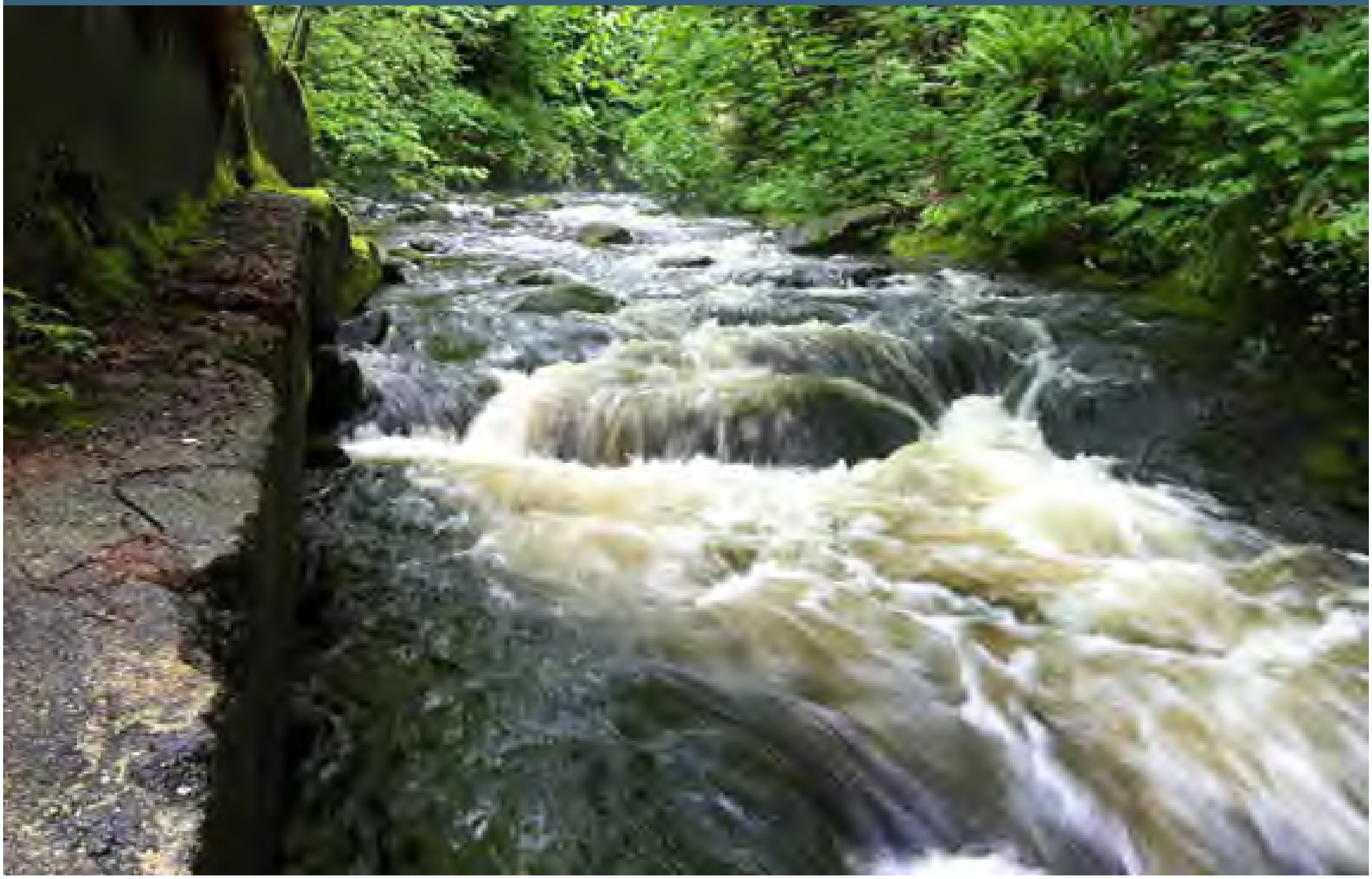

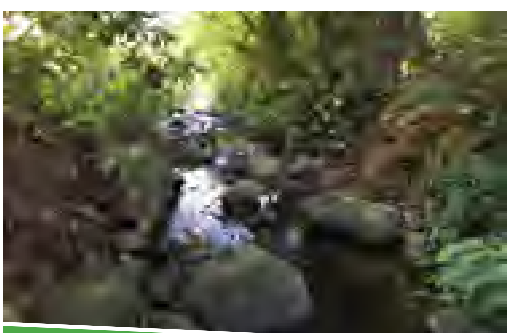

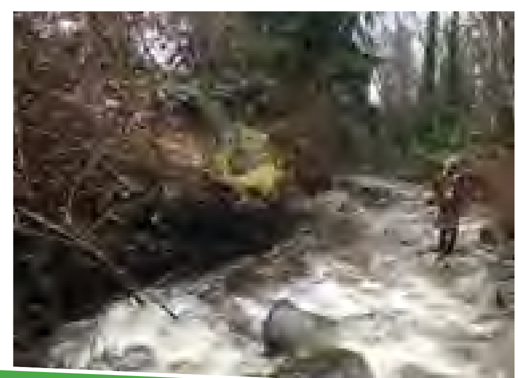

Final Report

Vinson, Brothers, and Hadden Creeks Integrated Stormwater Management Plan

October 2017
KWL File No. 409.073-300

Submitted by:

KERR WOOD LEIDAL
consulting engineers

Contents

Figures at end of each Section

Tables

Appendices

Executive Summary

The Vinson, Brothers, and Hadden Creeks Integrated Stormwater Management Plan (ISMP) study looks at the current management and planning issues for the study watersheds and future issues for the health of the watersheds. This ISMP is comprised of the adjacent watersheds of the following creeks, including their tributaries:

- Vinson Creek
- Vinson Creek East
- Brothers Creek
- West Brothers Creek
- Hadden Creek

These are all upland creeks that drain developed and undeveloped areas of the District of West Vancouver (the District) into Burrard Inlet.

The focus for this ISMP is on the health and condition of the creeks and creek infrastructure, including the connections between the conditions and activities in the watersheds and their impacts and benefits on the creeks. For these watersheds, the creeks themselves are the primary conveyance of runoff and flood waters and the ISMP considers the need for flood conveyance and public safety in concert with environmental health and benefits. This report fulfills the goals of the ISMP process including:

- Document the existing condition of the creek conveyance system and the ecological health of the watershed;
- Identify enhancement opportunities for aquatic and wildlife habitats;
- Determine how re-development can proceed with minimal effects on flooding, erosion, water quality and ecological health; and
- Identify required remedial and new capital work items for the creek conveyance system.

Components of the Study

The work of the ISMP was broken down into four phases as shown in the table below. The work and its results are documented in this report and the attached Appendices.

Work Description	Report Section
Stage 1: Review and Assessment of Existing Conditions and Data	
1.a Review of Background Information	1.2, 1.3, 2.1, & 2.4
1.b Engineering Field Inventory	2.2 and Appendix B
1.c Environmental Field Inventory	3.1 and Appendix C
1.d Environmental Assessment	3.2 & 3.3 and Appendix C
1.e Assessment of Changing Land Use	2.3 and Appendix D
1.f Existing Conditions Culvert Capacity Assessment	4.2 and Appendix D
Stage 2: Visioning Exercise	
2.a Supporting Work for Watershed Vision	5.1 & 5.2
2.b Proposed Vision for the ISMP	5.3
2.c Stakeholder Consultation	5.4 and Appendix A

Work Description		Report Section
Stage 3: Implementation Plan		
3.a	Discussion of Mitigation for Expected Re-development	6.1 and Appendix F
3.b	Simulation of Future Conditions Without and With Mitigation	6.2 and Appendix D
3.c	Recommended Mitigation for Expected Re-development	7.2
3.d	Recommend Environmental Enhancement Projects	7.3
3.e	Bylaw, Process and Planning Recommendations	7.4
3.f	Recommend Capital Plan for Upgrade of Undersized Culverts	7.5 and Appendix E
3.f	Discuss and Recommend Funding Options	8.1
Stage 4: Monitoring and Assessment		
4.a	Recommend Performance Indicators for Monitoring	8.2
4.b	Recommend Adaptive Management Approach and Process	8.3

The work and recommendations together form the ISMP for these watersheds. The plan for guiding the protection of watershed health for the future is comprised of Section 7 of this report which, while it references other sections of the report, is a stand-alone plan for the watersheds.

The funding, monitoring, and adaptive management recommended to support implementation of the ISMP are comprised of Section 8 of this report. The recommended actions for the District to use this ISMP beyond the limits of the Study comprise Section 9 of this report and are also shown below.

Recommendations for the District to Implement this ISMP

The following are recommendations resulting from the ISMP study and process for Vinson, Brothers and Hadden Creeks ISMP. These recommendations refer to elements that are discussed in detail in this report and its appendices. Based on this work, it is recommended that the District:

1. Adopt the proposed mitigation for anticipated watershed re-development of single family residential lots by formalizing and implementing the *District of West Vancouver Single Family Re-development Lot Rainwater Management Guidelines (KWL, 2015)* including recommended changes, as discussed in Section 7.1.
2. Adopt the proposed mitigation criteria for all non-single-family-residential land uses within the watersheds, as discussed in Section 7.1.
3. Work with streamkeepers and private property owners to pursue and enable environmental compensation and enhancement projects as recommended in Section 7.2.
4. Continue to work with stakeholders such as the West Vancouver Streamkeepers and pursue opportunities for public engagement and involvement in watershed health stewardship and enhancement as discussed in Section 7.3.
5. Pursue bylaw and policy changes and enhancements to enable and support protection of watershed health, sustainable re-development, community involvement, and public safety, as discussed in Section 7.4.
6. Develop a schedule and plan for pursuing upgrade of under-capacity in-stream culverts, focusing on the highest priority structures (Priority 1, then 2, etc.) as discussed in Section 7.5 and in Appendix E.
7. Plan for further study of potential flood risks due to inadequate capacity of the existing creek cross-sections to determine whether further mitigation may be required, as discussed in Section 7.5.

8. Asses current funding sources relative to recommended capital items and evaluate whether additional funding sources, as discussed in Section 8.1, or approaches will benefit implementation of capital projects.
9. Continue monitoring of watershed health metrics in accordance with the Metro Vancouver Monitoring and Adaptive Management Framework (MAMF) and with recommendations as discussed in Section 8.2.
10. Develop a schedule for reviewing and assessing monitoring data to evaluate whether implementation approaches may need to be revised, as discussed in Section 8.3.

1. Introduction and Framework for ISMP

1.1 Introduction

The Vinson, Brothers, and Hadden Creeks Integrated Stormwater Management Plan (ISMP) study looks at the current management and planning issues for the study watersheds and future issues for the health of the watersheds. This ISMP is comprised of the adjacent watersheds of the following creeks, including their tributaries:

- Vinson Creek
- Vinson Creek East
- Brothers Creek
- West Brothers Creek
- Hadden Creek

These are all upland creeks that drain developed and undeveloped areas of the District of West Vancouver (the District) into Burrard Inlet.

ISMP Study Area

Figure 1-1 shows the study area and watershed boundaries for the ISMP. Figure 1-1 shows both an overall study area and the boundaries of the watershed models for this ISMP. The study area and the model boundaries are not identical because only catchment areas draining to the study creeks were included in the modelling. Other areas that fall within the study area but fall outside of the model boundaries are also part of the ISMP and subject to the same recommendations, as appropriate. The overall study area is 13.1 km^2, with 12.2 km^2 of catchment area modeled. The study area is built out below the Upper Containment Boundary (areas below 1,200 feet elevation) with predominantly single family residential land use.

Vinson, Brothers, and Hadden Creeks ISMP Purpose and Objectives

The focus for this ISMP is on the health and condition of the creeks and creek infrastructure, including the connections between the conditions and activities in the watersheds, and their impacts and benefits on the creeks. For these watersheds, the creeks themselves are the primary conveyance of runoff and flood waters and the ISMP considers the needs for flood conveyance and public safety in concert with environmental health and benefits. This report fulfills the goals of the ISMP process including:

- Document the existing condition of the creek conveyance system and the ecological health of the watershed;
- Identify enhancement opportunities for aquatic and wildlife habitats;
- Determine how re-development can proceed with minimal effects on flooding, erosion, water quality and ecological health; and
- Identify required remedial and new capital work items for the creek conveyance system.

Project Requirements

The District has identified the following objectives and requirements for the ISMP:

- The ISMP should follow the technical guidance provided in the Metro Vancouver ISMP Template 2005. This includes meeting the minimum effort tasks of the 35 clauses outlined in the template as a base level of effort for an ISMP.
- The ISMP should recommend and prioritize projects, programs, and policies that allow for safe conveyance of stormwater, protect and enhance existing aquatic and riparian habitat, and maintain or improve watershed health; while also supporting the viable re-development of lands within the watershed;
- The ISMP process should include a stakeholder process, including internal and external stakeholders and public consultation. The stakeholder consultation program should include a visioning process to frame values and priorities for the ISMP, including watershed drainage, stream protection, and water quality objectives for the watersheds. The ISMP goals may be revised or adapted based on the visioning process.

The ISMP should consider the effects of climate change and sea level rise in the Burrard Inlet by reviewing applicable existing governing documents and guidelines and taking them into consideration for recommendations for development approaches and drainage improvements.

Key Elements of the ISMP

The following are key items that form the focus of this work to provide a successful ISMP:

- Addressing impacts of expected single family residential re-development;
- Environmental protection, monitoring, and assessment; and
- Watershed visioning and stakeholder consultation.

1.2 LWMP Stormwater Commitments

The 2001 Metro Vancouver *Liquid Waste Management Plan* (LWMP) included commitments for stormwater management that incorporated:

- Sharing of information and knowledge through the Stormwater Interagency Liaison Group (SILG);
- Stakeholder participation;
- Updating and adopting policies and bylaws; and
- Undertaking watershed-scale ISMPs.

In 2002, Metro Vancouver, SILG members and KWL developed the Terms of Reference Template for ISMPs to provide guidance and a flexible framework to the ISMP planning process. The Template document was updated in 2005 based on feedback from member municipalities on its application.

Metro Vancouver updated the LWMP in 2010 to create the *Integrated Liquid Waste and Resource Management Plan (ILWRMP), May 2010*. The key stormwater points are summarized as follows:

- Continue requirement for ISMP planning and implementation;
- Place emphasis on managing rainwater runoff at the site level which reduces negative quality and quantity effects;
- Integrate land use planning and stormwater management;

- Improve stormwater bylaws and development of design standards and guidelines;
- Promote the collection and use of rainwater for non-potable water uses; and
- Develop watershed health indicators.

The Ministry of Environment's accompanying letter requires the development of a coordinated program to monitor stormwater, and assess and report the implementation and effectiveness of ISMPs using a weight-of-evidence performance measurement approach. The ISMP completion deadline was extended from 2014 to 2016.

Metro Vancouver and its members provide progress reports to the province every two years and review and update the ILWRMP on an eight-year cycle.

1.3 Review of Background Information

KWL reviewed existing background information in order to:

- Develop base maps and databases for the engineering and environmental inventories and assessments (including computer hydrologic and hydraulic modelling).
- Develop the foundation for the stakeholder consultation strategy, watershed vision, and future program and policy recommendations.
- Help define the existing conditions and values for the watersheds.

A summary of reviewed information is included in Table 1-1.

Table 1-1: Background Information Reviewed

Category of Information	Examples
District's Digital Data	GIS Database, Storm Conveyance System, Air Photos, Contour Data, Cadastral, As-Built Data.
Historical Consulting Reports	West Vancouver Drainage Report (Dayton & Knight, 1973); Hydrometric Monitoring Reports (KWL, 2012-Present); 2013 Outfall Inspection Program (Delcan, 2013); 2012 Culvert Inspection Program Final Report (Delcan, 2013); Rogers and Marr Creeks ISMP (Associated Engineering, 2008) McDonald and Lawson Creeks ISMP (KWL, 2004) Integrated Stormwater Management Plan for Pipe, Westmount, Cave, Turner and Godman Creeks (OPUS Dayton Knight, 2013); and Sanitary System Asset Management Plan (AECOM. 2010).
District's Website, Internal Initiatives, Studies, Policies, and Programs	Official Community Plan (2004) & Existing Bylaws; Upper Lands Study (2015); Draft Community Outreach and Engagement Policy (2016); Council Direction & OCP Update.
External Source for Climate and Environmental Data	The Ecological Reports Catalogue (EcoCAT); Fisheries Inventories Information System; BC Conservation Data Centre; West Vancouver Streamkeeper Society (WVSK) Survey Reports and Water Quality Monitoring Data; Pacific Streamkeepers Federation (PSKF) Watershed Profiles; and Rainfall Data from Metro Vancouver and Environment Canada.

In addition to reviewing the information listed above, information was gathered through personal communication with the West Vancouver Streamkeepers (WVSK) and the District's planning and engineering departments. WVSK provided input into the environmental inventory. The planning department provided input into upcoming OCP updates and current land use and development patterns. Since the current OCP for West Vancouver is from 2004, it provides limited information on current development trends and future planned development. The District is in the process of updating the OCP and provided KWL with information on the OCP process by responding to questions via email.

It was found that the District's GIS database lacked information on existing culverts. KWL addressed the gap through a survey program of major culverts on Vinson, Brothers, and Hadden Creeks. The data collected during the survey is presented with the engineering inventory findings.

1.4 Stakeholder Consultation Strategy

In collaboration with the District staff, a stakeholder consultation program was developed (see Appendix A). The stakeholders for the project are divided into two major groups: internal stakeholders and external stakeholders. The internal stakeholders, the District, its departments and staff guide the ISMP. KWL is working closely with District staff and key internal stakeholders to develop the ISMP.

As defined in the District's *Draft Community Outreach and Engagement Policy (2016)*, key external stakeholders and the public will be consulted through the ISMP planning process. The goal of community consultation is to receive input and feedback on specific items in a plan, to identify projects' strengths and weaknesses, and identify any unforeseen effects/consequences. The community stakeholders provide input on existing conditions in the watersheds, and feedback on vision and plan elements through the District website, through discussions with stream keepers, and at open houses.

The Stakeholder Consultation Strategy provides a framework and details of the consultation process to integrate internal District needs and policies with external needs and values from key external stakeholders and the public. The strategy guides the process of understanding balancing competing needs and values in the watersheds, such as for development and watershed health, and public access and environmental protection. The Stakeholder Consultation Strategy is provided in Appendix A.

1.5 Project Scope and Team

Scope of Work

The work program is summarized in Table 1-2.

Table 1-2: ISMP Work Program

Task	Description
Stage 1: Review and Assessment of Existing Conditions and Data	1.1 Review Existing Information
	1.2 Project Initiation Meeting (Mtg #1)
	1.3 Engineering Watershed Field Inventory
	1.4 Environmental Watershed Inventory & Analysis
	1.5 Analyze Drainage Systems with Existing Land Use
	1.6 Analyze Drainage Systems with Future Land Use
	1.7 Develop a Strategy for Public Consultation
	1.8 Stage 1 Progress Memo and Documentation

Task	Description
Stage 2: Visioning Exercise	2.1 Stakeholder Contact and Preparations
	2.2 Vision Development with Internal and External Stakeholders
	2.3 Stage 2 Progress Memo and Documentation
Stage 3: Implementation Plan	3.1 Develop Alternatives & Conduct Cost-Benefit Analysis
	3.2 Interim Report: Alternatives
	3.3 Develop Implementation Plan (including funding strategies)
	3.4 Model Future Vision and Assess Mitigation Strategies
	3.5 Bylaw, Process and Planning Recommendations
	3.6 Stage 3 Progress Memo and Documentation
Stage 4: Monitoring and Assessment	4.1 Develop Monitoring and Adaptive Management Plan
	4.2 Stage 4 Progress Memo and Documentation
Reporting	5.1 Draft Report
	5.2 Final Report

Project Team

This project was undertaken by an inter-disciplinary team of professionals. The team members involved are outlined in the following table.

Table 1-3: ISMP Project Team

Firm	Team Members
District of West Vancouver	Jenn Moller - Utilities Engineer Andy Kwan, P.Eng. – Manager, Utilities
Kerr Wood Leidal Associates Ltd.	Laurel Morgan, M.Sc., P.Eng. - Project Manager David Zabil, M.A.Sc., P.Eng. - Technical Review Sara Pour, P.Eng. - Project Engineer Shayna Scott, EIT - Junior Engineer and Modeller Jack Lau - GIS Specialist Patrick Lilley, M.Sc., R.P.Bio. - Biologist Peter deKoning, R.P.Bio. - Junior Biologist

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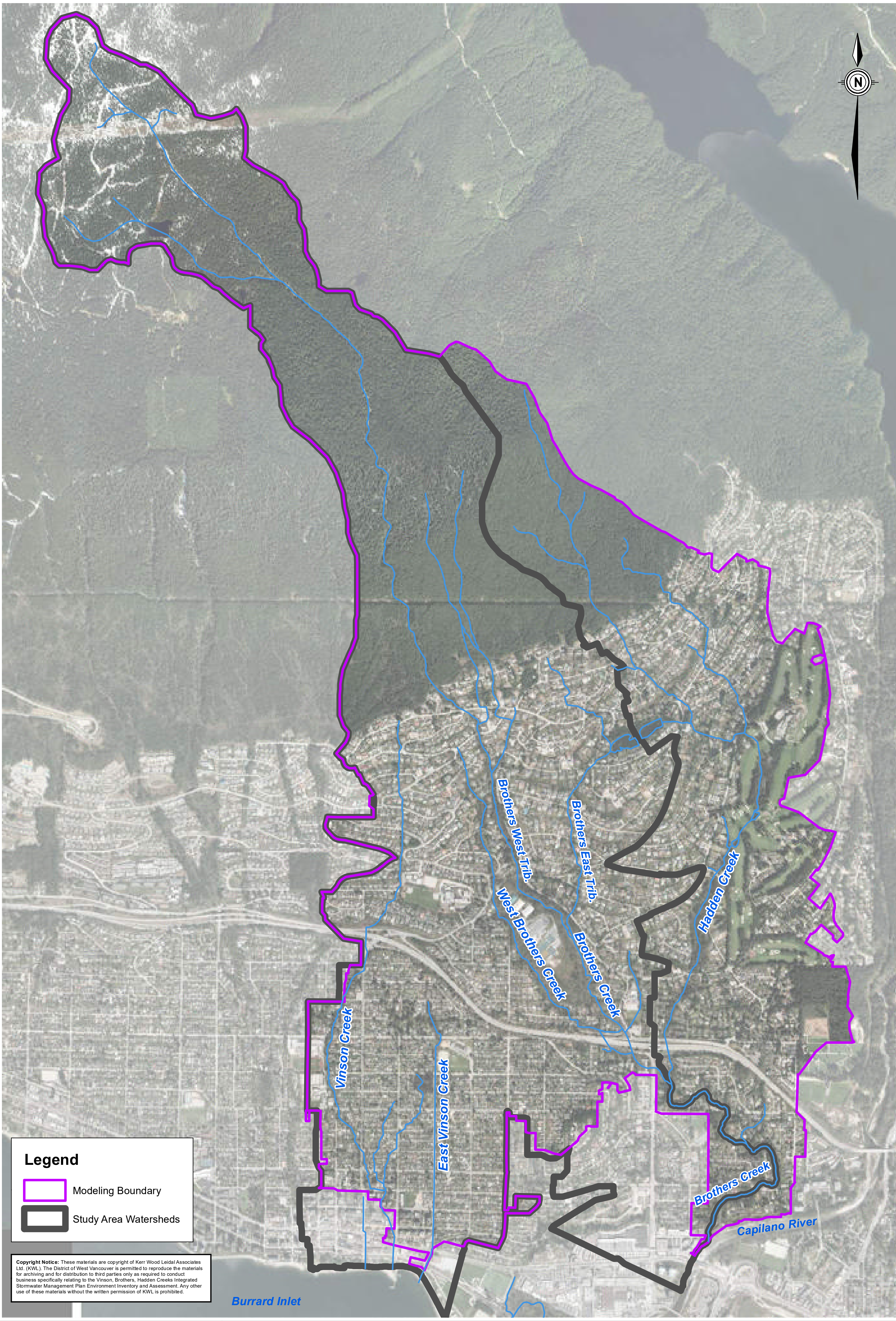

KERR WOOD LEIDAL
consulting engineers

District of West Vancouver
Vinson, Brothers, Hadden Creeks ISMP

Project No.	Date
409-073	March, 2017

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Study Area

Figure 1-1

2. Watershed Overviews and Inventory

The engineering assessment portion of the ISMP includes basic information about the location and elevations of the creeks, the types of soils in the watersheds, and evaluation of the land uses, level of development and impervious cover in the watersheds. The engineering assessment incorporates field inventory of aspects that impact the development of the ISMP recommendations, including infrastructure, hydraulic concerns in the creeks, and observed erosion of creek beds or banks.

2.1 Overview of Study Watersheds

Vinson Creek Overview

Vinson Creek is the eleventh largest watershed in West Vancouver with an area of approximately 3.7 km^2 and is approximately 6 km in length. The flow is generally north to south, originating on the side of Hollyburn Ridge and discharging into Burrard Inlet at the bottom of 15th Street.

Vinson Creek has two branches and three diversions that divert flows from the main channel of Vinson Creek to Brothers Creek in the upper portion of the watershed. The diversions are located at:

- Millstream Road, diverting all flow from areas above El. 366 m to Brothers Creek at Eyremount;
- Chartwell Drive, diverting flow from areas above El. 275 m to West Brothers Creek; and
- Cammeray Road, diverting all flow from areas above El. 230 m to West Brothers Creek.

This study also includes Vinson Creek East, which is a smaller creek that is culverted for much of its length before discharging into Burrard Inlet near the bottom of 13th Street. The watersheds are fully built out within the Upper Containment Boundary (UCB). The land use mainly consists of single family residential and is highly impervious.

Brothers Creek Overview

Brothers Creek is the third largest watershed in West Vancouver with an area of approximately 5.6 km^2 and is approximately 7 km in length. Originating on the southeast side of Hollyburn Ridge, it flows generally north to south and discharges into the Capilano River just upstream of Marine Drive.

Brothers Creek has two main tributaries, West Brothers Creek and Hadden Creek, as well as several lakes and wetlands in the headwaters. The watershed is fully built out within the UCB, and developed land use mainly consists of single family residential.

Hadden Creek Overview

Hadden Creek is the sixth largest watershed in West Vancouver with an area of approximately 2.7 km^2 and is approximately 5 km in length. The flow is generally toward the north to south, before Hadden Creek discharges to Brothers Creek just south of the Upper Levels Highway (ULH).

Hadden Creek has one significant tributary which flows into the mainstem of the creek below Southborough Drive, near the edge of the Capilano Golf and Country Club. The watershed is largely developed within the UCB, with the majority of land use being single family residential. The Capilano Golf and Country Club represents a significant area of recreational land use with low-impervious-coverage in the watershed.

2.2 Engineering Watershed Field Inventory

KWL undertook an engineering field inventory between November 2015 and February 2016. The scope of work included the main stems and significant tributaries of Brothers Creek, Hadden Creek, and Vinson Creek south of the UCB. The purpose of the inventory was to supplement the District's existing GIS database by locating, photographing, and assessing the following features along each stream:

- culverts and bridges;
- hydraulic structures and stormwater outfalls;
- significant deposition in channel;
- significant bank or channel erosion sites;
- bank protection; and
- channel obstructions.

The creeks were walked by staff and an iPad was used to record the GPS coordinates and data on the above features. The data collected during the engineering inventory is shown in Appendix B which will be included in the final report. Figures 2-1 to 2-4 present the infrastructure and observations documented during the engineering inventory and culvert survey (described below).

Culverts and Diversions

In addition to the engineering inventory, KWL surveyed all accessible culverts on Vinson, Brothers, and Hadden Creeks. Information collected during the survey included culvert location, inverts, length, shape, size and material. The information collected during the survey was used for the modelling and hydraulic assessment of the District's drainage system. The data collected during the survey is presented in Appendix B with the engineering inventory findings. While 63 culverts within the three study watersheds were initially identified in the District's GIS files, over 130 culverts were identified and documented by survey and field staff.

Where culverts were not accessible for survey or inventory for this project, information from the 2012 District Culvert Inspection Program was used, where available. Eleven Culverts were identified for which no information could be obtained as they were inaccessible when the survey was carried out. These are identified on Figure 2-1.

Record drawings of the creek diversions in these watersheds were obtained from the District to supplement survey and engineering inventory.

Obstructions and In-Stream Structures

Eleven obstruction sites were noted on all 3 creeks (refer to Figure 2-2). Some were large woody debris (LWD) sites and some were manmade fences and structures. Note that sewer lines that cross Brothers and Hadden creeks at several points are not shown on the obstruction figure as the crossings and manholes do not significantly obstruct the creek but the sewer lines are a source of concern. The *2012 AECOM Sanitary System Asset Management Plan* identifies the sanitary pipe within Brothers Creek as a priority project due to I&I concerns and risk of a sewage spill into Brothers Creek. The 2003 Pacific Streamkeepers Federation Watershed Profile for Hadden Creek (PSFK, 2003a) identifies that the creek is crossed in several places by sewer lines with potential for leakage.

Erosion Sites

Bank erosion is of concern as it has the potential to damage infrastructure, private property, and/or pose a risk to public safety. The erosion sites identified during the Engineering Inventory were assigned a hazard and consequence level and ranked based on the qualitative risk framework presented in Table 2-1. The intent of the risk framework is to provide a simple and straightforward method to assess relative risk associated with erosion.

Of the sites observed during the inventory, 3 sites were assigned High Risk and 3 were assigned Moderate Risk (refer to Figure 2-3). A High Risk site poses likely or immediate risk to public safety, or damage to structures or infrastructure. In the case of the sites identified for this project, further review indicates that immediate risk is minor, and these sites do not warrant immediate repairs. One of the identified sites has already been repaired since the field inventory was completed. However, these sites should be reviewed every two years as increasing risk may develop over time.

Note that the District is not the owner of the creek bank and that individual property owners are responsible for maintaining and repairing the creek banks. The District will work with property owners to monitor the issue and facilitate work if needed.

Table 2-1: Qualitative Risk Framework for Erosion Assessment

Hazard: based on the measured height of visible scour or slippage.

- Low: height of erosion < 0.3 m;
- Moderate: height of erosion from 0.3 m to 1.2 m; and
- High: height of erosion > 1.2 m.

Consequence: based on the proximity of manmade features (sheds, fences, buildings, retaining structures, etc.) to the eroding bank

- Low: setback > 10 m;
- Moderate: setback between 5 m and 10 m; and
- High: setback < 5 m.

Risk: is the product of hazard (i.e., probability of occurrence) and consequence. Risk is rated on a qualitative scale from Very Low (green) to Very High (burgundy).

Qualitative Risk Matrix

Likelihood of Occurrence (Hazard)	Consequence		
	Low	Moderate	High
High	Moderate	High	Very High
Moderate	Low	Moderate	High
Low	Very Low	Low	Moderate

Above Risk designations may be understood to have the following general characteristics:

- **Very High / High Risk:** likely or immediate risk to public safety, or damage to structures or infrastructure.
- **Moderate Risk:** no anticipated risk to structures and no significant risk to public safety, but increasing risk may develop over time.

