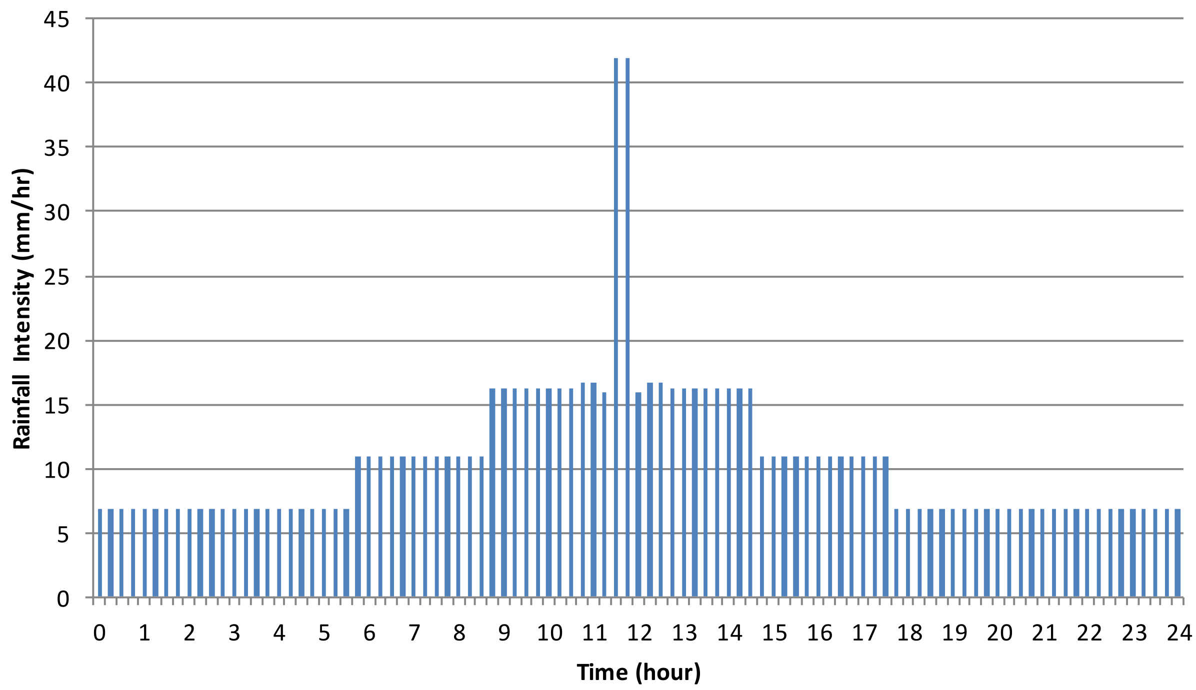


Figure 4.3: 100-Year Design Storm ("All Duration")



4.3.1. Climate Change

Design storm hyetographs representing the impacts of climate change on rainfall volume were developed by increasing the intensity of existing design storms by an additional 15% in accordance with the Master Municipal Construction Documents (MMCD) guidelines. The climate change scenario was only considered to size recommended improvements.

5. Existing Stormwater System

The existing GIS dataset previously collected for the Village's Asset Management Plan was used as the basis of existing information to define the scope of the field data collection. This GIS dataset was compiled from CAD and record drawings, and staff knowledge. It was understood that this dataset was not complete and lacked key information for the development of the hydraulic model. As such, field surveys and condition assessments were conducted as part of this study.

5.1. Field Data Collection

With the Village GIS dataset at hand, USL completed culvert surveys and condition assessments. The field data was collected digitally and was provided to the Village in an ArcGIS geodatabase file. Additional culverts were identified while the field crew was on site. 27 additional culverts were identified, surveyed, and assessed for physical and operational condition.

5.1.1. Culvert Survey

USL completed the survey of over 265 culverts with diameters greater than 300 mm, collecting the precise location and invert elevations using a high accuracy grade system (TS15, GS24, CS15 system). The expected accuracy from this system is about 1 cm.

The location and invert elevations of the remaining smaller diameter culverts were collected using a backpack SX Blue II + GNSS system. The expected accuracy of this system ranges from 20 cm to 100 cm, depending on location of the culvert.

USL provided a technical memorandum that outlines the information used when starting the data compilation and collection and highlighting the existing data gaps at the outset of the field collection and condition assessment. Refer to **Appendix A** for the USL *GIS-Based Stormwater Data Review Documentation and Field Data Collection Methodology* tech memo.

5.1.2. Culvert Condition Assessment

The data collection and culvert condition assessment were performed throughout a 3-week period from January 15th – February 2nd, 2018. USL were tasked to assess all culverts in the Village. The inventory of the culverts included capturing the diameter, material, length, condition, notable deficiencies, maintenance needs and photos of assets and found deficiencies such as blockages, damaged ends, visible scour, degraded conduits, etc. **Table 5.1** summarizes the culvert condition rating categories.

Table 5.1: Culvert Condition Ratings

Condition Rating	Description	Estimated Remaining Life*
1 - Very Good	Only normal maintenance required	75% – 100%
2 - Good	Minor maintenance required	50% – 75%
3 - Fair	Maintenance required to return to accepted level of service	25% – 50%
4 - Poor	**Requires renewal (significant renewal/upgrade required)**	**0% – 25%**
5 - Critical	**Asset unserviceable**	**0%**

**Based on typical service life of approximately 60 years.*

Table 5.2 summarizes the condition rating statistics of the Village of Anmore culverts.

Table 5.2: Village of Anmore Culvert Condition Ratings

Condition Rating	Number of Culverts*
1 - Very Good	184
2 - Good	164
3 - Fair	57
4 - Poor	**37**
5 - Critical	**1**

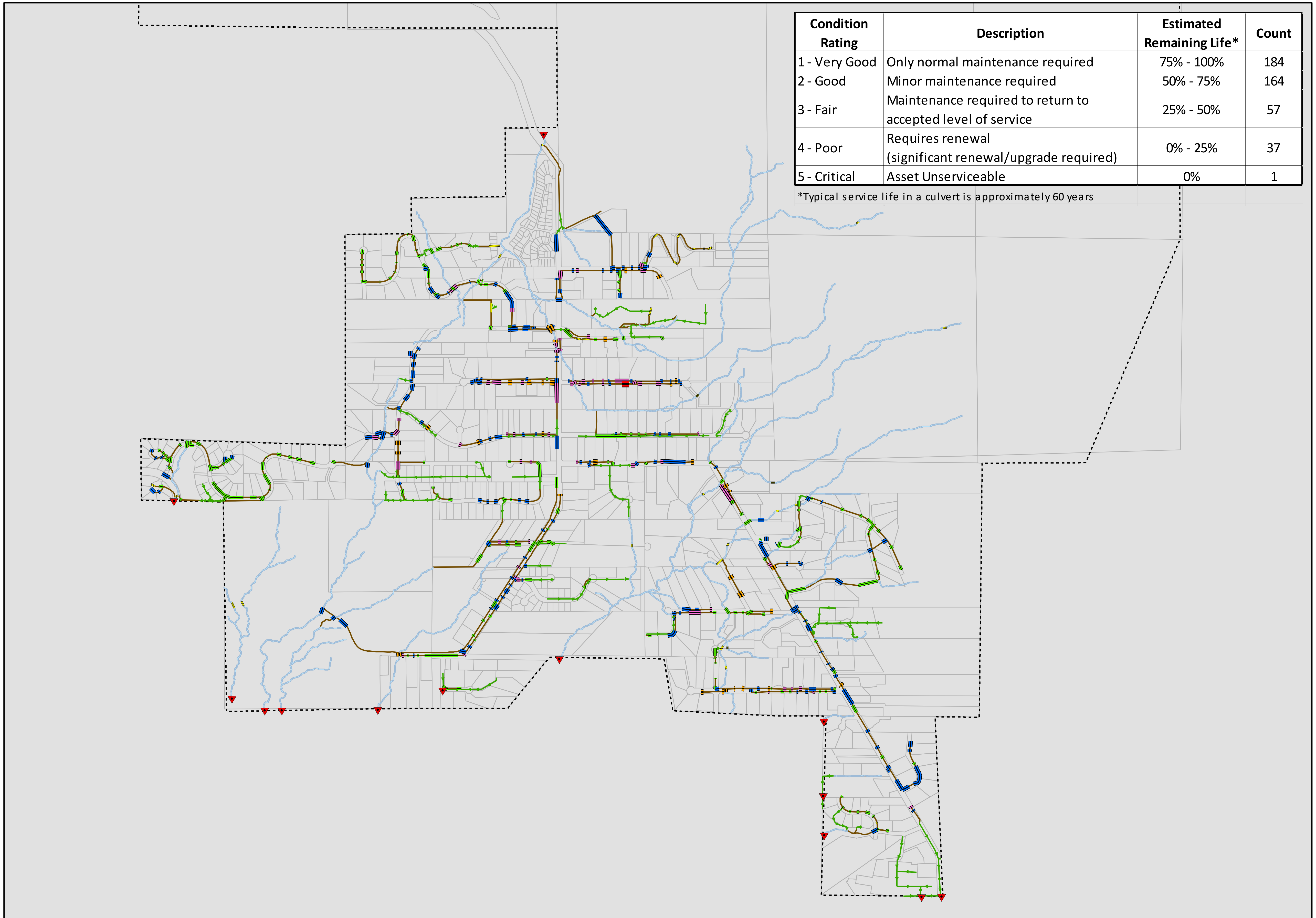
Several culverts could not be assessed for their condition (Refer to **Appendix A).*

USL provided a technical memorandum that documents the culvert condition assessment framework and coding system used for the field condition assessment component of the SMP. Refer to **Appendix B** for the USL *Culvert Condition Assessment Framework and Coding System* tech memo.

Figure 5.1 shows the condition ratings of the Village of Anmore culvert based on USL field work.

Condition Rating	Description	Estimated Remaining Life*	Count
1 - Very Good	Only normal maintenance required	75% - 100%	184
2 - Good	Minor maintenance required	50% - 75%	164
3 - Fair	Maintenance required to return to accepted level of service	25% - 50%	57
4 - Poor	Requires renewal (significant renewal/upgrade required)	0% - 25%	37
5 - Critical	Asset Unserviceable	0%	1

*Typical service life in a culvert is approximately 60 years



GeoAdvice Engineering Inc.

Legend

- Village of Anmore Boundary
- Outfall
- Creek
- Culvert
- Ditch
- Storm Main

Condition Rating

- 1 *Very Good*
- 2 *Good*
- 3 *Fair*
- 4 *Poor*
- 5 *Critical*

2018 Urban Systems Culvert Assessment Condition Rating

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

0 0.25 0.5 1
Kilometers

N W E S

Figure 5.1

5.2. Flow Monitoring Program

GeoAdvice retained Bot Corp to conduct a stormwater flow monitoring program to measure, record and collect rainfall and flow monitoring data that were used to calibrate the model. The flow monitoring program consisted of four (4) flow monitoring sites and one (1) rain gauge, for a period of record of about two months from January 2, 2018 to March 7, 2018. The purpose of the flow monitoring program was to obtain field data for model calibration.

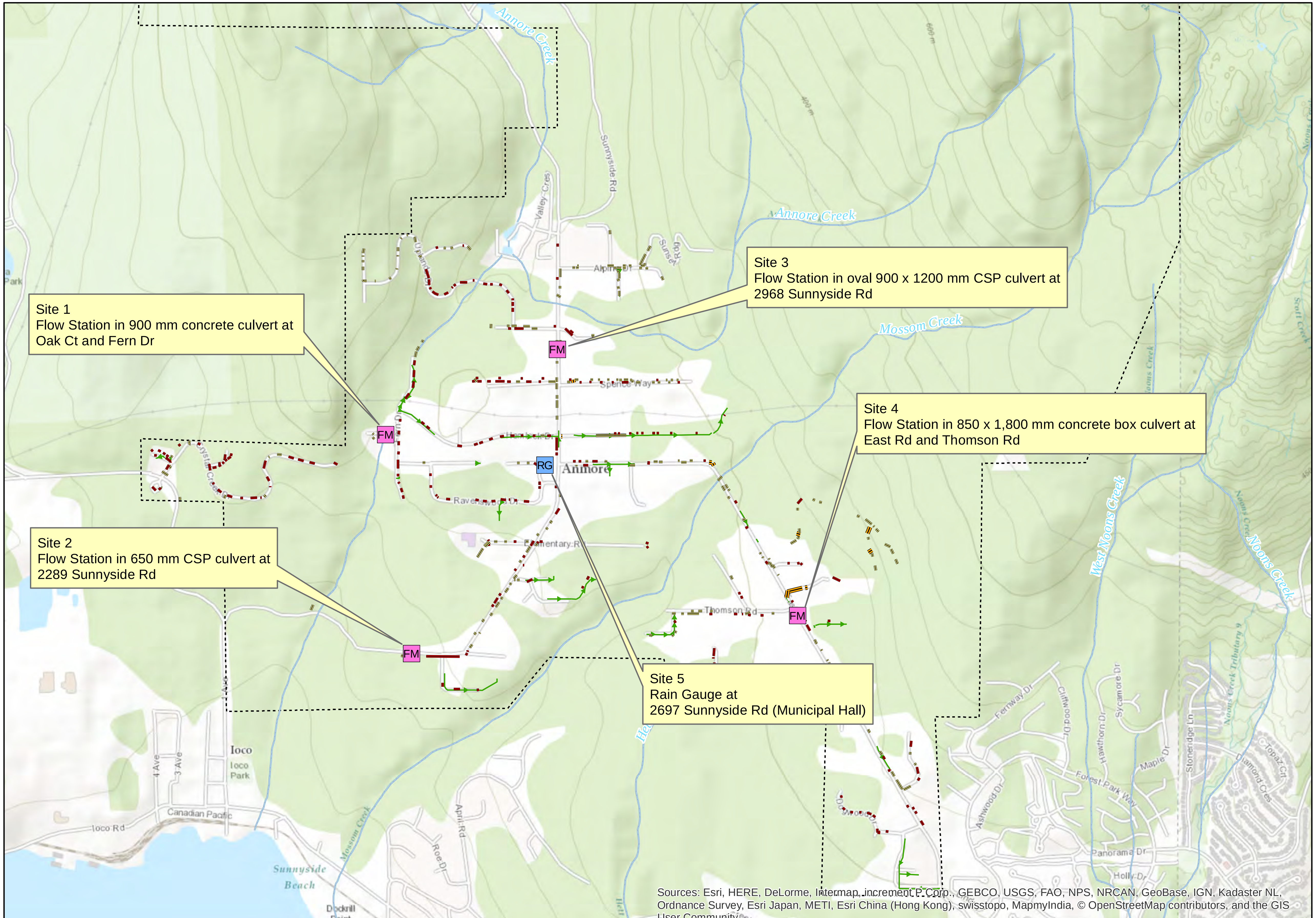
Table 5.3 describes the location of the four (4) flow monitoring stations installed by Bot Corp.

Table 5.3: Flow Monitoring Stations

Site No.	Site Location	Culvert ID	Approx. Civic Address
1	Oak Ct Culvert	D0167	147 Oak Ct
2	Discharge to Anmore Creek from Pond	D0279	2195-2289 Sunnyside Rd
3	Sunnyside Rd Culvert	D0159	2915-2967 Sunnyside Rd
4	East Rd Culvert	D0430_2	1001 Thomson Rd

One rain gauge was installed at 2697 Sunnyside Rd on January 4, 2018. Unfortunately, the rainfall data of this rain gauge was not usable due to a malfunction of the device. Therefore, rainfall data from Metro Vancouver rain gauge station QT57 – Westwood Plateau was used instead.

Figure 5.2 shows the location of the rain gauge and flow monitoring stations.



GeoAdvice Engineering Inc.

Legend

- Village of Anmore Boundary
- Creek
- Storm Sewer Main

Culvert

- <= 300 mm
- 350-650 mm
- >900 mm

Monitoring Locations

- FM Flow Station
- RG Rain Gauge

Stormwater Flow Monitoring Program

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: JH
Reviewed by: WdS

0 0.25 0.5 1
Kilometers

N W E S

Figure 5.2

5.2.1. Summary of Installation

The four (4) flow monitoring stations and one (1) rain gauge and the corresponding catchment size and installation notes are summarized in **Table 5.4** below.

Table 5.4: Flow Monitoring Catchment and Installation Notes

Site No.	Catchment Size (ha)	Bot Corp Installation Notes
1	23	Installed flow meter in the 900 mm culvert and performed verification.
2	16	Installed the flow meter in the 650 mm culvert and performed verification.
3	52	Installed flow meter in the oval culvert (900 x 1,200 mm) and performed verification.
4	94	Installed flow meter in the box culvert (850 x 1,800 mm) and performed verification. As there was a significant amount of sediment on the bottom on the culvert, a rectangle weir was installed. Flow was then measured based on the depth of flow over the weir crest.
5 (Rain Gauge)	N/A	Installed the rain gauge on the top of the Atco trailer at Anmore Municipal Hall.

Bot Corp field pictures and sketches of each monitoring device are provided in the following pages.