Low / Very Low Risk: minimal risk of impact to private property or public safety in the near or foreseeable future.

Storm Outfalls

Storm outfalls into the creeks were observed and documented during the field inventory, however this fieldwork did not develop a complete inventory of discharges into the creeks as there are a large number of small pipes discharging runoff from private properties, typically homes, to the creeks and not all of them were documented. The field inventory attempted to document storm outfalls that:

- Are storm system discharges rather than small discharges from individual private homes,
- Exhibit some concern due to condition or installation of the of the outfall pipe (e.g. sediment blockage or no headwall), or
- Appear to be contributing to erosion or water quality problems (e.g., visibly polluted discharge).

Figure 2-4 shows the storm outfalls documented in the field inventory along with photos of some of the outfalls and/or concerns.

2.3 Land Use

Above the UCB, 1200 ft. elevation line, the study area watersheds are forested. Below the UCB, the majority of the area in all three watersheds is mature neighbourhoods with mostly single-family land use and pockets of multi-family development (duplex and townhouses). Other significant land uses in the watersheds include:

- Mixed density residential and commercial areas in south Vinson (Ambleside Town Centre) and south Brothers (Marine Drive Corridor and Park Royal Shopping Centre), and
- Recreational/Institutional land uses: Hollyburn Country Club (Brothers), Capilano Golf and Country Club (Hadden), and Ambleside Waterfront (Vinson).

The land use is used to assign impervious area coverage to catchments in the hydrologic model for runoff analysis. To do this more accurately, the existing single family land use was divided into multiple categories to account for different styles of development. Older developments, below the Upper Levels Highway, typically have buildings with smaller footprints and smaller paved area coverage relative to total lot area (lower Total Impervious Area (TIA)). Developments above the Upper Levels Highway typically have larger building footprints and more pavement on lots (higher lot coverage and TIA). Single family lots along the study creeks typically have the smallest building footprints relative to lot area. These lots often include some of the creek's riparian buffer and as a result have the lowest TIA of all single-family land use categories.

The single-family neighbourhoods are experiencing significant re-development. The re-development pattern aligns with observed trends in the watersheds, particularly replacement of older homes with larger ones with more paved area. A 2014 update to land use regulations permitted the addition of "detached secondary suites" in much of the study areas. Although not yet prevalent, addition of detached secondary suites could become part of the re-development pattern.

As part of the Official Community Plan (OCP) review, area plans will be prepared for town centres and important corridors including Ambleside, Marine Drive and Taylor Way. Potential land use scenarios will be explored with the community, and are subject to Council approval. The District is also currently processing development applications in the area that will also be subject to Council approval. Potential land use changes could include:

- Infill (mid-rise development) in Ambleside Apartment Area. Infill (conversion of single family to duplexes) and addition of low-rise development (townhouses) in single family neighbourhoods adjacent to Ambleside Town Centre.
- High-rise development clustered at the Marine Drive/Taylor Way intersection and at Park Royal Shopping Centre.
- Shift from single family to ground oriented housing (townhouses, low-rise buildings, and care facilities) in the Taylor Way Corridor (between the Highway and Clyde Avenue).

Land use in the study area for existing conditions is based on the BC Assessment classifications for each lot as provided by the District and is shown in Figure 2-5. The future conditions land use scenario is shown in Figure 2-6, and is based on zoning as per the OCP, with refinements provided by planning staff at the District who are in the process of updating the OCP. Total impervious area assigned to each land use type is summarized in Table 2-2. Figure 2-7 illustrates the increase in percentage impervious area from existing to future land use scenarios.

2.4 Surficial Geology

To determine the characteristics of the surficial geology, information from Natural Resources Canada and the Geological Survey of Canada was reviewed. These sources suggest that the study area is underlain principally by granitic rock in the upper watersheds, and till, gravel and sand in the lower watersheds.

Refer to Figure 2-8 for soils mapping, which shows the approximate boundaries of the different soil types.

Table 2-2: Land Use Categories and Associated Total Impervious Area Values for Existing and Future Land Use

Category	Location / Description	Existing Land Use				Future Land Use				Expected Increase in TIA (%)	Notes	
		Area (ha)	% of Watersheds	TIA (%)	TIA (ha)	Area (ha)	% of Watersheds	TIA (%)	TIA (ha)		Existing Land Use	Future Land Use
Single family BP	In British Properties, north of Highway 1, larger lots	268	22	60	161	273	22	75	204	15		Single family redevelopment and (in most cases) detached secondary suites permitted
Single family BP south	In British Properties, north of Highway 1, southern section with smaller lots	29	2.4	50	14	29	2.4	65	19	15		
Single family	South of Highway 1	132	11	45	59	120	10	60	72	15		
Single family riparian	North and south of Highway 1, lots that include riparian forest	32	2.6	20	6.3	32	2.6	30	9.5	10	At least 25% of lot area is riparian forest	Assumed that single family redevelopment may occur, but no further encroachment on creeks.
High rise	Includes high rise towers and apartments	4.3	0.4	75	3.2	4.3	0.4	75	3.2	0		
Duplex	Categorized as duplex by BC Assessment	0.4	0.04	80	0.4	3.0	0.2	80	2.4	0		
Easement	Forested/hedge/vegetation areas between lots, green space not an official park	17	1.4	5	0.9	17	1.4	5	0.9	0		
Right-of-way	Roads	179	15	70	125	179	15	70	125	0		
Row housing	Multi-family condos	2.3	0.2	45	1.0	13	1.0	85	11	40		
Park	Includes official parks, greenspace, golf courses, cemetery	81	6.6	10	7.5	81	6.6	10	7.5	0		
Forested/alpine	Above development boundary	423	35	0	0	423	35	0	0	0		
Undeveloped greenfield	Lots that are undeveloped at time of air photo but fall within single family or residential blocks	5.5	0.4	5	0.3	-	-	-	-	-	TIA = 5% because of compacted gravel in many undeveloped lots	Assumed all lots developed for future scenario
Institution	Schools, churches, nursing homes, government buildings, utility facilities	45	3.7	60	21	45	3.7	60	21	0		
Commercial	Includes parking lots	1.8	0.2	95	1.8	1.8	0.2	95	1.8	0		
	Total	**1221**		**33%**	**403**	**1221**		**39%**	**478**			

Note: BP = British Properties

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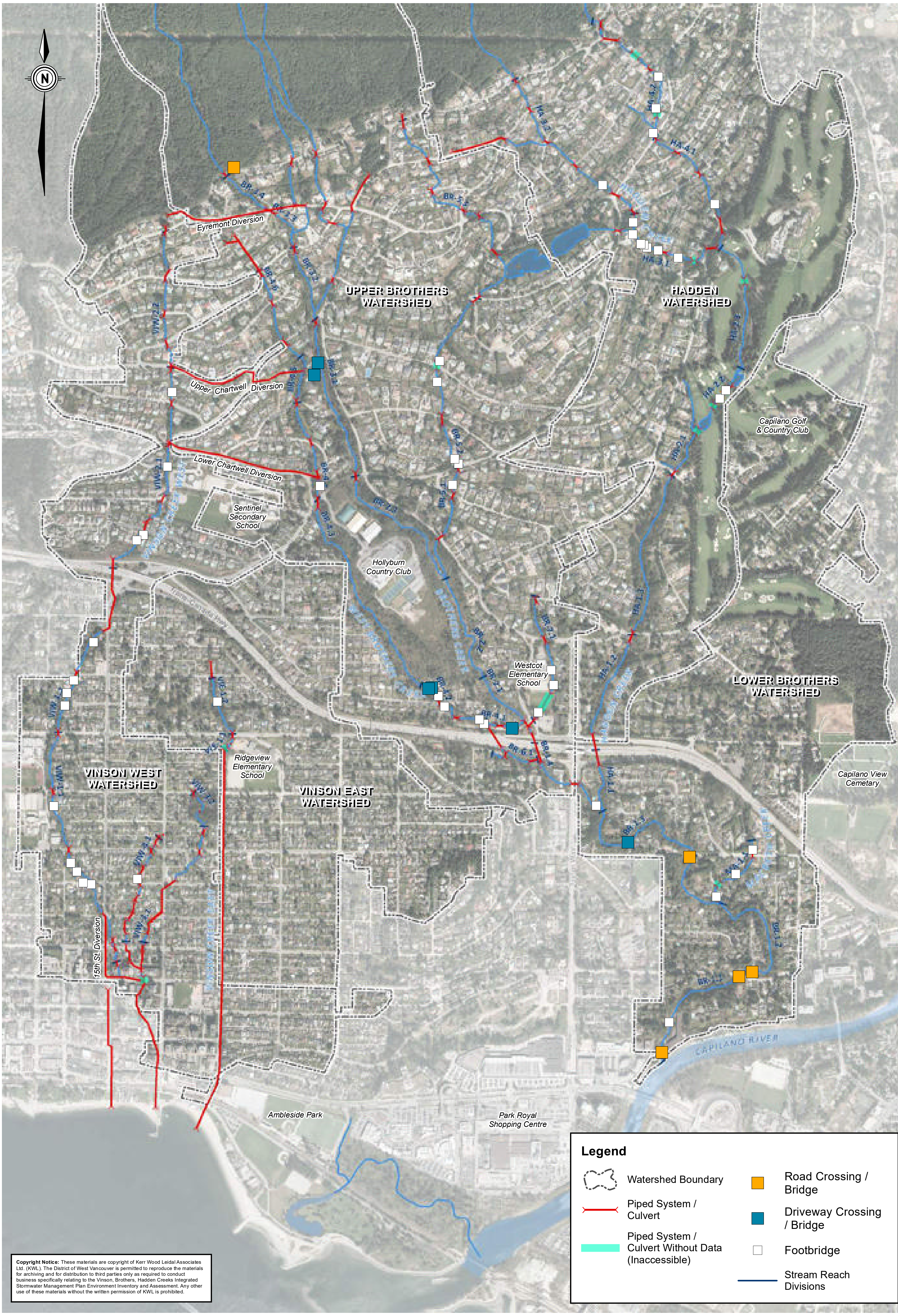

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Project No.	Date
409-073	March, 2017

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Culverts and Bridges

Figure 2-1

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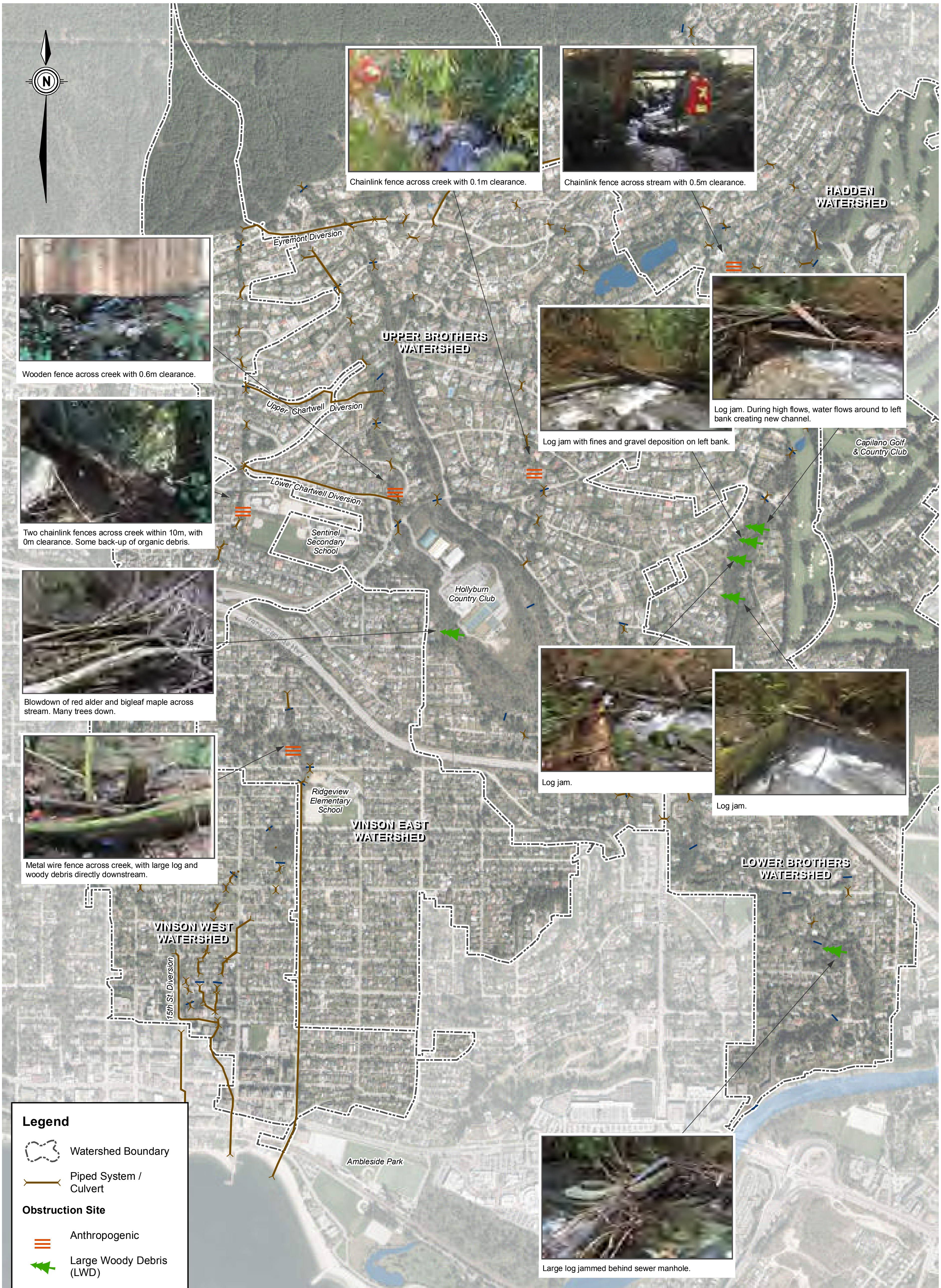

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Project No.	Date
409-073	March, 2017

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Obstruction Sites

Figure 2-2

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Project No. 409-073
Date November, 2017

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Observed Erosion Sites

Figure 2-3

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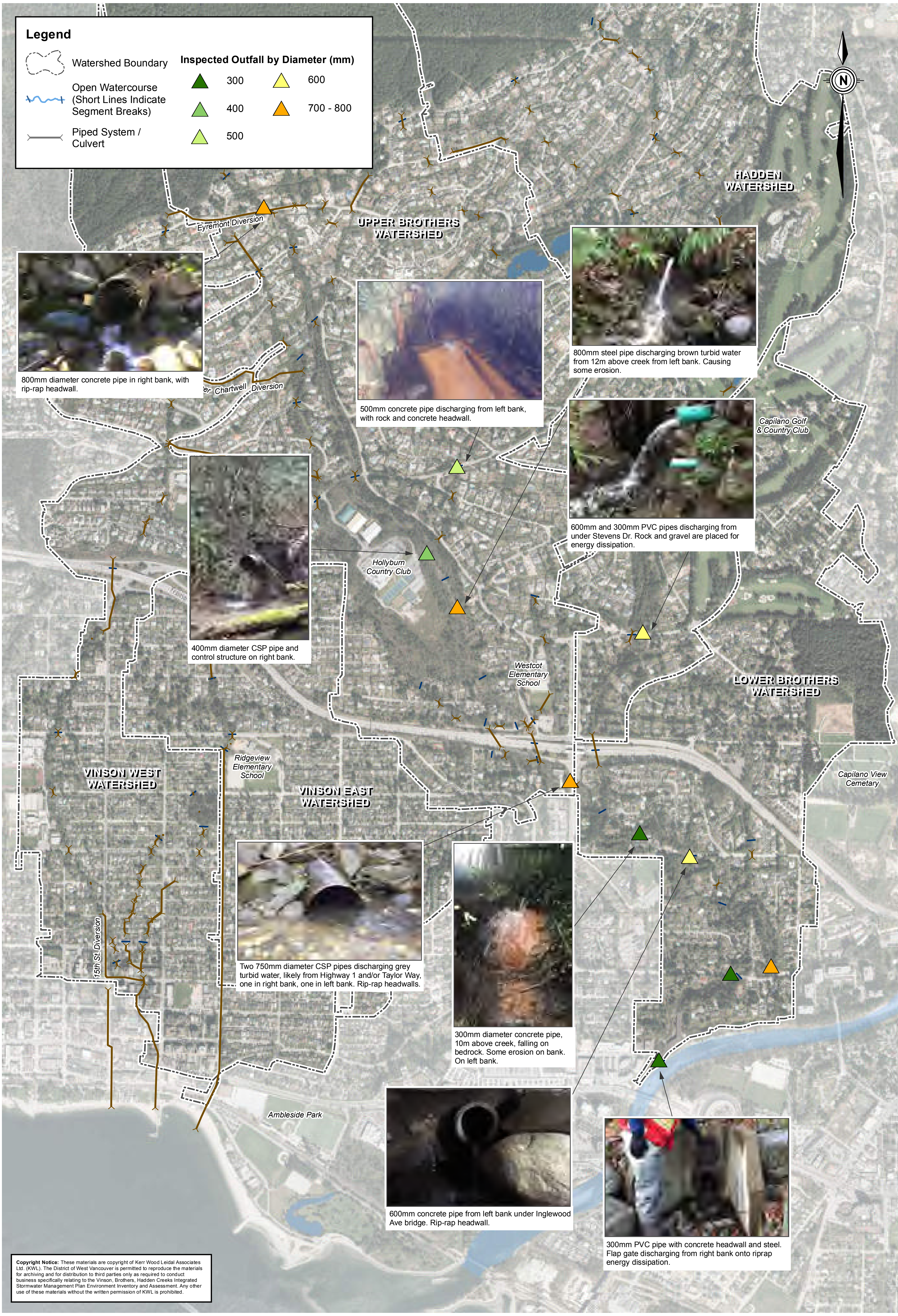

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Date March, 2017

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Documented Storm Outfalls

Figure 2-4

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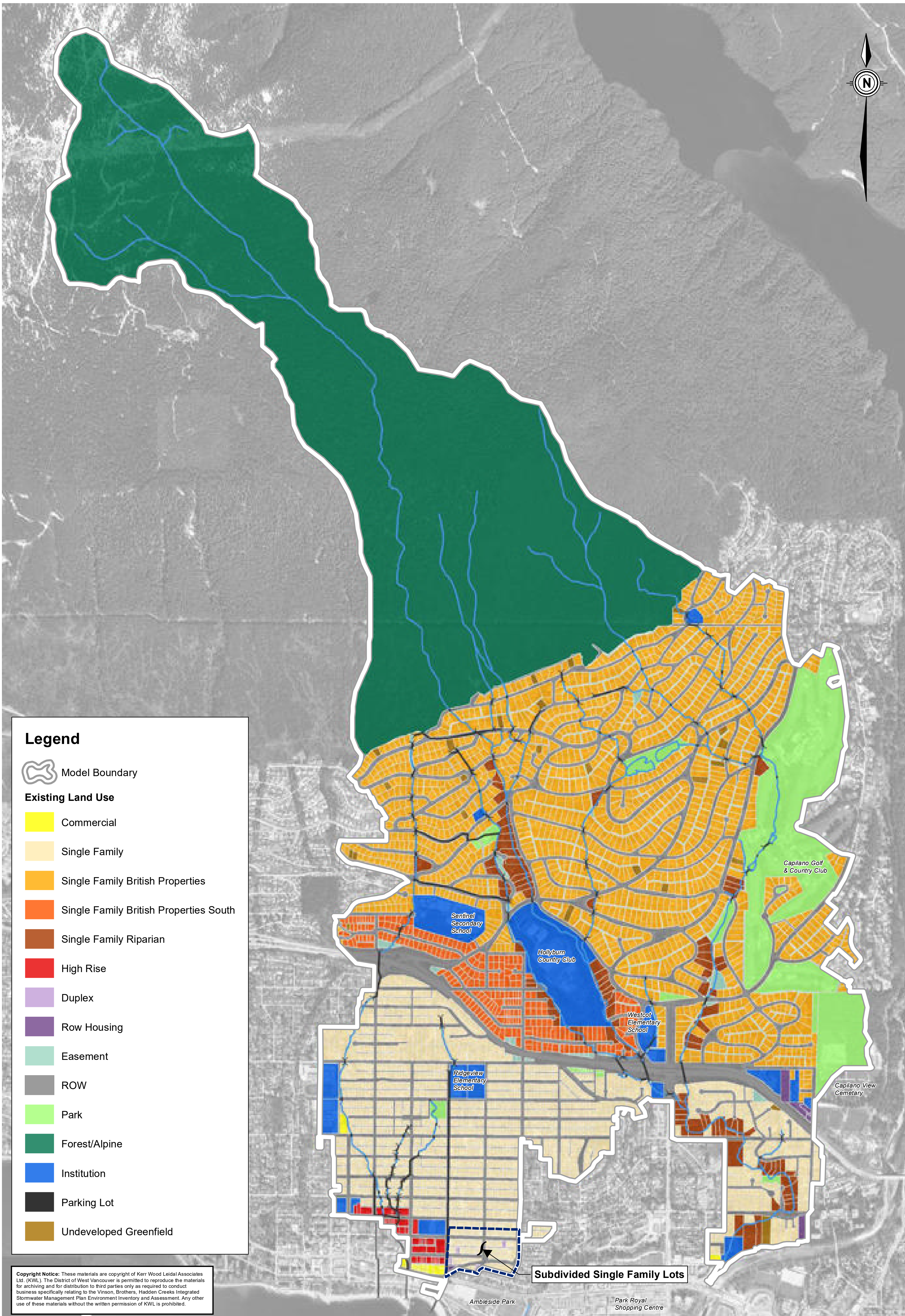

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Project No. 409-073

Date March, 2017

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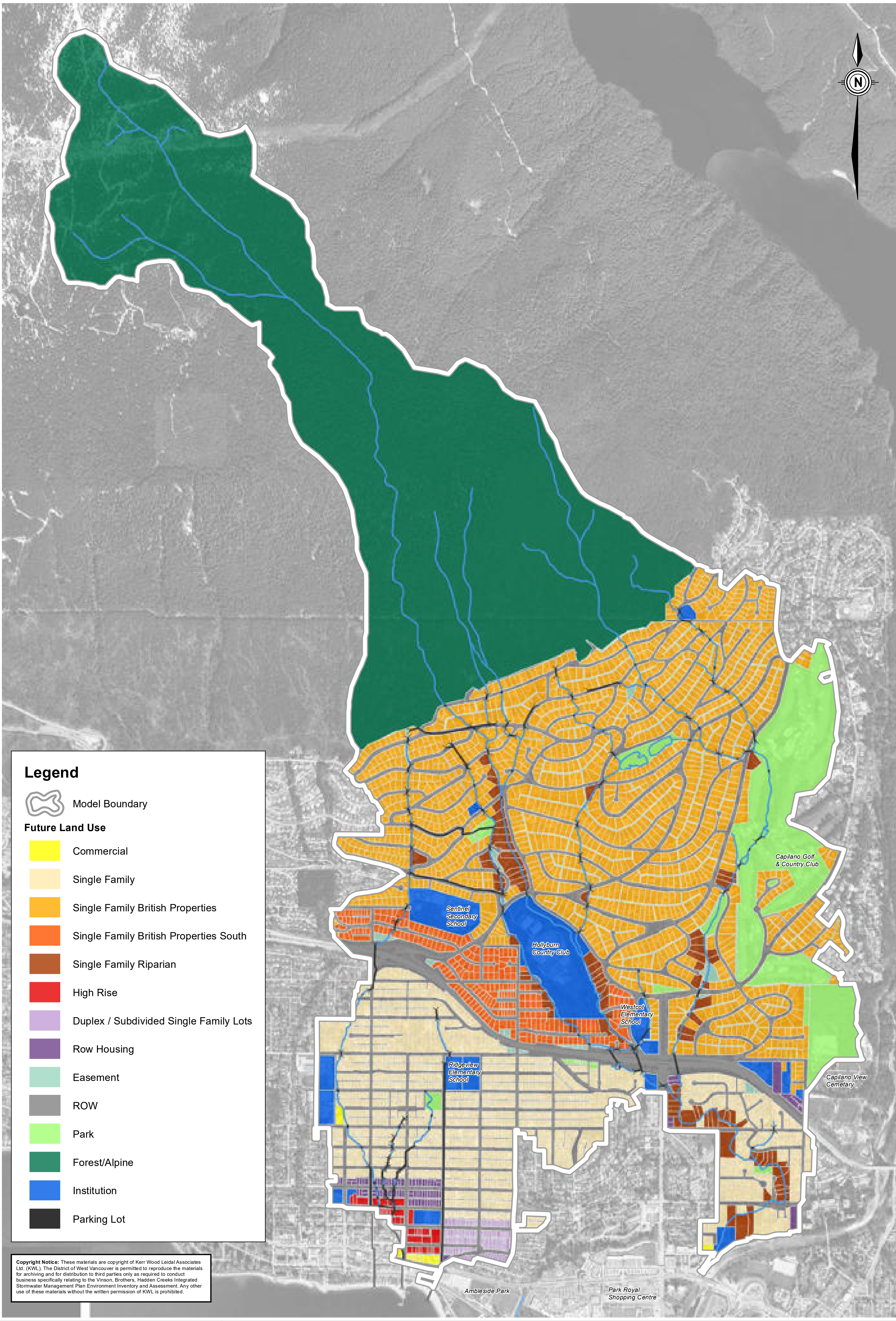
Existing Land Use

Figure 2-5



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Project No. 409-073
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Potential Future Land Use Scenario (prepared by KWL for modelling purposes)

Figure 2-6

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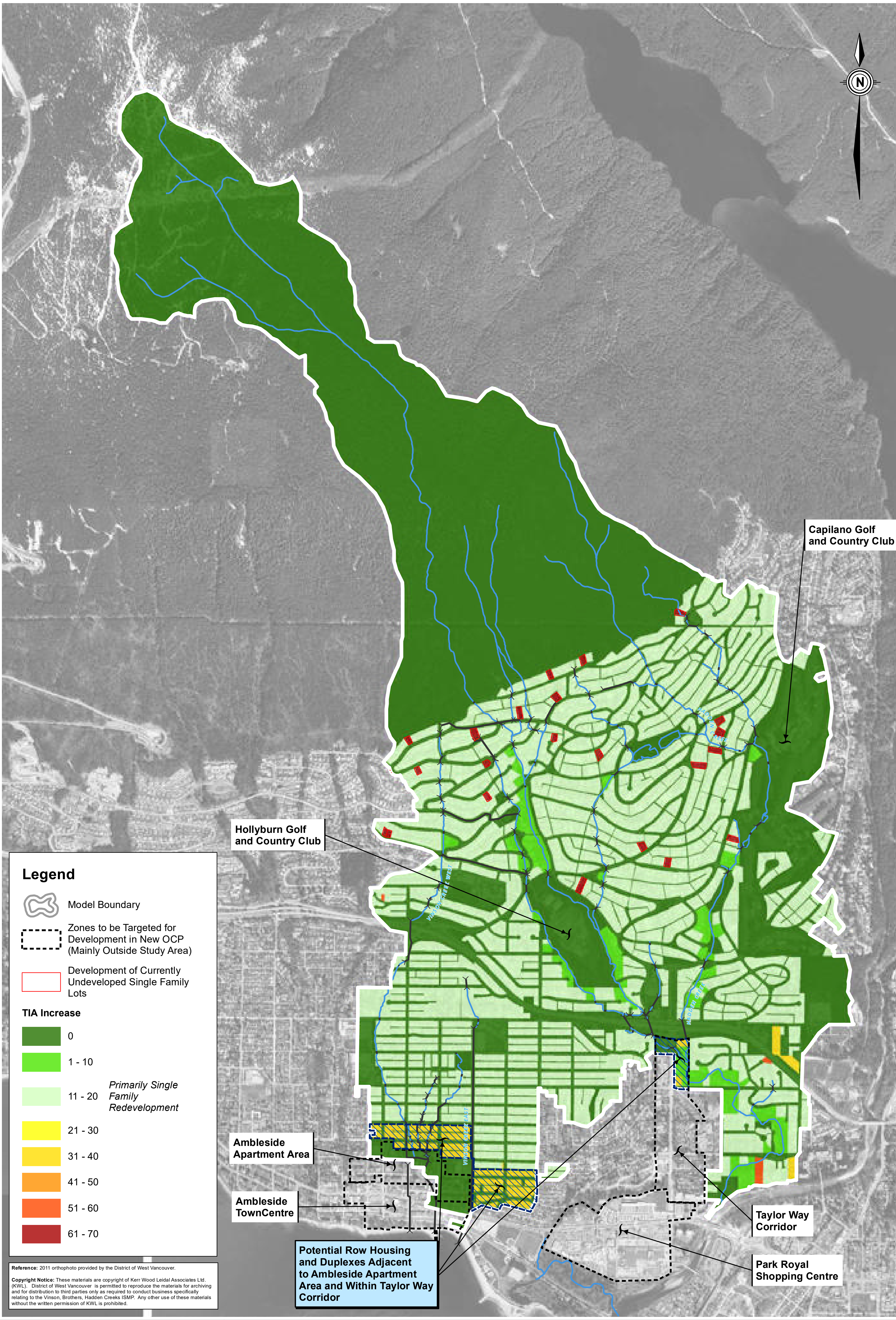

Reference: 2011 orthophoto provided by the District of West Vancouver.