Flow Site 1:

Site Picture	Inlet Picture
	Not available

Upstream Conduit Picture	Downstream Conduit Picture
Not available	Not available

<u>Flow Site 2:</u>

Site Picture

Inlet Picture

Upstream Conduit Picture

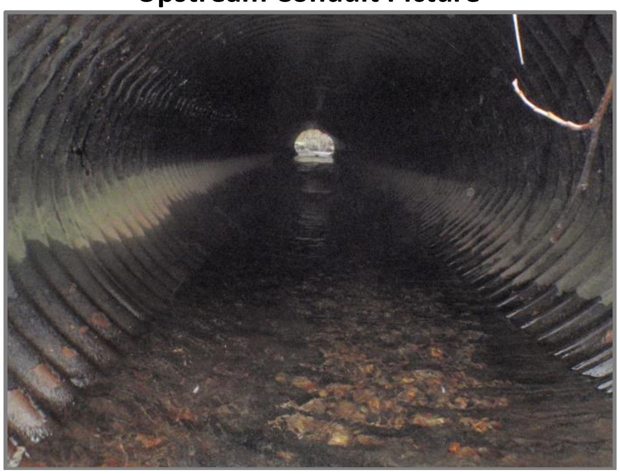
Downstream Conduit Picture

Flow Site 3:

Site Picture

Inlet Picture

Upstream Conduit Picture



Downstream Conduit Picture

Flow Site 4:

Site Picture

Inlet Picture (Weir Not Installed Yet)

Upstream Conduit Picture

Downstream Conduit Picture

Rain Gauge Site 5:

Site Picture

5.2.2. Flow Monitoring Hydrographs

Figure 5.3 to **Figure 5.6** show the flow monitoring hydrographs for each of the four sites.

Figure 5.3: Flow Monitoring Hydrograph – Site 1

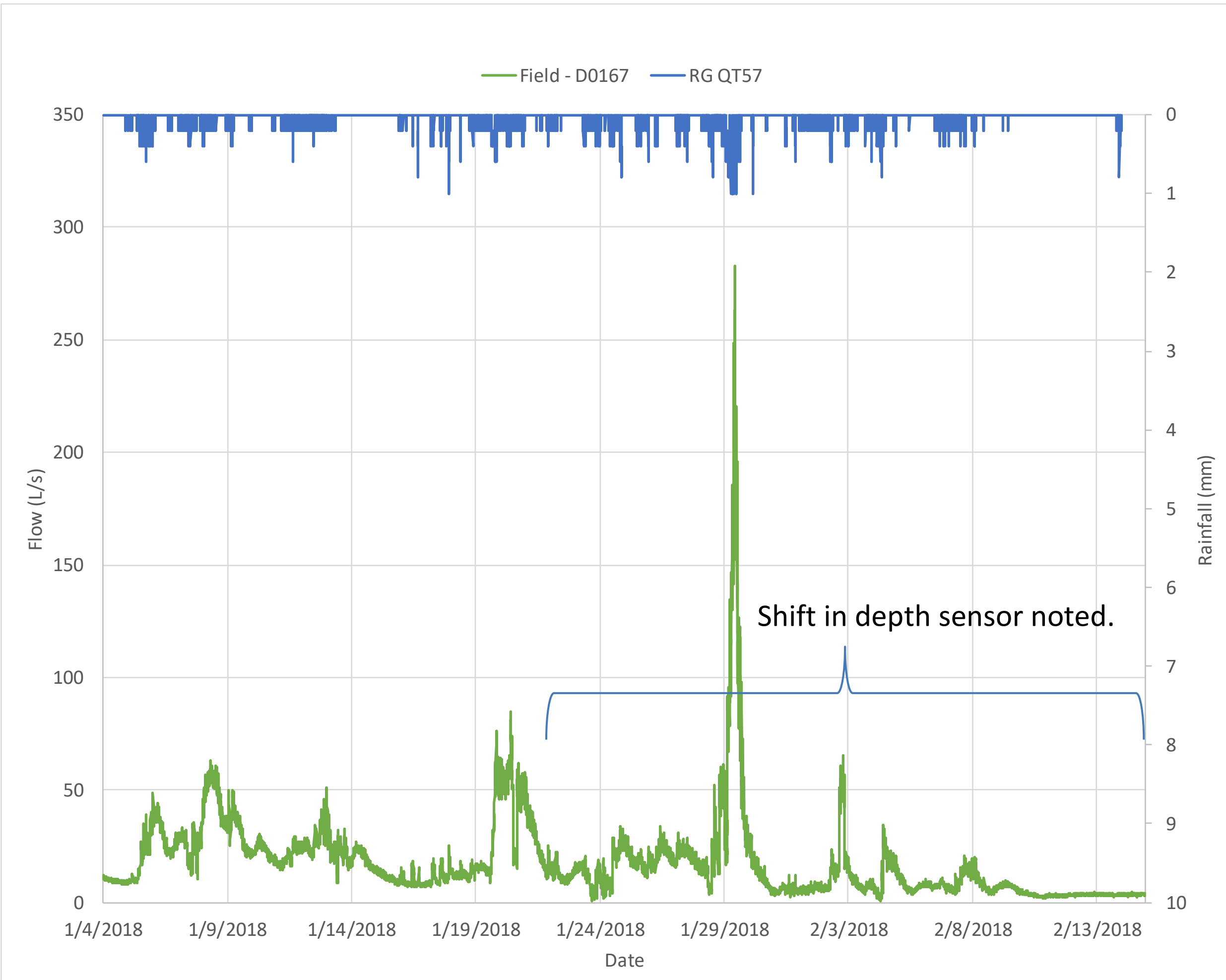


Figure 5.4: Flow Monitoring Hydrograph – Site 2

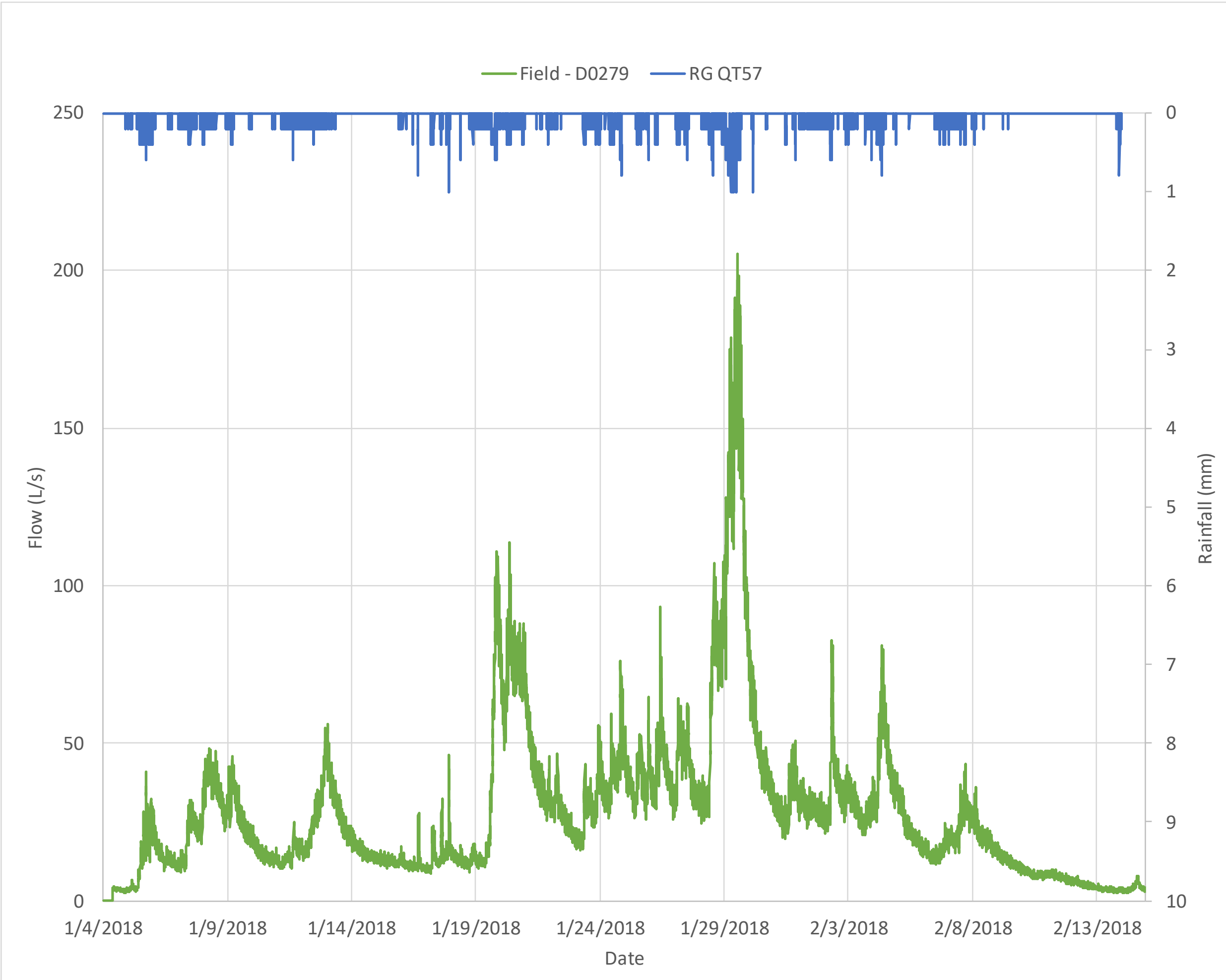


Figure 5.5: Flow Monitoring Hydrograph – Site 3

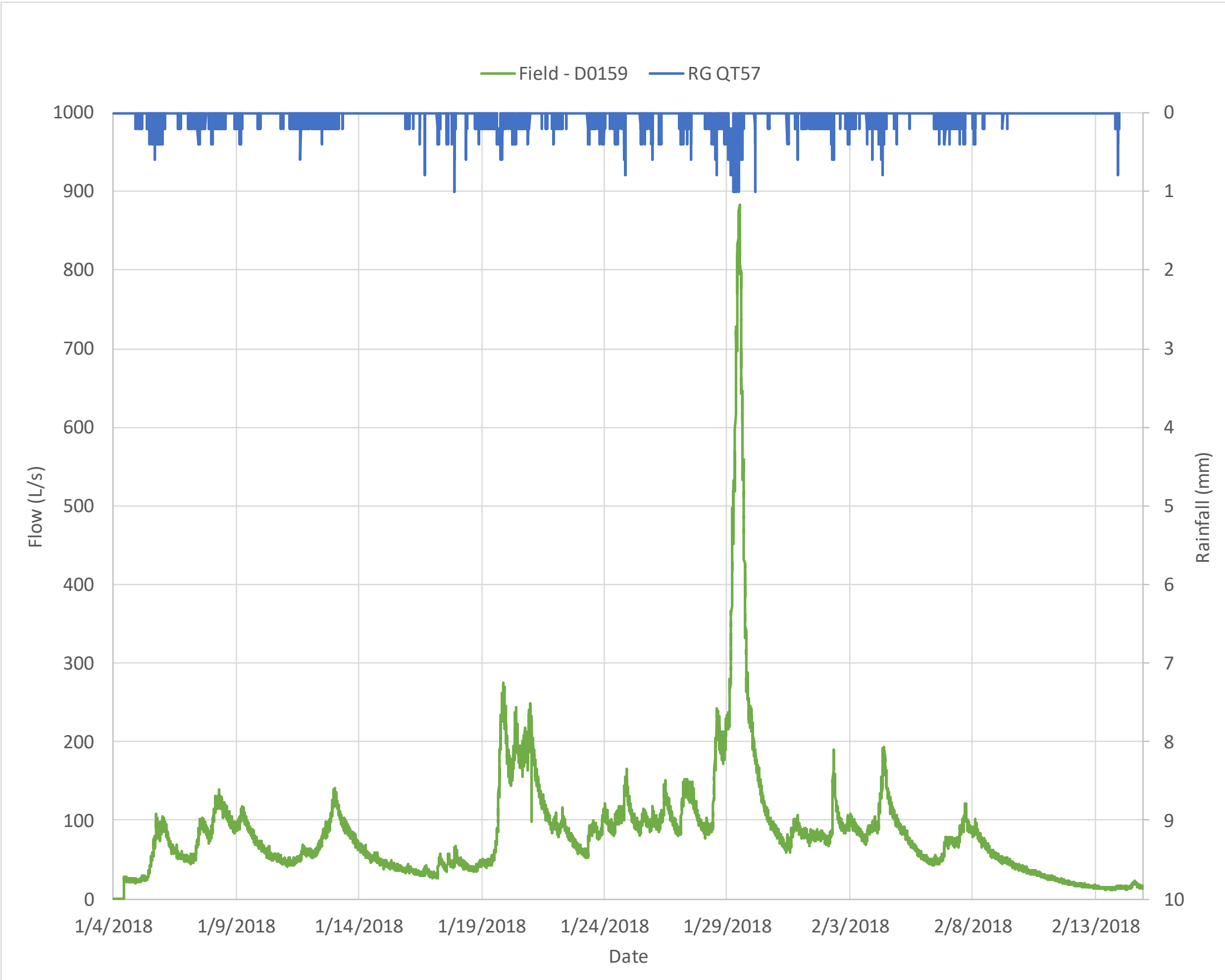
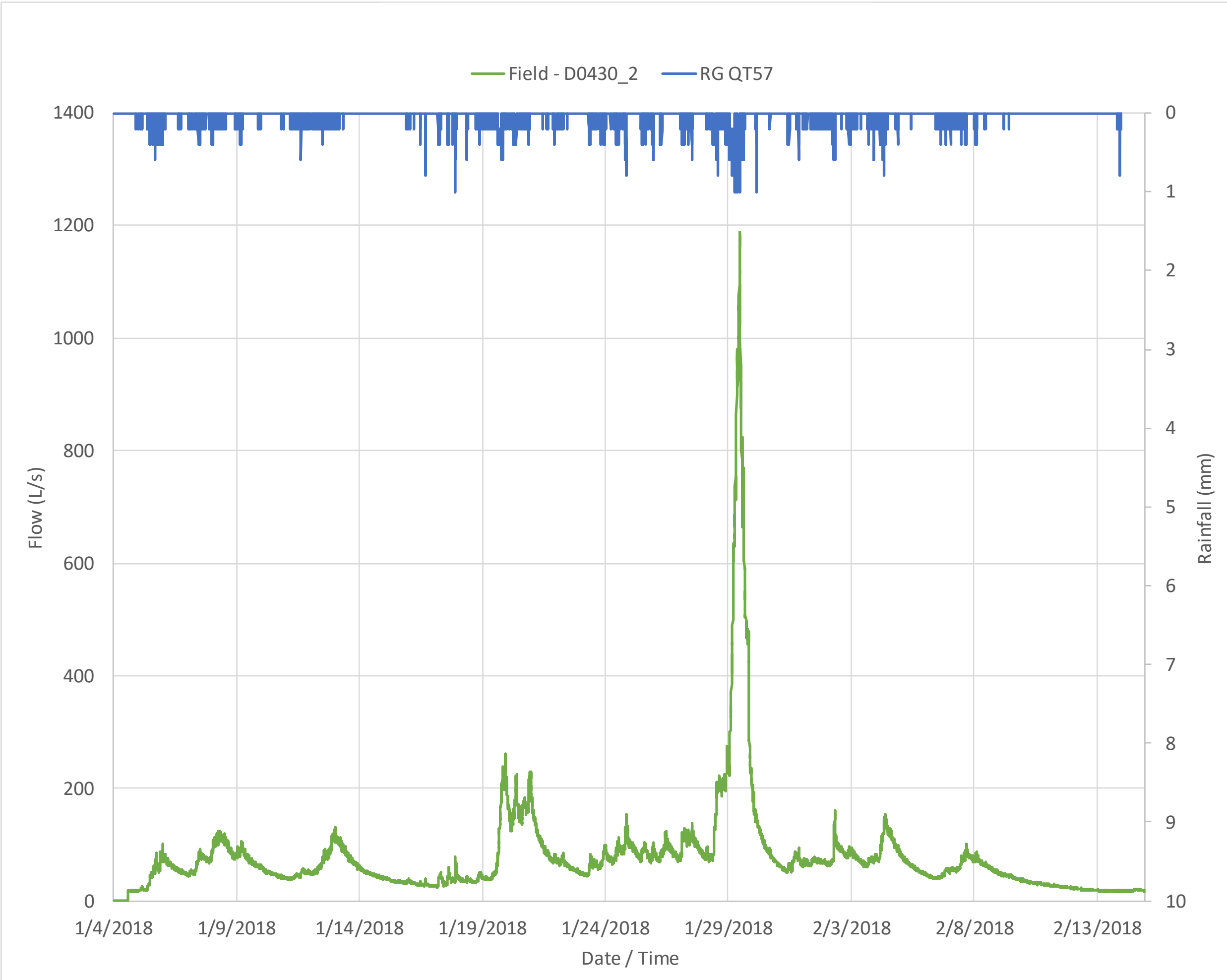


Figure 5.6: Flow Monitoring Hydrograph – Site 4



5.2.3. Storm Event Summary

By analyzing the rainfall data in conjunction with the flow monitoring data, individual storm events were identified. The storm event data from the QT57 rain gauge are summarized in **Table 5.5**.