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409-073	March, 2017

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Existing to Future Land Use Total Impervious Area Increase

Figure 2-7

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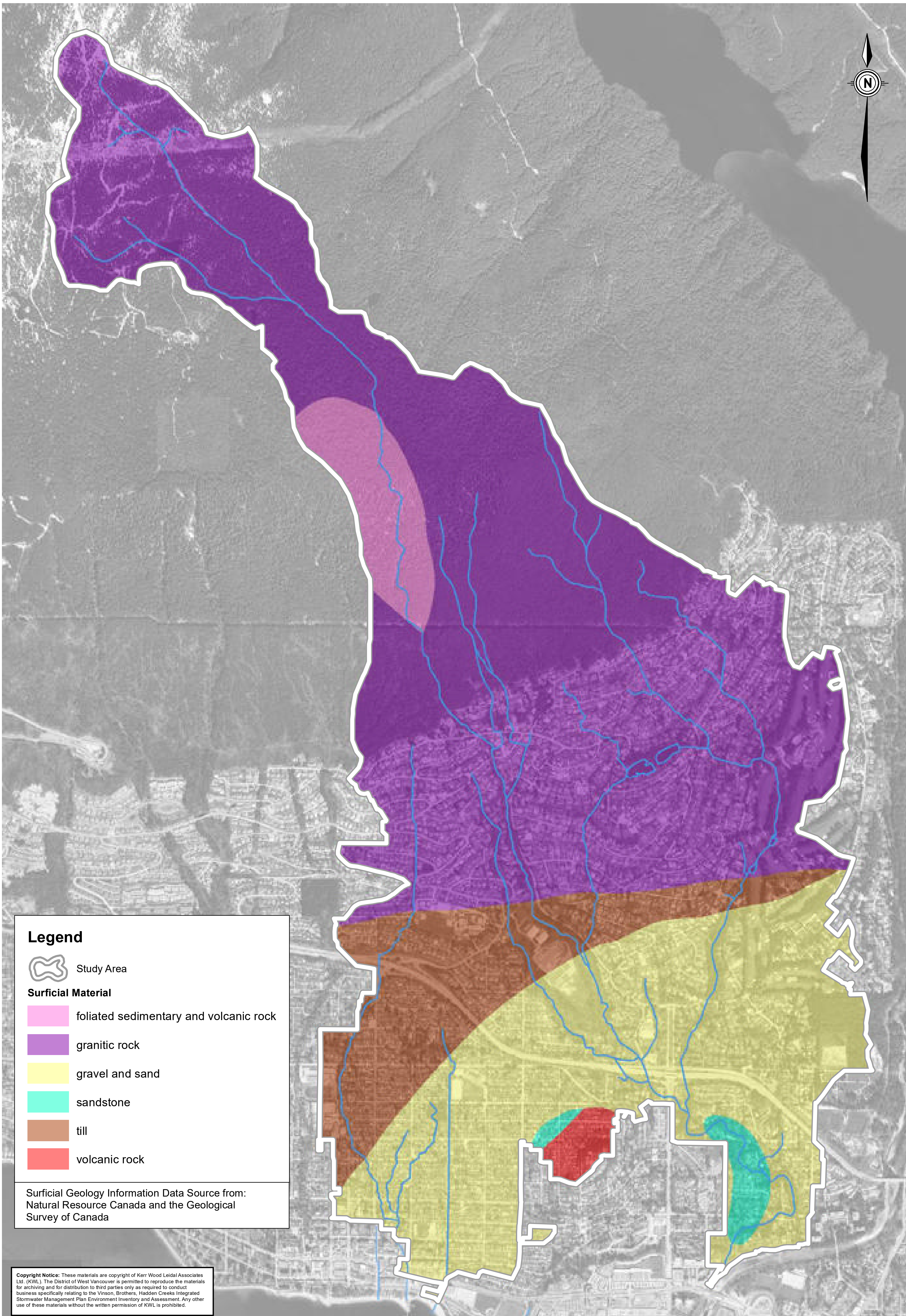

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Project No.	Date
409-073	November, 2017

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Soils Map

Figure 2-8

3. Environmental Values and Assessment

An inventory and assessment of environmental values in the study watersheds was completed as part of the ISMP which included aquatic species and habitats, riparian and watershed forest cover, terrestrial species and habitat, and water quality. The purposes of the assessments were to:

- assess status and trends in watershed health in the study watersheds;
- identify priority environmental issues to be addressed in the ISMP; and
- identify environmental enhancement opportunities within the study area.

Details of inventory and assessment are included below.

3.1 Environmental Inventory and Assessment

An environmental field inventory of Vinson, Brothers, and Hadden Creeks was carried out in January and February of 2016. The scope of work included the main stems and significant tributaries of the three creeks south of the UCB. The inventory was based on the Stream Inventory Standards and Procedures section of *Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures* (Resource Inventory Committee 2001) with a simplified sampling design and a segment-by-segment approach. The biophysical inventory focused on assessing aquatic habitat values in the three creeks, including:

- presence and distribution of fish and other species (existing information supplemented by limited fish observations as fish sampling was not part of the scope of the project);
- quality of aquatic habitat, especially for spawning and rearing salmonids;
- barriers to fish passage;
- key areas of concern (e.g., habitat degradation, erosion);
- previously undertaken fish habitat enhancement projects; and
- future potential restoration and enhancement opportunities.

In addition to the field inventory, the following assessments of environmental values were also completed:

- an analysis of the riparian corridor and overall forest cover in the watersheds, including calculations of Riparian Forest Integrity (RFI) for sub-catchments;
- an overview assessment of terrestrial species and wildlife habitat, including species at risk and invasive species; and
- a review of available water quality and benthic invertebrate sampling data and ongoing water quality monitoring programs.

Depending on the assessment task, the work included collation and review of existing information, field inventories, and data summarization and analysis.

Field inventory data and detailed methodology is provided in Appendix C. Detailed methodology and findings will be included in the final report. Figures 3-1 to 3-7 present the findings of the environmental inventory and assessment.

3.2 Key Findings

Key findings of the environmental inventory and assessment are included in the table below

Table 3-1: Key Findings of Environmental Inventory and Assessment.

Fish Community	**Brothers** supports 10 species of fish, including four species of anadromous salmon (Coho, Chum, Chinook, and Pink) and two species of trout (Cutthroat Trout and Rainbow Trout). **Hadden** provides habitat for Coho, Chum, Chinook, and Pink salmon, as well as Cutthroat Trout. **Vinson** has records of Cutthroat Trout. Multiple barriers at the mouth of Vinson and extensive habitat alteration can explain the absence of salmon from this watershed. No recorded salmon returns to Vinson Creek in recent past (all piped systems at ocean).
Instream Aquatic Habitat	**Brothers**: Spawning gravels throughout. Moderate rearing habitat throughout lower watershed and north of Upper Levels Highway (Highway 1). Excellent rearing habitat in West Brothers Creek and main stem upstream of Upper Levels Highway. **Hadden**: Spawning gravels throughout. Sections of high quality fish habitat including rearing habitat. **Vinson**: Overall marginal to poor fish habitat.
Barriers to Fish Mitigation	**Brothers:** Seven definite barriers and eight potential barriers. **Hadden:** Four definite barriers and four potential barriers. **Vinson:** Four definite barriers and one potential barrier.
Riparian Corridor	Overall watershed Riparian Forest Integrity is 57%. Brothers watershed has the highest RFI at 70% followed by Hadden at 60% and Vinson at approximately 20%.
Terrestrial Habitat	Forested habitat is contiguous and largely intact above the UCB. Some large forest patches (ranging from 2.2 to 15.3 ha in size) in Brothers and Hadden watersheds below the UCB. Vinson has been heavily urbanized and lacks significant forest patches. There is a total of 580.3 ha (47.6%) of forest cover across the three watersheds
Wildlife	Wildlife known in the study area include Black Bear, River Otter, Beaver, Coyote, Great Blue Heron, American Dipper, Belted Kingfisher, Ensatina, and Western Red-backed Salamander, among others.
Invasive Species	Several invasive plant species are common throughout the study area, including Himalayan blackberry, cherry laurel, spurge laurel, English ivy, common periwinkle, and lamium (yellow archangel). Specific UTM locations of giant hogweed (9 locations) and knotweed (38 locations) were recorded.

Species at Risk	Five species at risk known to occur in the study area: Coastal Cutthroat Trout, Coastal Tailed Frog, Northern Red-legged Frog, Great Blue Heron, and Green Heron.
Water Quality and Benthic Invertebrates	WVSK has monitored water temperatures continuously from April 2011 to present at four sites. No other water quality or benthic invertebrate data was available. Water quality is impaired, likely due to stormwater runoff from developed areas.
Overall Status	**All creeks** were classified as endangered (DFO 1997) due to impacts of urbanization: channelization, extensive culverts on creeks, and watershed effective impervious area higher than 10%. **Vinson** is extensively culverted and has poor RFI.

3.3 Environmental Priority Issues

The following priority issues were identified:

- **Contamination risk from sewer line:** Sewer line crossings in **Brothers Creek** and **Hadden Creek** pose risks to **water quality** due to leakage or a sewer line break**.**
- **Water quality impacts of stormwater runoff:** Outfalls and non-point source runoff may be detrimental to water quality, especially around the Upper Levels Highway and Taylor Way.
- **Fish passage:** In **Hadden Creek**, culverts downstream of and within the Capilano Golf and Country Club currently prevent fish access to high quality spawning and rearing habitat within the golf course and farther upstream. Culverts on some smaller tributaries in the **Brothers Creek** watershed also prevent access to potential anadromous fish habitat.
- **Riparian forest cover:** Overall riparian forest cover is moderate for an urban watershed. There is poor riparian cover in some areas, especially on **Vinson Creek** and in the **upper reaches of Brothers Creek and Hadden Creek** near the UCB.
- **Riparian encroachment and development setbacks:** Past and current development is encroaching on riparian areas, causing a loss of riparian vegetation. It is understood that the District's current riparian protection approach is under review by staff for possible changes required to be in compliance with the Province's Riparian Areas Regulation (RAR).
- **High priority invasive species:** A significant number of locations of giant hogweed and knotweed were found in the study area. These species have been identified as high priority for control by the District due to their potential to affect human health, damage infrastructure, and degrade natural ecosystems.

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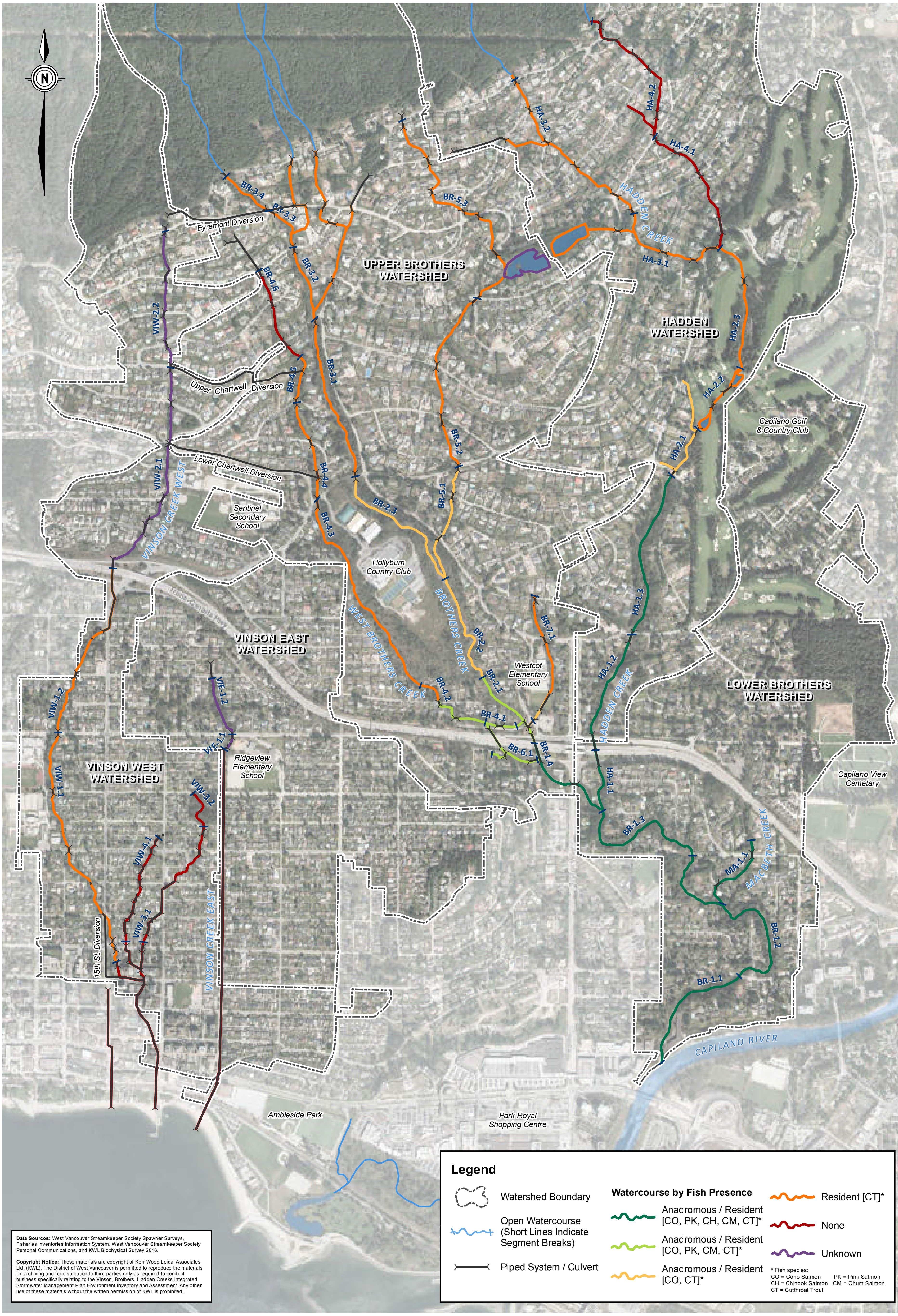

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Project No.	Date
409-073	March, 2017

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Fish Distributions

Figure 3-1

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409-073	March, 2017

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Barriers to Fish Migration

Figure 3-2

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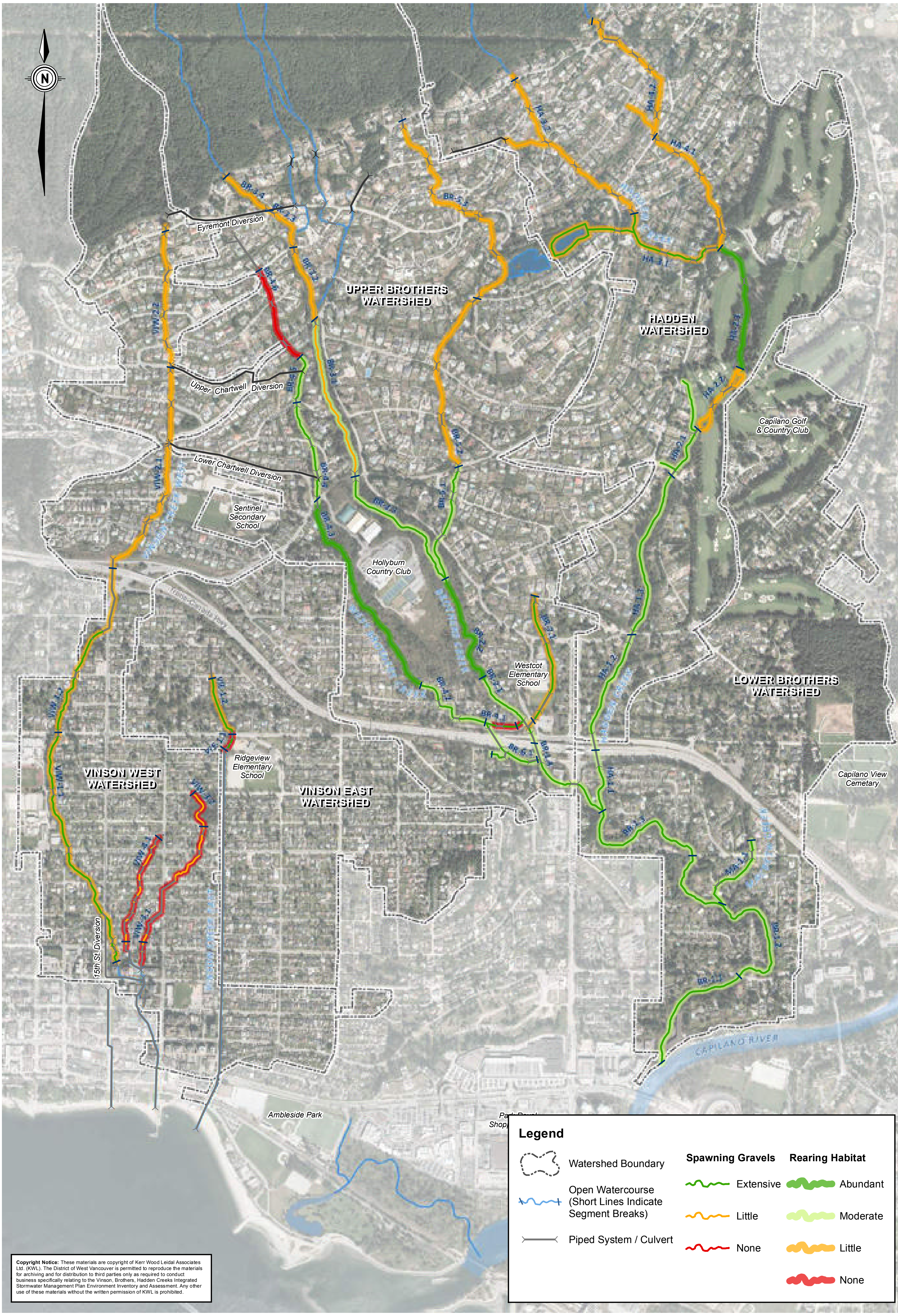

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409-073	March, 2017

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Salmonid Spawning and Rearing Habitat

Figure 3-3

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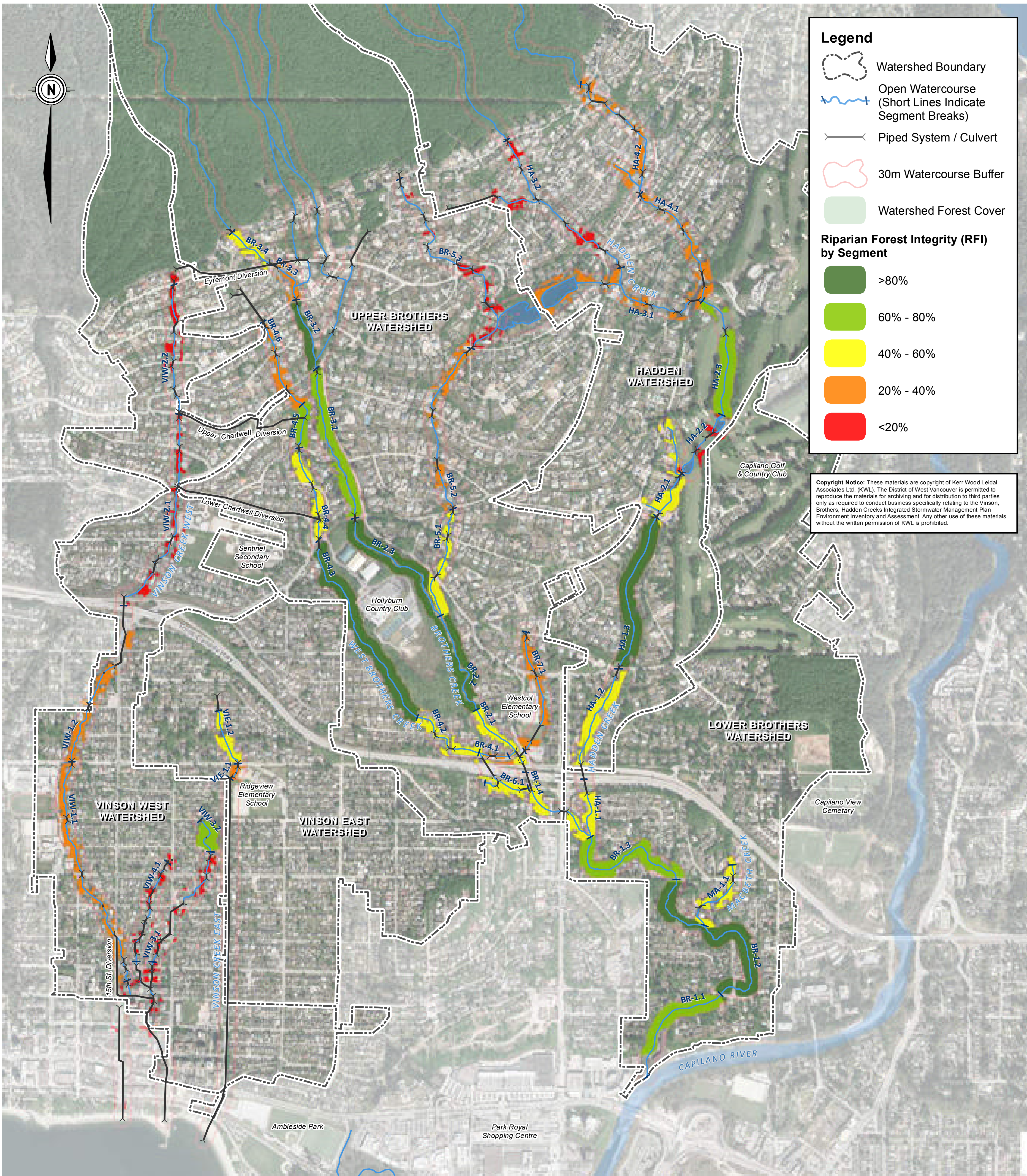

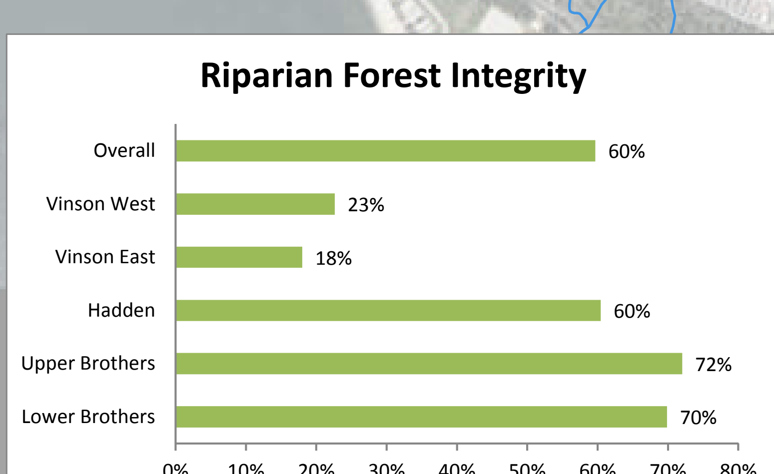

Riparian Forest Integrity (%)			
Catchment	Total forested riparian area (ha)	Total riparian area (ha)	Riparian Forest Integrity (%)
Lower Brothers	8	12	70%
Upper Brothers*	75	104	72%
Hadden*	28	47	60%
Vinson East	2	10	18%
Vinson West*	6	28	23%
Overall	**120**	**201**	**60%**

Watershed Forest Cover			
Catchment	Total forested area (ha)	Total area (ha)	% Forested area
Lower Brothers	44	130	34%
Upper Brothers*	370	561	66%
Hadden*	123	268	46%
Vinson East	11	98	11%
Vinson West*	32	158	20%
Overall	**580**	**1219**	**48%**

* Includes areas above urban containment boundary.

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Project No. 409-073

Date March, 2017

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Riparian and Watershed Forest Cover

Figure 3-4

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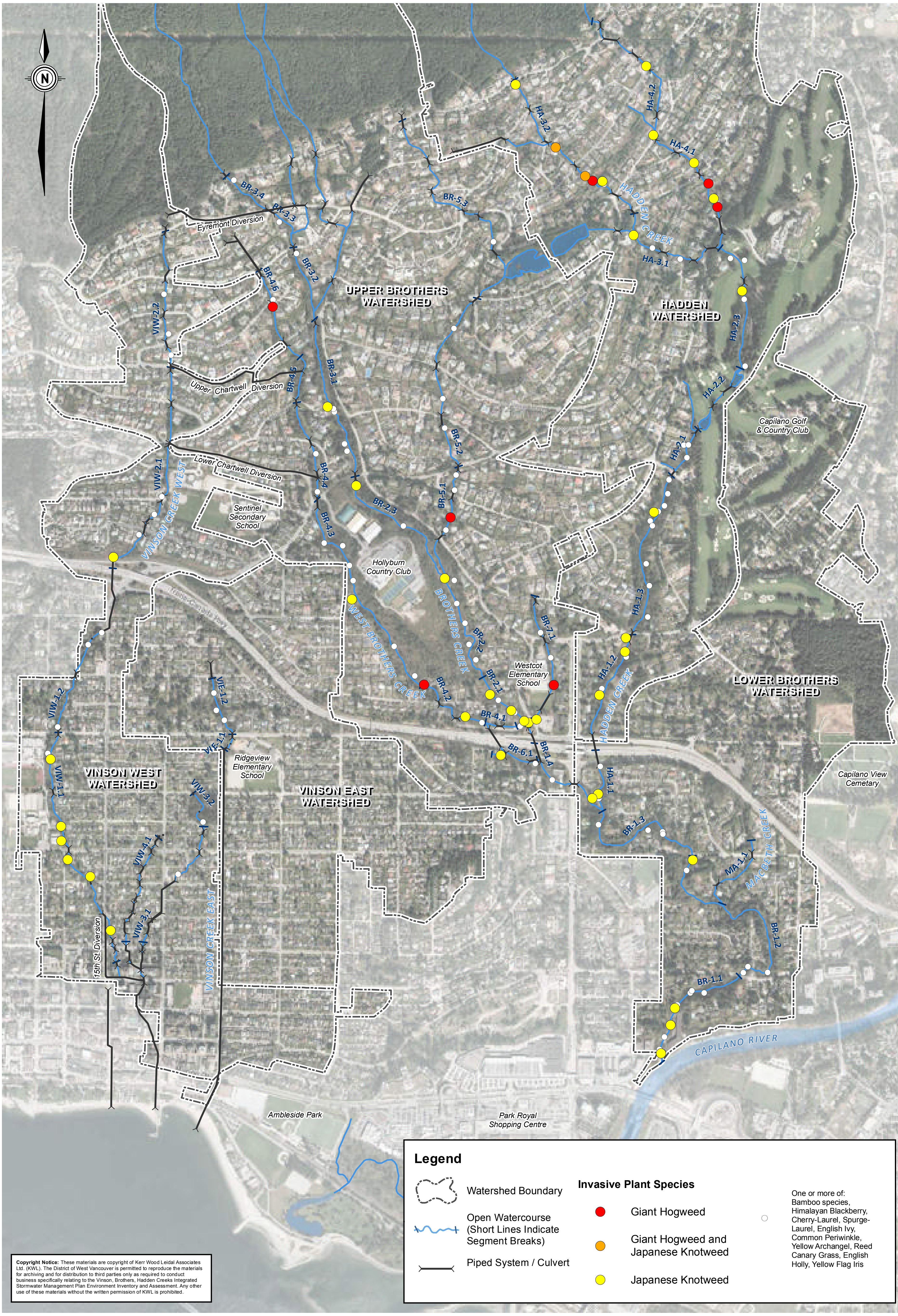

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Project No.	Date
409-073	March, 2017

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High Priority Or Dangerous Invasive Plant Species

Figure 3-5

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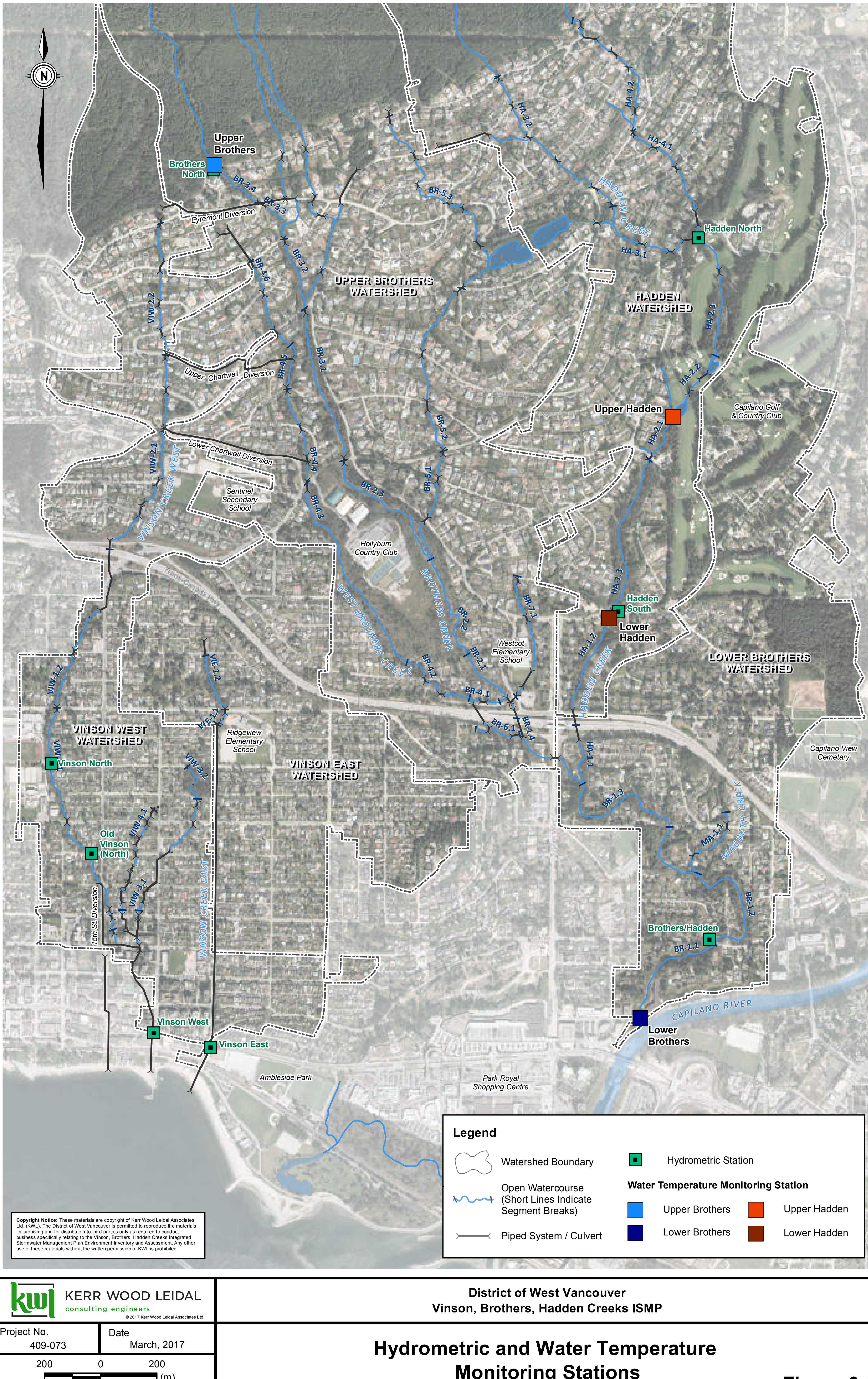

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Project No.	Date
409-073	March, 2017

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Hydrometric and Water Temperature Monitoring Stations

Figure 3-6

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Enhancement Opportunities and Priority Environmental Points of Concern

Figure 3-7

4. Modelling and Engineering Assessments

Hydrologic and hydraulic modelling using PCSWMM software was undertaken for the entire Vinson, Brothers, and Hadden Creek watersheds and their major drainage systems.

4.1 Model Development and Calibration

The model includes 12 undeveloped catchments (above the UCB), 3,642 urban catchments, 199 road catchments, 161 conduits, 297 nodes, 2 storage facilities, and all the creek and major tributary channels within the study area. Models were created for both existing and future (unmitigated) land use conditions. This section briefly describes the modelling for this ISMP, and further details of the modelling and calibration process are available in Appendix D.

Rainfall Data

The table below summarizes rainfall monitoring stations in the vicinity of the study area.