Table 5.5: Storm Event Summary (Rain Gauge QT57)

Event	Start Date / Time	Duration (hr)	Maximum Rainfall Intensity (mm/hr)	Total Rainfall (mm)	Return Period*
1	1/5/2018 8:00	19	3.8	27.4	< 2yr
2	1/7/2018 1:00	37	2.0	31.0	< 2yr
3	1/11/2018 4:00	54	1.8	36.4	< 2yr
4	1/18/2018 18:00	55	4.2	61.6	< 2yr
5	1/28/2018 2:00	40	8.0	106.8	< 2yr
6	1/31/2018 8:00	52	4.6	29.4	< 2yr
7	2/2/2018 19:00	44	3.6	35.6	< 2yr
8	2/6/2018 10:00	51	2.4	33.0	< 2yr

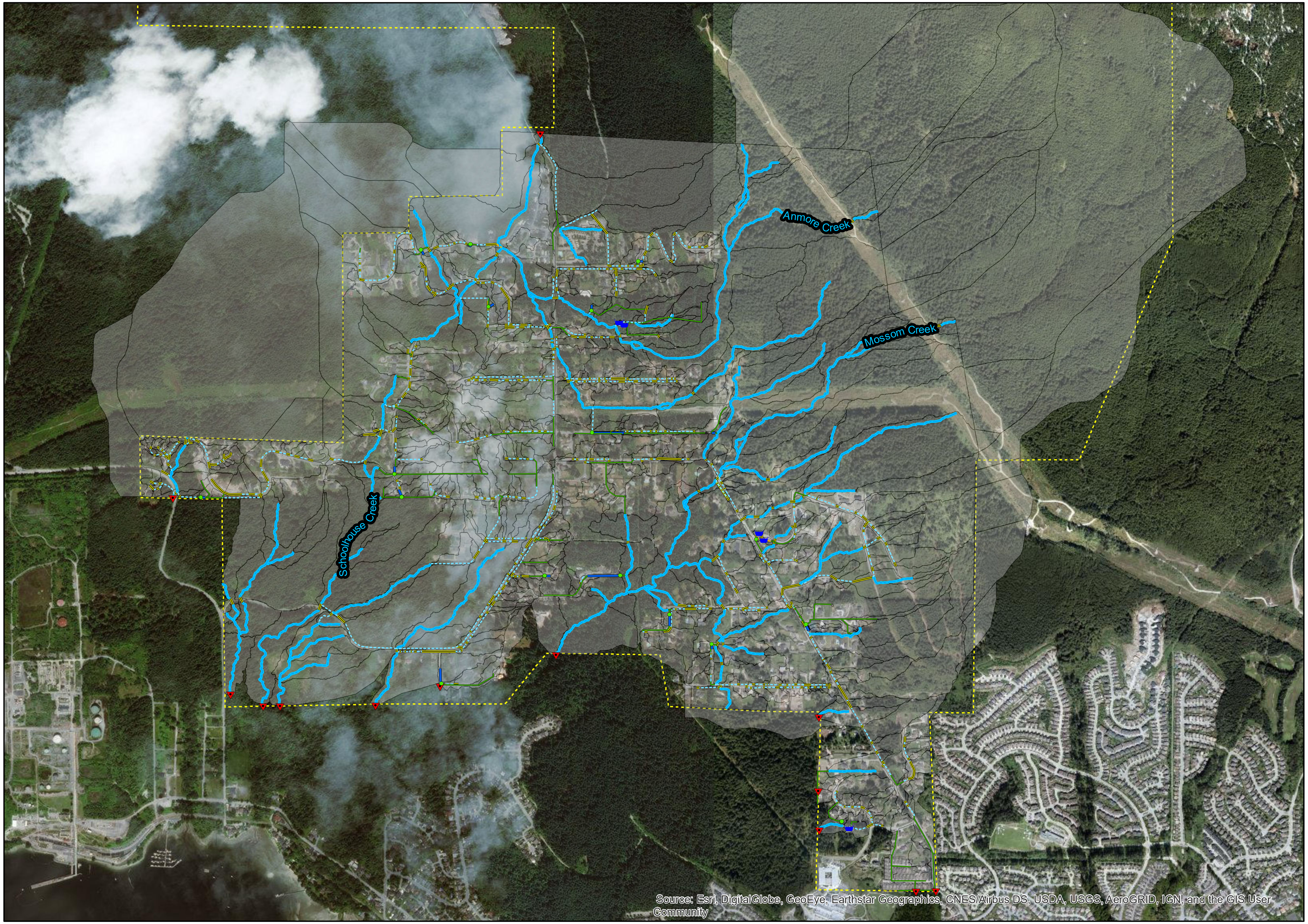
**Estimated return period based on the Metro Vancouver QT57 – Westwood Plateau IDF curves.*

It is important to note that the statistics presented in **Table 5.5** are based on the QT57 rain gauge located in Westwood Plateau. Although rain gauge QT57 is thought to be a good representation of the rainfall in Anmore, the actual rainfall that occurred over the Village of Anmore may vary.

5.3. Stormwater Model

5.3.1. Hydraulic Model Development

Figure 5.7 shows the modeled drainage system elements including storm sewers, culverts, creeks, detention ponds and subcatchments. As agreed with the Village, the drainage model consisted of all pipes, plus the open-channel ditch and creek systems. In addition, some of the larger detention facilities were included. To be conservative, the on-lot detention facilities were excluded from the Village model as these facilities typically fail due to a lack of maintenance. Finally, catch basins and swales were also not included in the model.



GeoAdvice Engineering Inc.

Legend

- Control Manhole
- Detention Pond
- Outfall
- Culvert
- Storm Main
- Creek
- Ditch
- Connectivity
- Detention
- Subcatchments
- Village of Anmore Boundary

Model Study Area

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

Figure 5.7

Storm Mains and Culverts

A review of the asbuilt record drawings was completed to develop an inventory of the underground storm mains. Information such as location, diameter, and invert elevations were extracted and used to develop the hydraulic model. The following set of asbuilt record drawings were reviewed:

- Alder Way
- Alpine Dr Sunset Ridge
- Anmore Creek Way
- Birch Wynde
- Blackberry Dr
- Burrard Thermal-Gas
- Canterwood Court
- Charlotte Crescent
- Chestnut Drive
- Countryside
- Crystal Creek
- Dogwood Dr
- Eaglecrest Dr
- East Rd
- Elementary Rd
- Fern Dr
- Hemlock Dr (West)
- Hummingbird
- Kinsey Dr (Pinnacle Ridge)
- Lancaster
- Magnolia Way
- Mountain Ayre
- Ravenswood Dr
- Seymour View
- Sparks Way
- Spence Way
- Strong Rd
- Sugar Mountain
- Summerwood
- Sunnyside
- Thompson Rd
- Uplands
- Wollny Court
- Wyndam Crescent

Culverts were defined in the model based on data collected during the culvert survey conducted by USL. In addition to the culverts surveyed by USL, additional culverts were identified during model development. The geometry of each additional culvert was field-verified by GeoAdvice, while the invert elevations were assumed based on an assumed depth below ground.

Manning's "n" roughness coefficients were assigned to the storm mains and culverts based on material according to **Table 5.6**.

Table 5.6: Storm Main and Culvert Roughness Coefficient

Material Type	Manning's Roughness Coefficient*
Concrete	0.013
PVC	0.013
CMP	0.024
Unknown	0.013

**Roughness coefficients based on information from the Village of Anmore Works and Services Bylaw Consolidated No. 242 1998.*

Modeled storm mains and culverts with an inlet or outlet were assigned an entrance loss coefficient of 0.5 and an exit loss coefficient of 1.0, respectively.

Ditches and Creeks

Ditches connecting driveway culverts were manually created in the model with assumed maximum side slopes of 1.5:1 (Horizontal:Vertical) and a minimum bottom width of 0.3 m, as defined in the Village design criteria. Note that some roadside ditches are known to be either larger or smaller than these assumed dimensions; however, field survey to establish the actual size of all roadside ditches was beyond the scope of this project.

The major creeks including the Anmore, Mossom, and Schoolhouse Creeks were defined based on LiDAR digital elevation data. Creek locations, transects and invert elevations were extracted from this digital data.

Manning's "n" roughness coefficients were assigned to open channels based on industry standards and as shown in **Table 5.7**.

Table 5.7: Open Channel Roughness Coefficient

Feature Type	Manning's Roughness Coefficient
Excavated Ditch	0.03
Natural Channels	0.05

Junctions and Control Structures

Junctions were added in the model to provide pipe-to-pipe and open channel-to-channel connectivity. Additionally, some of the junctions were used in the model to represent where runoff is loaded into the system or to allow stormwater to exit the system. Junctions also provide connectivity where transitions between different physical attributes such as size and slope occur.

The following GIS point layers were provided by the Village and used to define the junction features in the model:

- Manholes
- Control manholes
- Inlets
- Outlets

Rim elevations for junctions with missing ground elevation data were extracted from LiDAR data. For the junctions with missing invert elevations, an assumed depth below ground value was assigned to establish inverts.

Control manholes are utilized to provide hydraulic control in the storm main system. **Table 5.8** summarizes the modeled control manholes and the corresponding asbuilt drawings provided by the Village.

Table 5.8: Modeled Control Manholes

Control Manhole ID	Location	Asbuilt Drawing No.
J0214	2160 Summerwood Ln	02.104-10
J0285	1130-1150 Mountain Ayre Lane	96.47(PH.2)-3
J0352	Uplands Drive & Anmore Creek Way	07.79-5
J0767	768 Sunset Ridge	N/A
J1162	206 Kinsey Drive	4569-DP-02
J1166	1770 Lancaster Court	96.47(PH.3)-10
J1182	98-2 Leggett Drive	09.57-23
J1193	2665 Fern Drive	02.65(PH.2)-18
J1199	2664 Fern Drive	Assumed
J1209	39 Birch Wynde	03.28-6 (Storm MH 3)
J1212	1 Alder Way	03.28-6 (Storm MH 1)
J1251	1078-1080 Uplands Drive	2111-02136-0 no. 29/36
J1255	1040 Heron Way	2111-02136-0 no. 30/30
J1261	1780 East Road	06.40-14
J1294	1462 Crystal Creek Drive	133758 no. 07
J1299	149 Dogwood Drive	01.20-16
J1332	Eaglecrest Road New Development	2015-08 p.11

Detention Facilities

Drainage within the study area is managed in part by detention facilities. These facilities serve a key role in creek flow and flood management.

The storage geometry and volume for each of the modeled detention facilities were either extracted from asbuilt drawings or estimated using the LiDAR data. Inlet and outlet controls of each detention facility were defined using weirs and/or orifices based on information from asbuilt drawings. **Table 5.9** summarizes the detention facilities included in the model.

Table 5.9: Modeled Detention Facilities

Storage ID	Type	Location	Asbuilt Drawing No.
SU01	Detention Pond	206 Kinsey Drive Detention Pond 1	4569-PP-08 4569-DP-01 4569-DP-02
SU02	Detention Pond	206 Kinsey Drive Detention Pond 2	4569-PP-08 4569-DP-01 4569-DP-02
SU03	Detention Pond	110 Dogwood Drive Detention Pond	01.20-16
SU04	Detention Pond	Eaglecrest Dr & Chestnut Ct Detention Pond 1	2015-08 p.10-11
SU05	Detention Pond	Eaglecrest Dr & Chestnut Ct Detention Pond 2	2015-08 p.10-11
D0207	Storage Pipe	2664 Fern Drive	Assumed
D0208	Storage Pipe	2676 Fern Drive	02.65(PH.2)-13
D0523	Storage Pipe	1770 Lancaster Court	96.47(PH.3)-7
D0532 D0533 D0534 D0536	Storage Pipe	10 Leggett Drive	09.57-13
D0556	Storage Pipe	39 Birch Wynde	03.28-4
D0559	Storage Pipe	8 Alder Way	03.28-3
D0565	Storage Pipe	768 Sunset Ridge	2011-01712-1 p.1
D0576	Storage Pipe	Mountain Ayre Lane	96.47(PH.2)-3
D0578	Storage Pipe	2160 Summerwood Lane	02.104-10
D0587 D0588	Storage Pipe	Heron Way & Uplands Drive	2111-02136-0 p.29 2111-02136-0 p.29
D0592	Storage Pipe	1046 Heron Way	2111-02136-0 p.30
D0619	Storage Pipe	Between Bedwell Bay Road & Crystal Creek Drive	133758 no. 07

Storage ID	Type	Location	Asbuilt Drawing No.
D0691	Storage Pipe	Uplands Drive & Anmore Creek Way	07.79-5
D0646	Storage Pipe	Eaglecrest Road New Development	2015-08 p.11
D0702			2015-08 p.11
D0707	Storage Pipe	Wollny Court & East Road	06.40-9
D0708			
D0709			
D0710			

5.3.2. Hydrologic Model Development

Subcatchment Delineation

Subcatchments are hydrologic units of land whose topography and drainage system elements combine to direct surface runoff and groundwater interflow into the network system. Model subcatchments were delineated based on surface topography and location of conveyance features. The result is over 1,100 subcatchments, each consisting of smaller subcatchments in developed areas and larger subcatchments located in the natural undeveloped areas. The calibrated subcatchment parameters are summarized below.

Subcatchment Width and Length
Width and length subcatchment properties characterize the overland flow path and the time of concentration for sheet flow runoff to the loading point.

Subcatchment widths for small subcatchments (less than or equal to 0.2 ha) were estimated based on the assumption that the flow length is 50 m, representing the typical distance between the furthest point of the parcel to the fronting storm sewer. The subcatchment width formula is:

$$width = \frac{Area}{length} = \frac{Area}{50\ m}$$

Subcatchment widths for larger subcatchments (greater than 0.2 ha) were estimated based on the presumption that both catchment shape and local flow barriers increase the overland flow length. The subcatchment width formula is:

$$width = \frac{Area}{length};\ length = 1.7\ \times\ \sqrt{Area}$$

A factor of 1.7 was used to define the subcatchment width as shown in the above formula. This factor was used based on engineering judgement from similar models.

Subcatchment Slope
Subcatchment slopes were estimated based on calculating the average slope over the catchment using LiDAR data and then dividing by 2. The division by 2 provides for a longer simulated time of concentration due to meandering channels and piped networks that are not parallel with the direction of the average slope.

Subcatchment Hydrologic Parameters

Table 5.10 summarizes the hydrologic parameters that were uniformly applied to all the subcatchments. These values were selected based on industry publications and engineering judgement.

Table 5.10: Subcatchment Hydrologic Modeling Parameters

Hydrologic Parameter	Value
Depression Storage *Pervious Area (mm)* *Impervious Area (mm)*	 5.0 0.5
Manning's "n" Roughness Coefficient *Pervious Area "n"* *Impervious Area "n"*	 0.40 (undeveloped) 0.20 (developed) 0.05

Source: Parameter values based on consideration of ASCE (1992)[2] *and McCuen, R. et al. (1996)*[3].

Subcatchment Impervious Percentage

The impervious percentage and the portion assumed to be routed to pervious area for each subcatchment, as defined in **Table 5.11**, were estimated based on existing land use coverage as defined in **Section 3**.

Table 5.11: Village of Anmore Subcatchment Imperviousness per Landuse

Zone	Description	Total Imperviousness (%)	Runoff Routed to Pervious Area (%)
RS-1	Residential 1	50	25
RCH-1	Compact Housing 1	70	25
RCH-2	Compact Housing 2	70	25
CD	Comprehensive Development	70	25
C-1	Local Commercial	80	25
C-2	Campground Commercial	60	25
C-3	Equestrian Commercial	60	25
P-1	Civic Institutional	50	25
P-2	Park	20	100
W-1	Watershed	10	100
I-1	Industrial	80	25
Road	Road	70	25

[2] *ASCE (1992). Design & Construction of Urban Stormwater Management Systems, New York, NY*
[3] *McCuen, R. et al. (1996). Hydrology, FHWA-SA-96-067, Federal Highway Administration, Washington, DC*

It was assumed that 25% of runoff from developed areas is routed to pervious surfaces, and 100% of runoff from natural areas (P-2 and W-1) is routed to pervious surfaces.

Base Flow

The 2018 flow monitoring data showed that Sites 2 and 3 experienced the greatest base flows. Indeed, Sites 2 and 3 captured upstream catchments that consist of primarily flatter terrain (less than 20% slope) which has a greater potential for groundwater discharge into the drainage system. Based on recorded flow data and using Site 2 as a proxy for the other areas, a baseflow of 1 L/s/ha was applied to catchments with flatter terrain. No base flow was applied for catchments with slopes greater than 20%.