Table 4-1: Rainfall Monitoring Stations in Vicinity of Study Area

Station	Location	Elevation	Operated By
VW14	District of West Vancouver Municipal Hall	41 m	Metro Vancouver
District Works Yard	Cypress Bowl Road, near Upper Levels Highway	200 m	District of West Vancouver
VW51	Capilano Golf and Country Club	201 m	Metro Vancouver
Bonnymuir	North of Bonnymuir Drive and Bonnymuir Place	~270 m	District of West Vancouver
Cypress Ranger Station	Cypress Bowl Road, near Cypress Mountain Ski Area	930 m	District of West Vancouver

Recorded storm events at Cypress Ranger Station and District of West Vancouver Municipal Hall (VW14) were used for calibration. These stations were selected for their consistency of record and proximity to the study area. VW14 rainfall data was applied to catchments from 0 – 100 m elevation, and scaled by a factor of 1.45 and applied to catchments from 100 – 400 m elevation. Cypress Ranger Station rainfall data was applied to catchments greater than 400 m in elevation.

Topography

Topography information was based on 2011 contour data provided by the District. A Digital Elevation Model (DEM) was created from the contours and used to cut transects along the creeks. Cross-sections were refined based on typical creek cross-sections identified during the engineering and environmental watershed inventories.

Calibration Data

The existing conditions model was calibrated and validated using flow monitoring data collected at the following hydrometric stations:

- Brothers North
- Hadden North
- Hadden South
- Vinson North
- Vinson West

The flow monitoring stations have been in operation and recording data since 2012. The Brothers Creek gauge below the confluence with Hadden Creek was not used for calibration as it was found that the stage-discharge curve for the gauge requires revision for the flows to be consistent with gauged flows from the upper watersheds. The Vinson East gauge was not used due to inconsistencies in its flow record.

Unit Peak Flows

Peak flows were compared against a KWL database of calibrated model peak flows for similar creeks to confirm the model is producing expected results. As shown in the table below, 200-year peak flows for existing land use produced at four different locations within the watersheds are in line with estimates for similar creeks.

Table 4-2: Unit Peak Flow Comparison

Location	200-Year Unit Peak Flow ($m^3/s/ha$)
Undeveloped Catchments	
Brothers Main / Centre Branch at 1200 ft. contour (240 ha, 0% TIA)	**0.0789**
McDonald West Branch at 1200 ft. contour (69 ha, 0% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0809
Lawson East Branch/Main Branch at 1200 ft. contour (129 ha, 0% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0827
Partially Developed Catchments	
McDonald West Branch at Upper Levels Highway (119 ha, 19% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0372
Hadden Creek at Upper Levels Highway (268 ha, 32% TIA)	**0.0395**
McDonald East Branch at Upper Levels Highway (54 ha, 25% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0536
Brothers Main / Centre Branch at Upper Levels Highway (483 ha, 17% TIA)	**0.0620**
Lawson Creek at Outlet to Burrard Inlet (243 ha, 15% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0716
McDonald Creek at Outlet to Burrard Inlet (374 ha, 17% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0719
Mackay Creek at Montroyal Boulevard (307 ha, 16% TIA) - *2016 Mackay and Mosquito Creeks ISMP, Draft*	0.0749
Vinson East Branch at Outlet to Burrard Inlet (97 ha, 53% TIA)	**0.0894**

4.2 Hydrotechnical Assessment

Design Events

The calibrated model was used to simulate 2-, 5-, 10-, 100-, and 200-year return period 1-, 2-, 4-, 6-, 12-, and 24-hour duration design events and to determine governing duration peak flows and volumes for each conduit. The District employs the 200-year return period design event for assessment of their creeks. This is consistent with provincial guidelines for flood protection recommended by the Ministry of Environment (MOE, 2004). Major system conduits were therefore assessed on their ability to pass the 200-year event, while the 2-year to 100-year rainfall events were used to determine existing levels of service.

The design rainfall for the analysis was based on the existing IDF curves for the GVRD West Vancouver Municipal Hall gauge VW14. Design storms were developed based on the Atmospheric Environmental Services (AES) Pacific Coastal distribution; the 30th percentile curve was applied to the short duration storms (1-, 2-, and 4-hours), and the 50th percentile curve was applied to the longer duration storms (6-, 12-, and 24-hours).

Scale factors of 1.45 and 1.9 were applied to the rainfall depths for elevations between 100 m and 400 m, and greater than 400 m, respectively. The 200-year design storms were created by multiplying the 100-year design storm rainfall depths by 1.15 and adding a snowmelt allowance of 40 mm per day snow water equivalent (SWE) for elevations greater than 400 m.

To account for projected increases in rainfall due to climate change, a factor of 1.1 was applied to all rainfall depths for the modelled climate change scenarios.

The short duration storm events (<6 hours), typically convective summer storms, were modelled using unsaturated soil conditions. The longer duration storm events (≥6 hours), which typically occur in the winter months when the soil doesn't have sufficient time to dry out between storm events, were modelled using saturated soil conditions.

Model Results

Major System Conduits

Major system conduits include creek culverts, piped sections of creek, and diversions. All major system conduits were assessed on their ability to pass the 200-year instantaneous peak flow under both existing and future land use without surcharging. Surcharging refers to the condition when the water level at a node is higher than the crown of any connected conduit. The analysis assumed that there are no constrictions upstream of those identified and therefore the flow peaks were able to reach these pipes. In actuality, the predicted flow may only reach these pipes once the upstream conveyance system is upgraded. The results of the capacity assessment are shown in Table 4-3. Figure 4-1 shows the locations of conduits and identifies those that are undersized for existing and future flows as well as indicating where flooding is predicted at the 200-year return period. In Table 4-3, the capacity of a conduit to convey the 200-year instantaneous peak flow is expressed as a ratio of the 200-year peak flow (existing, future, and future with climate change) to the existing culvert/pipe capacity (q/Q). A q/Q ratio greater than 1 signifies that the pipe/culvert is undersized for that scenario. It does not, however, convey any information about the depth of surcharge or flooding.

Upgrades for those conduits found to have insufficient capacity were sized to pass the 200-year future land use with climate change peak flow. It was assumed that diversions, where undersized, would not be upgraded to accommodate the 200-year peak flows, and instead excess flows would continue down the creek. Required upgrade sizes are reported in Table 4-3.

To assist with the prioritization of upgrades, the 2-, 5-, 10-, 25-, 50-, and 100- year design storms were modelled to determine the existing service level of all major system conduits. Existing service levels are reported in Table 4-3 and shown on Figure 4-2.

Of the 159 major system conduits in the Vinson, Brothers, and Hadden watersheds: 108 are undersized for the 200-year existing land use scenario, four more are undersized for the future land use scenario, and two more conduits are undersized for the future land use with climate change scenario.

Based on the service level assessment, 45 conduits (~28%) are providing an existing service level of 100 years or greater, 54 conduits (~34%) are providing an existing service level between 10 and 100 years, and 49 conduits (~31%) are providing a service level of less than 10-year return period. Of most concern are the 6 conduits providing a service level of less than 2 years, and the 11 conduits providing unknown service levels due to insufficient information on culvert size and invert elevations.

Bridges

Similar to the major system conduits, bridges were assessed on their ability to pass the 200-year peak flow without surcharging. Five major road bridges were identified during the engineering inventory and survey, all of which were predicted by the modelling to be able to convey the 200-year peak flows for existing land use, future land use, and future land use with climate change.

Table 4-3: Major System Conduits Capacity Assessment

Conduit ID	Description	Existing Size	Existing Capacity (m³/s)	200-yr Instantaneous Peak Flow (m³/s)			200-yr Peak Flow vs. Capacity (q/Q)			Existing Level of Service	Required Upgrade Size
				Existing Land Use	Future Land Use	Future Land Use with Climate Change	Existing Land Use	Future Land Use	Future Land Use with Climate Change		
C152_1	Culvert	UNKNOWN	-	8.54	10.93	11.27	-	-	-	UNKNOWN	2.4 m ⌀
KWL996	Culvert	UNKNOWN	-	6.60	8.06	8.06	-	-	-	UNKNOWN	2.1 m ⌀
KWL997	Culvert	UNKNOWN	-	8.64	10.43	10.99	-	-	-	UNKNOWN	2.4 m ⌀
KWL998	Culvert	UNKNOWN	-	9.13	10.93	11.78	-	-	-	UNKNOWN	3.05 m ⌀
C198	Culvert	UNKNOWN	-	2.67	3.14	3.34	-	-	-	UNKNOWN	1.5 m ⌀
KWL999	Culvert	UNKNOWN	-	4.30	4.46	5.19	-	-	-	UNKNOWN	1.8 m ⌀
C197	Culvert	UNKNOWN	-	4.40	5.28	5.77	-	-	-	UNKNOWN	2.1 m ⌀
C2	Culvert	UNKNOWN	-	1.99	3.15	3.57	-	-	-	UNKNOWN	1.65 m ⌀
C244	Culvert	UNKNOWN	-	1.44	2.08	2.08	-	-	-	UNKNOWN	1.35 m ⌀
C241	Culvert	UNKNOWN	-	1.34	1.34	2.03	-	-	-	UNKNOWN	1.35 m ⌀
496	Culvert	UNKNOWN	-	2.77	3.48	3.76	-	-	-	UNKNOWN	1.65 m ⌀
296	Culvert	0.15 m ⌀	0.01	2.27	2.27	2.37	204.3	204.6	213.1	<2yr	1.35 m ⌀
292	Culvert	0.3 m ⌀	0.06	2.45	2.46	2.47	39.0	39.1	39.2	<2yr	1.35 m ⌀
444	Culvert	0.75 m ⌀	0.62	4.79	4.95	5.36	7.7	8.0	8.6	<2yr	1.8 m ⌀
453	Culvert	0.75 m ⌀	0.62	4.79	4.93	5.35	7.7	7.9	8.6	<2yr	1.8 m ⌀
460	Culvert	0.75 m ⌀	0.62	4.73	4.74	5.26	7.6	7.6	8.5	<2yr	1.8 m ⌀
385	Culvert	0.9 m ⌀	0.57	2.85	3.33	3.57	5.0	5.8	6.2	<2yr	1.8 m ⌀
347	Culvert	0.75 m ⌀	0.62	7.09	7.98	8.94	11.4	12.8	14.4	2yr	2.4 m ⌀
471	Culvert	0.75 m ⌀	0.62	5.07	5.93	6.67	8.1	9.5	10.7	2yr	2.1 m ⌀
423	Culvert	0.75 m ⌀	0.62	4.57	5.77	5.84	7.4	9.3	9.4	2yr	2.1 m ⌀
404	Culvert	0.66 m x 0.9 m elliptical (squished circular)	0.98	5.07	5.93	10.13	6.8	6.0	10.3	2yr	2.4 m ⌀
349	Culvert	0.9 m ⌀	0.98	6.51	8.24	8.89	6.6	8.4	9.1	2yr	2.4 m ⌀
Kwl1005	Culvert	0.75 m ⌀	0.62	4.05	4.79	5.15	6.5	7.7	8.3	2yr	1.8 m ⌀
408	Culvert	1.05 m ⌀	1.44	8.71	9.71	10.30	6.0	6.7	7.1	2yr	2.4 m ⌀
407	Culvert	1.05 m ⌀	1.44	8.61	9.63	10.26	6.0	6.7	7.1	2yr	2.4 m ⌀
414_1	Culvert	0.9 m ⌀	0.98	5.81	6.60	6.99	5.9	6.7	7.1	2yr	2.1 m ⌀
470	Culvert	0.9 m ⌀	0.98	5.22	6.01	7.33	5.3	6.1	7.5	2yr	2.1 m ⌀
465	Culvert	0.9 m ⌀	0.98	5.08	5.84	7.25	5.2	6.0	7.4	2yr	2.1 m ⌀
318	Culvert	0.9 m ⌀	0.98	4.93	5.71	6.51	5.0	5.8	6.6	2yr	2.1 m ⌀
411	Culvert	1.2 m ⌀	2.02	8.63	9.99	10.92	4.3	5.0	5.4	2yr	2.4 m ⌀

Table 4-3: Major System Conduits Capacity Assessment

Conduit ID	Description	Existing Size	Existing Capacity (m^3/s)	200-yr Instantaneous Peak Flow (m^3/s)			200-yr Peak Flow vs. Capacity (q/Q)			Existing Level of Service	Required Upgrade Size
				Existing Land Use	Future Land Use	Future Land Use with Climate Change	Existing Land Use	Future Land Use	Future Land Use with Climate Change		
415	Culvert	1.2 m ⌀	2.02	8.74	10.34	10.99	4.3	5.1	5.5	2yr	2.4 m ⌀
393	Culvert	0.75 m ⌀	0.62	2.67	2.98	3.42	4.3	4.8	5.5	2yr	1.5 m ⌀
437	Culvert	0.75 m ⌀	0.62	2.64	2.92	3.30	4.2	4.7	5.3	2yr	1.5 m ⌀
Kwl1003	Culvert	0.6 m ⌀	0.36	1.36	1.73	2.13	3.8	4.9	6.0	2yr	1.35 m ⌀
440	Culvert	0.75 m ⌀	0.62	2.37	2.92	3.23	3.8	4.7	5.2	2yr	1.5 m ⌀
379	Culvert	1.05 m ⌀	1.44	5.47	6.36	6.98	3.8	4.4	4.8	2yr	2.1 m ⌀
490	Culvert	0.9 m ⌀	0.98	3.66	4.34	4.90	3.7	4.4	5.0	2yr	1.8 m ⌀
375	Culvert	1.05 m ⌀	1.44	5.37	6.15	6.67	3.7	4.3	4.6	2yr	2.1 m ⌀
493	Culvert	0.75 m ⌀	0.62	2.24	2.25	2.35	3.6	3.6	3.8	2yr	1.35 m ⌀
381	Culvert	1.05 m ⌀	1.44	5.18	5.96	6.90	3.6	4.1	4.8	2yr	2.1 m ⌀
409	Culvert	0.6 m ⌀	0.36	1.24	1.45	1.55	3.5	4.1	4.3	2yr	1.2 m ⌀
425	Culvert	0.9 m ⌀	0.98	3.38	3.92	4.11	3.4	4.0	4.2	2yr	1.65 m ⌀
455	Culvert	0.6 m ⌀	0.36	1.17	1.18	1.76	3.3	3.3	4.9	2yr	1.2 m ⌀
438	Culvert	1.1 m ⌀	1.62	5.34	5.42	6.04	3.3	3.3	3.7	2yr	2.1 m ⌀
Kwl1001	Culvert	0.6 m ⌀	0.36	1.11	1.12	1.37	3.1	3.1	3.8	2yr	1.05 m ⌀
414_2	Culvert	1.2 m ⌀	2.02	5.90	6.56	7.11	2.9	3.3	3.5	2yr	2.1 m ⌀
Kwl1000	Culvert	0.6 m ⌀	0.36	1.04	1.04	1.44	2.9	2.9	4.0	2yr	1.05 m ⌀
KWL016	Culvert	3 @ 0.6 m ⌀	0.98	5.07	5.93	6.67	5.2	6.0	6.8	5yr	2 @ 1.35 m ⌀, 1 @ 1.05 m ⌀
474 and 474_2	Culvert	0.75 m ⌀ and 0.6 m ⌀	0.98	5.01	5.80	10.50	5.1	5.9	10.7	5yr	2.1 m ⌀, 1.65 m ⌀
419	Culvert	1.2 m ⌀	2.02	8.10	9.49	10.33	4.0	4.7	5.1	5yr	2.4 m ⌀
431	Culvert	0.75 m ⌀	0.62	2.24	2.40	2.68	3.6	3.9	4.3	5yr	1.35 m ⌀
476	Culvert	0.75 m ⌀	0.62	1.81	1.95	2.20	2.9	3.1	3.5	5yr	1.35 m ⌀
Kwl1004	Culvert	0.75 m ⌀	0.62	1.73	2.17	2.38	2.8	3.5	3.8	5yr	1.35 m ⌀
405	Culvert	2 m x 3 m box	11.69	33.12	34.27	38.60	2.8	2.9	3.3	5yr	3 @ 3.05 m x 2.44 m box
555_2	Culvert	0.5 m ⌀	0.23	0.61	0.69	0.74	2.7	3.0	3.3	5yr	0.9 m ⌀
KWL011	Culvert	0.75 m ⌀	0.62	1.69	1.95	2.04	2.7	3.1	3.3	5yr	1.35 m ⌀
KWL008	Culvert	0.9 m ⌀	0.98	2.64	3.31	3.65	2.7	3.4	3.7	5yr	1.65 m ⌀
KWL501	Culvert	2.25 m x 3 m box	13.89	33.49	34.77	39.51	2.4	2.5	2.8	5yr	3 @ 3.05 m x 2.44 m box

Table 4-3: Major System Conduits Capacity Assessment

Conduit ID	Description	Existing Size	Existing Capacity (m^3/s)	200-yr Instantaneous Peak Flow (m^3/s)			200-yr Peak Flow vs. Capacity (q/Q)			Existing Level of Service	Required Upgrade Size
				Existing Land Use	Future Land Use	Future Land Use with Climate Change	Existing Land Use	Future Land Use	Future Land Use with Climate Change		
KWL012	Culvert	1.05 m ⌀	1.44	3.37	4.12	4.22	2.3	2.9	2.9	5yr	1.65 m ⌀
417	Culvert	2 m x 3 m box	11.70	25.63	25.89	28.92	2.2	2.2	2.5	5yr	3 @ 2.7 m x 1.5 m box
C97	Culvert	0.5 m ⌀	0.23	1.05	1.42	2.06	4.6	6.3	9.1	10yr	1.35 m ⌀
304	Culvert	0.45 m ⌀	0.17	0.77	1.36	1.57	4.5	7.9	9.1	10yr	1.2 m ⌀
297	Culvert	0.5 m ⌀	0.23	0.81	1.39	1.95	3.6	6.2	8.7	10yr	1.2 m ⌀
310	Culvert	0.5 m ⌀	0.23	0.79	1.36	1.59	3.5	6.0	7.0	10yr	1.2 m ⌀
314	Culvert	0.5 m ⌀	0.23	0.69	1.08	1.38	3.0	4.8	6.1	10yr	1.05 m ⌀
319	Culvert	0.5 m ⌀	0.23	0.59	0.89	1.03	2.6	3.9	4.6	10yr	1.05 m ⌀
307	Culvert	0.6 m ⌀	0.36	0.86	1.36	1.46	2.4	3.8	4.1	10yr	1.2 m ⌀
KWL014	Culvert	0.5 m ⌀	0.23	0.53	0.76	0.78	2.3	3.4	3.4	10yr	0.9 m ⌀
555	Culvert	0.75 m ⌀	0.62	1.33	1.49	1.62	2.1	2.4	2.6	10yr	1.2 m ⌀
492	Culvert	0.9 m ⌀	0.98	1.99	2.34	2.42	2.0	2.4	2.5	10yr	1.35 m ⌀
KWL005	Culvert	0.9 m ⌀	0.98	1.97	2.49	2.77	2.0	2.5	2.8	10yr	1.5 m ⌀
402	Culvert	2.25 m x 3.5 m box	17.46	33.55	34.77	39.13	1.9	2.0	2.2	10yr	3 @ 3.05 m x 2.44 m box
394	Culvert	0.75 m ⌀	0.62	1.21	1.21	1.42	1.9	1.9	2.3	10yr	1.05 m ⌀
KWL021	Culvert	0.6 m ⌀	0.36	0.69	1.15	1.44	1.9	3.2	4.0	10yr	1.05 m ⌀
361	Culvert	1.8 m ⌀	5.56	10.60	13.96	15.65	1.9	2.5	2.8	10yr	3.05 m ⌀
C4	Culvert	0.6 m ⌀	0.36	0.68	1.08	1.48	1.9	3.0	4.2	10yr	1.2 m ⌀
KWL009_1	Culvert	1.1 m ⌀	1.62	3.03	3.77	4.12	1.9	2.3	2.5	10yr	1.65 m ⌀
316	Culvert	0.6 m ⌀	0.36	0.65	1.03	1.24	1.8	2.9	3.5	10yr	1.05 m ⌀
355	Culvert	1.5 m ⌀	3.52	6.30	8.38	8.89	1.8	2.4	2.5	10yr	2.4 m ⌀
500	Culvert	0.9 m ⌀	0.98	1.75	2.29	2.29	1.8	2.3	2.3	10yr	1.35 m ⌀
317	Culvert	0.45 m ⌀	0.17	0.30	0.54	0.55	1.7	3.1	3.2	10yr	0.75 m ⌀
416	Culvert	1.2 m ⌀	2.02	3.36	4.19	4.39	1.7	2.1	2.2	10yr	1.65 m ⌀
388	Culvert	1.2 m ⌀	2.02	3.36	3.36	3.83	1.7	1.7	1.9	10yr	1.65 m ⌀
434	Culvert	2.3 m x 3.2 m box	15.04	25.56	25.73	28.60	1.7	1.7	1.9	10yr	2 @ 3.05 m x 2.44 m box
391	Culvert	1.2 m ⌀	2.02	3.31	3.31	3.77	1.6	1.6	1.9	10yr	1.65 m ⌀
372	Culvert	1.35 m ⌀	2.71	4.32	4.55	5.44	1.6	1.7	2.0	10yr	1.8 m ⌀
2977	Diversion	0.75 m ⌀	0.62	0.98	0.98	1.08	1.6	1.6	1.7	10yr	-

Table 4-3: Major System Conduits Capacity Assessment

Conduit ID	Description	Existing Size	Existing Capacity (m^3/s)	200-yr Instantaneous Peak Flow (m^3/s)			200-yr Peak Flow vs. Capacity (q/Q)			Existing Level of Service	Required Upgrade Size
				Existing Land Use	Future Land Use	Future Land Use with Climate Change	Existing Land Use	Future Land Use	Future Land Use with Climate Change		
371	Culvert	1.35 m ⌀	2.71	4.25	4.40	5.46	1.6	1.6	2.0	10yr	1.8 m ⌀
C92	Culvert	0.75 m ⌀	3.34	5.46	6.19	7.11	1.6	1.9	2.1	10yr	1.05 m ⌀
469_2	Piped	0.9 m ⌀	4.15	6.63	7.89	9.12	1.6	1.9	2.2	10yr	1.35 m ⌀
469_3	Piped	0.9 m ⌀	4.15	6.52	7.75	8.92	1.6	1.9	2.1	10yr	1.2 m ⌀
450	Culvert	1.54 m x 2.4 m box	6.62	9.98	9.99	11.08	1.5	1.5	1.7	10yr	3 @ 2.7 m x 1.5 m box
450_2	Culvert	1.7 m x 2 m box	5.79	9.98	9.99	11.08	1.7	1.7	1.9	10yr	
376	Culvert	1.35 m ⌀	2.71	4.16	4.16	4.91	1.5	1.5	1.8	10yr	1.8 m ⌀
396	Culvert	0.75 m ⌀	0.62	0.94	0.94	1.08	1.5	1.5	1.7	10yr	1.05 m ⌀
KWL500	Culvert	0.9 m ⌀	0.98	1.44	1.81	2.41	1.5	1.8	2.5	10yr	1.35 m ⌀
380	Culvert	1.35 m ⌀	2.71	3.92	4.16	4.91	1.4	1.5	1.8	10yr	1.8 m ⌀
306_1	Diversion	1.2 m ⌀	2.02	2.72	3.24	3.62	1.3	1.6	1.8	10yr	-
384	Culvert	1.35 m ⌀	2.71	3.46	3.46	3.92	1.3	1.3	1.4	10yr	1.65 m ⌀
KWL009_2	Culvert	1.1 m ⌀	1.62	1.92	2.71	3.01	1.2	1.7	1.9	10yr	1.5 m ⌀
377	Culvert	1.5 m ⌀	3.52	4.16	4.16	4.91	1.2	1.2	1.4	10yr	1.8 m ⌀
495_1	Diversion	0.6 m ⌀	1.19	1.42	1.42	1.41	1.2	1.2	1.2	10yr	-
495_8	Diversion	0.525 m ⌀	1.14	1.32	1.33	1.33	1.2	1.2	1.2	10yr	-
495_13	Diversion	0.525 m ⌀	1.19	1.32	1.33	1.33	1.1	1.1	1.1	10yr	-
495_9	Diversion	0.525 m ⌀	1.21	1.32	1.33	1.33	1.1	1.1	1.1	10yr	-
495_3	Diversion	0.6 m ⌀	1.30	1.39	1.39	1.39	1.1	1.1	1.1	10yr	-
495_2	Diversion	0.6 m ⌀	1.33	1.40	1.40	1.41	1.1	1.1	1.1	10yr	-
495_5	Diversion	0.525 m ⌀	1.34	1.33	1.33	1.34	1.0	1.0	1.0	10yr	-
495_6	Diversion	0.525 m ⌀	1.37	1.32	1.33	1.33	1.0	1.0	1.0	10yr	-
495_7	Diversion	0.525 m ⌀	1.40	1.32	1.33	1.33	0.9	0.9	1.0	10yr	-
495_15	Diversion	0.525 m ⌀	1.43	1.32	1.33	1.33	0.9	0.9	0.9	10yr	-
495_4	Diversion	0.6 m ⌀	1.82	1.35	1.35	1.36	0.7	0.7	0.7	10yr	-
2978	Diversion	0.75 m ⌀	2.93	0.98	0.98	1.08	0.3	0.3	0.4	10yr	-
2980	Diversion	0.75 m ⌀	3.16	0.98	0.98	1.08	0.3	0.3	0.3	10yr	-
KWL004	Culvert	2.2 m x 3.4 m box	15.42	20.13	20.18	22.39	1.3	1.3	1.5	100yr	2 @ 2.7 m x 1.5 m box
356	Culvert	1.4 m x 2.1 m box	4.97	5.18	6.52	7.32	1.0	1.3	1.5	100yr	2 @ 2.1 m X 1.2 m box
315	Culvert	0.5 m ⌀	0.23	0.36	0.56	0.81	1.6	2.5	3.6	100yr	0.9 m ⌀

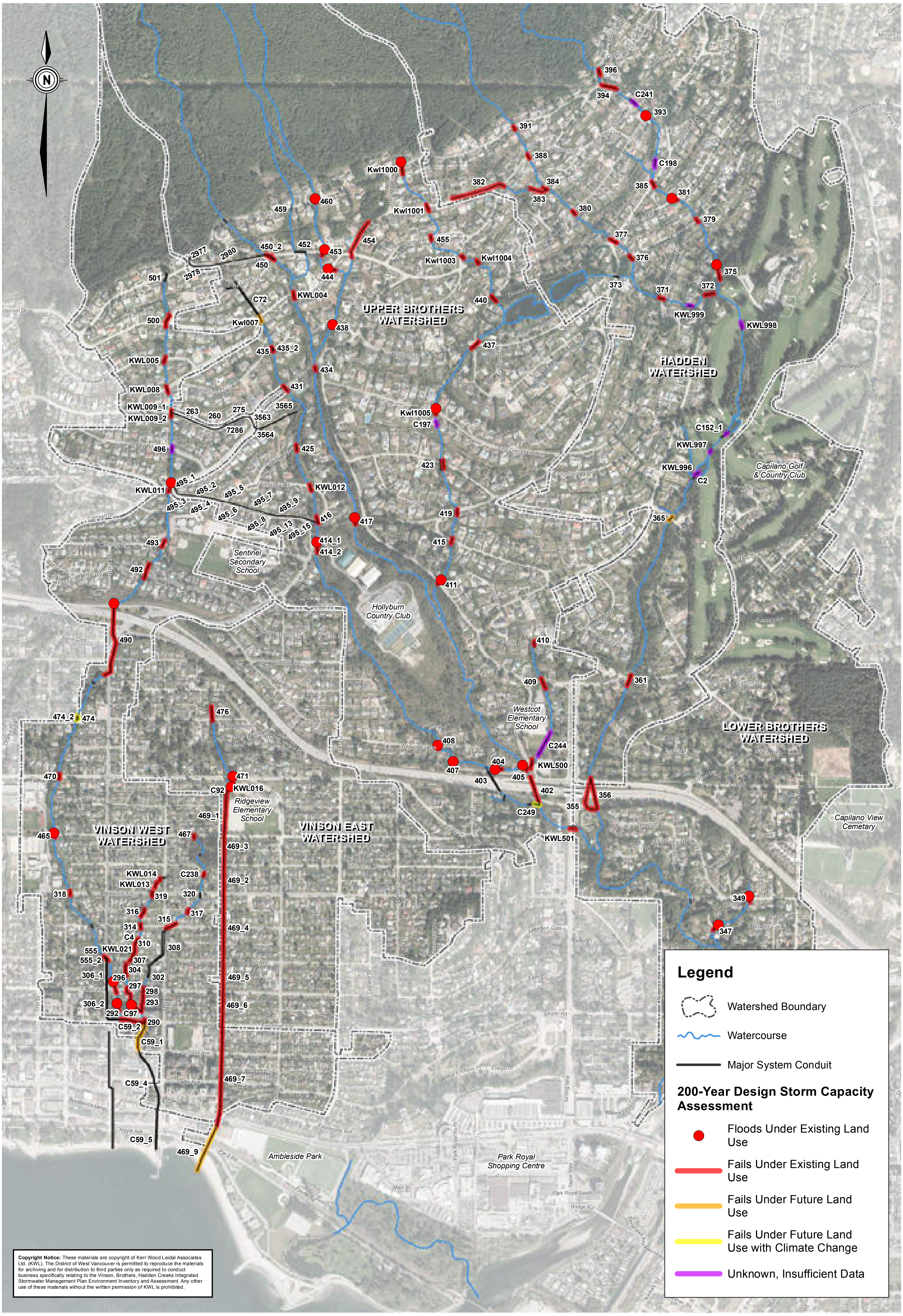
Table 4-3: Major System Conduits Capacity Assessment