Soil and Catchment Infiltration

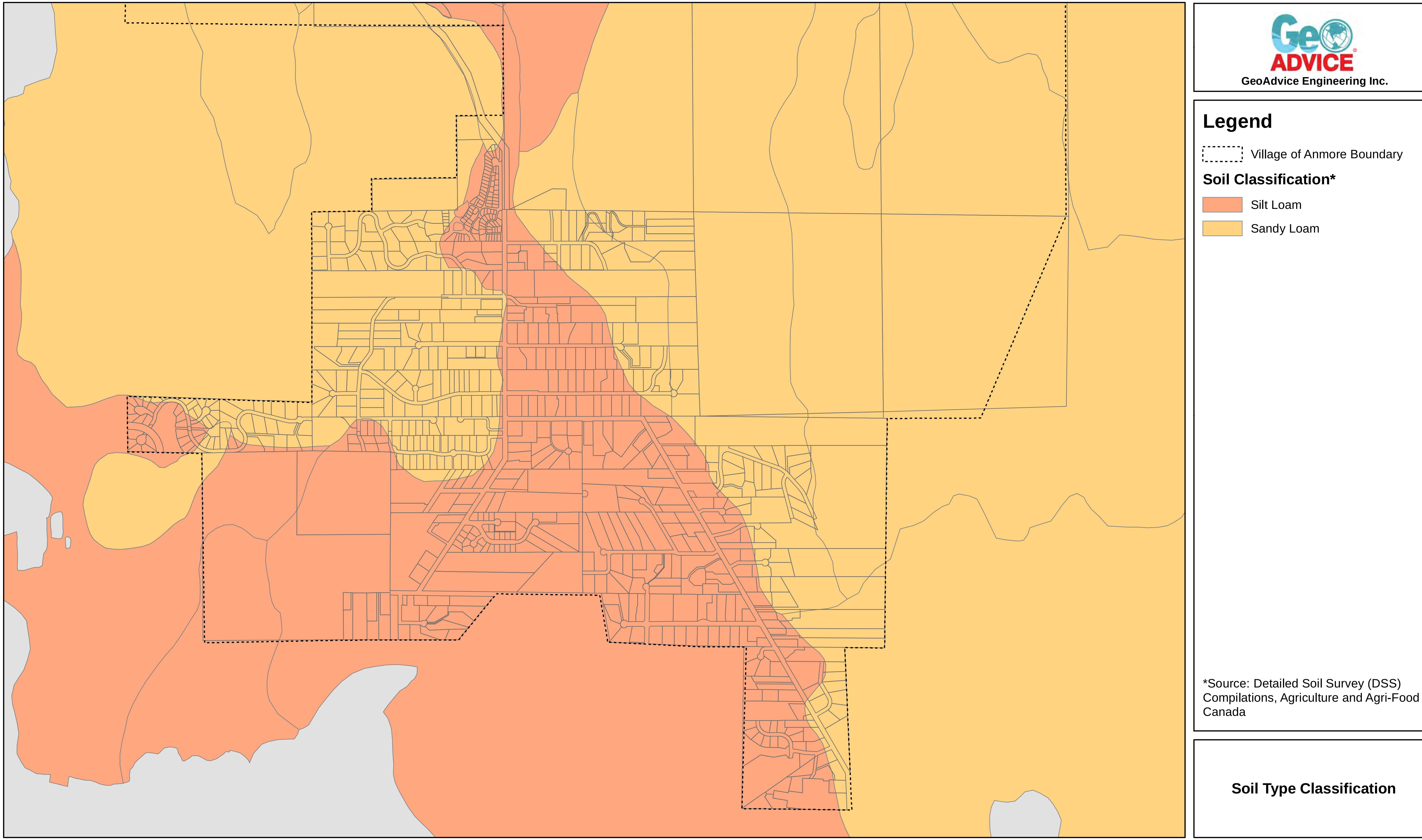
Soil information was extracted from the Detailed Soil Survey (DSS) Compilation GIS layer available through Agriculture and Agri-Food Canada. The infiltration rates assumed for each soil type were extracted from the EPA-SWMM Manual 5.1 (Rawls W. J. et al., (1983). J. Hyd. Engr.). The modified Horton infiltration process was used to characterize soil infiltration characteristics in the model. The Horton infiltration parameters are summarized in **Table 5.12**.

Table 5.12: Horton Infiltration Parameters

Soil Group	Minimum Infiltration Rate (mm/hr)	Maximum Infiltration Rate (mm/hr)	Decay Constant	Drying Time (days)
Sandy Loam	10.9	54.5	4.14	5
Silt Loam	6.6	33.0	4.14	5

Decay Constant: Decay constant for the Horton infiltration curve (mm/hr).
Drying Time: Time for a fully saturated soil to completely dry (days).

Figure 5.8 shows the distribution of soil groups within the watershed.



Soil Type Classification

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

Figure 5.8

Groundwater

The 2018 flow monitoring data show that groundwater interflow is present in the system. The groundwater flow was modeled using the following equation:

$$Groundwater\ flow = A_1(D_1 - BC)^{B_1},$$

Where:

- A_1 is the groundwater flow coefficient
- B_1 is the groundwater flow exponent
- BC is the channel bottom elevation above bottom of surficial aquifer
- D_1 is the average water table elevation above bottom of surficial aquifer taken midway between channel and edge of sub-basin

The 2018 data also showed that groundwater flow from catchments with steeper terrain was different than catchments with flatter terrain. As such, calibration of groundwater parameters for subcatchments with slopes greater or equal to 20% differed from subcatchments with slopes less than 20%, as shown in **Table 5.13**.

Table 5.13: Groundwater Parameters Calibrated Values

Parameter	Flatter Terrain (Slope < 20%)	Steeper Terrain (Slope >= 20%)
A_1	0.2	0.05
B_1	2	2

The groundwater module in the SWMM engine requires that a surficial aquifer be defined. The aquifer parameters used in the Village model are presented in **Table 5.14**.

Table 5.14: Aquifer Parameters

Aquifer Parameter (Unit)	Calibrated Value
Porosity (Fraction)	0.5
Wilting Point (Fraction)	0.15
Field Capacity (Fraction)	0.28
Conductivity (mm/hr)	20
Conductivity Slope	10
Tension Slope	15
Upper Evaporation Fraction	0.35
Lower Evaporation Depth (m)	14
Lower GW Loss Rate (mm/hr)	0.002
Bottom Elevation (m)	0
Water Table Elevation (m)	10
Unsaturated Zone Moisture (Fraction)	0.28

5.3.3. Model Calibration

Rather than simulating individual storm events for model calibration, a continuous simulation from January 2 to March 7, 2018 was run. Continuous simulation allows the model to simulate the impacts of antecedent moisture conditions on catchment flows between back-to-back storm events. The model parameters were adjusted in an iterative manner until model results achieved an acceptable correlation with the measured flow data for the storm events identified. The calibrated model parameters were presented in **Section 5.3.2**.

Figure 5.9 to **Figure 5.12** show the calibration flow hydrographs comparing the modeled and measured flows at each flow monitoring site.