Conduit ID	Description	Existing Size	Existing Capacity (m^3/s)	200-yr Instantaneous Peak Flow (m^3/s)			200-yr Peak Flow vs. Capacity (q/Q)			Existing Level of Service	Required Upgrade Size
				Existing Land Use	Future Land Use	Future Land Use with Climate Change	Existing Land Use	Future Land Use	Future Land Use with Climate Change		
C238	Culvert	0.4 m ⌀	0.13	0.20	0.35	0.36	1.5	2.7	2.8	100yr	0.675 m ⌀
467	Culvert	0.4 m ⌀	0.13	0.19	0.29	0.33	1.5	2.2	2.6	100yr	0.6 m ⌀
469_6	Piped	1.05 m ⌀	6.27	8.55	11.01	12.74	1.4	1.8	2.0	100yr	1.5 m ⌀
469_5	Piped	1.05 m ⌀	6.26	8.32	10.59	12.25	1.3	1.7	2.0	100yr	1.5 m ⌀
469_1	Piped	0.9 m ⌀	4.15	5.37	6.09	6.98	1.3	1.5	1.7	100yr	1.2 m ⌀
469_7	Piped	1.05 m ⌀	6.78	8.70	11.47	13.16	1.3	1.7	1.9	100yr	1.35 m ⌀
469_4	Piped	1.05 m ⌀	6.26	7.76	9.65	11.16	1.2	1.5	1.8	100yr	1.35 m ⌀
C59_2	Piped	1.05 m ⌀	3.89	4.67	5.54	6.04	1.2	1.4	1.6	100yr	1.35 m ⌀
298	Culvert	0.75 m ⌀	0.62	0.75	1.34	1.54	1.2	2.2	2.5	100yr	1.2 m ⌀
382	Culvert	0.75 m ⌀	0.62	0.75	0.84	1.06	1.2	1.3	1.7	100yr	1.05 m ⌀
293	Culvert	0.75 m ⌀	0.62	0.74	1.35	1.72	1.2	2.2	2.8	100yr	1.2 m ⌀
383	Culvert	0.75 m ⌀	0.62	0.73	0.87	0.95	1.2	1.4	1.5	100yr	0.9 m ⌀
KWL013	Culvert	0.6 m ⌀	0.36	0.42	0.79	0.80	1.2	2.2	2.2	100yr	0.9 m ⌀
435	Culvert	0.9 m ⌀	0.98	1.12	1.37	1.43	1.1	1.4	1.5	100yr	1.05 m ⌀
454	Culvert	0.6 m ⌀	0.36	0.39	0.54	0.63	1.1	1.5	1.8	100yr	0.9 m ⌀
410	Culvert	0.6 m ⌀	0.36	0.37	0.45	0.51	1.0	1.3	1.4	100yr	0.75 m ⌀
290	Culvert	1.2 m ⌀	2.02	2.10	3.02	3.37	1.0	1.5	1.7	100yr	1.5 m ⌀
469_9	Piped	1.35 m ⌀	9.11	8.68	11.54	13.17	1.0	1.3	1.4	200yr	1.65 m ⌀
Kwl007	Culvert	0.9 m ⌀	0.98	0.91	1.11	1.26	0.9	1.1	1.3	200yr	1.05 m ⌀
260	Culvert	0.525 m ⌀	1.06	0.91	1.06	1.10	0.9	1.0	1.0	200yr	0.6 m ⌀
365	Culvert	2.25 m x 2.45 m box	11.10	9.32	12.25	13.74	0.8	1.1	1.2	200yr	3.05 m x 2.44 m box
C59_1	Piped	1.2 m ⌀	7.66	5.84	7.91	9.22	0.8	1.0	1.2	200yr	1.35 m ⌀
C249	Culvert	1.05 m ⌀	1.44	1.08	1.41	2.44	0.7	1.0	1.7	200yr	1.35 m ⌀
263	Diversion	0.525 m ⌀	1.11	0.91	1.06	1.12	0.8	1.0	1.0	200yr	-
3565	Diversion	0.6 m ⌀	1.24	0.91	1.06	1.10	0.7	0.9	0.9	200yr	-
7286	Diversion	0.525 m ⌀	1.24	0.91	1.06	1.10	0.7	0.9	0.9	200yr	-
275	Diversion	0.525 m ⌀	1.22	0.91	1.06	1.10	0.7	0.9	0.9	200yr	-
C59_5	Piped	1.5 m ⌀	13.88	7.91	10.40	11.96	0.6	0.7	0.9	200yr	-
3564	Diversion	0.6 m ⌀	1.48	0.91	1.06	1.10	0.6	0.7	0.7	200yr	-
452	Culvert	0.75 m ⌀	0.62	0.37	0.45	0.51	0.6	0.7	0.8	200yr	-

Table 4-3: Major System Conduits Capacity Assessment

Conduit ID	Description	Existing Size	Existing Capacity (m^3/s)	200-yr Instantaneous Peak Flow (m^3/s)			200-yr Peak Flow vs. Capacity (q/Q)			Existing Level of Service	Required Upgrade Size
				Existing Land Use	Future Land Use	Future Land Use with Climate Change	Existing Land Use	Future Land Use	Future Land Use with Climate Change		
403	Culvert	0.55 m ⌀	0.29	0.16	0.16	0.16	0.6	0.6	0.6	200yr	-
3563	Diversion	0.6 m ⌀	2.19	0.91	1.06	1.10	0.4	0.5	0.5	200yr	-
308	Culvert	0.5 m ⌀	0.98	0.41	0.61	0.72	0.4	0.6	0.7	200yr	-
302	Culvert	0.9 m ⌀	0.98	0.40	0.61	0.71	0.4	0.6	0.7	200yr	-
C59_4	Piped	1.5 m ⌀	13.87	6.04	8.17	9.46	0.4	0.6	0.7	200yr	-
320	Culvert	0.9 m ⌀	0.98	0.27	0.41	0.48	0.3	0.4	0.5	200yr	-
306_2	Diversion	1.2 m ⌀	10.09	2.72	3.27	3.64	0.3	0.3	0.4	200yr	-
373	Culvert	0.9 m ⌀	0.98	0.26	0.19	0.23	0.3	0.2	0.2	200yr	-
501	Culvert	0.75 m ⌀	0.62	0.08	0.09	0.10	0.1	0.1	0.2	200yr	-
459	Culvert	0.6 m ⌀	0.36	0.03	0.03	0.04	0.1	0.1	0.1	200yr	-
C72	Culvert	1.5 m ⌀	3.52	0.28	0.38	0.44	0.1	0.1	0.1	200yr	-
435_2	Culvert	0.7 m ⌀	0.52	0.00	0.00	0.03	0.0	0.0	0.1	200yr	-

1. Conduit IDs with underscores are pipes that had to be split in the model. Conduit IDs beginning with C or KWL are conduits that were found during the survey or engineering inventory that were not in the District's GIS database.
2. Grey shading represents end of life upgrades only.
3. Assumed that diversions will not be upgraded.



KERR WOOD LEIDAL
consulting engineers

District of West Vancouver
Vinson, Brothers, Hadden Creeks ISMP

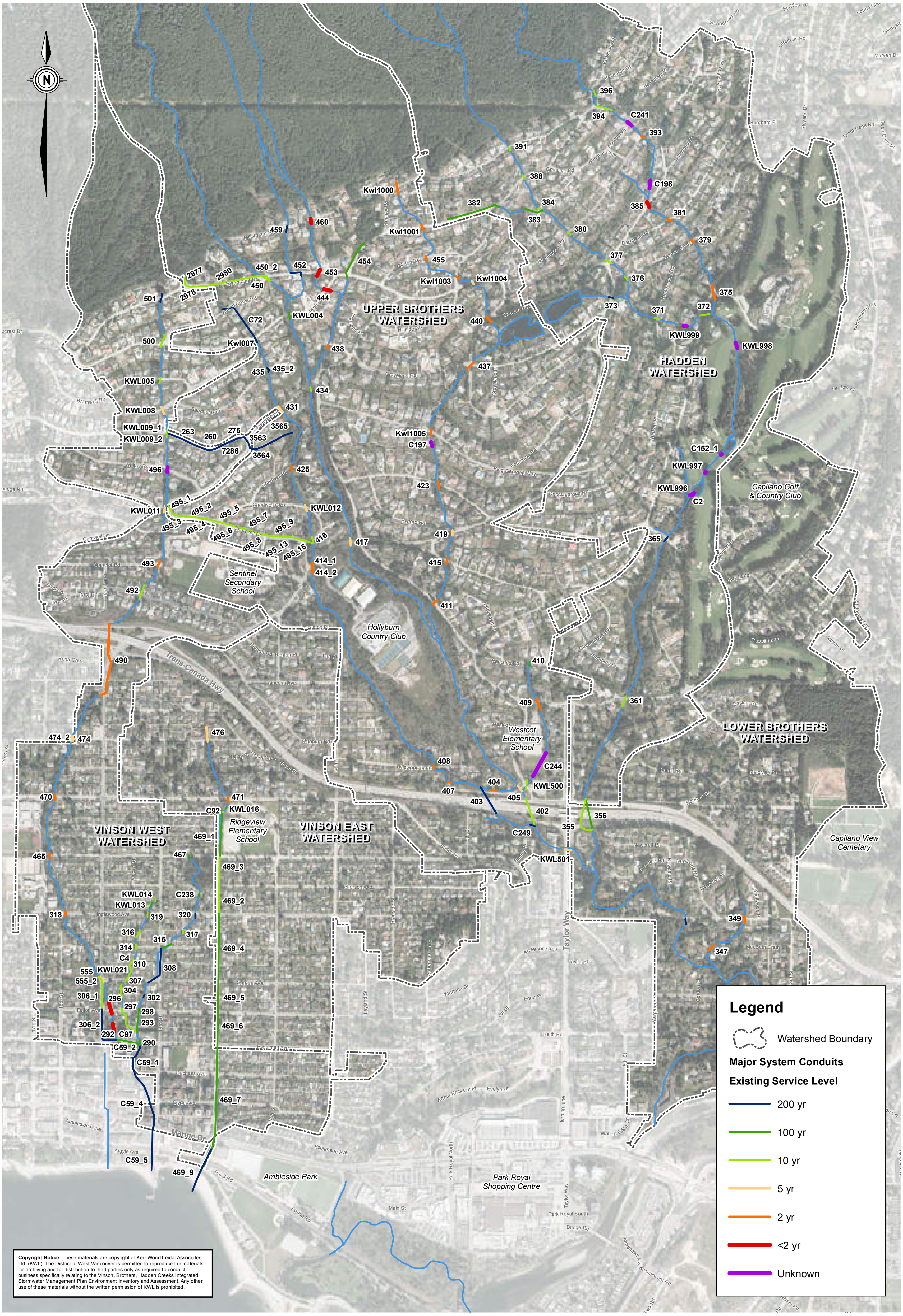
Project No.	Date
409-073	March, 2017

250 0 250 (m)
1:12,500

Major System Conduits Capacity Assessment
200-Year Design Storm

Figure 4-1

Path: O:\0400-0499\409-073\430-GIS\MXD-Rp\Draft Report\409073_Fig4-2_ExModelResults.mxd Date Saved: 22/03/2017 4:27:46 PM
Author: lmorgan



KERR WOOD LEIDAL
consulting engineers

District of West Vancouver
Vinson, Brothers, Hadden Creeks ISMP

Project No. 409-073

Date March, 2017

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Major System Conduits Existing Service Level

Figure 4-2

5. Vision for the Future of the Watersheds

Phase 2 work for the Vinson, Brothers, and Hadden Creeks ISMP involved developing a guiding vision for the future of the study watersheds. Phase 2 of the project included:

- Review of background information,
- Visioning Workshop with internal District of West Vancouver stakeholders,
- Launching project website and public consultation,
- Seeking input and feedback from external stakeholders on draft vision, and
- Finalizing draft vision.

This section of the report presents a description of the work completed in Stage 2, summary of feedback received from internal and external stakeholders, and the proposed watershed vision. Detailed description and discussion of the work, findings, results, and recommendations are provided in Appendix A along with the Stakeholder Consultation Strategy.

5.1 Review of Existing District Guidance and Priorities

KWL reviewed existing background information to develop alternatives for a draft vision and goals for the watershed.

Reviewed information included:

- District's website content namely: District's vision, mission, Council priorities, citizen initiatives, and current projects.
- DWV 2004 Official Community Plan (OCP).
- Upper Lands Study (2015): Recent study that was led by citizens, included extensive stakeholder and community consultation, and defined core values for the upper lands.
- Existing stormwater, environment, drainage, and development related bylaws.

Through the review of the existing information, it became clear that the District:

- Highly values its environmental assets and seeks to be a leader in environmental management by protecting important natural features and restoring natural areas were feasible;
- Strives to develop in a socially, economically, and environmentally sustainable manner. This includes integration of stormwater management in development and servicing;
- Governs collaboratively with its citizens and facilitates citizen participation;
- Values fiscal responsibility; and
- Prioritizes public safety.

Excerpts from existing District documents in support of the findings are included below:

District of West Vancouver's Vision for the municipality (Current)

West Vancouver will inspire excellence and lead by example. Collaborative government and a spirit of personal civic commitment will power the innovations that shape our shared future. The strength of this relationship will secure our treasured quality of life and will be the measure of our success as a community.

District of West Vancouver's Mission (Current)

We champion the opportunities that demonstrate our deep commitment to:

- Foster a sense of shared and individual responsibility for community well-being, social unity, inclusion and respect for our full heritage.
- Protect, restore, and defend our natural environment; legislate efforts to effect positive change.

Official Community Plan Objectives (2004)

Municipal utilities policies in the OCP provide for environmentally and fiscally sustainable services, and are based on the following objectives:

- Support environmentally, socially and economically sustainable development.
- Balance service levels with financial impact.
- Consult with the public in the planning and design process for major works and services. Consider, as a part of the approval process, public safety, potential off-site impacts and the provision of amenities in all infrastructure construction and rehabilitation projects.
- Encourage the integration of road and services layouts wherever possible.

Natural environment policies in the OCP promote environmental stewardship, and are based on the following objectives:

- Protect important natural features: water courses, forests, the shoreline and foreshore and other environmentally sensitive areas and habitats.
- Demonstrate leadership in environmental management, practices and use of resources.
- Integrate storm water management practices with community planning.
- Ensure the safety of people and property from natural hazards in environmentally sensitive areas and creek corridors.
- Develop a thorough understanding of West Vancouver's natural environment in order to maintain and enhance its qualities.

The District's existing mission, vision, and objectives were used as a basis for developing the ISMP vision.

5.2 Visioning Workshop

KWL hosted a visioning workshop on May 31, 2016 at the District of West Vancouver which was attended by internal stakeholders from various Districts' departments. The attendees included managers and staff from engineering, development, planning, and parks. The goal of the visioning workshop was to present the Stage 1 progress to the District and to collaborate with District staff on a watershed vision. The meeting minutes from the visioning workshops is attached. During the workshop participants completed a questionnaire that asked the following three questions:

- What does "Project Vision" mean to you?
- Why do you think the Vision is important?
- In your opinion, what are the top 3 priorities for the Vision for Brothers Vinson Hadden Creeks ISMP?

Four key themes emerged as priorities for the Vinson, Brothers, and Hadden Creeks ISMP. The themes and supporting statements by the District staff are summarized below. The statements are quotes from District staff with the exception of a few edits to add clarity.

Watershed Health/Habitat/Environment

- A non-restrictive vision. Don't say Vinson cannot be restored. We don't know what the future holds. All of Ambleside could be multifamily one day. Could that change bring anticipated opportunities?
- Revise land condition so that the future condition is better than current condition.
- Seek opportunities to improve the health of the watershed.
- Ensure 'No Net Loss' and work towards enhancements.
- Net Gain.
- Creek health, at least stays the same, better if improvement can be achieved.
  - Better fish passage and improved habitat.
- Habitat and environmental improvement/protection.
  - Water quality, invasive species reduction, and tree cover.
- Habitat & Environment.
- Revised Environmental Development Permit Areas to improve environmental outcomes.
  - Abandon the current 'no net loss' policies; provide for increased watercourse setbacks (protection of the Streamside Protection and Enhancement Areas (SPEA); implement Riparian Area Regulation (RAR).

Safety/Flooding/Servicing/Infrastructure

- Minimize flooding.
- To minimize flooding due to future flows, change day to day development procedures.
- Determine upgrades required for 2 year, 10 year, and 200 year structure for both the private and public infrastructures.
- Infrastructure – flood control, mitigation.
- Understand and prioritize District infrastructure upgrades and incorporate to other priorities of Vision.

• Infrastructure protection/private property protection. • Flood protection/resilience. • Safety. • Revised hazardous development permit areas. Require additional geotechnical reports for issues like debris flood/flow, and for bank stability (setbacks for geotechnical issues).
Neighbourhood Design / Land Use Design / Development Patterns • Understand impact of existing design. • Goal and objectives of future land use. • Creeks remain/become neighborhood assets/features. • Creeks inform/structure land use changes or patterns (designed with/for). • Scope of works – How to apply to current development practices? • Naturalized features achieving watershed and water quality objectives. • With respect to planning and development → Incorporate District' values to development. • Opportunity to coordinate land re-development and land use changes in improvements to watershed health. • Community – Recreation/education/access/interaction. • Revise setbacks for environmental and safety objectives.
Funding and Implementation • How to deal with infill development. Funding source for improvements. • Public safety & cost of infrastructure. • Look at funding mechanisms for habitat improvements. Consider creek as a neighborhood amenity infrastructure. Pursue a range of partnerships on restoration projects (MOTI, stream keepers, other private landowners, etc.).

5.3 Proposed ISMP Vision

The proposed vision for the watershed incorporates the existing District vision, goals, and policies, as well as internal stakeholder input gathered during the visioning workshop. The vision includes core values, a mission statement, and guiding principles that provide context for how the ISMP vision will be achieved.

ISMP Vision

The ISMP strives to maintain and improve watershed health to provide watersheds for the future that:

- Inspire excellence in environmental leadership,
- Provide safe, reliable and resilient drainage and ecosystem services, and
- Foster engaged communities that are the care-takers of the watersheds where they live, work, and play.

ISMP Core Values

The recommendations for the ISMP will be built on ISMP core values of:

- Leadership: Demonstrate leadership in environmental management.
- Pragmatism: Provide practical and fiscally responsible solutions Consider District of West Vancouver's unique constraints and opportunities.
- Safety: Prioritize safety of residents and property.
- Resiliency: Develop solutions that increase reliability and resiliency of services and watersheds.
- Collaboration: Create and build opportunities for collaboration between government, stewards, and residents.

ISMP Mission and Guiding Principles

The ISMP will achieve the vision through the following principles while adhering to the core values.

- Improve watershed health. Consider **Healthy Environment** and **Healthy People**
  - Take environmental leadership in preserving, restoring, and creating significant ecological features (i.e., habitat, riparian areas, etc.).
  - Retain and adopt land development principles that result in no-net-loss of watershed health and work with and for the benefit of the creeks.
  - Creeks remain and become neighborhood assets and neighbourhood features. Creeks inform and structure land use changes or patterns.
- Provide sustainable watershed services including: **Safe**, **Reliable,** and **Resilient** drainage and ecosystem services within the watersheds.
  - Provide for the safety and security of citizens and protect public and private property from flooding hazards for existing and future scenarios. Meet regulatory requirements and relevant industry standards.
  - Provide reliable and resilient drainage servicing for current and future land use and climate conditions at the District's desired level of service.
  - Promote and adopt land development principles (i.e. low impact development principles) that increase watershed resiliency for the future.
  - Promote and adopt watershed management principles (i.e. increase riparian forest integrity) that increase watershed resiliency for the future.
- Serve an engaged community by building **civic responsibility**, **stewardship,** and **collaborative government**.
  - Collaborate with watershed stewards in development and implementation of the ISMP**.**
  - Create a range of opportunities and support for citizen engagement and watershed stewardship.
  - Use outreach and education to raise awareness of the ISMP and work with residents, landowners, and businesses to achieve ISMP outcomes.

Vinson, Brothers, and Hadden ISMP Vision in Graphic Form:

5.4 Public Consultation

Members of the public were notified about the ISMP through a post card mail-out and were given a chance to provide input into the plan via the website after the development of the project Vision and at a Public Open House following development of Stage 3 Alternatives. A webpage was created for the ISMP and updated throughout the project so that interested members of the public as well as other stakeholder stayed informed. Major public consultation activities included:

- Setting up a webpage with basic project information and comment form. Updating the website with notices about major milestones and deliverables.
- Mailing out ISMP and Public Open House notification: designing an information post card for the ISMP to notify residents and businesses of project and directing them to the project website, as well as inviting the public to the open house.
- Open House: The keystone of the public consultation process, the open house provided the opportunity for the public to learn about study findings and recommendations and to provide feedback.

Public responses from the consultation were incorporated into the ISMP by:

- Utilizing information from the public on concerns and issues and environmental values,
- Considering preferences from the public on mitigation solutions and habitat enhancement options, and
- Addressing public comments on the ISMP and its outcomes.

The public open house was held on October 20, 2016. Feedback from the open house was obtained via response forms that could be filled out on-site or emailed to the District afterward.

6. Mitigation of Future Development

Increase in impervious area in the watersheds caused by development and re-development results in increase in volume and rate of runoff to streams. Increase in impervious area can also lead to increased pollution in receiving water bodies from non-point sources. To protect in-stream aquatic habitat, the increase in rate and volume of runoff needs to be mitigated. Water quality treatment is necessary to protect the water quality of the streams as well as Burrard Inlet and the District's foreshore areas.

To mitigate the hydrological and water quality impacts of land development, the District had the option to pursue some or all of the following options:

District-Wide Low Impact Development Design Principles

Low Impact Development (LID) is a design-with-nature approach that reduces development's ecological footprint. There are many interpretations of LID design. For the purposes of this ISMP, LID principles focus on reducing impervious area runoff in the watersheds through zoning regulation and design standards that can apply broadly to various land uses. LID concepts incorporated at planning stages are low cost measures of reducing negative impacts of land development. Examples include:

- Reduced Road Width – Adopt 'Green Street' standards.
- Reduced Building Footprint and Impervious Area – Limit Impervious Area Allowed; Promote Pervious Paving (for parking lots, tennis courts, sidewalks, patios, etc.).
- Reduced Parking Standards – Reduce required number of parking stalls to reduce parking areas.
- Preserve and maintain existing riparian areas, vegetation buffers, and trees.

LID principles are most effective in combination with other stormwater best management practices such as source control technologies. LID is more straightforward with new development or complete re-development situations than with retrofits in existing built environments.

On-Site Stormwater Source Control Measures

Stormwater Source Controls, also called Best Management Practices or BMPs, reduce the runoff that discharges to the stream network by managing the water balance at the site level. They are typically designed to provide volume reduction, rate control, and water quality treatment for the frequently occurring rainfall events (up to approximately the 6-month event). Some types of source control can be designed to provide rate control for the 2-year, 5-year, and up to the 10-year event. Examples of source controls include:

- Surface Infiltration: Absorbent Landscaping and Pervious Paving.
- Bio-Retention Facilities: Rain Gardens and Bio-Swales.
- Sub-Surface Infiltration: Rock-filled and open chamber infiltration trenches.
- Storage with Slow Release: Cisterns and Tanks with slow release orifices.
- Structural BMPs (for large paved areas or parking lots): Oil & Grit Separators, Oil & Water Separators, Filters, and other WQ Treatment Units, etc.

Selection of source controls depends on the type of land use, site characteristics (site slope, subsurface soil infiltration rate, water table, etc.), and stormwater management objectives.

Regional Facilities

Regional facilities manage and treat runoff from a portion of a watershed and assist with restoring the watershed water balance on a regional basis. Regional facilities can be designed to provide one or more of the following: detention, infiltration, water quality treatment, and base flow augmentation. Detention ponds and water quality wetlands are examples of regional facilities.

In mature, built-out neighbourhoods, retrofitting with regional facilities can be challenging due to space and routing constraints.

In the study area watersheds, future increase in impervious area is primarily attributed to single family re-development, as discussed in Section 2. To mitigate the impacts of increasing impervious area, the District preferred options for pursuing on-lot source control measures. The following section focuses on possible criteria and targets for design and implementation of source controls on single family lots and the implication of various targets. The proposed ISMP also includes source control recommendations for other land use types in the watershed including multi-family, institutional, and roads, but these are a lower priority as they constitute only a small portion of the predicted increase in impervious coverage in the watershed.

If there is a trend in the District to increase road width and impervious area with re-development, then measures for mitigating the specific impacts of increase in road impervious area should be considered. Adopting 'Green Street' standards for residential and other streets is one method of improving runoff quality and quantity from road rights-of-way district-wide.

Possible Design Targets for Stormwater Source Controls

Single family residential (SFR) land use is the largest category of land use within the study watersheds, covering approximately 40% of the total area of the watersheds. The impervious coverage of the SFR land use varies but on average is approximately 50% impervious (roofs, paved driveways, etc.). It is predicted that through re-development, the SFR impervious coverage will increase, on average, by 15%, which results in 6% increase in total impervious area across the whole of the study area watersheds.

Volumetric Reduction

The source controls should be designed to result in no additional runoff generated and conveyed to the creeks due to the increase in the watershed impervious area coverage for typical daily rainfall events. To assess this, the design criteria or design targets for source controls are developed to mitigate the increase in impervious area. When the increased impervious area is mitigated, a site performs as if it has a lower impervious coverage than it actually does, and the apparent level of impervious coverage is called the "effective impervious area" (EIA) for a site. When a site is unmitigated and all the impervious area is directly connected to the municipal storm drainage system, the EIA for the site is the same as the actual impervious coverage (TIA) on the site.

A range of design criteria for source controls is used in the Lower Mainland. The following three tables summarize levels of criteria used in the region as well as criteria proposed in neighbouring ISMPs in the District. For the purposes of this ISMP, it was assumed that design criteria would be applicable to the entire site (entire development). This is consistent with other guidelines developed for the District, including previous ISMPs. It should be noted that some municipalities adopt design criteria that are only applicable if the total impervious area of a site exceeds a certain threshold and/or criteria that only apply to additional impervious area due to development/re-development.

The Department of Fisheries and Oceans (DFO) and the *Metro Vancouver Options for a Region Wide Baseline for On-Site Rainwater Management* (KWL, 2015*)* (the Baseline) provide the range of design criteria that have been accepted in the region. DFO criteria would result in nearly full mitigation of impervious area while the Baseline sets the minimum acceptable standard for partial mitigation of residential re-development impervious area.

Table 6-1 summarizes options for volume control criteria. Where a treatment target is shown for the study area watersheds, the IDF data from the Metro Vancouver rain gauge at the District Municipal Hall (VW 14) is used. Rainfall in the study watersheds increases with elevation. The District should consider the possibly of adopting an elevation-based criterion if a target rainfall management depth is to be defined. Adopting any of the criteria will result in some level of mitigation of the predicted increase in impervious coverage of the study watersheds, however the criteria from the Rodgers and Marr ISMP predates the Baseline, and does not comply with that as a minimum standard for mitigation. Table 6-1 indicates the benefit in level of mitigation associated with adopting the different criteria.

Table 6-1: Volume Control Criteria Options for Source Controls

Volume Capture Criteria	Rainfall Depth Management Target*	Expected Result
DFO Criteria[1] Retain the 6-month/24-hour (or 72% of 2-year/24-hour) post-development volume from impervious areas on-site and infiltrate. If infiltration is not possible release at the calculated release rate of an infiltration facility.	50 mm*	Reduces Effective Impervious Area (EIA) of treated impervious areas to 10%.
Metro Vancouver Region Wide Baseline for On-Site Rainwater Management (Baseline)[2] Retain the storm depth equivalent to 40% of the 2-year/24-hour event and infiltrate or release at baseflow-equivalent rate.	28 mm*	Reduces Effective Impervious Area (EIA) of treated impervious areas to 25%.
Proposed District of West Vancouver Single Family Re-development Lot Rainwater Management Guidelines[3] Redevelopment of a site shall include the necessary measures to infiltrate or re-use the first 31 mm of rainfall assuming dry conditions. This can also be expressed as capturing 75% of the annual rainfall amount. This shall apply to all surfaces: existing and proposed.	31 mm	Reduces Effective Impervious Area (EIA) of the Site to approx. 25%.
McDonald/Lawson ISMP[4] Capture 50% of Mean Annual Rainfall (MAR) on-site. As per BC Stormwater Guidebook For McDonald and Lawson rainfall capture targets are: Below El. 100 m: 39 mm. Between El. 100 m to 400 m: 56 mm.	35 mm*	Reduce Effective Impervious Area (EIA) to 10%-20%.

Volume Capture Criteria	Rainfall Depth Management Target*	Expected Result
Rodgers and Marr ISMP[5] Retain 24 mm in 24 hours on entire development area.	24 mm	"additional management techniques are required to meet the objectives of the GVRD target in maintaining existing hydrological regime"[5]

*Target options for Vinson Brothers and Hadden Creeks ISMP, based on rainfall gauge VW14 (41 m elevation): 2 yr-24 hour intensity: 2.9 mm/hr (69.9 mm total depth)
[1] Metro Vancouver (2012)
[2] Kerr Wood Leidal (2015a)
[3] Kerr Wood Leidal (2015b) – the target rainfall depth is based on a weighted average for all of West Vancouver
[4] Kerr Wood Leidal (2004) – capture volumes are calculated by multiplying 50% of the mean annual rainfall (equivalent to approx. 50% of the 2-year 24 hour rainfall total) by the site area.
[5] Associated Engineering (2008)

Table 6-2 shows that the current level of development in the study watersheds is correlated with a 'degraded' condition of stream health due to the level of TIA of existing development. If future increases in impervious area are not mitigated, the watershed would be expected to become further degraded. However, if capture source controls are applied to redeveloping parcels and sized for the runoff from the entire parcel (not just the additional impervious area), the watershed health would improve from 'degraded' to 'impacted' as the entire area redevelops.

Note that the existing watershed health assessment presented in Table 6-2 is solely based on overall TIA of the study watersheds. It is expected that the EIA of the existing conditions in the watersheds is lower than the TIA, however at this time the EIA for the existing conditions is not quantified. The future mitigated EIA is a high level approximation to assess with evaluation of alternatives.

Table 6-2: Stream Health Relative to Impervious Area

Theoretical Watershed Health Based on Ultimate Imperviousness		Vinson, Brothers & Hadden Creeks Watersheds		
Watershed Health	Watershed Impervious Area	Existing TIA	Future Un-Mitigated TIA	Future Mitigated EIA
Stressed (minor changes to watershed health)	1 – 10%			
Impacted (moderate changes to watershed health)	11 – 25%			18% (DFO) - 23% (Baseline)
Degraded (severe changes to watershed health)	26 – 100%	33%	39%	

Reference: Schueler (1994)

Peak Flow Attenuation

Table 6-3 summarizes the range of possible detention criteria for the watersheds. Based on modelling of the study area watersheds, the projected increase in impervious area will result in significant increases in peak flows in some of the study creeks[1]. As such, it is recommended that detention should be provided for runoff generated by future additional impervious area. DFO recommends that detention is provided for the 6-month, 2-year, and 5-year precipitation events. The proposed DWV Single Family Re-development Guideline recommends detention for the 10-year event in the interest of protection for downstream infrastructure. While DFO's objective is protecting environmental values, the proposed Re-development Guidelines detention criterion addresses capacity issues in the District's storm sewer network. The District can adopt a detention criterion that addresses both environmental and pipe capacity/flooding concerns.

Table 6-3: Design Criteria Options for On-Lot Detention

Detention Criteria	Mitigation Target Return Period	Expected Result
DFO Criteria Reduce post-development flows (peak instantaneous rates and shape of hydrograph) to pre-development (natural forested conditions) levels for the 6-month/24-hours, 2 year/24-hour, and 5 year/24-hour precipitation events.	6 months, 2-year, 5-year	Detention for Environmental Protection
Proposed District of West Vancouver Single Family Re-development Lot Rainwater Management Guidelines For re-development, there shall be no net increase in the rate of rainwater runoff from existing conditions (state of land prior to any alternations proposed as part of permit application). Redevelopment of a site shall include design to handle any runoff increase above existing conditions during the 10-year return period storm event on-site. All sites shall have a storage facility to assist in attenuating rainwater runoff flows for the 10-year event under six design storm durations ranging from 1-hours to 24-hours.	10-year	Detention for Infrastructure Capacity & Environmental Protection
McDonald/Lawson ISMP Control post-development flows to pre-development levels for storms larger than 50% MAR and smaller than 2-year return period. As Per Provincial Stormwater Guidebook.	50% MAR[1] to 2-year	Detention for Environmental Protection

[1] Peak flow increases have a large range for the creeks in this study, from 6% (Brothers and Hadden at mouth of Brothers) to 387% (East Tributaries to Vinson West Creek). These increases are due to increased impervious coverage in the future but also to changes in the governing regime for the peak, in the case for Vinson West from groundwater dominated to runoff dominated. Therefore though the predicted increase in peak flow is very large, two things should be remembered: (1) the actual predicted peak flow is not all that large, and (2) as the peak flow regime change is triggered by the change in impervious coverage, the mitigation for impervious coverage may mitigate the increase in peak flow even at the 200-year level.

Detention Criteria	Mitigation Target Return Period	Expected Result
Rodgers and Marr ISMP No design criterion for on-lot detention is recommended as peak flows are treated through diversion.	NA	Peak flow diversion reduces erosive forces in the creeks during extreme storm events exceeding the threshold of 50% of 2-year return period.

1. Capture volumes are calculated by multiplying 50% of the mean annual rainfall (equivalent to approx. 50% of the 2-year 24-hour rainfall total) by the site area.

Table 6-4 summarizes possible water quality criteria. Source controls designed to provide volume capture can also be designed to provide water quality treatment. Water quality is a watershed wide issue that can also be addressed through improving municipal catch basin maintenance programs and through prioritizing water quality treatment of pollutant hot spots (i.e. major roads and parking lots).

Table 6-4: **Water Quality Criteria Options for Source Control Design**

Water Quality Criteria	Treatment Target as Rainfall Depth	Expected Result
DFO Criteria Collect and Treat volume of the 24-hour event equalling 90% of the average annual runoff from impervious areas with suitable BMPs.	50 mm*	Treats 90% of typical annual runoff
Metro Vancouver Region Wide Baseline for On-Site Rainwater Management Improve WQ by treatment of ground surfaces. Ground surface must be: • Drained to Vegetated Areas OR • Be Pervious Paving OR • Be Collected and Drained Through a Sump	N/A	“Minimum Acceptable Level of Treatment for Single Family Residential Lots”

* VW14 (41 m elevation): 2 yr-24 hour intensity: 2.9 mm/hr (69.9 mm total depth)

Achieving the Baseline Capture Target – What does it look like?

To assist the District with visualizing the implications of adopting various targets, there are a number of drawings and documents attached to this report in Appendix F. These include the proposed *District of West Vancouver Single Family Re-development Guidelines* (KWL, 2015) and Appendix B of the *Options* for a *Region Wide Baseline for On-Site Rainwater Management Final Report* (KWL, 2015). The proposed Single Family Re-development Guidelines includes descriptions of measures intended to achieve the 75% rainfall capture target as well as detention of 10-year peak flows. The drawings from the Baseline report show how various source controls can be designed to achieve the 75% capture target for ‘typical’ Metro Vancouver lots. These are tools to assist with understanding and visualization of the use of this approach for on-lot mitigation of re-development on single family lots.

6.1 Continuous Simulation of Mitigation Strategies

Once the mitigation approach has been selected, the concept is tested by modelling the application of the mitigation on the predicted future conditions models of the watershed. Continuous simulation is used to look at the performance of a watershed over time using real rainfall records. For the ISMP, continuous simulation is used to simulate and compare the effects of future development and re-development on the flows in the study area creeks, with flows under existing land use conditions. The future conditions model is then revised to include the mitigation for development and re-development recommended in the ISMP, and the mitigated development creek flows are compared with both the existing conditions and the future unmitigated conditions flows. The intent is to show that the proposed mitigation approaches reduce the effects of future development such that the creek flows under future mitigated conditions are similar to the flows under the existing conditions.

Continuous simulation modelling uses recorded rainfall data over a long period to evaluate the performance of the drainage system. Variables such as rainfall duration and intensity, time between storms, changing antecedent soil moisture and storage conditions within the watershed, and the effects of evaporation are accounted-for in the continuous simulation analysis.

Modelling Continuous Simulation

The PCSWMM model of the creeks was set up and run for a continuous simulation of almost ten years of consecutive rainfall data (January 2007 – November 2016). This was the longest contiguous record for the West Vancouver Municipal Hall rain gauge (VW14). The model was run for four scenarios: Existing Land Use, Unmitigated Future Land Use, Unmitigated Future Land Use – Impervious Areas Directly Connected, and Mitigated Future Land Use.

The Unmitigated Future Land Use scenario simulates how the future developed watershed would respond if no mitigation strategies are implemented. This model assumes that the existing impervious area continues to behave as in the Existing Land Use model, but the additional impervious areas would be connected to the storm system.

The Unmitigated Future Land Use – Impervious Areas Directly Connected scenario simulates how the future developed watershed would respond if runoff from all impervious surfaces was directly connected to the storm system.

The Mitigated Future Land Use scenario simulates how the future developed watershed would respond with implementation of the recommended mitigation strategies watershed-wide, as described in Section 7 of the ISMP Report. This involved changing the modelled soil parameters to simulate the recommended topsoil depth, and adding detention storage to model attenuation from recommended on-lot storage facilities.

Results of Continuous Simulation

The results of the continuous simulation of the different land use scenarios are shown using exceedance duration curves. Exceedance duration curves generally show the amount of time any given flow or velocity is exceeded during the modelled time frame. The curves are created using the exceedance duration tool in PCSWMM. Comparison of existing and future flow durations helps to illustrate where increased erosion will likely occur due to changes in the flow regime.

Exceedance-duration curves were developed for each of the modelled scenarios at four key locations in the creeks. These curves are shown in Figures 6-1 to 6-4.

The Unmitigated Future Land Use curves show higher peak flows in the creeks than the Existing Land Use curve and, in general, these flows are sustained for longer durations. The Unmitigated Future Land Use - Impervious Areas Directly Connected scenario shows a longer duration of exceedance for the mid-range flows in addition to the peak flows. The duration of low flows are decreased as compared to all other scenarios because the smaller rain events which would typically infiltrate into the soil and return to the creeks as baseflow are now showing up as runoff, returning to the creeks at higher peak flows.

The Mitigated Future Land Use curve shows decreased magnitude and duration of flows as compared to the Unmitigated Future Land Use curves. The additional topsoil depth provides volume capture to mitigate the increased runoff from impervious areas, while the storage facilities attenuate peak flows. This draws the exceedance-duration curve down to meet the Existing Land Use curve, showing that the recommended mitigation measures are effective in maintaining both the magnitude and duration of flows in the creeks.

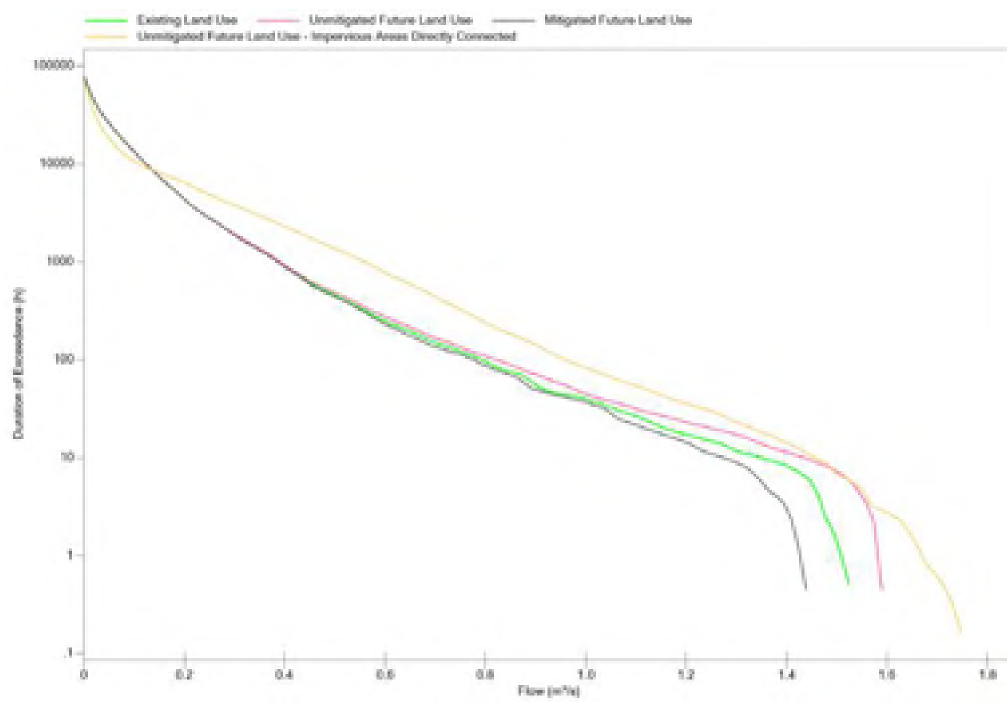

Figure 6-1: Flow Exceedance-Duration Curves for Vinson Creek at Gordon Ave.

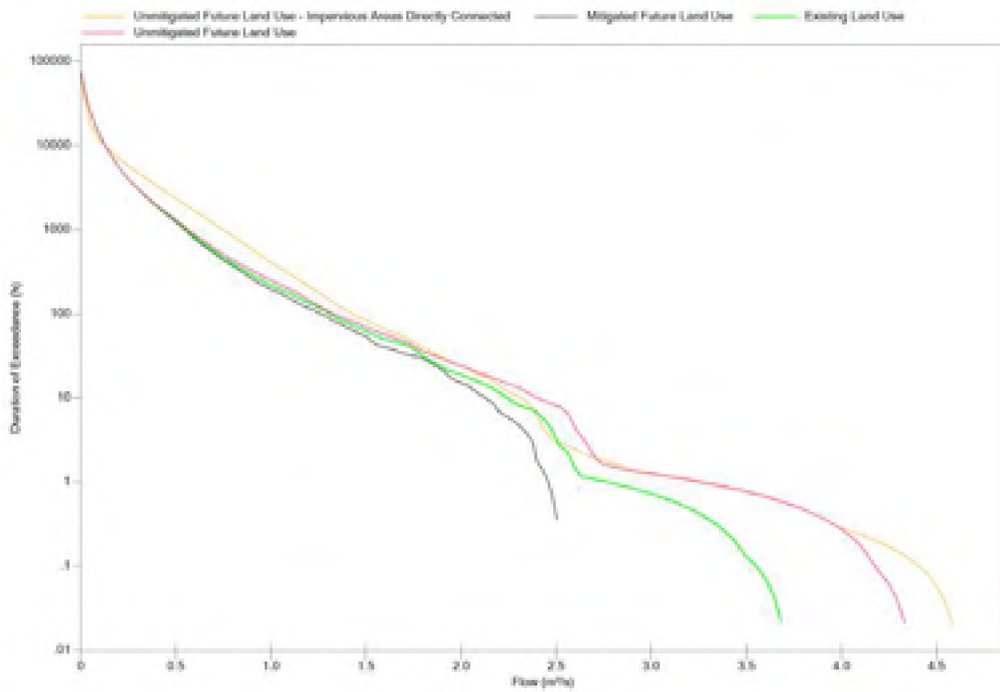

Figure 6-2: Flow Exceedance-Duration Curves for Brothers Creek East Tributary at Highland Drive

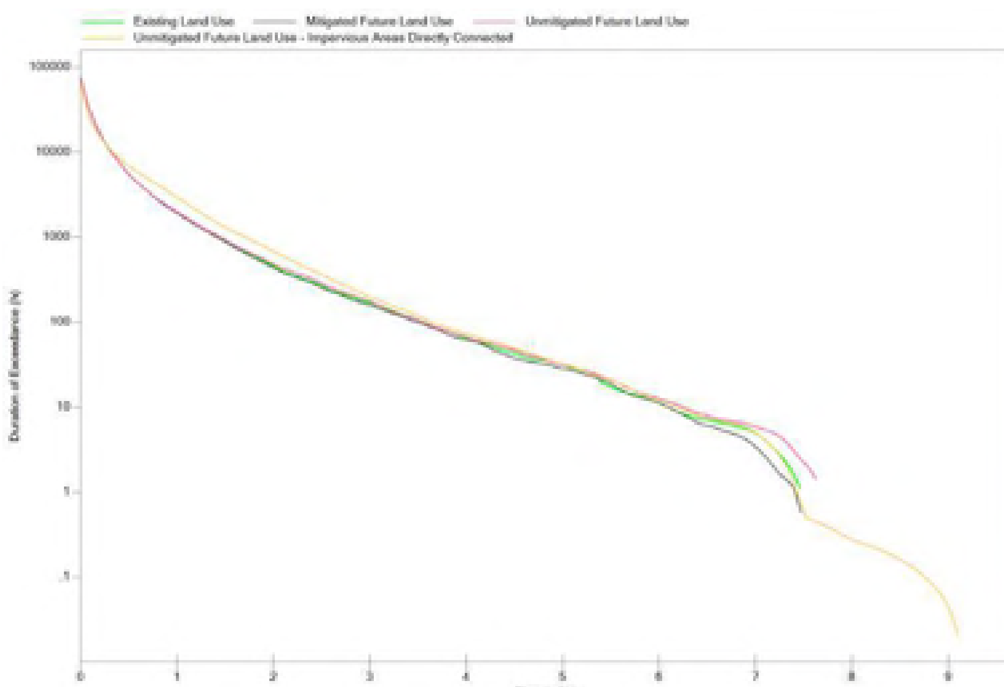

Figure 6-3: Flow Exceedance-Duration Curves for Hadden Creek at Mathers Avenue

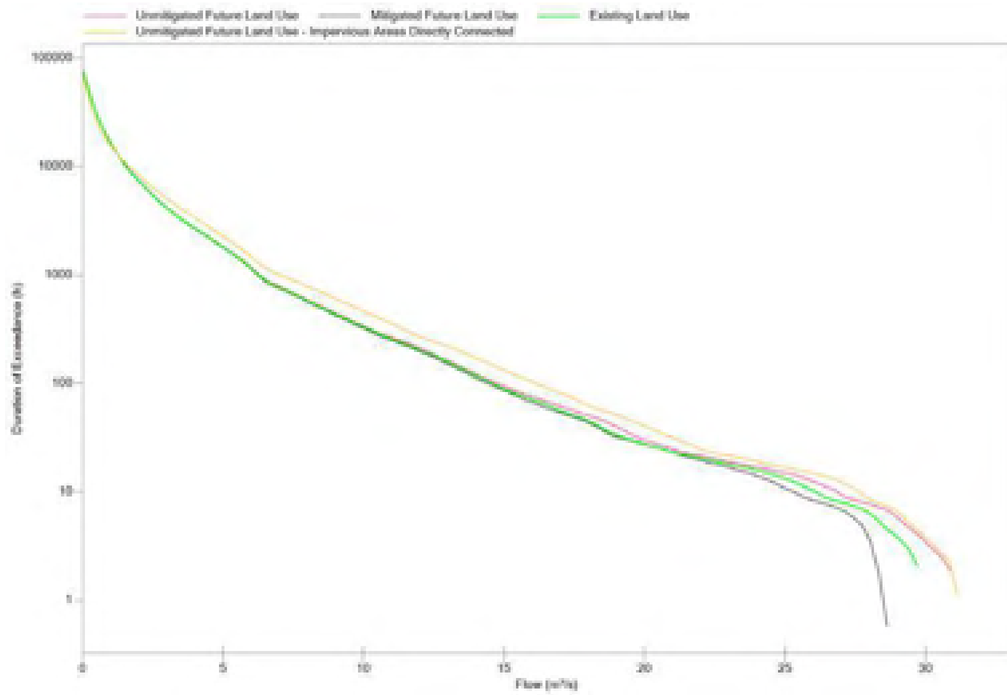

Figure 6-4: Flow Exceedance-Duration Curves for Brothers/Hadden Creek at Confluence with Capilano River

7. Integrated Stormwater Management Plan

This section of the report comprises the recommendations and implementation plan for the Vinson, Brothers, Hadden Creeks ISMP. These include recommendations for achieving the ISMP objectives as well as strategies for funding the recommendations. Recommendations are based on the analysis presented in the Stage 3 Interim Memorandum and incorporate feedback received from the District staff and the public open house (held on October 20, 2016).

Summary of Recommendations

The recommended options are divided into five broad categories:

1. **On-Site Development Mitigation Measures** have two primary objectives:
   - Provide environmental protection to prevent re-development from negatively impacting creek health.
   - Provide rate control of discharges to reduce the need for upgrades to the District storm sewer network due to increase in lot impervious area and associated runoff from re-development of lots.
2. **Environmental Compensation and Enhancement Projects** are targeted at improving existing watershed health and enhancing conditions for fish and aquatic species. The projects are grouped into five categories:
   - **Fish Passage Improvements** target high priority culverts or other features that pose barriers or potential barriers to fish and limit access to quality habitat.
   - **Instream Habitat Enhancements** improve the quality and productivity of fish habitat present through measures such as removing bank armouring, adding channel complexity using large wood or boulders, and placing spawning gravels.
   - **Riparian Protection, Restoration and Planting** provide ecological benefits such as:
     - moderating water temperature;
     - providing sources of food, nutrients, and organic matter;
     - stabilizing the soil with root systems, thereby minimizing erosion;
     - providing area for natural creek movement and erosion processes; and
     - filtering sediment and pollution.
   - **Invasive Species Management** targets removal of high priority invasive species.
   - **Stream Daylighting** accomplishes multiple objectives of improving fish habitat listed above.
3. **Community Engagement Programs** acknowledge that several of the ISMP recommended projects have cross-benefits in community building, and creating public amenities. They also acknowledge the important role of volunteer stewards in watershed management in the District. These recommendations highlight instances when community engagement is a prerequisite or key to project success as well as opportunities for collaboration between the District and the community to enhance project outcomes.
4. **Process and Bylaw Amendments** describe changes to the District's policies, bylaws, and operations and maintenance processes required to implement the ISMP recommendations and to achieve the plan's objectives.

5. **Major System Conveyance Upgrades** aim to protect life and property by ensuring that the creek channel and the instream hydraulic infrastructures including culverts, creek diversions, and bridges (bridge structure information was limited) have adequate conveyance capacity. The recommendations include a capital plan for culvert upgrades, and highlight where further investigation of creek channel capacity is needed.

The recommendations align with the ISMP vision, mission, and guiding principles. Details of the recommendation are provided in the following sections.

7.1 On-Site Mitigation for Impacts of Development

The recommendations for updating and developing new land development guidelines/criteria are divided into two categories based on land use:

- Updating the proposed *District of West Vancouver Single Family Re-development Lot Rainwater Management Guidelines 2015* (DWV Single Family Re-development Guidelines, KWL, 2015).
- Non-single-family lot re-development and road right-of-way criteria.

The following section outlines changes to the District's bylaw, policies, and programs that are needed to support these recommendations for mitigation of impacts of development.

Single Family Re-development Guidelines

In 2015, KWL developed a draft document for the District to guide rainwater management on redeveloping single family lots (KWL, 2015). The guidelines were reviewed as part of the ISMP. The ISMP recommends that the District adopt the guidelines (with proposed changes summarized in this section) and implement the guidelines not just for these ISMP watersheds but district-wide. The objectives of the guidelines are to*:*

- **Provide environmental protection during frequently occurring events through runoff volume reduction and water quality treatment.** Meet the minimum requirements for stormwater management on single family residential developments (Metro Vancouver, 2016).
- **Provide environmental protection and stormwater pipe capacity relief through detaining peak flow rates**. Detain runoff from the site such that, under re-development conditions, there will be no net increase in runoff above existing conditions during the 2-, 5-, and 10-year return period storms.

The criteria recommended for the *DWV Single Family Re-development Guidelines* can be found in Table 7-1; this includes the proposed changes discussed below. Note that the criteria are intended to be applied to the development of single detached homes, duplexes, and triplexes on single residential lots.

Table 7-1: On-Site Stormwater Management Criteria for Single Family Re-development

Application	Criteria/Methodology
Hydrotechnical Component (Flood and Erosion Protection)	
Minor Drainage System – On-Site Rate Control[1]	**Criteria** • Flows up to the 10-year must be controlled on-site and/or conveyed to a storm system connection. • Control 10-year event post-development flow rates from the site to corresponding 10-year pre-development flow rates (pre-development is defined as state of land prior to any alternations proposed as part of permit application). **On-Site Practices to Achieve Requirements** • All sites shall have a storage facility to assist in attenuating rainwater runoff flows for the 10-year event for design storm durations ranging from 1 hour to 24 hours.
Major Drainage System – On-Site Grading	• Lot design and grading should provide for flows between 10-year and 100-year return period design events to be conveyed safely off-site to a major flow route.
Environmental Component (Environmental Protection)	
Volume Reduction Source Controls[2]	**Criteria** On-site rainfall capture and infiltration of 40% of the 2-year 24-hour storm rainfall depth (from the entire site): • Below El. 100 m – 28 mm in 24 hours • Between El. 100 m and 400 m – 40 mm in 24 hours. **On-Site Practices to Achieve Requirements** Single family residential lots should: • Have a maximum 70% total impervious area; and • Have a minimum topsoil depth of 450 mm on vegetated pervious areas; and • Disconnect downspouts and allow flow to infiltrate across a minimum of 15% of the lot area (except for steep sloped lots and other exemptions as determined by the District). For any lot where the total impervious area exceeds 70% of the lot and/or less than 15% of the lot is pervious and available to infiltrate runoff at the surface, one or more of the following should be used to meet the capture criteria: • Pervious paving; • Rain garden; • Rock pit; • Cistern/retention tank (above or underground); or • Conduct a site-specific study to determine suitable stormwater management practices. Refer to proposed *DWV Single Family Re-development Guidelines* for details.

Application	Criteria/Methodology
Water Quality Treatment[2]	Follow Metro Vancouver Baseline Practice Standard for Water Quality as follows. Paved ground areas must: • Drain to vegetated areas; or • Be pervious; or • Be collected and drained through a sump.
Watercourse Erosion Prevention/ Rate Control	**Criteria** • Control 5-year, 2-year, and 6-month event post-development flows from development site to corresponding 5-year, 2-year, and 6-month pre-development flow rates.[3] **On-Site Practices to Achieve Requirements** • This facility designed for the hydrotechnical detention may also be used for the environmental rate control as long as predevelopment flows are achieved.

1. District of West Vancouver Drainage Survey (1973).
2. Metro Vancouver Single Family Baseline (2016).
3. DFO Urban Stormwater Guidelines and BMPs for the Protection of Fish and Fish Habitat (2001).

Proposed Changes to *DRAFT District of West Vancouver Single Family Re-development Lot Rainwater Management Guidelines (KWL, 2015)*

The following changes are proposed to the current version of the *DRAFT District of West Vancouver Single Family Re-development Lot Rainwater Management Guidelines* developed by KWL and delivered to the District in 2015 and are incorporated in the recommended criteria in Table 7-1*:*

- Map areas in the District that will be granted exceptions and append the mapping to the Guidelines. The exceptions may include, but are not limited to, areas with steep slopes, areas with retaining walls, and areas at tops of ravines.
- Include case study design examples of downslope lots with no lane and sloping lots with a ditch frontage.
- Expand requirements for detention facilities on-site to include an outlet designed to detain the 6-month, 2-year, and 5-year events, in addition to the 10-year storms, and release at pre-development rates. Pre-development refers to the existing conditions of sites at the time of the re-development application. Add that detention criteria can be accomplished with tanks or rock pits.
- Delete requirement for additional on-lot infiltration beyond absorbent landscaping and pervious paving except in cases where impervious area is greater than 70% of the lot and/or available area for infiltration is less than 15% of lot. Note that in order to strictly meet the MV Baseline (2016) requirements, the additional volume capture measures, presently included in the DWV Guidelines, would be needed for lots located above 100 m elevation. However, the addition of the detention criteria for environmental protection, noted above , is above and beyond the requirements of the MV Baseline and should balance some of the volume impacts for these areas to approximate the targets of the MV Baseline for the higher elevation properties.
- Describe the steps for detention sizing in a worksheet such that proponents can use the methodology to build a spreadsheet.

On-Site Development Guidelines for All Non-Single-Family Land Uses

For new development and all other lot re-development applications, including non-single family residential, commercial, and institutional development, and parks adopt the recommended provincial and regional guidelines included in the following table. The criteria also apply to re-development within the road right-of-way. The criteria are similar to those for single family with the exception of the volume reduction and water quality targets (both highlighted in blue boxes) which are higher standards for all land use types other than single family.

7.2 Environmental Compensation and Enhancement Projects

Based on the environmental inventory and assessment, KWL identified environmental concerns and enhancement opportunities in Vinson, Brothers, and Hadden Creeks. Figure 7-1 shows the recommended environmental enhancement projects for improving watershed health in these watersheds. For reference, the identified barriers to fish passage are shown in Figure 3-2, earlier in this report.

Table 7-3 provides details on the description, benefits, estimated cost, and priority of the enhancement projects. The following recommendations align with the ISMP Mission and Guiding Principles of a healthy environment, resilient ecosystem services, civic responsibility, and stewardship.

In addition to the specific enhancement projects, continued effort is recommended to address invasive plant species in the watersheds, as identified in Figure 3-5 earlier in this report. As this work would be performed primarily by District staff, it is considered part of Operations and Maintenance work, and is Section 7.4.

Table 7-2: On-Site Stormwater Management Criteria for Land Re-development for Non-Single-Family Lots and Road Right-of-Way

Application	Criteria/Methodology
Hydrotechnical Component (Flood and Erosion Protection)	
Minor Drainage System – On-Site Rate Control	**Criteria** • Flows up to the 10-year must be controlled on-site and/or conveyed to a storm system connection. • Control 10-year event post-development flow rates from the site to corresponding 10-year pre-development flow rates (pre-development is defined as state of land prior to any alternations proposed as part of permit application). **On-Site Practices to Achieve Requirements** • All sites shall have a storage facility to assist in attenuating rainwater runoff flows for the 10-year event for design storm durations ranging from 1 hour to 24 hours.
Major Drainage System – On-Site Grading	• Lot design and grading should provide for flows between 10-year and 100-year return period design events to be conveyed safely off-site to a major flow route.
Environmental Component (Environmental Protection)	
Volume Reduction Source Controls	**Criteria** On-site rainfall capture and infiltration of 50% of the 2-year 24-hour storm rainfall depth[1]: • Below El. 100 m – 35 mm in 24 hours • Between El. 100 m and 400 m – 50 mm in 24 hours. **On-Site Practices to Achieve Requirements** • Refer to *Metro Vancouver Stormwater Source Control Design Guidelines 2012* for details.
Water Quality Treatment	**Criteria** Collect and treat 72% of the 2-year 24 hour storm rainfall depth from impervious areas[2]: • Below El. 100 m – 50 mm in 24 hours • Between El. 100 m and 400 m – 72 mm in 24 hours. **On-Site Practices to Achieve Requirements** • Refer to Metro Vancouver Stormwater Source Control Design Guidelines 2012 for details.
Watercourse Erosion Prevention/ Rate Control[2]	**Criteria** • Control 5-year, 2-year, and 6-month event post-development flows from development site to corresponding 5-year, 2-year, and 6-month pre-development flow rates.[2] **On-Site Practices to Achieve Requirements** • The facility designed for the hydrotechnical detention may also be used for the environmental rate control as long as predevelopment flows are achieved.

1. Provincial Stormwater Guidebook (2002) (Stormwater Planning: A Guidebook for British Columbia).
2. DFO Urban Stormwater Guidelines and BMPs for the Protection of Fish and Fish Habitat (2001).