Figure 5.9: Anmore Calibration Hydrograph – Site 1

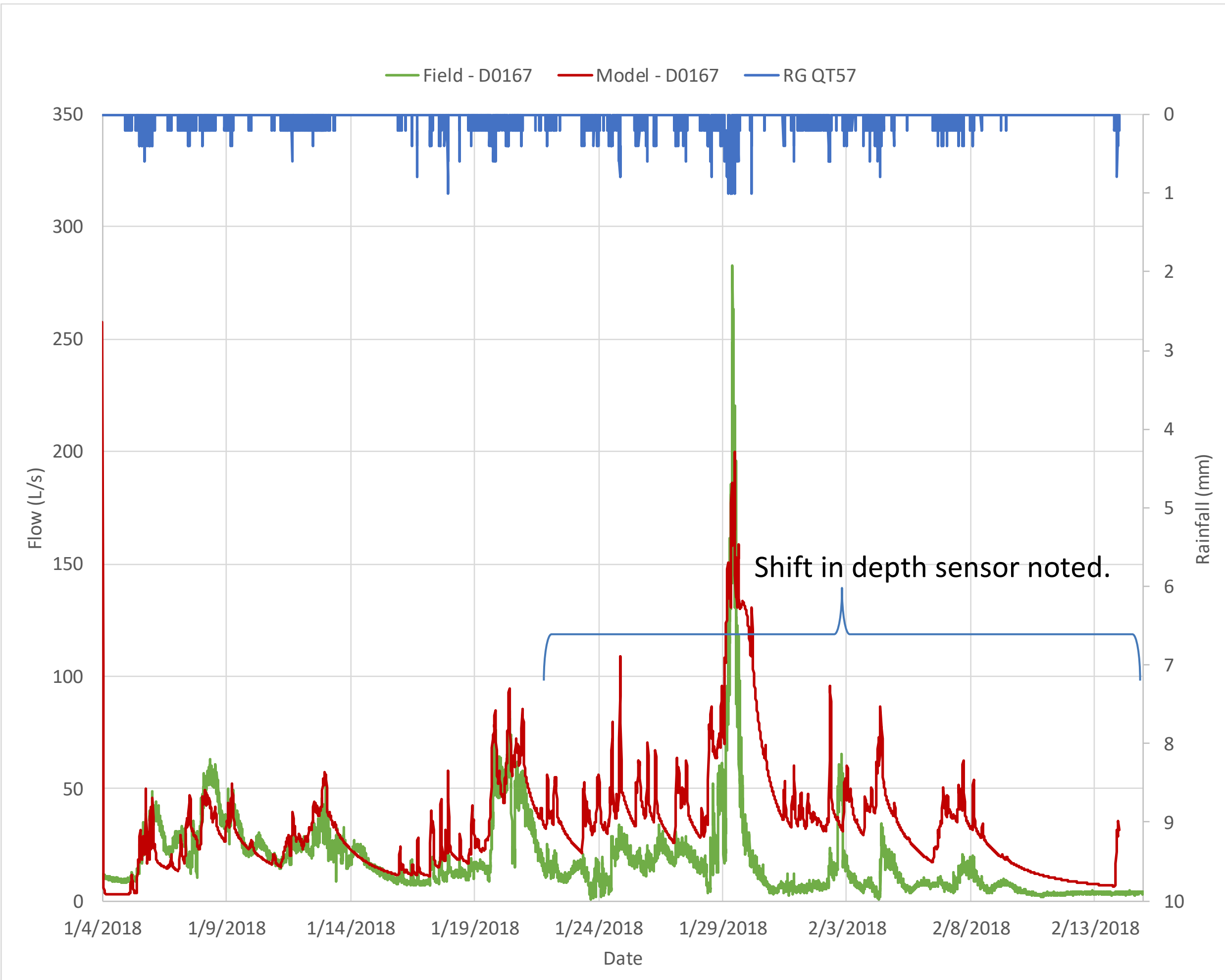


Figure 5.10: Anmore Calibration Hydrograph – Site 2

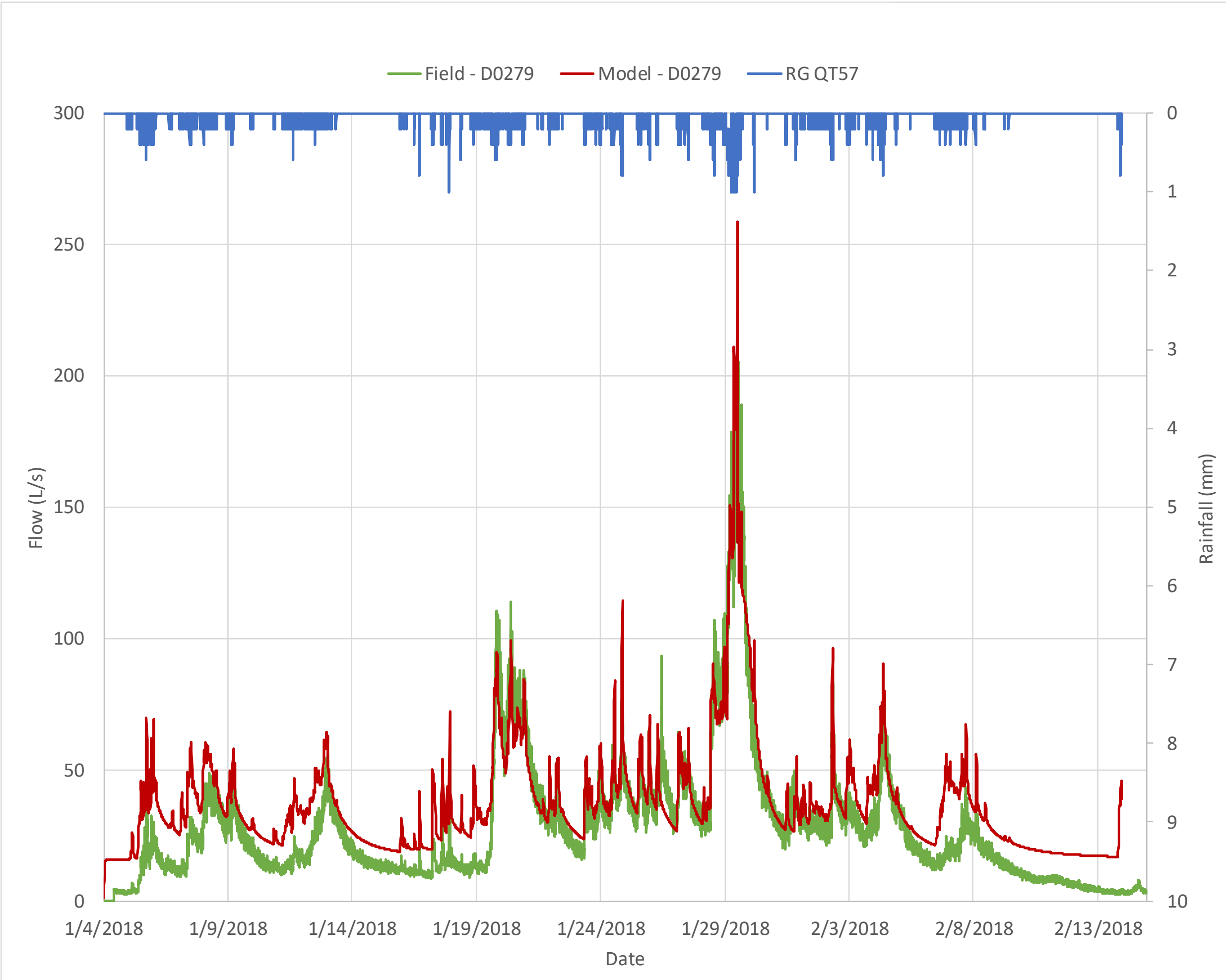


Figure 5.11: Anmore Calibration Hydrograph – Site 3

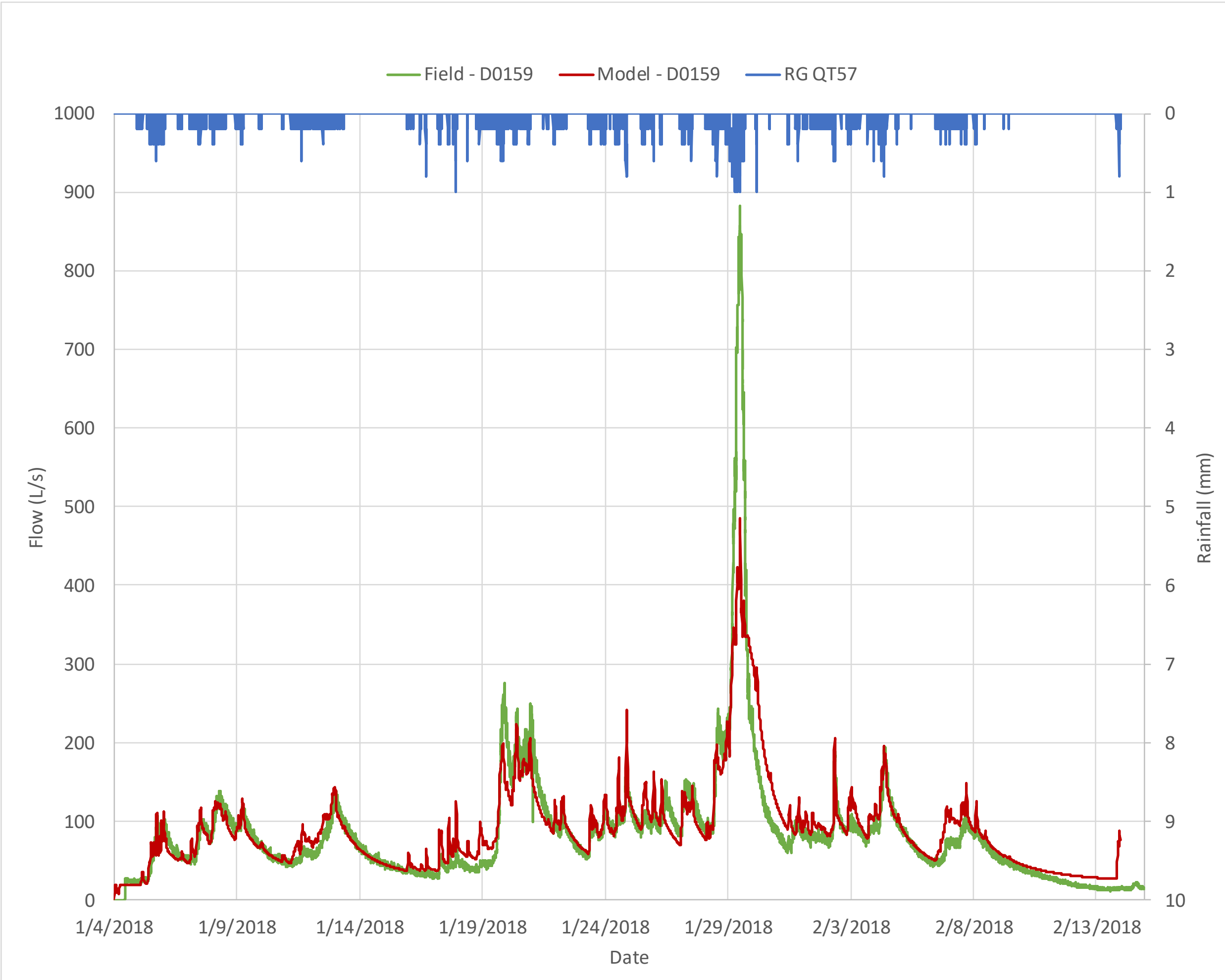
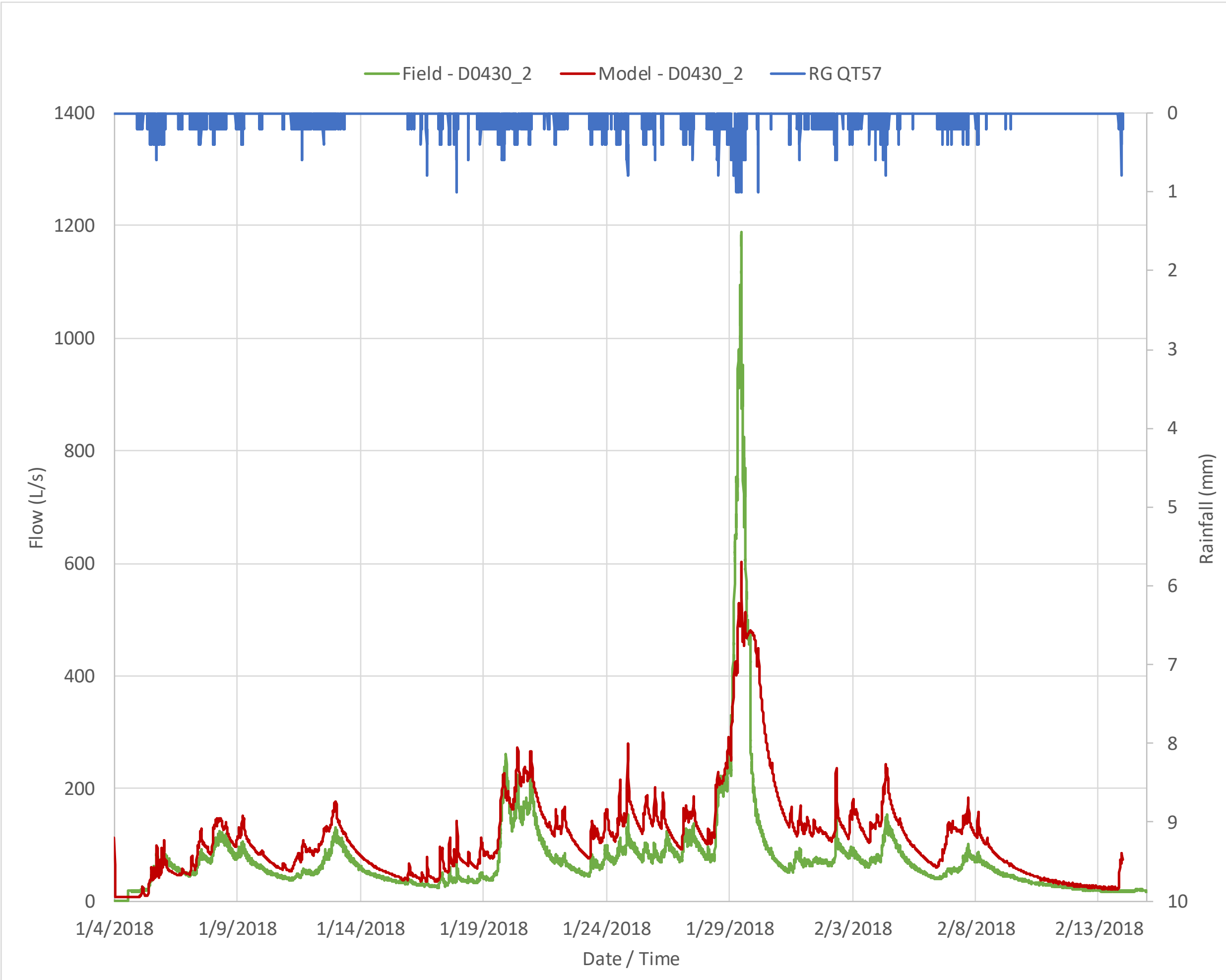


Figure 5.12: Anmore Calibration Hydrograph – Site 4



Overall, the model shows an acceptable agreement with the measured flows at the four flow stations. Event 5 (January 28, 2018), the largest event captured, shows larger flow and volume discrepancies at Sites 1, 3 and 4, which may be caused by precipitation inaccuracies as described below:

- Rain gauge QT57 located in Westwood Plateau is approximately 3 km away from the Anmore Village Centre.
- There is a certain degree of uncertainty when rainfall data recorded at a fixed location are applied to large or distant areas. Microclimates often exist within large areas and often cause variations in localized precipitation volume and intensity that cannot be reflected in the model.
- Additionally, the storm events used for model calibration consisted of less than 2-year return periods. For best calibration results, it is recommended that the model be validated against larger storm events when data becomes available.

The parameters derived during calibration were applied to the remainder of the unmonitored study area. Final catchment characteristics and calibrated parameters are summarized in **Table 5.15**.

Table 5.15: Catchment Characteristics and Calibrated Parameters

Site Number	1	2	3	4
Area (ha)	23	16	52	94
Average Flow Length (m)	276	231	404	331
Average Width (m)	96	81	140	115
Average Slope (%)	11	7	12	13
Average TIMP (%)	34	44	29	27
Average Routed to Perv. (%)	73	65	79	86
Average Max Infil. (mm/hr)	55	33	47	51
Average Min Infil. (mm/hr)	11	7	9	10
Flatter Terrain Slopes (%)	13%	100%	37%	9%
Steeper Terrain Slopes (%)	87%	0%	63%	91%
Land Use Distribution				
Residential 1	49%	53%	35%	23%
Comprehensive Development 6	0%	0%	3%	0%
Park	19%	31%	8%	44%
Watershed	27%	0%	50%	28%
Road	5%	16%	4%	5%

6. Assessment of Existing and Future Drainage Systems

6.1. Future Drainage System

To assess the impact on areas that are anticipated to undergo land use changes, the future OCP land use information as shown in **Figure 3.2** and the estimated hydrology parameters presented in **Section 5** were used to create the future modeling scenario. The primary difference between the existing and future scenario is the increased runoff resulting from the following:

- Increase in impervious areas;
- Increase in directly connected impervious areas; *and*
- Decrease in surface roughness of pervious areas.

When conducting the capacity analysis, future flow management controls were not considered as agreed with the Village. This approach is conservative and represents a worst-case scenario.

6.2. Capacity Assessment

Design storms were simulated to assess the hydraulic capacity of the existing conveyance system of culverts and storm mains under existing and future OCP land use conditions. The assessment was completed by simulating the design storms summarized in **Section 4.3** and applying the design criteria summarized in **Section 4.2**. Each asset was assessed using a capacity Likelihood of Failure (LoF) rating system as described below.

Capacity LoF was determined using the hydraulic capacity (q/Q) and hydraulic grade line (HGL) model results under peak conditions. **Table 6.1** and **Table 6.2** summarize the criteria used to define the capacity LoF rating for the culverts and storm mains.

Table 6.1: Hydraulic and HGL Scoring Criteria

Criteria	Result
Hydraulic Capacity (q/Q = peak flow / full pipe flow)	
q/Q < 1	A
q/Q >= 1	B
Hydraulic Grade Line (HGL)	
HGL < Crown Elevation OR Surcharge Duration <= 15 min	A
Crown Elevation <= HGL < Ground Elevation AND Surcharge Duration > 15 min	B
HGL >= Ground Elevation	C

Table 6.2: Capacity LoF Ratings

Capacity LoF	Hydraulic	HGL	Description
1	A	A	Conduit performing as designed
2	A	B or C	Adequate capacity, downstream condition causing backwater
3	B	A	Marginal capacity
4	**B**	**B**	**Capacity exceeded and surcharging likely**
5	**B**	**C**	**Capacity exceeded and flooding likely**

Table 6.3 and **Table 6.4** summarize the capacity LoF rating results.

Table 6.3: Existing Land Use Capacity LoF Rating Results

Capacity LoF	Number of Storm Mains*	Number of Minor System Culverts	Number of Major System Culverts
1	221	398	44
2	27	1	1
3	5	13	1
4	**6**	**0**	**0**
5	**4**	**11**	**7**

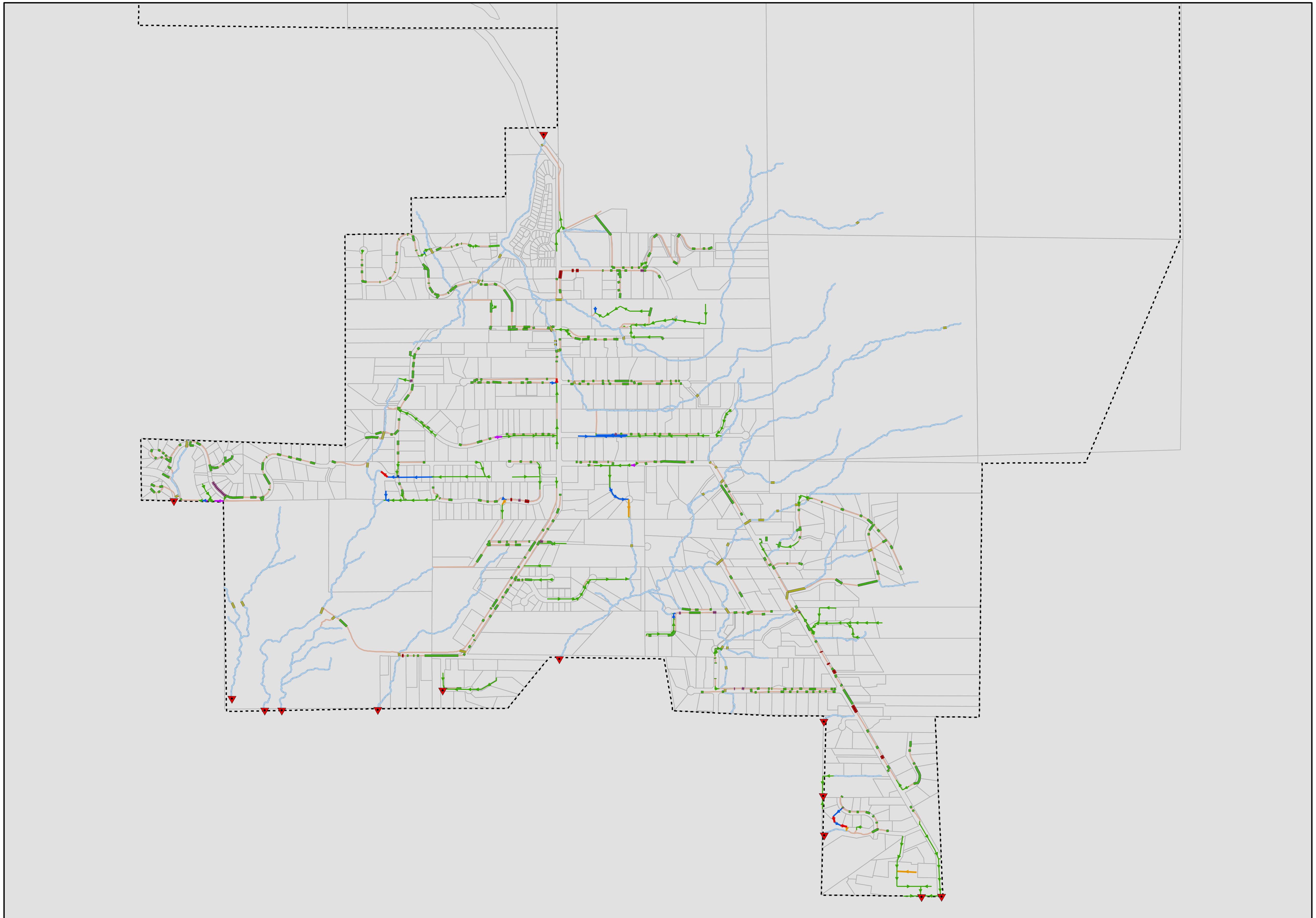
**Includes 23 detention pipes.*

Table 6.4: Future Land Use Capacity LoF Rating Results

Capacity LoF	Number of Storm Mains*	Number of Minor System Culverts	Number of Major System Culverts
1	210	394	44
2	34	1	1
3	8	14	1
4	**7**	**0**	**0**
5	**4**	**14**	**7**

**Includes 23 detention pipes.*

Figure 6.1 to **Figure 6.4** show the capacity LoF rating results for the existing and future land use scenarios.



GeoAdvice Engineering Inc.

Legend

- Village of Anmore Boundary
- Outfall
- Creek
- Major System Culvert
- Ditch

Minor System Culvert Capacity LoF Rating

1 *Culvert performing as designed*

2 *Adequate capacity, downstream condition causing backwater*

3 *Marginal capacity*

4 *Capacity exceeded and surcharging likely*

5 *Capacity exceeded and flooding likely*

Storm Main Capacity LoF Rating

1 *Conduit performing as designed*

2 *Adeqate capacity, downstream condition causing backwater*

3 *Marginal capacity*

4 *Capacity exceeded and surcharging likely*

5 *Capacity exceeded and flooding likely*

Existing Landuse
5yr Design Storm
Capacity Likelihood
of Failure Results
Minor System

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

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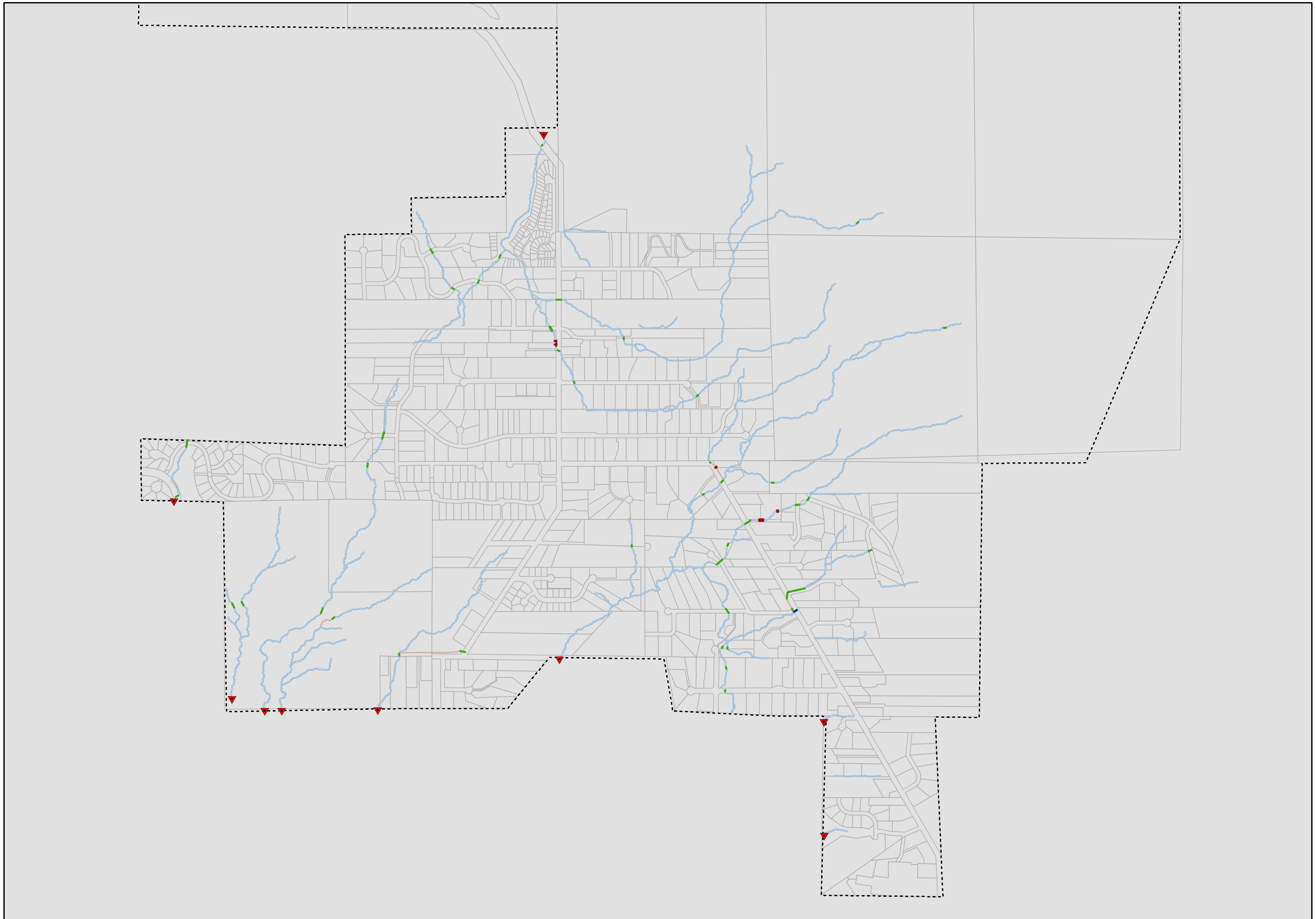
0 0.25 0.5 1
Kilometers

N W E S

Figure 6.1



GeoAdvice Engineering Inc.