Table 7-3: Environmental Restoration and Enhancement Projects

No.	Project	Rationale	Benefit	Estimated Cost	Priority
Fish Passage Improvements					
1	*Enhance fish passage and habitat quality in Hadden Creek within the Capilano Golf & Country Club:* *1. Replace culvert at outlet of Pond 5 with a fish passable structure.* *2. Replace two culverts under golf cart bridges between Ponds 4 and 5.* *3. Change the channel path at outlet of Pond 4 to lengthen the channel and reduce the stream gradient.* *4. Widen channel and replace vertical bank armouring between ponds 4 and 5 with natural boulder, cobble, and gravel banks.*	1. Perched culvert on Hadden Creek just downstream of Capilano Golf and Country Club is a barrier to upstream fish migration. 2. Golf cart bridges over Hadden Creek within Capilano Golf and Country Club are potential fish barriers, especially for juvenile salmon, especially the one at the outlet of Pond 4. 3. Improve fish passage by reducing gradient of stream. 4. Existing channel is narrow with little complexity to break up flows or provide cover. Naturalizing banks and widening channel will reduce flow velocities and improve habitat quality and fish passage to upstream spawning and rearing habitat. Adding channel complexity in the channel or ponds such as woody debris, lunkers, etc. will improve quality of rearing habitat.	1-4. Provide access to 840 m of spawning gravels and 460 m of excellent rearing habitat. 4. Enhance rearing habitat quality of 250 m of Hadden Creek.	N/A (project already in planning stages)	High (to be completed 2017)
2	*Investigate and, if necessary, improve fish passage through culvert on West Brothers Creek at Wildwood Lane.*	At Wildwood Lane, near 921 Wildwood Lane, culvert invert has steel grating that accumulates gravel and may prevent spawners from swimming upstream. Investigate during spawning season to determine if spawners can pass upstream.	Improve fish access to 1.4 km of spawning gravels and 750 m of excellent rearing habitat.	$275,000 to replace culvert, less to modify invert	Medium
3	*Investigate and, if necessary, improve fish passage through culvert on Burley Creek at confluence with Brothers Creek just downstream of Highway 1.*	Culvert on Burley Creek at confluence with Brothers Creek is a potential barrier to adult salmon and blocks access to 120 m of good spawning habitat and moderate rearing habitat in Burley Creek. Options for improving passage include removing culvert and replacing with natural channel, redirecting channel south around culvert and blocking culvert, or cleaning out culvert if it is blocked.	Provide access to 120 m of spawning gravels and moderate rearing habitat in Burley Creek.	$10,000-$200,000 dependent on methods	Medium
In-Stream Habitat Enhancement					
4	*Improve instream habitat on West Brothers Creek along Wildwood Lane.*	From its confluence with Brothers Creek upstream for 250 m (parallel to Wildwood Lane), creek is channelized with bank armouring and lacks riparian vegetation. Aquatic habitat could be improved by removing bank armouring, naturalizing the channel banks, and adding large woody debris or other forms of channel complexing. Sections of bank that are bare or have invasive plants could be naturalized by removing invasives and planting native species. The highest priority is the eastern section from the confluence of West Brothers and Brothers mainstem to the diversion under Highway 1. Enhancement work should maintain flow through the diversion to Burley Creek (under Highway 1) at approximately 25% of total flow in West Brothers Creek.	Enhance rearing habitat quality of 250 m of West Brothers Creek and increase connectivity to 750 m of excellent rearing habitat upstream of enhancement reach.	$80,000	Medium

Table 7-3: Environmental Restoration and Enhancement Projects

No.	Project	Rationale	Benefit	Estimated Cost	Priority
5	*Investigate and, if appropriate, construct an off-channel rearing pond connected to Hadden Creek in private forested area between Hadden Drive and the Capilano Golf and Country Club.*	Off-channel rearing habitat is uncommon in the study watersheds. Off-channel habitat could be created along Hadden Creek by establishing an off-channel rearing pond for juvenile coho. This forested section has a small tributary on the right bank of Hadden Creek which has eroded around a culvert. Construction of an off-channel pond could be done in conjunction with the removal of this culvert. The tributary has potential to feed into the off-channel pond. Alternatively, the pond could be constructed on the east side of Hadden Creek in this forested area.	Create approximately 50 m² of off-channel rearing habitat.	$80,000	Low
6	*Investigate and, if appropriate, improve instream habitat of Brothers Creek near 651 Inglewood Place.*	There is an old broken dam, aqueduct, and breakwater in Brothers Creek adjacent to 651 Inglewood Place (also known as Dr. Ballard's property). The dam is not a fish passage barrier but the surrounding bank armouring and breakwater is failing and reduces the channel width by half in some places. If the structures are removed, the channel width would be greater and could be enhanced to increase habitat complexity with the addition of large wood complexes, deep pools, spawning habitat, or side channel habitat depending on hydrology. Priority would be for creating off-channel rearing habitat for juvenile salmonids and spawning and staging habitat for adult salmon.	Create 500 m² of instream habitat behind existing breakwater and increase habitat complexity with the addition of deep pools; remove legacy structures that have potential for further failure.	$200,000	Low
	Stream Daylighting				
7	*Daylight section of tributary to Brothers Creek beside Westcot Elementary School.*	The tributary, which originates east of Westcot Elementary School, flows under the school field through a 90 m culvert that is likely a barrier to fish passage. Juvenile coho have been observed in the tributary downstream of this culvert. Abundant spawning gravels for trout are present upstream beside the school. The project will increase spawning areas available for trout, create an outdoor classroom space, increase riparian cover in the watershed, and increase wetland area. The fish ladder that currently connects the tributary to Brothers Creek is perched during low flow and should be investigated and improved if necessary.	Daylight 90 m of instream habitat, create 1,700 m² of riparian habitat, enhance 3,800 m² of riparian habitat, create an outdoor classroom, improve access to natural spaces, and build community around a stewardship project.	$500,000	Low
8	*Daylight section of West Vinson Creek.*	Much of West Vinson Creek has been piped. A section of the creek could be daylighted as a step towards further restoring an open creek channel over time. Daylighting opportunities include the mouth of West Vinson Creek near the Ferry Building Gallery, or at or downstream of Fulton Ave where culverts are undersized.	Daylight 50-100 m of instream habitat, opportunity for public engagement on issue of daylighting creeks and stormwater management. Coordinate with enhancements to forage fish spawning habitat at Ambleside Park.	$500,000	Low

Table 7-3: Environmental Restoration and Enhancement Projects

No.	Project	Rationale	Benefit	Estimated Cost	Priority
Riparian Protection, Restoration, and Planting					
9	*Assess and repair failing bank protection on right bank of Brothers Creek at 778 Westcot Place*	On right bank of Brothers Creek at 778 Westcot Place, gabion bank protection is failing, and is at risk of falling into creek. Wall is ~2 m tall and 15 m long, and is sagging to more than 45 degrees from vertical. Upstream stacked rocks that supported gabions have eroded.	Remove risk of instream habitat loss, obstruction, and future erosion and property damage.	$50,000	High (completed 2016)
10	*Improve riparian habitat along Hadden Creek within Capilano Golf & Country Club*	The riparian areas of Hadden Creek between Ponds 4 and 5 and along a tributary of Hadden Creek in Capilano Golf & Country Club lack trees and water temperatures downstream of the golf course are higher than expected. Enhancing habitat would improve water quality and increase connectivity between riparian forest patches upstream and downstream.	Create 4,000-8,000 m² of riparian habitat, increasing shade, water quality, and rearing habitat potential of channel; connect upstream 35,000 m² riparian forest patch to downstream riparian forest, increasing connectivity for wildlife.	$40,000-$80,000	Low
Invasive Species Management					
11	*Remove Giant Hogweed and replant with native vegetation.*	Giant Hogweed is present throughout Brothers and Hadden catchments. Toxic plant for humans and wildlife and currently a health hazard. Position in upper sections of watershed means that it could spread downstream. Species is not widespread, so there is still a chance to remove it before it spreads.	Remove hazard to people and wildlife, reduce risk of further spread in watershed	Staff time	High
12	*Remove Japanese knotweed and replant with native vegetation.*	Widespread throughout watersheds. Decreases riparian habitat quality and can cause damage to infrastructure such as culverts.	Remove hazard to infrastructure and risk of spread; increase quality of riparian habitat.	Staff time/alternative methods	High
Other Projects					
13	*Replace and decommission DWV sewer line within lower Brothers Creek.*	The sanitary sewer running down lower Brothers Creek is at least 40 years old and is a risk to the aquatic ecosystem. Three possible methods are available to decommission old sanitary sewer line: (1) dry pack grout at each manhole; (2) grout entire pipe system; or (3) grout entire pipe system and remove manholes.	Eliminate risks of raw sewage entering Brothers Creek, damage to sewer line via debris and tree roots, manholes forming obstructions.	Option 1: $180,000 Option 2: $630,000 Option 3: $1,200,000 (decommissioning costs only)	High
14	*Coordinate with Metro Vancouver to decommission GVS&DD sewer line within lower Brothers Creek.*	The sanitary sewer running down lower Brothers Creek is at least 40 years old and is a risk to the aquatic ecosystem. Replace and decommission portion of old sanitary sewer line within Brothers Creek operated by the GVS&DD.	Eliminate risks of raw sewage entering Brothers Creek, damage to sewer line via debris and tree roots, manholes forming obstructions.	Staff time for coordination	High
15	*Investigate and, if appropriate, construct stormwater treatment structures to address high priority sources of pollution to Brothers Creek.*	Currently, turbid grey stormwater from Highway 1/Taylor Way discharges to Brothers Creek through three outfalls (one east and two west of Taylor Way), and turbid brown stormwater (likely from Highland Drive) discharges to Brothers Creek through an outfall on the left bank from Hollyburn Country Club. Options for installing stormwater treatment structures such as oil-grit separators, infiltration chambers, etc. should be investigated and installed if appropriate.	Improve the water quality of Brother Creek by treating stormwater from major roads and institutional properties.	$200,000 per site (oil-grit separator)	Medium

7.3 Community Engagement Programs

Several of the recommended projects above have cross-benefits in community building, recreation opportunities, and amenities. Collaborative effort between the District and the community will be required to carry out some projects and will augment the benefits of others.

Outreach and Education

Targeted at the Public

- Daylighting of tributary to Brothers Creek at Westcot Elementary School (Project 7) has high potential for outreach, education, and volunteer stewardship opportunities:
  - Design as a “living classroom” to be used by classes from Westcot Elementary School and others;
  - Public education during construction to teach community members about stream restoration, environmental protection during construction, and design of outdoor learning environments;
  - Exhibits leadership in District and the opportunity to be a leader in restoration projects with multiple benefits to the environment and the public; and
  - Volunteer opportunities for some aspects of restoration (e.g., plantings), maintenance, and ongoing stewardship of the site.
- Daylighting of West Vinson Creek (Project 8) has potential for outreach, education, and volunteer, stewardship opportunities:
  - Interpretive opportunities to teach about historical stormwater management, new strategies, stream daylighting, and restoration; and
  - Volunteer opportunity for public stewardship through construction (e.g., plantings) and ongoing maintenance.
- Create targeted outreach and education programs for each of landowners, developers, and contractors on source control design, construction, and maintenance requirements.
- Provide District staff working near creeks (e.g., removing invasive species) with information pamphlets to share with the public that explain how to identify giant hogweed and knotweed and provide a phone number to call if discovered.

Targeted at the Residents with Properties on the Creeks

- Create an outreach and education program for landowners and residents with properties within the creek riparian area to raise awareness of best practices and requirements within riparian areas.

Targeted at the District Staff

- Provide staff training on ISMP recommendations and implementation needs. Target information sessions and training at departments and staff that will be responsible for implementation of the ISMP recommendations.
- Pursue and facilitate dialogue/conversations/consultation internally and with Metro Vancouver on alternatives for addressing the issues identified with the existing sewer line in Brothers Creek. (Projects 13 and 14.).

Stewardship Opportunities

- Restoration projects provide opportunities and motivation for public to get involved with stewardship; projects should be advertised through schools and community events with information and signup opportunities, as well as notices of projects and how people can help on District website news items.
- Programs and incentives for landowners can encourage individuals to practice stewardship on their own properties while improving watershed health. Some programs/incentives may be eligible for grant funding to cover all or a portion of the costs.
- District staff can collaborate with stewardship groups such as the West Vancouver Streamkeeper Society to incorporate community efforts in maintenance and monitoring activities.

Recreation and Public Access

- Enhancing 380 m of West Brothers creek along Wildwood Lane (Project 4) could provide access for walking along enhanced creek.
- Daylighting of West Vinson Creek mouth at Ambleside (Project 9) would enhance the area's livability and recreational value.
- Potential daylighting of the outlet of Vinson East Creek below the plaza so that the creek discharges at the foreshore would bring the creek functions into an area of high visibility and easy public access.

Outreach and education to engage District staff and watershed residents is necessary to support the watershed vision and to promote successful implementation of the ISMP.

7.4 Processes and Bylaw Recommendations

Operations and Maintenance

- **Street Sweeping and Catch Basin Cleaning** – Investigate frequency and timing of street sweeping and catch basin cleaning, and alter if necessary to reduce pollution load that reaches the creeks from streets. Identify catch basins that tend to accumulate sediment more quickly and increase frequency of cleaning in those areas. Set a schedule to review annually or as appropriate.
- **Culvert Inspection and Maintenance** – Following the recommendations of to the *2012 Culvert Inspection Program* (Delcan, 2012), continue to regularly monitor culverts with known issues. Coordinate replacement of deteriorating culverts (that have reached end of service life) with capital capacity upgrade projects. The District should consider setting a schedule to update the culvert inspection on a 10- to 20-year cycle, depending on what would work best with current repair and replacement schedules and funding of capital costs.
- **Invasive Species Tracking** – Continue with District-wide treatment and control programs of giant hogweed and Japanese knotweed using contracted crews to remove manually or treat with herbicides. Cross-check occurrences recorded as part of KWL creek inventory with District's database of sites and add any new sites to be managed, as well as track sites treated and note success of treatments. Conduct annual follow-up surveys downstream of known sites to detect newly established populations as quickly as possible before they grow in size and are more difficult to treat and manage.

- **Native Species Planting** – After removing invasive species and replanting with native plants, monitor sites regularly to ensure that native plants are establishing, are healthy, and are out-competing any invasive plants present. Remove invasive plants and replant native plants if necessary until established.
- **Consider Salmon-Safe Certification for Municipal Parks** – Salmon-Safe is a third-party eco-certification program that encourages land managers to use practices that protect Pacific salmon habitat and water quality.

Policies for Development Mitigation

- Adopt the DRAFT *District of West Vancouver Single Family Re-development Lot Rainwater Management Guidelines* (KWL, 2015) with proposed changes or equivalent guidelines to outline the requirements of on-site rainwater management mitigation measures to compensate for increases in impervious area on single family residential lots.
  - The Single-Family Re-development Lot Guidelines share the basic principles of the recently adopted Zoning Bylaw Amendment No. 4895, 2016 (a bylaw to regulate and require provision of landscaping and to require the control of surface runoff in residential zones) and provide criteria and methodology for achieving the shared rainwater management objectives.
  - Review and if necessary update the following guideline document for Drainage Permit requirements: *Building Drainage Requirements: Drainage Notes: sewer, sumps & water services* (February 2014). Either update this document to include on-lot rainwater mitigation measures or combine with the Single-Family Redevelopment Lot Guideline as part of development of the District's Engineering Design Criteria Manual (in process of development).
  - Consider a public consultation process as part of finalization and adoption of the Guidelines.
- Review the District's Zoning Bylaw (Bylaw 4662, 2010) and consider addition of maximum allowable total impervious area to various zoning categories.
  - Suggested maximum allowable impervious area for single family zones (including single detached, duplex and triplex) is 70% in accordance with the Metro Vancouver Baseline (Metro Vancouver, 2016).
  - Zoning Bylaw Amendment No. 4895, 2016 provides precedent for limiting maximum allowable impervious area on lots in the District. Article 4.1 (7) states "Impermeable surfaces in front yards must not exceed 50% of the area of the front yard as defined in this Zoning Bylaw […]." A further amendment to the Zoning Bylaw could add maximum impervious coverage for the lot overall.
- Review and if necessary update the District's Building Bylaw (No. 4400, 2004).
  - Consider revisions to allow for disconnection of roof leaders and discharge of roof runoff to absorbent landscaping or other pervious surfaces. Specifically consider article 10.5: "All roof and paved areas are to drain to a storm water connection or where unavailable to an approved storm water disposal location."
  - Ensure the Building Inspector (as designated by the Building Bylaw) is aware of any newly adopted re-development guidelines for rainwater management and has the necessary training, knowledge, and resources to allow appropriate inspection.

- The District is in the process of developing engineering design guidelines. Consider incorporating or referencing any adopted rainwater management guidelines or criteria including the criteria presented in Section 7.1, above, for single family lot re-development, and all other development and re-development.
- Consider incorporating Low Impact Development design principles in the Official Community Plan and in applicable bylaws and design standards.
  - Where surface parking is required, consider pervious paving. (Could be added to Boulevard Bylaw (No. 4886, 2016).
  - Consider pervious paving for roads, sidewalks, and patios.
  - Consider developing guidelines for treatment of road runoff (i.e., bump-out rain gardens, infiltration swales, water quality treatment units).

Invasive Species Management

- Continue to implement District of West Vancouver's Invasive Plant Strategy (DWV, 2014) for the treatment and control of invasive species in riparian areas and creek corridors using appropriate methods for working in and around water. Many herbicides are not safe to use near aquatic habitat, so alternative treatment methods should be explored. The District may want to consider novel methods such as grazing by goats as a method to control the growth of knotweed near watercourses where herbicide application is prohibited, and in locations where bank slopes and accessibility would allow. A growing number of private contractors offer this service in BC. The best approach involves repeated grazing treatments each year for multiple years.

Riparian Protection, Restoration and Replanting Policies

Preserve and maintain existing riparian areas, vegetation buffers, and trees.

- Review and, if necessary, update Development Permit Area for Watercourse Protection guidelines in OCP (current OCP Policy NE-13 Provisions of Watercourse Protection) to bring into compliance with provincial RAR and, if desired by the District, increase riparian protection. At a minimum, the review should include:
  - Reviewing the setback distances used to trigger the Environmental Development Permit process (currently 15 m from top of watercourse bank) to ensure the District's triggers meet the minimums set out in the SPEAs definitions for different watercourse types in the RAR;
  - Reviewing the types of developments exempted from the Environmental Development Permitting process to ensure compliance with the RAR; and
  - For cases where there is little or no buildable area outside of the setbacks, reviewing the flexibility or variance options employed by the District to approve these developments to ensure they are compliant with the RAR.

  To maximize the benefits to watershed health, it is recommended that new developments should strive for a minimum 30 m setback on all permanent natural watercourses. Other factors may also influence the width of setbacks, such as property boundaries and geotechnical considerations.

- As part of the review and consultation process for the District's Interim Tree Bylaw, consider changes to enhance the protection of trees and other vegetation, such as:
  - Specific requirements to plant one or more replacement trees or other vegetation for every hazardous tree removed, particularly in riparian areas;
  - Minimum lot-level canopy cover targets to guide tree removal permitting and requirements for replanting; and
  - Requirement for tree protection barriers during construction activities.

Additional Environmental Protection Policy Enhancements

- Create a long-term, phased strategy for the restoration of sections of Vinson West and Vinson East Creeks in concert with expected future re-development in the vicinity of the creeks. The restoration program may focus on or include daylighting sections of stream where the existing infrastructure is under capacity and requires upgrade. The strategy should also consider daylighting of the outfalls for Vinson West and Vinson East creeks up to the developed foreshore to make the creeks and their connection to the ocean visible, as well as to remove any need for changes or upgrades to the outfall due to future impacts of sea level rise on the outfall pipes.
- Watercourse Protection Bylaw (No. 4364, 2005) includes an open watercourse policy. Article 6.1 states: "Open Watercourses and ditches shall remain above ground and may only be closed where no alternative exist, as determine by the District." Open ditches provide important rainwater management services and the ISMP encourages the open ditch policy.

7.5 Major System Conveyance

Creek Channel Capacity and Diversions

While creek infrastructure should be adequately sized to convey the 200-year flows, the design level for protection of property from flooding is the 100-year event. Additional model runs were carried out to determine where potential creek overbank flows may occur during the 100-year event under future land use with climate change conditions. Even with culverts adequately sized to convey the 200-year flows, the modeling indicates there are a number of locations where flows may overtop creek banks and potentially cause flooding.

Note that the capacity of creek channels in the models is defined using contour mapping provided by the District and the accuracy and level of definition of the creek channels in the contour mapping is not known. Where needed, due to lack of definition of the creek channel in the contour mapping, the modelled creek channel capacity has been modified based on measurements of the channel taken during the engineering and environmental inventory of the creeks.

The current accuracy of data available on the channel geometry and capacity is not adequate to determine with certainty that the creek channels are inadequate for the predicted 100-year return period flow. However, the current analysis would indicate that there may be some risks due to lack of channel capacity for the major (100-year) event. In particular, Vinson Creek, both West and East tributaries, may have inadequate channel capacity for a majority of the length of the Creek. The available terrain mapping indicates that flow from Vinson Creek would tend to flow overland westward and into Lawson Creek, if the flows in the creek exceed the channel capacity.

Diversions were proposed to reduce creek flows in previous studies. Further studies are needed to assess whether these diversions are still needed for any of the study creeks. The studies would include further refinement of the hydraulic model of the creeks with surveyed cross sections where the terrain mapping indicates that the creek channel has inadequate capacity to convey the 100-year or 200-year flow.

Culvert Upgrades

The capacity assessment identified major system conduits with insufficient capacity to convey the 200-year flows without surcharging. Of the 159 major system conduits in the Vinson, Brothers, and Hadden watersheds, 108 are undersized for the 200-year existing land use scenario, four more are undersized for the future land use scenario, and two more conduits are undersized for the future land use with climate change scenario. These results are shown in Figure 7-24 at the end of this section. Major system conduits that do not have the capacity to pass the 200-year design storm should be upgraded to the required size necessary to pass the 200-year future land use with climate change flows.

Prioritization of upgrades was completed based on the exiting level of service of the major system conduits as summarized in Table 7-4 and detailed in Table 7-5. Recommended upgrades are prioritized first by existing service level and then by flood potential. The flood potential was evaluated by modeling overflow weirs to represent the road elevations above the culverts. A culvert is said to “flood” when the modeled water elevation at the upstream end of the culvert exceeds the road elevation. Not all undersized culverts flood over the road for the design event and those that surcharge but do not flood over the road are given a lower priority than those that do flood over the road. Priority categories for upgrades are defined as follows:

Priority 1a. Culverts that have an existing service level of less than 2 years and result in potential flooding over the road during the 200-year existing land use design event.

Priority 1b. Culverts that have an existing service level of less than 2 years.

Priority 2a. Culverts that have an existing service level of 2 to 5 years and result in potential flooding over the road during the 200-year existing land use design event.

Priority 2b. Culverts that have an existing service level of 2 to 5 years.

Priority 3a. Culverts that have an existing service level of 5 to 10 years and result in potential flooding over the road during the 200-year existing land use design event.

Priority 3b. Culverts that have an existing service level of 5 to 10 years.

Priority 4a. Culverts that have an existing service level of 10 to 100 years and result in potential flooding over the road during the 200-year existing land use design event.

Priority 4b. Culverts that have an existing service level of 10 to 100 years.

Priority 5. Culverts that have an existing service level of 100 to 200 years.

Priority 6. Culverts that have a future service level of less than 200 years, regardless of whether or not surface flooding occurs. These upgrades are recommended as end-of-life or development opportunity upgrades only.

Figure 7-2 shows the prioritized upgrades.

Cost Estimate Assumptions

The cost estimates for the proposed capital works are of Class C accuracy. This means that the general requirements for upgrading including size and approximate depth of excavation, as well as some general site conditions are known. The projects identified have not considered the following factors that may affect construction and costs:

- Relocation of adjacent services (water, hydro, etc.);
- Special permitting requirements (fisheries windows, contaminated sites, etc.);
- Geotechnical issues requiring special construction such as pile-supported piping, buoyancy problems or rock blasting; and
- Critical market shortages of materials.

Surveys and more detailed assessments of proposed capital works should be conducted prior to preliminary and detailed design of upgrades.

Costs for each priority are summarized in Table 7-4. A breakdown of costs for individual culvert upgrades is included in Table 7-5.

Table 7-4: Culvert Upgrades Estimated Capital Costs

Priority	Description of Upgrade	Cost
Existing Land Use Capacity Issues		
1a	Floods During 200-Year Event, Existing Service Level < 2 years	$3,081,000
1b	Existing Service Level <2 years	$228,000
2a	Floods During 200-Year Event, Existing Service Level 2 to 5 years	$6,559,000
2b	Existing Service Level 2 to 5 years	$6,289,000
3a	Floods During 200-Year Event, Existing Service Level 5 to 10 years	$2,192,000
3b	Existing Service Level 5 to 10 years	$5,539,000
4a	Floods During 200-Year Event, Existing Service Level 10 to 100 years	$251,000
4b	Existing Service Level 10 to 100 years	$26,955,000
5	Existing Service Level 100 to 200 years (End-of-life upgrades)	$29,832,000
Future Land Use with Climate Change Capacity Issues		
6	Future Service Level <200 years (End-of-life or development opportunity upgrades)	$7,856,000
	Culvert Upgrades Program Total	**$88,782,000**

Climate Change and Sea Level Rise Considerations

Sea level rise projections for Burrard Inlet are as follows:

- Year 2050 – 0.5 m;
- Year 2100 – 1 m; and
- Year 2200 – 2 m.

While the projected sea level rise will impact the foreshore area, no buildings within the study area are affected by sea level rise up to the 2 m, Year 2200 level (see Figure 7-3). The coastal design flood level (DFL) includes consideration of tide (Higher High Water, Large Tide, HHWLT), storm surge (200-year return period), projected sea level rise, and local ground uplift rate (approximately 1.2 mm/year). These factors combine to make a DFL of approximately 4.96 m Geodetic. The District of West Vancouver has previously recommended that an Extreme Water Level of 4.5 m be used for design of bank protection and outfall stability. The expected risk of the 200-year storm surge and HHWLT occurring at the same time as a 200-year return period rainfall event is very small, therefore the effects of those events coinciding is not considered.

The elevations of the Vinson and East Vinson pipe outfalls were unavailable for this study, but based on its location the Vinson East outlet is expected to be affected by sea level rise. According to KWL records, the flow gauge on Vinson East Creek has had past issues due to backwatering, therefore projected sea level rise is expected to cause further backwater in the outfall pipe. Potential effects of the backwatering would be expected to include:

- Salt intrusion issues into the pipe along with potential accelerated corrosion and deterioration of the pipe material;
- Reduced pipe capacity; and
- Hydraulic jump in the outfall pipe with the potential for pressure waves to lift manhole covers during storm events.

No measures to protect either the Vinson Creek or Vinson East outfalls from the effects of sea level rise are expected to be required within the horizon of this ISMP; however, future changes to the outfall pipes should bear in mind the potential for sea level rise impacts. Possible accommodations for sea level rise could include daylighting the creeks beyond the foreshore up to the limits of the expected effects of sea level rise to remove the constriction of the pipes in the system, or increasing the capacity of the pipes.

Table 7-5: Class C Cost Estimates for Recommended Culvert Upgrades

Priority	Existing Level of Service	Conduit ID	Length (m)	Existing Size	Required Upgrade Size	200-Yr FLU w/ Climate Change Peak Flow (m^3/s)	Earthworks ($)	Roadworks ($)	Restoration and Planting ($)	Culvert/ Headwalls ($)	Total Cost ($)	Total Cost with Mark-ups ($)
1a	<2yr	296	40.9	0.15 m	1.35 m	2.4	$201,000	$53,000	$47,000	$143,000	$444,000	$804,000
1a	<2yr	292	26.7	0.3 m	1.35 m	2.5	$133,000	$34,000	$47,000	$127,000	$341,000	$618,000
1a	<2yr	444	25.6	0.75 m	1.8 m	5.4	$128,000	$33,000	$47,000	$131,000	$339,000	$614,000
1a	<2yr	453	24.1	0.75 m	1.8 m	5.4	$121,000	$31,000	$47,000	$129,000	$328,000	$594,000
1a	<2yr	460	13.6	0.75 m	1.8 m	5.3	$70,000	$17,000	$47,000	$115,000	$249,000	$451,000
1b	<2yr	385	20.1	0.9 m	1.8 m	3.6	$25,000	$12,000	$22,000	$67,000	$126,000	$228,000
2a	2yr - 5yr	347	26.6	0.75 m	2.4 m	8.9	$133,000	$34,000	$47,000	$152,000	$366,000	$662,000
2a	2yr - 5yr	471	18.0	0.75 m	2.1 m ⌀	6.7	$24,000	$11,000	$22,000	$74,000	$130,000	$236,000
2a	2yr - 5yr	404	4.8	0.66 m x 0.9 m elliptical (squished circular)	2.4 m	10.1	$13,000	$6,000	$21,000	$57,000	$96,000	$174,000
2a	2yr - 5yr	349	22.7	0.9 m	2.4 m	8.9	$114,000	$29,000	$47,000	$143,000	$333,000	$603,000
2a	2yr - 5yr	Kwl1005	21.5	0.75 m	1.8 m	5.2	$63,000	$21,000	$35,000	$94,000	$214,000	$387,000
2a	2yr - 5yr	408	12.9	1.05 m	2.4 m	10.3	$31,000	$11,000	$30,000	$80,000	$152,000	$276,000
2a	2yr - 5yr	407	9.7	1.05 m	2.4 m	10.3	$23,000	$7,000	$29,000	$71,000	$130,000	$236,000
2a	2yr - 5yr	414_1	18.1	0.9 m	2.1 m	7.0	$40,000	$15,000	$30,000	$87,000	$172,000	$311,000
2a	2yr - 5yr	465	16.5	0.9 m	2.1 m	7.3	$84,000	$21,000	$47,000	$127,000	$279,000	$505,000
2a	2yr - 5yr	411	19.5	1.2 m	2.4 m	10.9	$39,000	$15,000	$28,000	$91,000	$173,000	$313,000
2a	2yr - 5yr	393	11.7	0.75 m	1.5 m	3.4	$16,000	$7,000	$21,000	$46,000	$90,000	$163,000
2a	2yr - 5yr	490	265.0	0.9 m	1.8 m	4.9	$191,000	$133,000	$18,000	$411,000	$753,000	$1,362,000
2a	2yr - 5yr	375	53.1	1.05 m	2.1 m	6.7	$48,000	$29,000	$19,000	$139,000	$235,000	$426,000
2a	2yr - 5yr	381	19.6	1.05 m	2.1 m	6.9	$21,000	$10,000	$20,000	$74,000	$125,000	$226,000
2a	2yr - 5yr	438	12.9	1.1 m	2.1 m	6.0	$52,000	$14,000	$41,000	$103,000	$210,000	$380,000
2a	2yr - 5yr	Kwl1000	44.1	0.6 m	1.05 m	1.4	$56,000	$28,000	$23,000	$58,000	$165,000	$299,000
2b	2yr - 5yr	423	29.7	0.75 m	2.1 m	5.8	$58,000	$23,000	$29,000	$107,000	$217,000	$393,000
2b	2yr - 5yr	470	17.3	0.9 m	2.1 m	7.3	$81,000	$21,000	$45,000	$123,000	$270,000	$488,000
2b	2yr - 5yr	318	15.5	0.9 m	2.1 m	6.5	$40,000	$13,000	$32,000	$87,000	$173,000	$312,000
2b	2yr - 5yr	415	20.2	1.2 m	2.4 m	11.0	$133,000	$30,000	$54,000	$161,000	$378,000	$684,000
2b	2yr - 5yr	437	33.0	0.75 m	1.5 m	3.3	$48,000	$22,000	$24,000	$84,000	$179,000	$324,000
2b	2yr - 5yr	Kwl1003	12.4	0.6 m	1.35 m	2.1	$41,000	$12,000	$36,000	$81,000	$170,000	$308,000
2b	2yr - 5yr	440	26.3	0.75 m	1.5 m	3.2	$131,000	$34,000	$47,000	$136,000	$349,000	$631,000
2b	2yr - 5yr	379	14.2	1.05 m	2.1 m	7.0	$53,000	$15,000	$39,000	$102,000	$209,000	$378,000
2b	2yr - 5yr	493	24.7	0.75 m	1.35 m	2.4	$55,000	$21,000	$30,000	$73,000	$178,000	$322,000
2b	2yr - 5yr	409	39.2	0.6 m	1.2 m	1.5	$193,000	$51,000	$47,000	$125,000	$416,000	$752,000
2b	2yr - 5yr	425	20.4	0.9 m	1.65 m	4.1	$121,000	$29,000	$51,000	$135,000	$336,000	$608,000
2b	2yr - 5yr	455	15.3	0.6 m	1.2 m	1.8	$79,000	$20,000	$47,000	$107,000	$252,000	$456,000
2b	2yr - 5yr	Kwl1001	22.6	0.6 m	1.05 m	1.4	$89,000	$26,000	$41,000	$93,000	$249,000	$451,000
2b	2yr - 5yr	414_2	18.8	1.2 m	2.1 m	7.1	$13,000	$7,000	$14,000	$66,000	$100,000	$182,000
3a	5yr - 10yr	KWL016	4.8	3 @ 0.6 m	2 @ 1.35 m and 1 @ 1.05 m	6.7	$13,000	$6,000	$21,000	$61,000	$100,000	$181,000
3a	5yr - 10yr	405	23.6	2 m x 3 m box	3 @ 3.05 m x 2.44 m box	38.6	$105,000	$29,000	$44,000	$382,000	$559,000	$1,012,000
3a	5yr - 10yr	417	24.7	2 m x 3 m box	3 @ 2.7 m x 1.5 m box	28.9	$124,000	$32,000	$47,000	$350,000	$552,000	$999,000
3b	5yr - 10yr	474 and 474_2	16.3	0.75 m and 0.6 m	2.1 and 1.65 m	10.5	$70,000	$19,000	$43,000	$136,000	$268,000	$486,000
3b	5yr - 10yr	419	17.3	1.2 m	2.4 m	10.3	$54,000	$17,000	$36,000	$102,000	$208,000	$377,000
3b	5yr - 10yr	431	23.6	0.75 m	1.35 m	2.7	$148,000	$34,000	$53,000	$142,000	$377,000	$683,000
3b	5yr - 10yr	476	49.5	0.75 m	1.35 m	2.2	$138,000	$48,000	$35,000	$112,000	$333,000	$603,000
3b	5yr - 10yr	Kwl1004	12.0	0.75 m	1.35 m	2.4	$33,000	$10,000	$33,000	$62,000	$138,000	$249,000
3b	5yr - 10yr	555_2	23.0	0.5 m	0.9 m	0.7	$115,000	$30,000	$47,000	$105,000	$297,000	$537,000
3b	5yr - 10yr	KWL011	14.7	0.75 m	1.35 m	2.0	$69,000	$18,000	$45,000	$106,000	$237,000	$430,000
3b	5yr - 10yr	KWL008	24.2	0.9 m	1.65 m	3.7	$61,000	$22,000	$33,000	$89,000	$205,000	$370,000