Legend

Village of Anmore Boundary

Outfall

Creek

Ditch

Major System Culvert Capacity LoF Rating

1 *Culvert performing as designed*

2 *Adequate capacity, downstream condition causing backwater*

3 *Marginal capacity*

4 *Capacity exceeded and surcharging likely*

5 *Capacity exceeded and flooding likely*

Existing Landuse
100yr Design Storm
Capacity Likelihood of Failure Results
Major System

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

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Kilometers

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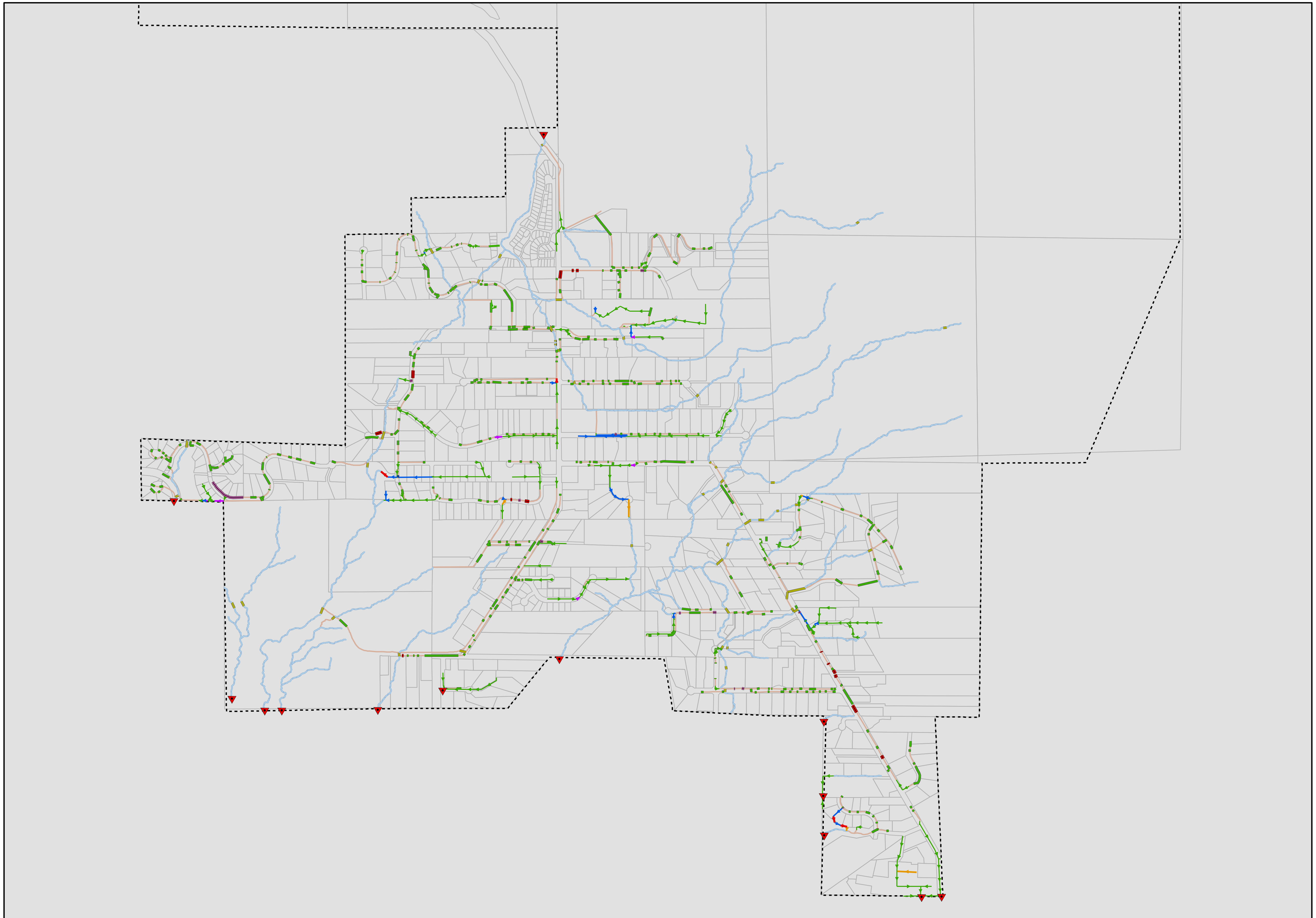
Figure 6.2



GeoAdvice Engineering Inc.

Legend

Village of Anmore Boundary
Outfall
Creek
Major System Culvert
Ditch

Minor System Culvert Capacity LoF Rating

1 *Culvert performing as designed*
2 *Adequate capacity, downstream condition causing backwater*
3 *Marginal capacity*
4 *Capacity exceeded and surcharging likely*
5 *Capacity exceeded and flooding likely*

Storm Main Capacity LoF Rating

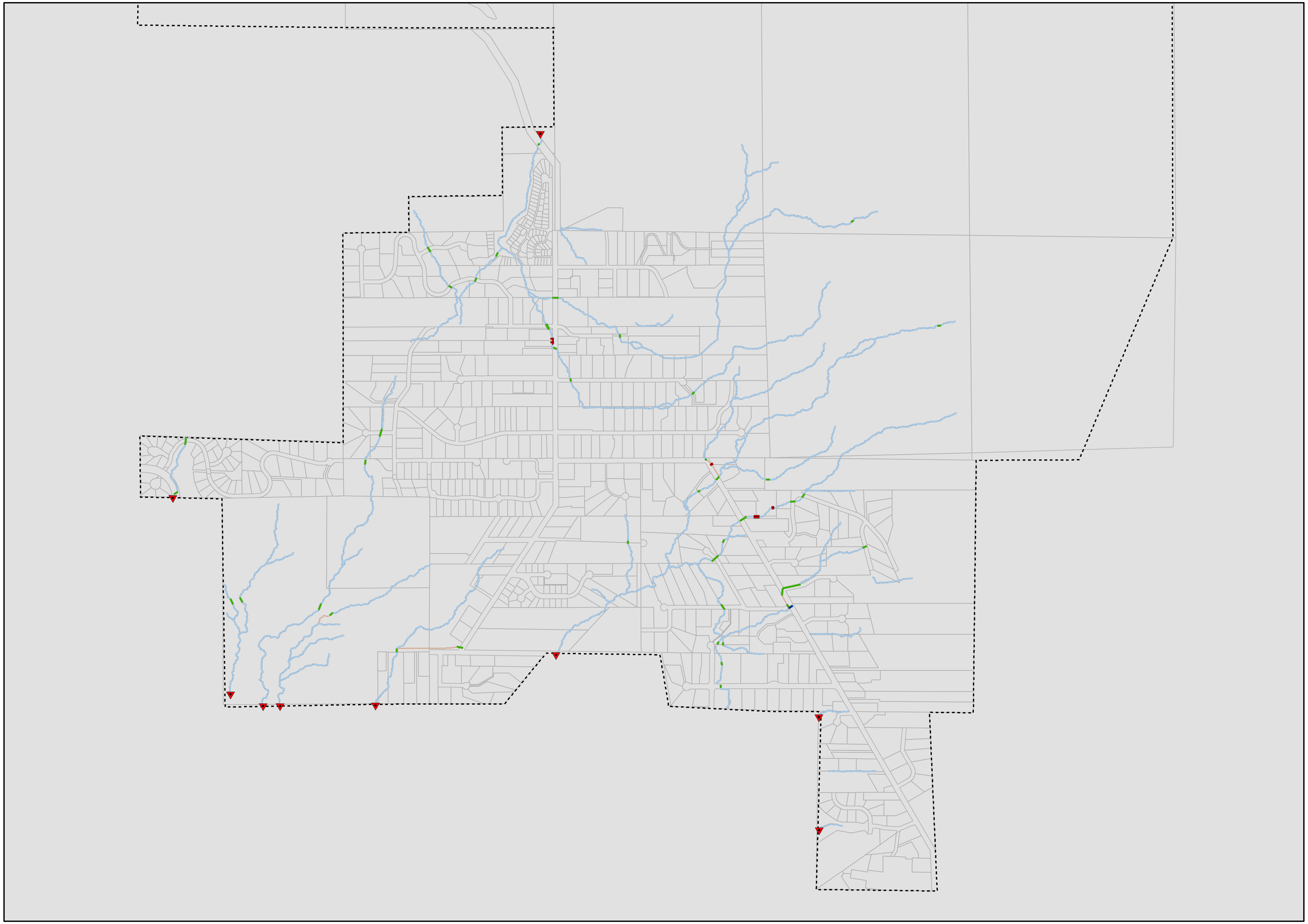
1 *Conduit performing as designed*
2 *Adeqate capacity, downstream condition causing backwater*
3 *Marginal capacity*
4 *Capacity exceeded and surcharging likely*
5 *Capacity exceeded and flooding likely*

Future Landuse 5yr Design Storm Capacity Likelihood of Failure Results Minor System

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

Figure 6.3



GeoAdvice Engineering Inc.

Legend

Village of Anmore Boundary

Outfall

Creek

Ditch

Major System Culvert Capacity LoF Rating

1 *Culvert performing as designed*

2 *Adequate capacity, downstream condition causing backwater*

3 *Marginal capacity*

4 *Capacity exceeded and surcharging likely*

5 *Capacity exceeded and flooding likely*

Future Landuse
100yr Design Storm
Capacity Likelihood of Failure Results
Major System

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

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Kilometers

N W E S

Figure 6.4

6.3. Risk Assessment

To assess the risk associated with each culvert and storm main should the asset fail, condition and capacity LoF ratings were analyzed together with its corresponding consequence of failure to develop an overall risk score. The methodology to determine an asset's consequence of failure rating is described below.

Consequence of Failure

The consequence of failure was defined in this study as a function of the road classification as agreed with the Village. For example, the consequence of failure of a culvert or storm main located in a park will impact fewer people and cost less to repair damages than a culvert located under a heavily traveled roadway such as East Rd or Sunnyside Rd. **Table 6.5** defines the consequence of failure based on road classification.

Table 6.5: Village of Anmore Consequence of Failure Ratings

Consequence of Failure	Road Classification
1	No Road
2	Local Road
3	**Arterial Road (i.e. East Rd/Sunnyside Rd)**

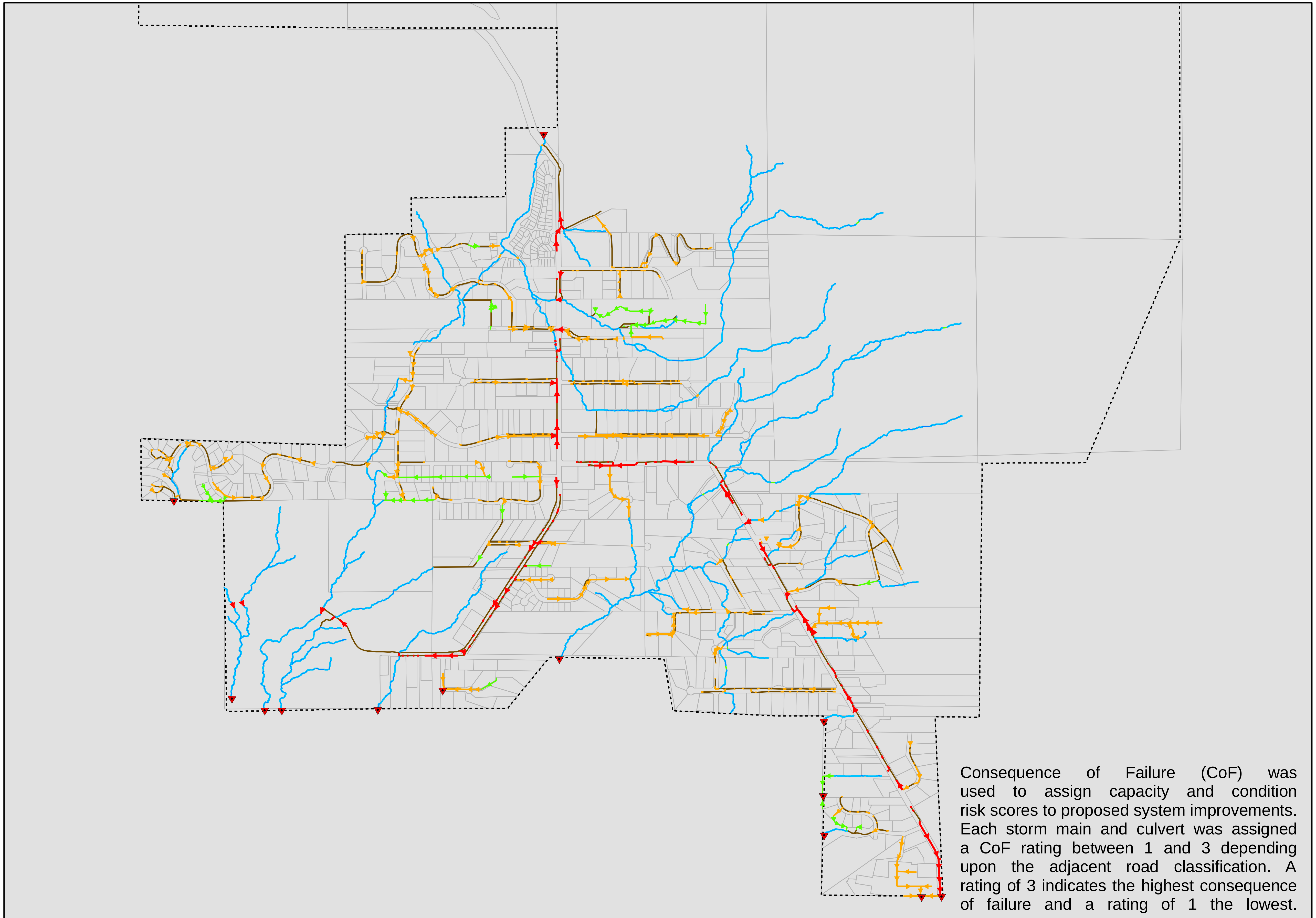
A consequence of failure rating of '1' represents the least impact, while a consequence of failure rating of '3' represents the greatest impact. **Table 6.6** summarizes the consequence of failure ratings statistics.

Table 6.6: Village of Anmore Consequence of Failure Rating Results

Consequence of Failure	Number of Storm Mains*	Number of Culverts
1	68	14
2	152	356
3	**43**	**106**

**Includes 23 detention pipes.*

Figure 6.5 shows the consequence of failure ratings for the storm mains and culverts.



Consequence of Failure (CoF) was used to assign capacity and condition risk scores to proposed system improvements. Each storm main and culvert was assigned a CoF rating between 1 and 3 depending upon the adjacent road classification. A rating of 3 indicates the highest consequence of failure and a rating of 1 the lowest.

GeoAdvice Engineering Inc.

Legend

- Village of Anmore Boundary
- Outfall
- Creek
- Ditch

Consequence of Failure

- 1 *No Road*
- 2 *Local Road*
- 3 *Arterial Road (East Rd/Sunnyside Rd)*

Culvert and Storm Main Consequence of Failure Rating

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: WdS

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0 0.25 0.5 1
Kilometers

N
W E
S

Figure 6.5

Risk Score

Matrices of the relationship between an asset's condition and capacity LoF ratings and its consequence of failure ratings are shown in **Figure 6.6**. The matrices were used to assign condition and capacity risk scores to each asset. A risk score of '1' represents the lowest risk while a risk score of '3' represents the highest risk.

Figure 6.6: Condition and Capacity Risk Score Matrices

Condition Risk Score Matrix

Consequence of Failure					
3	1	1	2	3	3
2	1	1	1	2	3
1	1	1	1	1	2
	1	2	3	4	5

Likelihood of Failure

Capacity Risk Score Matrix

Consequence of Failure					
3	1	1	2	3	3
2	1	1	1	2	3
1	1	1	1	1	2
	1	2	3	4	5

Likelihood of Failure

Table 6.7 below summarizes the condition and capacity risk score results.

Table 6.7: Condition and Capacity Risk Results

	Condition***		Existing Land use - Capacity			Future Land use - Capacity		
Risk Score	Storm Main*	Culvert **	Storm Main*	Minor System Culvert	Major System Culvert	Storm Main*	Minor System Culvert	Major System Culvert
1	42	389	253	410	45	251	407	45
2	220	75	9	2	1	11	2	1
3	**1**	**12**	**1**	**11**	**7**	**1**	**14**	**7**

**Includes 23 detention pipes.*

***Includes minor and major systems culverts.*

****Culverts and storm mains with unknown condition were assumed a condition risk score of 2 (Refer to **Appendix A**).*

Prioritization

A benefit of developing risk scores for the Village's drainage assets is that it provides a decision-making process for near-term and long-term capital planning. Priority ratings were assigned to each asset based on the asset's condition and capacity risk scores. The overall priority rating, as presented in **Table 6.8**, combines the condition, capacity and consequence failure risk assessments into a single 1 to 5 priority rating. A rating of '1' represents the highest priority and a rating of '5' represents the lowest priority.

Table 6.8: Overall Level of Priority Rating System

Priority	Risk Score			Total Risk Score
	Condition	Existing Capacity	Future Capacity	
1 (highest priority)	**3**	**3**	**3**	**Total risk score = 9**
2	3	2	3	Total risk score = 8
	2	3	3	
3	3	2	2	Total risk score = 7
	3	1	3	
	2	2	3	
	1	3	3	
4	3	1	2	Total risk score = 6
	2	1	3	
	1	2	3	
5 (lowest priority)	3	1	1	Total risk score = 5
	1	1	3	

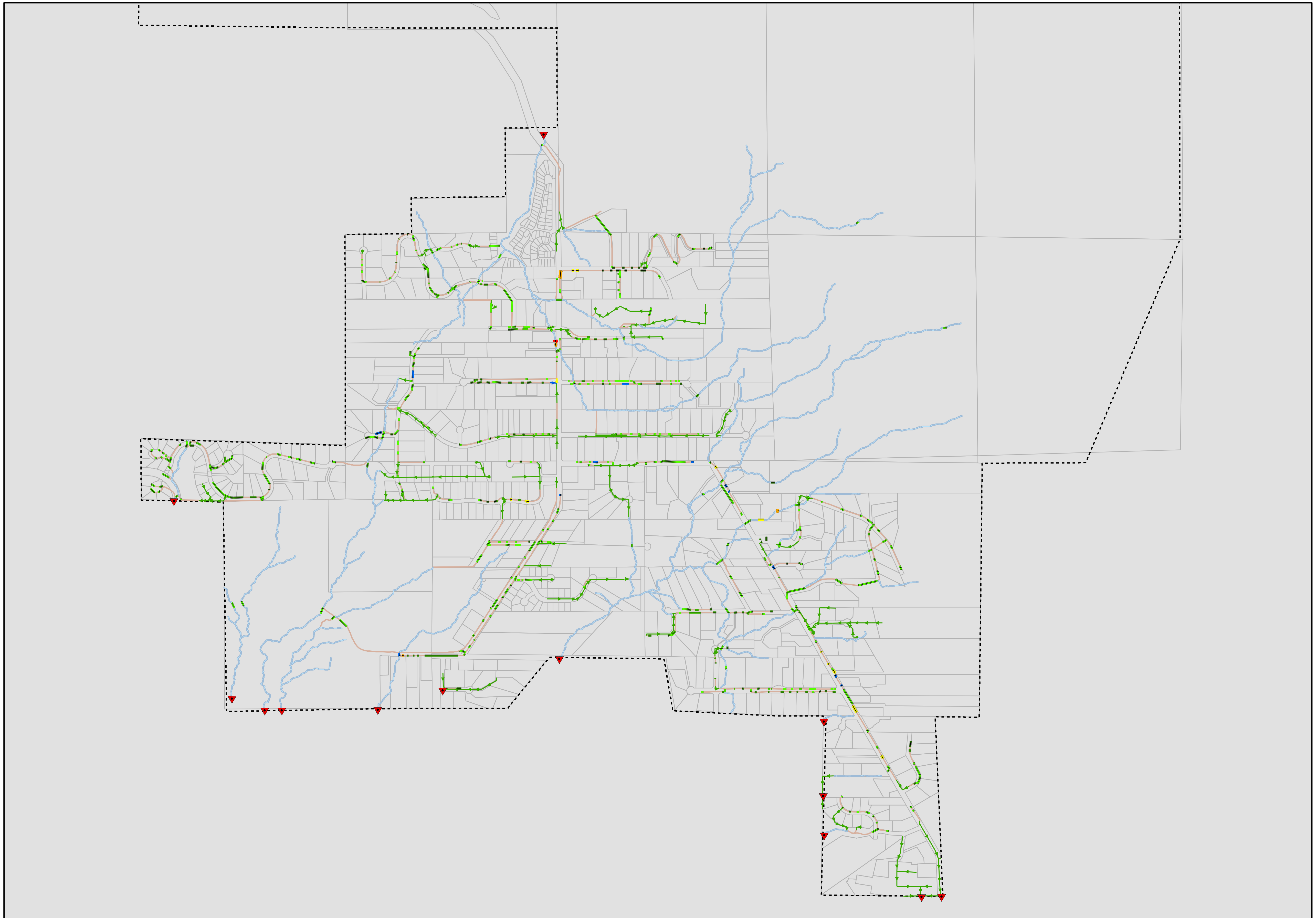
Assumptions:
- *Only culverts or storm mains with at least one risk score equal to 3 were considered for upgrade.*
- *Culverts and storm mains with unknown condition LOF rating were assumed a condition risk score of 2.*

Only culverts and storm mains with a condition or capacity risk score of '3' were considered critical and were considered for improvement. **Table 6.9** summarizes the priority rating results.

Table 6.9: Culverts and Storm Mains Priority Rating Results

Priority	Number of Storm Mains	Number of Minor System Culverts	Number of Major System Culverts
1	**0**	**0**	**2**
2	0	2	3
3	1	9	2
4	0	0	0
5	1	12	1

Figure 6.7 shows the location of culverts or storm mains with priority ratings of 1 to 5.



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Legend

- Outfall
- Culvert
- Storm Main
- Creek
- Ditch
- Village of Anmore Boundary

Culvert Upgrade Priority Rating

1 *Highest Priority*
2 *High Priority*
3 *Medium Priority*
4 *Low Priority*
5 *Lowest Priority*

Storm Main Upgrade Priority Rating

1 *Highest Priority*
2 *High Priority*
3 *Medium Priority*
4 *Low Priority*
5 *Lowest Priority*

Culverts and Storm Mains Upgrade Priority Rating

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: April 2018
Created by: RD
Reviewed by: DRAFT

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0 0.25 0.5 1
Kilometers

N W E S

Figure 6.7

7. Recommended Improvements

7.1. Culvert and Storm Main Improvements

Recommended improvements were sized to convey the flows simulated under the future land use scenario with consideration of impacts from climate change. All culvert and storm main upgrades were assumed to be circular shape with the same existing slope and a Manning's 'n' roughness coefficient of 0.013. For condition-driven improvements where the required size was smaller than the existing size, the existing size or the minimum required size defined in the design criteria, whichever is greater, was recommended.

Table 7.1 lists the culvert and storm main improvements triggered by capacity and condition risks. The recommended improvements were grouped into projects based on physical location and flow path. The project ID indicates the priority for the projects. Finally, the cost estimates for each upgrade were provided by ISL and are not a guarantee of actual construction costs.

Table 7.1: List of Culvert and Storm Main Improvements

Project ID	Model ID	Location	Length (m)	Existing Diameter (mm)	Upgrade Diameter (mm)	Design Peak Flow (L/s)****	Upgrade Trigger	Priority	System	Conduit Type	Cost Estimate ($)
1***	D0227	Sugar Mountain/ Sunnyside	27.8 m	450 mm	450 mm	158 L/s	Condition	5	Minor	Storm Main	$24,000
	D0158	Sunnyside Rd	18.1 m	450 mm	675 mm	592 L/s	Capacity	3	Minor	Storm Main	$15,000
	D0153	Sunnyside Rd	6.8 m	800 mm	1,200 mm x 2,400 mm	2,480 L/s	Capacity	2	Major	Culvert	$34,000
	D0154			800 mm							
	D0151	Sunnyside Rd	7.1 m	600 mm	1,200 mm x 2,400 mm	2,296 L/s	Cond & Cap	1	Major	Culvert	$36,000
	D0152			800 mm							
2	D0491	East Rd/ North of Kinsey Dr	11.1 m	450 mm	1,200 mm	2,597 L/s	Capacity	2	Major	Culvert	$27,000
	D0017	East Rd/ North of Kinsey Dr	22.8 m	450 mm	1,500 mm	2,662 L/s	Capacity	3	Major	Culvert	$42,000
	D0375	East Rd	30.1 m	450 mm	1,500 mm	2,690 L/s	Capacity	5	Major	Culvert	$109,000
	D0085	Seymour View Rd	14.2 m	450 mm	1,500 mm	2,772 L/s	Capacity	5	Major	Culvert	$62,000
	D0002	Seymour View Rd	34.0 m	900 mm	1,500 mm	3,097 L/s	Capacity	5	Major	Culvert	$120,000
3	D0307	Alpine Dr	9.1 m	450 mm	600 mm	364 L/s	Capacity	3	Minor	Culvert	$11,000
	D0308	Alpine Dr	7.5 m	450 mm	600 mm	370 L/s	Capacity	3	Minor	Culvert	$10,000
	D0146	Alpine Dr/ Sunnyside Rd	30.4 m	450 mm	675 mm	376 L/s	Capacity	2	Minor	Culvert	$32,000
4	D0210	Sunnyside Rd	7.1 m	350 mm	450mm**	2 L/s	Condition	5	Minor	Culvert	$4,000
	D0278	Sunnyside Rd	6.1 m	300 mm	450 mm	296 L/s	Capacity	2	Minor	Culvert	$4,000
	D0279	Sunnyside Rd	14.4 m	650 mm	675mm*	1,056 L/s	Condition	5	Major	Culvert	$14,000
5***	D0479	East Rd	12.3 m	250 mm	450 mm	233 L/s	Capacity	3	Minor	Culvert	$6,000
	D0464	East Rd	30.7 m	300 mm	450 mm	479 L/s	Capacity	3	Minor	Culvert	$12,000
	D0465	East Rd	6.4 m	450 mm	450 mm	207 L/s	Condition	5	Minor	Culvert	$4,000
	D0466	East Rd	6.7 m	450 mm	450 mm	348 L/s	Condition	5	Minor	Culvert	$4,000
	D0467	East Rd	12.6 m	450 mm	675 mm	949 L/s	Capacity	5	Minor	Culvert	$13,000
	D0468	East Rd	14.7 m	450 mm	750 mm	1,054 L/s	Capacity	3	Minor	Culvert	$21,000

Project ID	Model ID	Location	Length (m)	Existing Diameter (mm)	Upgrade Diameter (mm)	Design Peak Flow (L/s)****	Upgrade Trigger	Priority	System	Conduit Type	Cost Estimate ($)
	D0469	East Rd	9.3 m	450 mm	750 mm	1,057 L/s	Capacity	5	Minor	Culvert	$17,000
	D0470	East Rd	4.9 m	450 mm	900 mm	1,139 L/s	Capacity	3	Minor	Culvert	$15,000
	D0471	East Rd	5.1 m	450 mm	900 mm	1,155 L/s	Capacity	3	Minor	Culvert	$15,000
	D0472	East Rd	9.6 m	450 mm	900 mm	1,153 L/s	Capacity	5	Minor	Culvert	$19,000
	D0474	East Rd	26.2 m	450 mm	1,050 mm	1,426 L/s	Capacity	5	Minor	Culvert	$41,000
	D0475	East Rd	5.5 m	900 mm	1,200 mm	1,608 L/s	Capacity	5	Minor	Culvert	$18,000
	D0429	East Rd	5.5 m	900 mm	1,200 mm	1,599 L/s	Capacity	5	Minor	Culvert	$18,000
	D0424	East Rd	14.3 m	650 mm	675mm*	401 L/s	Condition	5	Minor	Culvert	$20,000
6	D0373	East Rd	7.4 m	450 mm	450 mm	53 L/s	Condition	5	Minor	Culvert	$4,000
	D0372	East Rd	12.6 m	450 mm	450 mm	185 L/s	Condition	5	Minor	Culvert	$6,000
	D0368	East Rd	9.4 m	900 mm	1,200 mm	1,660 L/s	Capacity	3	Major	Culvert	$24,000
	D0107	East Rd	11.6 m	375 mm	450mm**	7 L/s	Condition	5	Minor	Culvert	$6,000
	D0021	East Rd	17.7 m	300 mm	450mm**	50 L/s	Condition	5	Minor	Culvert	$8,000
7	D0347	Spence Way	25.3 m	300 mm	450mm**	44 L/s	Condition	5	Minor	Culvert	$10,000
8	D0212	Ravenswood Dr	17.2 m	300 mm	450 mm	194 L/s	Capacity	3	Minor	Culvert	$8,000
	D0211	Ravenswood Dr	8.4 m	300 mm	450 mm	201 L/s	Capacity	5	Minor	Culvert	$5,000
	D0198	Ravenswood Dr	6.0 m	300 mm	450 mm	223 L/s	Capacity	3	Minor	Culvert	$4,000
	D0204	Ravenswood Dr	4.0 m	300 mm	450 mm	228 L/s	Capacity	5	Minor	Storm Main	$5,000
	D0165	Ravenswood Dr	23.6 m	300 mm	600 mm	409 L/s	Capacity	5	Minor	Storm Main	$18,000
	D0374	Ravenswood Dr	55.4 m	300 mm	600 mm	409 L/s	Capacity	5	Minor	Storm Main	$42,000
9	D0033	Fern Dr	28.6 m	300 mm	450 mm	185 L/s	Capacity	5	Minor	Culvert	$12,000
	D0179	Oak Ct/Fern Dr	25.4 m	300 mm	450mm**	55 L/s	Capacity	5	Minor	Culvert	$11,000

**Assumed next available culvert size based on industry standards.*
***Bylaw requires minimum diameter of 450 mm but smaller diameter could be hydraulically acceptable.*
**** D0153 and D0154 are parallel culverts that will be upgraded to a single box culvert. D0151 and D0152 are parallel culverts that will be upgraded to a single box culvert. D0465 and D0466 are parallel culverts that could be replaced by a single culvert. D0474 has a parallel culvert that is not deficient.*
*****Represents the Future Land Use 5-Year Design Storm with Climate Change for the Minor System and Future Land Use 100-Year Design Storm with Climate Change for the Major System.*

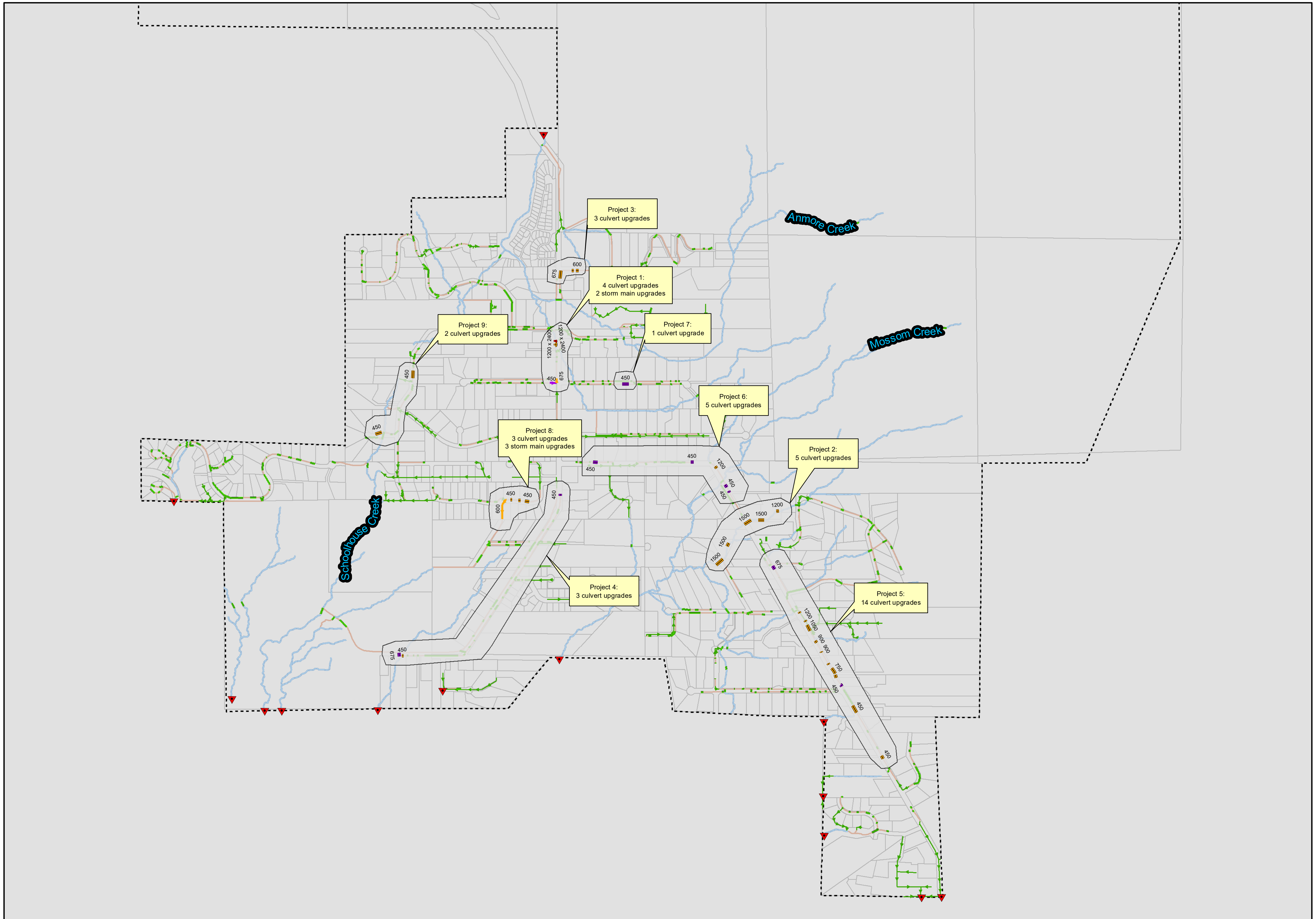
The Village of Anmore is planning to revitalize and develop the lands around the current Village Hall as a Community Gathering Place. Project ID 8 should be reviewed at that time as there may be an opportunity to divert the stormwater flows to Sunnyside Rd instead.

Table 7.2 summarizes the culvert and storm main improvements for the minor and major systems.

Table 7.2: Culvert and Storm Main Improvements Summary

Priority	Minor System Upgrade Length (m)	Major System Upgrade Length (m)
1	-	7
2	37	18
3	126	32
4	-	-
5	351	93
Total	**514**	**150**

Figure 7.1 shows the location of the culverts or storm mains improvements.



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Legend

- Culvert
- Storm Main
- Ditch
- Creek
- Village of Anmore Boundary
- Outfall

Culvert Improvement

- Triggered by Capacity
- Triggered by Condition
- Triggered by Condition and Capacity

Storm Main Improvement

- Triggered by Capacity
- Triggered by Condition

The labels represent the proposed diameters in mm. The project ID indicates the priority for the project.

Culvert and Storm Main Improvements

VILLAGE OF ANMORE

Project: Stormwater Master Plan
Client: Village of Anmore, BC
Date: September 2018
Created by: RD
Reviewed by: WdS

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Kilometers

N W E S

Figure 7.1

7.2. Stormwater Control and Storage Facility Review

Flow control facilities limit the peak flow rate that is allowed to discharge into receiving creeks to protect downstream channels and culverts from excessive erosion and overtopping. In analyzing the simulation results for the future land use scenario, it was determined that during the 5-year design storm flows, three (3) storage facilities exceed their storage capacity and cause flooding to occur as summarized in **Table 7.3**.

Table 7.3: Flow Control Facilities Exceeding Capacity

Model ID	Future Land Use 5-Year Design Storm Results*	Flooding Location
Detention Pipe ID D0576	The model predicts flooding for 17 minutes and volume of 27 m^3.	Thomson Rd and Mountain Ayre Ln. If flooding occurs, it will be in the cul-de-sac on Thomson Rd with flow proceeding into the forested area.
Detention Pipe ID D0619	The model predicts flooding for 26 minutes and volume of 117 m^3.	Between Bedwell Bay Road & Crystal Creek Drive. If flooding occurs, it will be into the forested area.
Detention Pond ID SU03	The model predicts flooding for 37 minutes and volume of 121 m^3.	South of 110 Dogwood Drive. If flooding occurs, it will be into the forested area.

Includes improvements as identified in* ***Section 7.1*.

These facilities are characterized in the model based on available information and may not accurately represent actual operation conditions. Therefore, it is recommended that the facilities listed in **Table 7.3** be further evaluated to ensure that they are accurately defined in the model and that operational characteristics such as orifice and weir sizes and elevations and storage volumes are accurately defined. In the event that the facilities are accurately defined in the model, a review should be conducted to determine if the facilities can be optimized or require structural improvements to operate better under high flow conditions. Optimization could include increasing discharge rates to creeks, slowing bypass rates to storage, adding storage, etc.

8. Conclusions and Recommendations

8.1. Summary of Study Findings

The primary objective of this project was to create a Stormwater Master Plan (SMP) that provides a roadmap to direct the orderly expansion and improvement of the Village of Anmore stormwater system. To meet this objective, a hydrologic and hydraulic model of the Village of Anmore stormwater system was created using PCSWMM.

The intent of this project was to provide the Village with:

- A hydrologic/hydraulic model of the Village's stormwater system;
- A culvert inventory suitable for incorporation into the Village's GIS and asset management systems; and
- A Stormwater Master Plan report that:
    - describes the hydraulic condition of the existing stormwater system;
    - describes the physical condition of the existing culvert infrastructure; and
    - provides improvement recommendations to accommodate existing and future development.

With the Village GIS dataset at hand, USL completed culvert surveys and condition assessments. The data collection and culvert condition assessment were performed throughout a 3-week period from January 15, 2018 to February 2, 2018. USL were tasked to assess all culverts in the Village. **Table 8.1** summarizes the condition rating results of the Village of Anmore culverts.

Table 8.1: Village of Anmore Culvert Condition Ratings

Condition Rating	Number of Culverts
1 - Very Good	184
2 - Good	164
3 - Fair	57
4 - Poor	**37**
5 - Critical	**1**

The flow monitoring program consisted of four (4) flow monitoring sites and one (1) rain gauge, for a period of record of about two months from January 2, 2018 to March 7, 2018. The purpose of the flow monitoring program was to obtain field data for model calibration.

Rather than simulating individual storm events for model calibration, a continuous simulation from January 2, 2018 to March 7, 2018 was run. Overall, the model shows an acceptable agreement with the measured flows at the four flow stations.

To assess the impact on areas that are anticipated to undergo land use changes, the future OCP land use information and the estimated hydrology parameters were used to create a future conditions modeling scenario. The primary difference between the existing and future scenario is the increased runoff resulting from the following:

- Increase in impervious areas;
- Increase in directly connected impervious areas;
- Decrease in surface roughness of pervious areas; and
- Increased precipitation due to climate change.

Recommended improvements were sized to convey the flows simulated under the future land use scenario with consideration of impacts from climate change. **Table 8.2** lists the culvert and storm main improvements triggered by capacity and condition risks. The recommended improvements were grouped into projects based on physical location and flow path. The project ID indicates the priority for each project. A full list of projects with prioritization is provided in **Section 7**.

Table 8.2: List of Culvert and Storm Main Improvements

Project ID	Location	Length (m)	Existing Diameter (mm)	Upgrade Diameter (mm)	Conduit Type	Cost Estimate ($)
1	Sunnyside Rd	60	450 – 800	450 – 1,200 x 2,400	Culvert/Storm	$109,000
2	East Rd/Creek	112	450 – 900	1,200 – 1,500	Culvert	$360,000
3	Alpine Dr	47	450	600 – 675	Culvert	$53,000
4	Sunnyside Rd	28	300 - 650	450 – 675	Culvert	$22,000
5	East Rd	164	250 – 900	450 – 1,200	Culvert	$223,000
6	East Rd	59	300 – 900	450 – 1,200	Culvert	$48,000
7	Spence Way	25	300	450	Culvert	$10,000
8	Ravenswood Dr	115	300	450 – 600	Culvert/Storm	$82,000
9	Fern Dr	54	300	450	Culvert	$23,000
	Total	**664**			**Total**	**$930,000**

8.2. Recommendations Following the Study

Based upon the findings from this analysis, GeoAdvice recommends that the Village of Anmore plan to undertake the projects in the Stormwater Master Plan to relieve system deficiencies and prepare for future development. In addition, GeoAdvice recommends the following:

1. **Verification of Cost Estimates**
   The Village should verify the unit costs used in the costing analysis.

2. **Field Verification of Stormwater Collection System Information**
   The Village should undertake verification of the existing diameter and invert information for the proposed culvert and main upgrades summarized in **Section 7**.

3. **Additional Flow Monitoring**
   The Village should undertake additional flow monitoring to confirm flow assumptions made for the unmonitored areas and enhance model accuracy.

4. **Extended Modeling Support Services**
   We will assist the Village in maintaining and operating the model for a period of one (1) year from the date of completion of this assignment and update the Village of its operational status on a quarterly basis via a written status report. It is understood that during this period, we will respond to specific queries to model scenarios from the Village for capital planning and operational needs.

5. **Maintenance of Stormwater System Model**
   Ongoing development, zoning and infrastructure changes dictate that updates should be completed every year. Asset capacities should be updated where future investigations indicate discrepancies from assumptions used in the model development.

6. **Development Application Review**
   Development application reviews require detailed modeling to validate the system capacity and assess the hydraulic impact of proposed developments. We will assist the Village to complete the analyses required to assess a proposed development's impact on their stormwater system.

Submission

Prepared by:

Chuck Linders
Stormwater Modeling Expert / Senior Review

Reviewed and Approved by:

Sept 19 2018

Werner de Schaetzen, Ph.D., P.Eng.
Project Manager / Senior Review

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Statement of Qualifications and Limitations

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Appendix A USL Tech Memo #1 – Culvert Survey

MEMORANDUM

Date:	April 2, 2018
To:	Werner de Schaetzen, P.Eng.
cc:	Jonathan Hung, P.Eng.
From:	Wade Turner, GISP
File:	3275.0009.01
Subject:	Village of Anmore – Stormwater Master Plan GIS-Based Stormwater Data Review Documentation and Field Data Collection Methodology Technical Memo #1

The purpose of this memo is to outline the information used when starting the data compilation and collection and highlighting the existing data gaps at the outset of the field collection and condition assessment. The GIS-based stormwater data was provided by the Village of Anmore at the start of the Stormwater Master Plan project. This memo also outlines the methodology, equipment and expected accuracy of the field collected information from the field survey capture.

We understand that the GIS-based stormwater data provided by the Village was prepared though effort by ISL Engineering and Land Services Inc. and others. The data was provided by the Village to Urban System Ltd. and was reviewed for completeness and spatial accuracy. Inaccuracies and missing information were anticipated and had been verbally discussed with the Village.

The GIS-based stormwater data review enabled our project team to identify issues with the existing stormwater GIS data and develop a plan to address the issues and fill data gaps through field investigation and data collection. It was important to identify these deficiencies since the information will be used by GeoAdvice Engineering Ltd. to build the Village's stormwater model and conduct analysis of Anmore's stormwater systems.

Below are some of the notable deficiencies that were found in the data:

- Minimal attribution (missing diameter, material, inverts);
- Spatial inaccuracies (many culverts drawn off their actual location and not aligned with the roads visible from orthophoto);
- Attribute inaccuracies in the diameter and material of the culverts (some diameter and material incorrect based on field confirmation); and
- No available condition information for culverts.

Prior to commencing the field condition assessment and culvert survey, a meeting was held with GeoAdvice Engineering, Urban Systems and the Village of Anmore where priority culverts were determined to focus the field collection. It was determined that all culverts were to be assessed for condition including both large and small diameter culverts. From the field assessment, the final culvert count was 487. Data from the condition assessment and field survey was compiled into an updated GIS-based culverts dataset. This dataset included the condition assessment, invert elevation data and the pictures that were taken in the field. All data was provided to GeoAdvice Engineering and will be made available to Village staff at the end of the project.

The 265 culverts over 300mm diameter were surveyed by an Urban Systems land surveyor to collect the precise location and invert elevations of each of these culverts. The larger diameter culverts were surveyed using a high accuracy survey grade system (TS15, GS24, CS15 system). The expected accuracy from this system is 1 cm. The location of the remaining 222 smaller diameter culverts was collected by field staff using a backpack SX Blue II + GNSS system. The location accuracy of the backpack GPS ranged from 20 cm – 100 cm, depending on location of the culvert. Below are sample photos taken during the field investigation:



Please let us know if there are any questions or confirmation needed on the above.

Sincerely,

URBAN SYSTEMS LTD.

Wade Turner, GISP
Condition Assessment and Field Survey Coordinator

/wt

cc: Jonathan Hung, P.Eng. - GeoAdvice Engineering Ltd.

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Table A.1: Culvert Condition

Culvert Model ID	Condition
D0506	Unknown
D0504	Unknown
D0503	Unknown
D0501	Unknown
D0499	Unknown
D0497	Unknown
D0496	Unknown
D0495	Unknown
D0493	Unknown
D0492	Unknown
D0491	Unknown
D0355	Unknown
D0281	Unknown
D0230	Unknown
D0180	Unknown
D0085	Unknown
D0002	Unknown
D0650	Unknown
D0649	Unknown
D0627	Unknown
D0612	Unknown
D0572	Unknown
D0571	Unknown
D0570	Unknown
D0569	Unknown
D0568	Unknown
D0567	Unknown
D0473	Unknown
D0331	Unknown
D0330	Unknown
D0313	Unknown
D0285_4	Unknown
D0285_3	Unknown
D0500	1
D0487	1
D0484	1
D0481	1
D0480	1

Table A.2: Storm Main Condition

Storm Main Model ID	Condition
D0722	Unknown
D0721	Unknown
D0720	Unknown
D0719	Unknown
D0718	Unknown
D0717	Unknown
D0716	Unknown
D0706	Unknown
D0705	Unknown
D0704	Unknown
D0703	Unknown
D0701	Unknown
D0700	Unknown
D0699	Unknown
D0698	Unknown
D0697_2	Unknown
D0697_1	Unknown
D0697	Unknown
D0696	Unknown
D0695	Unknown
D0694	Unknown
D0693	Unknown
D0692	Unknown
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D0689	Unknown
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D0686	Unknown
D0685	Unknown
D0684	Unknown
D0683	Unknown
D0682	Unknown
D0681	Unknown
D0680	Unknown
D0679	Unknown
D0678	Unknown
D0677	Unknown
D0676	Unknown

D0479	1
D0472	1
D0468	1
D0464	1
D0462	1
D0460	1
D0458	1
D0450	1
D0448	1
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D0383	1
D0382	1
D0381	1
D0380	1
D0376	1

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D0023	4
D0021	4
D0347	5

Appendix B USL Tech Memo #2 – Culvert Condition Assessment

MEMORANDUM

Date:	March 28, 2018
To:	Werner de Schaetzen, P.Eng.
cc:	Jonathan Hung, P.Eng.
From:	Wade Turner, GISP
File:	3275.0009.01
Subject:	Village of Anmore – Stormwater Master Plan Culvert Condition Assessment Framework and Coding System – Technical Memo #2

The purpose of this memo is to document the culvert condition assessment framework and coding system used for the field condition assessment component of the Stormwater Master Plan Project for the Village of Anmore.

The framework was used to inform the type of data that was to be collected during the field inspections. The framework was developed with the following principles in mind:

Simple: The goal of this condition framework was to ensure it is simple so that operators can continue to use the framework after the project is completed. This will ensure the condition inspection program can be continuous rather than being completed just for this project.

Informative: The framework focuses on using the observed condition and collect information that can be used to adjust the theoretical service life assumed in the asset management plan by estimating the remaining life and identifying deficiencies (both capital and maintenance). This information will help refine the asset management investment plan, assist with capital planning and maintenance activities on a moving forward basis.

Develop Condition Assessment Framework and Coding System

The following activities were undertaken during the development of the framework and coding system:

- Review industry best practice condition inspection documents and detail desired by Anmore;
- Develop condition framework (in alignment with best practices; IPWEA, NAMS, etc.);
- Develop this technical memo documenting the condition framework.

Note: The below framework and coding system was prepared to help guide discussion with Village staff, the project team and field personnel to identify existing condition of each culvert noting deficiencies such as blockages, damaged ends, visible scour, degraded conduits, etc.

CULVERT ASSESSMENT FRAMEWORK

Notes By: ______________________ Time and Date: ______________________

Culvert Information:

Location: (collected by field survey)

Weather: ______________________

Number of Culverts: __________

Approximate Cover/Free board ;
Upstream (m) ______________ *Downstream (m)* ______________

Barrel Shape (circle one): Circular Box Elliptical Other

Diameter (mm) __________ / Width (mm) __________ x Height(mm): __________

Pipe Material (circle one): CSP / Concrete / Corrugated Plastic / Smooth Plastic / Masonry / Timber Other______

Flowing or Standing Water? Flowing Standing Depth (mm): ______________

Direction of Flow: ______________

Channel Blockage (circle one if yes): Upstream / Downstream / Both

Appurtenances (circle one):

Upstream: Projecting / Mitered / Headwall / Headwall & Wingwalls / Flared End / Other: __________

Downstream: Projecting / Mitered / Headwall / Headwall & Wingwalls / Flared End / Other: __________

Culvert Condition and Performance (check all those that apply):

Notable Problems	Middle	Inlet	Outlet
Debris/Veg. Blockage (> 1/3 of rise)	☐	☐	☐
Sediment Blockage (1/3 to 3/4 of rise)	☐	☐	☐
Deformation	☐	☐	☐
Local Scour	☐	☐	☐
Buried or Submerged	☐	☐	☐
Aggressive Abrasion / Corrosion / Chemical	☐	☐	☐
More detailed condition inspection required	☐	☐	☐

Notes:

Note: Typical service life in a culvert is approximately 60 years.

Coding System:

Condition Rating	Description 1	Description 2	Estimated Remaining Life*
1	Very Good	Only normal maintenance required	75% - 100%
2	Good	Minor maintenance required	50% - 75%
3	Fair	Maintenance required to return to accepted level of service	25% - 50%
4	Poor	Requires renewal (significant renewal/upgrade required)	0% - 25%
5	Critical	Asset Unserviceable	0%

Insert Photo's Here

For the field data collection, the condition framework was integrated with a GIS-based mobile form application (ArcGIS Collector). Collector was deployed to collect the current condition of each culvert along with the necessary attribution and associated photos required to support the development of the PC-SWMM model and support the analysis. This method of digital data capture ensured that the culvert condition and associated photos were collected efficiently, and that information could be provided to GeoAdvice and the Village in GIS format.

The data collection and culvert condition assessment were performed throughout a 3-week period from January 15th - February 2nd, 2018. during the hours of 8 am – 5 pm. Urban Systems field staff were tasked to assess all culverts in the Village. The final culvert count was 487. The inventory of the culverts included capturing the diameter, material, length, condition, notable deficiencies, maintenance needs and photos of assets and found deficiencies such as such as blockages, damaged ends, visible scour, degraded conduits, etc. Below are sample photos taken during the field condition assessment:



Please let us know if there are any questions or confirmation needed on the above.

Sincerely,

URBAN SYSTEMS LTD.

Wade Turner, GISP
Condition Assessment and Field Survey Coordinator

/wt

cc: Jonathan Hung, P.Eng. - GeoAdvice Engineering Ltd.

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