Table 7-5: Class C Cost Estimates for Recommended Culvert Upgrades

Priority	Existing Level of Service	Conduit ID	Length (m)	Existing Size	Required Upgrade Size	200-Yr FLU w/ Climate Change Peak Flow (m^3/s)	Earthworks ($)	Roadworks ($)	Restoration and Planting ($)	Culvert/ Headwalls ($)	Total Cost ($)	Total Cost with Mark-ups ($)
3b	5yr - 10yr	KWL501	22.0	2.25 m x 3 m box	3 @ 3.05 m x 2.44 m box	39.5	$140,000	$32,000	$53,000	$392,000	$617,000	$1,118,000
3b	5yr - 10yr	KWL012	21.1	1.05 m	1.65 m	4.2	$144,000	$32,000	$55,000	$149,000	$379,000	$686,000
4a	10yr - 100yr	C97	43.0	0.5 m	1.35 m	2.1	$30,000	$20,000	$16,000	$72,000	$138,000	$251,000
4b	10yr - 100yr	304	43.3	0.45 m	1.2 m	1.6	$87,000	$35,000	$29,000	$74,000	$226,000	$409,000
4b	10yr - 100yr	297	60.5	0.5 m	1.2 m	2.0	$63,000	$35,000	$21,000	$73,000	$192,000	$348,000
4b	10yr - 100yr	310	9.1	0.5 m	1.2 m	1.6	$49,000	$5,000	$49,000	$102,000	$205,000	$372,000
4b	10yr - 100yr	314	17.2	0.5 m	1.05 m	1.4	$59,000	$18,000	$38,000	$81,000	$195,000	$353,000
4b	10yr - 100yr	319	15.4	0.5 m	1.05 m	1.0	$20,000	$9,000	$21,000	$37,000	$87,000	$158,000
4b	10yr - 100yr	307	22.5	0.6 m	1.2 m	1.5	$36,000	$15,000	$25,000	$50,000	$126,000	$229,000
4b	10yr - 100yr	KWL014	8.0	0.5 m	0.9 m	0.8	$14,000	$7,000	$18,000	$34,000	$73,000	$132,000
4b	10yr - 100yr	555	23.0	0.75 m	1.2 m	1.6	$115,000	$30,000	$47,000	$112,000	$304,000	$550,000
4b	10yr - 100yr	492	52.5	0.9 m	1.35 m	2.4	$159,000	$54,000	$37,000	$129,000	$379,000	$685,000
4b	10yr - 100yr	KWL005	19.8	0.9 m	1.5 m	2.8	$56,000	$19,000	$34,000	$83,000	$192,000	$348,000
4b	10yr - 100yr	402	103.4	2.25 m x 3.5 m box	3 @ 3.05 x 2.44 m box	39.1	$1,118,000	$203,000	$70,000	$1,411,000	$2,802,000	$5,072,000
4b	10yr - 100yr	394	55.2	0.75 m	1.05 m	1.4	$74,000	$37,000	$24,000	$66,000	$201,000	$363,000
4b	10yr - 100yr	KWL021	31.6	0.6 m	1.05 m	1.4	$25,000	$15,000	$17,000	$43,000	$100,000	$181,000
4b	10yr - 100yr	361	39.2	1.8 m	3.05 m	15.6	$1,101,000	$123,000	$113,000	$554,000	$1,892,000	$3,425,000
4b	10yr - 100yr	C4	13.5	0.6 m	1.2 m	1.5	$70,000	$17,000	$47,000	$105,000	$240,000	$434,000
4b	10yr - 100yr	KWL009_1	8.6	1.1 m	1.65 m	4.1	$19,000	$2,000	$28,000	$58,000	$107,000	$194,000
4b	10yr - 100yr	316	28.6	0.6 m	1.05 m	1.2	$142,000	$37,000	$47,000	$113,000	$339,000	$613,000
4b	10yr - 100yr	355	142.2	1.5 m	2.4 m	8.9	$687,000	$187,000	$47,000	$396,000	$1,317,000	$2,384,000
4b	10yr - 100yr	500	48.9	0.9 m	1.35 m	2.3	$65,000	$32,000	$24,000	$89,000	$210,000	$381,000
4b	10yr - 100yr	317	13.9	0.45 m	0.75 m	0.5	$71,000	$18,000	$47,000	$100,000	$236,000	$427,000
4b	10yr - 100yr	416	24.5	1.2 m	1.65 m	4.4	$72,000	$24,000	$35,000	$95,000	$227,000	$411,000
4b	10yr - 100yr	388	14.3	1.2 m	1.65 m	3.8	$34,000	$12,000	$31,000	$72,000	$148,000	$269,000
4b	10yr - 100yr	434	12.7	2.3 m x 3.2 m box	2 @ 3.05 m x 2.44 m box	28.6	$42,000	$13,000	$37,000	$176,000	$268,000	$485,000
4b	10yr - 100yr	391	11.7	1.2 m	1.65 m	3.8	$28,000	$9,000	$30,000	$67,000	$135,000	$244,000
4b	10yr - 100yr	372	32.6	1.35 m	1.8 m	5.4	$170,000	$43,000	$48,000	$146,000	$408,000	$738,000
4b	10yr - 100yr	371	18.7	1.35 m	1.8 m	5.5	$53,000	$18,000	$34,000	$89,000	$194,000	$351,000
4b	10yr - 100yr	C92	8.2	0.75 m	1.05 m	7.1	$187,000	$8,000	$107,000	$364,000	$666,000	$1,205,000
4b	10yr - 100yr	469_2	94.8	0.9 m	1.35 m	9.1	$460,000	$124,000	$47,000	$207,000	$838,000	$1,516,000
4b	10yr - 100yr	469_3	100.5	0.9 m	1.2 m	8.9	$487,000	$132,000	$47,000	$171,000	$837,000	$1,515,000
4b	10yr - 100yr	450	35.4	1.54 m x 2.4 m box	3 @ 2.7 m x 1.5 m box	11.1	$98,000	$34,000	$44,000	$419,000	$595,000	$1,077,000
4b	10yr - 100yr	450_2	35.4	1.7 m x 2 m box								
4b	10yr - 100yr	376	16.7	1.35 m	1.8 m	4.9	$68,000	$19,000	$42,000	$104,000	$233,000	$421,000
4b	10yr - 100yr	396	19.5	0.75 m	1.05 m	1.1	$22,000	$11,000	$20,000	$38,000	$91,000	$164,000
4b	10yr - 100yr	KWL500	32.2	0.9 m	1.35 m	2.4	$31,000	$17,000	$19,000	$63,000	$131,000	$237,000
4b	10yr - 100yr	380	14.2	1.35 m	1.8 m	4.9	$28,000	$10,000	$27,000	$58,000	$123,000	$222,000
4b	10yr - 100yr	384	15.4	1.35 m	1.65 m	3.9	$49,000	$15,000	$36,000	$86,000	$186,000	$336,000
4b	10yr - 100yr	KWL009_2	15.7	1.1 m	1.5 m	3.0	$48,000	$15,000	$35,000	$88,000	$186,000	$336,000
4b	10yr - 100yr	377	26.1	1.5 m	1.8 m	4.9	$65,000	$23,000	$32,000	$84,000	$205,000	$370,000
5	100yr - 200yr	KWL004	23.0	2.2 m x 3.4 m box	2 @ 2.7 m x 1.5 m box	22.4	$291,000	$48,000	$75,000	$365,000	$779,000	$1,410,000
5	100yr - 200yr	356	108.0	1.4 m x 2.1 m box	2 @ 2.1 m x 1.2 m box	7.3	$772,000	$173,000	$57,000	$570,000	$1,572,000	$2,845,000
5	100yr - 200yr	315	38.6	0.5 m	0.9 m	0.8	$129,000	$41,000	$38,000	$88,000	$298,000	$539,000
5	100yr - 200yr	C238	9.9	0.4 m	0.675 m	0.4	$52,000	$12,000	$47,000	$98,000	$210,000	$379,000
5	100yr - 200yr	467	10.8	0.4 m	0.6 m	0.3	$20,000	$7,000	$25,000	$36,000	$88,000	$159,000
5	100yr - 200yr	469_6	109.6	1.05 m	1.5 m	12.7	$531,000	$144,000	$47,000	$266,000	$988,000	$1,788,000
5	100yr - 200yr	469_5	110.5	1.05 m	1.5 m	12.2	$535,000	$145,000	$47,000	$267,000	$995,000	$1,801,000

Table 7-5: Class C Cost Estimates for Recommended Culvert Upgrades

Priority	Existing Level of Service	Conduit ID	Length (m)	Existing Size	Required Upgrade Size	200-Yr FLU w/ Climate Change Peak Flow (m^3/s)	Earthworks ($)	Roadworks ($)	Restoration and Planting ($)	Culvert/ Headwalls ($)	Total Cost ($)	Total Cost with Mark-ups ($)
5	100yr - 200yr	469_1	150.4	0.9 m	1.2 m	7.0	$727,000	$198,000	$47,000	$208,000	$1,180,000	$2,136,000
5	100yr - 200yr	469_7	373.2	1.05 m	1.35 m	13.2	$1,796,000	$492,000	$47,000	$533,000	$2,868,000	$5,191,000
5	100yr - 200yr	469_4	228.7	1.05 m	1.35 m	11.2	$1,103,000	$301,000	$47,000	$363,000	$1,814,000	$3,283,000
5	100yr - 200yr	C59_2	94.9	1.05 m	1.35 m	6.0	$819,000	$166,000	$63,000	$263,000	$1,311,000	$2,373,000
5	100yr - 200yr	298	17.1	0.75 m	1.2 m	1.5	$34,000	$13,000	$28,000	$52,000	$127,000	$229,000
5	100yr - 200yr	382	190.0	0.75 m	1.05 m	1.1	$917,000	$250,000	$47,000	$212,000	$1,426,000	$2,581,000
5	100yr - 200yr	293	62.9	0.75 m	1.2 m	1.7	$116,000	$50,000	$28,000	$87,000	$281,000	$509,000
5	100yr - 200yr	383	63.6	0.75 m	0.9 m	1.0	$310,000	$83,000	$47,000	$122,000	$563,000	$1,018,000
5	100yr - 200yr	KWL013	21.0	0.6 m	0.9 m	0.8	$24,000	$12,000	$20,000	$36,000	$92,000	$166,000
5	100yr - 200yr	435	16.1	0.9 m	1.05 m	1.4	$72,000	$19,000	$44,000	$96,000	$230,000	$417,000
5	100yr - 200yr	454	138.4	0.6 m	0.9 m	0.6	$670,000	$182,000	$47,000	$154,000	$1,052,000	$1,904,000
5	100yr - 200yr	410	13.2	0.6 m	0.75 m	0.5	$68,000	$17,000	$47,000	$100,000	$232,000	$419,000
5	100yr - 200yr	290	21.1	1.2 m	1.5 m	3.4	$140,000	$31,000	$54,000	$153,000	$379,000	$685,000
6	>200yr	469_9	158.0	1.35 m	1.65 m	13.2	$763,000	$208,000	$47,000	$296,000	$1,314,000	$2,378,000
6	>200yr	Kwl007	22.0	0.9 m	1.05 m	1.3	$81,000	$24,000	$40,000	$89,000	$234,000	$424,000
6	>200yr	260	101.8	0.525 m	0.6 m	1.1	$493,000	$134,000	$47,000	$116,000	$790,000	$1,431,000
6	>200yr	365	20.8	2.25 m x 2.45 m box	3.05 x 2.44 m box	13.7	$380,000	$52,000	$91,000	$375,000	$897,000	$1,624,000
6	>200yr	C59_1	92.4	1.2 m	1.35 m	9.2	$449,000	$121,000	$47,000	$204,000	$821,000	$1,485,000
6	>200yr	C249	18.9	1.05 m	1.35 m	2.4	$96,000	$24,000	$47,000	$117,000	$284,000	$514,000

1. Conduit IDs with underscores are pipes that had to be split in the model. Conduit IDs beginning with C or KWL are conduits that were found during the survey or engineering inventory that were not in the District's GIS database.
2. Priority 6 represents end of life upgrades or upgrades at time of re-development only.
3. Assumed existing diversions will not be upgraded. Downstream infrastructure sized to convey remaining undiverted flows.
4. Where culvert inverts unknown, a depth of 4 m was assumed for cost estimates.
5. Where multiple box culverts have been recommended it may be more cost effective to replace with a bridge depending on site specific constraints.

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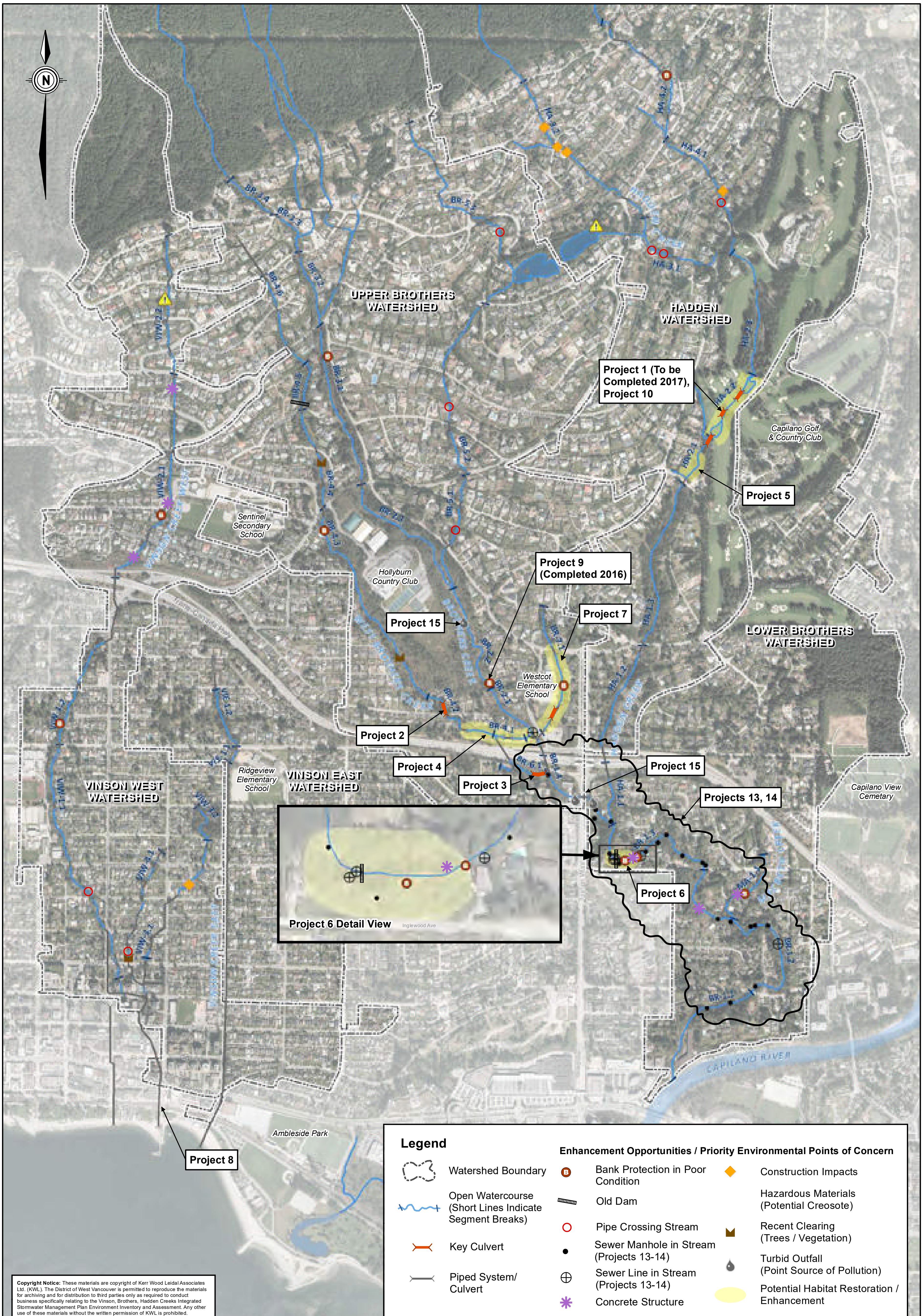

KERR WOOD LEIDAL consulting engineers

District of West Vancouver
Vinson, Brothers, and Hadden Creeks ISMP

Project No.	Date
409-073	March, 2017

200 0 200 (m)
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Enhancement Opportunities and Priority Environmental Points of Concern

Figure 7-1

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Project No.	Date
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Capital Plan
Culvert Upgrades

Figure 7-2

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Project No.	Date
409-073	March, 2017

250 0 250 (m)
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Projected Sea Level Rise

Figure 7-3

8. Implementation and Adaptation of the ISMP

8.1 Funding Strategies

Existing Funding Sources

Funding sources for each category of solutions are identified below.

- Funding strategies for environmental projects are identified in Table 7-3 where projects may be done with staff and volunteer time, and below where grant funding may be applicable for eligible projects. Environmental enhancements may also be completed with funds from the Districts capital program for enhancements done in conjunction with culvert or other infrastructure upgrades.
- On-lot development mitigation will be funded by property owners/developers.
- Culvert upgrades will be funded by District capital program funds. The District will need to review timelines and estimated costs of upgrades and assess the existing capital funding program with regards to the recommended timelines for upgrades.
- Any upgrades that are warranted due to development or re-development projects should be funded from Development Cost Charges paid by developers.

District bylaws that may be relevant to funding sources for drainage projects are identified below:

- Development Cost Charges Bylaw No. 3801, 1993.
- Sewer and Drainage Utility Fee Bylaw No. 4538, 2007. The bylaw identifies two types of fees:
  - Article 5.1 Connection Fees states "Any person making an application for the installation, connection, or disconnection of a sewer or drainage service pipe or street main shall pay fees set out in Schedule "C".
  - Article 5.2 Sewer Utility Fee states "Where the water supply to a property is metered, a quarterly charge, to be called a "metered sewer utility fee" is […] imposed on the owner of the property for the use of the Municipal Sewer System". The Sewer Utility Fee includes a base charge per connection for sanitary and drainage service as well as a per volume charge based on potable water use. Single Family Residential customers pay a lower volume charge based on winter usage rates where other land use customers pay based on total actual volume.

The District's allocation of funds derived from Connection Fees and Sewer Utility Fees must be split between sanitary and drainage works, and the funding must cover operations costs as well as capital projects.

Potential Funding Sources

Stormwater Utility Approach

Some municipalities across Canada are looking into creating a utility for stormwater infrastructure. Currently, the City of Victoria has just implemented a new stormwater utility to fund the management of stormwater in the City. The first stormwater utility bills are set to be sent out in the fall of 2016. Instead of charging a flat fee, the City of Victoria is using impervious percentage as the main factor in determining the rate per parcel. By basing the fee on impervious percentage, it provides residents and businesses a practical reason to limit the amount of impervious surfaces on the site. It also creates the opportunity for incentives for residents and businesses to implement source controls.

Investing in Canada Plan – Infrastructure Canada

The funding announced in Budget 2017 includes $800 million in green infrastructure funding for British Columbia (excluding the Lion's Gate WWTP project). The specific objectives of funding for BC have not yet been defined, but will include greenhouse gas mitigation, adaptation, resilience and disaster mitigation, and "environmental quality investments" that increase the capacity to treat and manage water and wastewater. The maximum federal share of municipal project costs under this program will be 40%. The Province of BC will be required to provide top-up funding of at least 33.3% of eligible municipal project costs.

Additional Information: http://www.infrastructure.gc.ca/plan/about-invest-apropos-eng.html

New Building Canada Plan – Infrastructure Canada

The new Building Canada Plan is providing provide federal funds to provinces, territories, and municipalities between 2014 and 2024. The plan includes the Gas Tax Fund, giving municipalities greater flexibility to spend federal funding on a broader range of infrastructure priorities. Although many components of the Plan are fully allocated, funding is renewed annually on an ongoing basis under the Gas Tax Fund. In BC, Gas Tax funding includes directly allocated funding to each municipality under the Community Works Fund, and application based funding under the Strategic Priorities Fund outside Metro Vancouver (where all unallocated funding is dedicated to regional transportation investments).

Additional information: http://www.infrastructure.gc.ca/plan/plan-eng.html ;

http://www.ubcm.ca/EN/main/funding/renewed-gas-tax-agreement.html

Municipalities for Climate Innovation (MCIP) – Federation of Canadian Municipalities

This fund is a five-year, $75-million program that helps municipalities prepare for, and adapt to, climate change, and to reduce emissions of greenhouse gases (GHGs). Delivered by the Federation of Canadian Municipalities (FCM) and funded by the Government of Canada, MCIP is available to all municipalities and their partners. The program provides up to $175,000 for climate change plans and studies, and up to $1 million or more for capital projects. Projects to address risks of flooding are included in the eligible scope of the program.

Additional information: https://fcm.ca/home/programs/municipalities-for-climate-innovation-program/municipalities-for-climate-innovation-program.htm

Green Municipal Fund – Federation of Canadian Municipalities

This fund provides funds for three types of environmental initiatives: plans, studies and projects. The funding is allocated into five sectors of municipal activity: brownfields, energy, transportation, waste and water. All municipal governments and their partners in eligible projects have access to the funding. Below-market rate loans usually combined with grants are available to implement capital projects.

Additional information: http://www.fcm.ca/home/programs/green-municipal-fund.htm

EcoAction Community Funding Program – Environment Canada

This program encourages completion of projects that will protect, rehabilitate or enhance the natural environment. The program supports projects that address the following:

- Clean air: to reduce emissions that contribute to air pollutants;
- Clean water: to divert and reduce substances that negatively affect water quality or to focus on water conservation and efficiency;
- Climate change: to reduce greenhouse gas emissions that contribute to climate change or to deal with the impacts of climate change; and
- Nature: to reduce biodiversity loss, protect wildlife and plants, and protect and improve the habitat where they live.

The funding is available for non-government, non-profit groups and organizations.

Additional information: www.ec.gc.ca/ecoaction

Evergreen Foundation (multiple programs)

The RBC-Evergreen Watershed Champions Award

This grant provides funding for school programs designed to teach students in publicly funded schools about their local watershed or about water in the context of their local watershed. Classes that provide participation in other watershed or water based programs through local outdoor education centres, conservation authorities, community groups, non-profit organizations and/or government programs are also eligible to apply.

Additional information: http://info.evergreen.ca/en/watershed-champions/award

Toyota Evergreen Learning Grounds School Ground Greening Grants

The purpose is to help schools create outdoor classrooms to provide students with a healthy place to play, learn and develop respect for nature. This grant is available for publicly funded and accessible schools up to $3,500 for schools and $2,500 for daycares. Eligible expenses include: native plant species, heritage berries, vegetable seeds and plants, tools, materials and professional services.

Additional information: http://www.evergreen.ca/en/funding/grants-available/school-ground-greening-grants/

We Are Cities: Community Innovation Grant

This grant provides funding to support projects that address issues critical to the success of communities, including mobility, the built and natural environment, citizen engagement, multi-sectoral collaboration, policy design, waste management and energy. Grants of $2,000 and $5,000 are available to Canadian community groups and non-profit organizations to be used on publicly accessible lands. Eligible expenses include: native plant species, heritage berries, vegetable seeds and plants, tools, materials and professional services.

Additional information: http://www.evergreen.ca/get-involved/funding-opportunities/community-innovation-grant/

8.2 Monitoring Plan

Condition 7 of the BC Minister of Environment's approval of Metro Vancouver's 2011 Integrated Liquid Waste Resource Management Plan (ILWRMP) requires that all municipalities, with coordination from Metro Vancouver, monitor stormwater to assess and report on the effectiveness of ISMP implementation. To fulfill this provincial requirement, Metro Vancouver and its member municipalities have developed a *Monitoring and Adaptive Management Framework for Stormwater* (MAMF) (Metro Vancouver, 2014). The MAMF takes a weight of evidence approach, using several types of monitoring and indicators to develop an overall assessment of watershed conditions. Through repeated sampling, watershed health and the response to specific watershed protection measures and management actions can be tracked over time.

The MAMF provides direction on the general types of monitoring to be utilized for higher gradient, lower gradient, and piped systems (see Table 8-1), the methods and parameters to be used for monitoring, and the reporting required.

Table 8-1: Standard MAMF Monitoring Program Elements Based on Stream Type

Stream Type	Water Quality	Hydrometric	Benthic Invertebrates
Lower Gradient	Yes	Yes (natural channels only)	Yes
Higher Gradient	Yes	Yes	Yes
Piped Systems	Yes	No	No

Based on the MAMF, all of the creeks within the study area are classified as higher gradient streams (average channel slope >1%), except East Vinson Creek, which is predominantly a piped system.

Monitoring Framework

The following sections detail the recommended monitoring framework for tracking ISMP implementation including the impact of development and re-development, the effectiveness of mitigation measures, and the influence of stormwater management activities on creek health in the Brothers/Hadden, West Vinson, and East Vinson catchments.

Monitoring Parameters

Table 8-2 provides the recommended parameters for monitoring implementation of the ISMP. The core monitoring parameters in the framework, based on MAMF requirements, can be grouped into three categories:

- Water quality monitoring indicators – selected general water quality parameters, nutrients, bacteriological parameters, and metals;
- Flow monitoring indicators – seven flow-related metrics characterizing watershed hydrology; and
- Benthic invertebrate biomonitoring indicators – benthic index of biotic integrity (BIBI) scores and mean taxa richness.

Table 8-2: Summary of ISMP Performance Monitoring Indicators

Performance Indicator	Indicator Type	Baseline Data Available?	Short-term Trend/Target	Long-term Target
Water Quality Performance Indicators				
Dissolved Oxygen	Primary	Yes	Increasing	>11 mg/L in summer
pH	Secondary		Stable	No change over time
Water Temperature	Primary		Decreasing in dry season	<16°C in summer
Conductivity	Secondary		Decreasing	<200 µs/cm
Turbidity	Primary		Decreasing in wet season	<5 NTU in dry season
Nutrients (Nitrate as N)	Primary		Decreasing	<2 mg/L
Bacteriological Parameters (*E. coli* and fecal coliform)	Primary		Decreasing, esp. in wet season	<77 CFU/100 mL (*E. coli*) <200 CFU/100 mL (fecal coliform)
Metals (Fe, Cd, Cu, Pb, Zn)	Primary		Decreasing, esp. in wet season	Varies – see MAMF
Flow Monitoring Performance Indicators				
T_{Qmean}	Primary	Yes, ongoing hydrometric program since 2012	Stable or increasing	Same as short-term
Low Pulse Count			Stable or decreasing	
Low Pulse Duration			Stable or increasing	
Summer Baseflow (L/s)			Stable	
Winter Baseflow (L/s)			Stable or increasing	
High Pulse Count			Stable or decreasing	
High Pulse Duration (days)			Stable of increasing	
Benthic Invertebrate Biomonitoring Performance Indicators				
B-IBI Scores	Primary	Yes	Stable or increasing	To be set based on 2016 results
Mean Taxa Richness	Primary		Stable or increasing	-
Recommended Supplemental Performance Indicators				
No. of Erosion Sites	Supplemental	Yes	Decreasing	No high conseq. sites
Total Impervious Area (TIA)	Supplemental	Yes	n/a (for tracking only)	n/a (for tracking only)
Riparian Forest Integrity (RFI)	Supplemental	Yes	Stable or increasing	Increasing
No., Species, and Locations of Spawners	Supplemental	Yes	Stable or increasing	Increase in spawners from current levels
No. of Fish Passage Barriers	Supplemental	Yes	Decreasing	No human-made passage barriers

Several supplemental performance monitoring indicators have also been recommended: number of erosion sites, effective impervious area (EIA), riparian forest integrity (RFI), number of returning spawning salmon, and number of fish passage barriers. For some of these supplemental indicators, data is already being collected and is readily available from existing monitoring programs (e.g., spawner surveys by West Vancouver Streamkeepers). Others of these indicators should be included as resources allow. Inclusion of these additional indicators will provide a more comprehensive assessment of watershed health and ISMP implementation over time.

The table also indicates the priority of each parameter for measurement (primary or secondary), whether baseline data has or is being collected, and sets short- and long-term targets for trends for different parameters.

Monitoring Sites

Table 8-3 provides location details for each of the recommended long-term monitoring sites for each of the three ISMP catchments. MAMF water quality monitoring sites have been established in each of the Brothers/Hadden, East Vinson, and West Vinson catchments. Sites were chosen based on their position in the watershed downstream of any major tributaries, their accessibility for long-term monitoring, and their suitability for sampling. Similarly, benthic invertebrate sampling reaches were established on Brothers/Hadden and West Vinson catchments at sites as near to Burrard Inlet as possible with suitable conditions (e.g., presence of appropriate substrates for sampling).

Hydrometric (flow) monitoring has been ongoing in the watershed since 2012 as part of a District-wide monitoring program. Five flow monitoring sites are currently active in the ISMP study area. Two other flow monitoring sites on East Vinson catchment (East Vinson) and Upper Hadden Creek (Hadden North) were discontinued in 2013 and 2015, respectively. The East Vinson site was discontinued because of tidal influence at its location and no other site exists within the catchment. However, flow monitoring is not required under the MAMF for piped systems. The station on Upper West Vinson Creek (Vinson North) was also moved upstream from its original location in August 2015.

Two of the five flow monitoring stations are required as per the MAMF; see Table 3. The other three flow monitoring sites are supplemental to provide better information on flows in the upper Brothers Creek watershed, Hadden Creek, and the upper Vinson West Creek watershed.

The closest rainfall gauge to the watershed is at West Vancouver Municipal Hall (17^{th} St and Fulton Ave).

Figure 8-1 shows the locations of the water quality, benthic invertebrate, and hydrometric monitoring sites, as well as West Vancouver Streamkeeper Society temperature monitoring sites and the West Vancouver Municipal Hall rainfall gauge. Figures 8-2 to 8-5 provide detailed maps of the locations of the three MAMF water quality and two benthic invertebrate sampling sites.

Monitoring Frequency

Under the MAMF, the core monitoring parameters are required to be monitoring at a minimum every five years, although more frequent monitoring may be undertaken. The MAMF recommends watersheds with stable land use are monitored every three to five years.

As the District already has a long-term District-wide flow monitoring program with permanent stations in several creeks, it is recommended this monitoring be continued. The accuracy of hydrologic statistics is greatly improved by collecting longer-term hydrologic records.

Table 8-3: Long-term MAMF Monitoring Sites for Vinson, Brothers, and Hadden Creeks ISMP

Monitoring Type	Location of Monitoring Site	Site Code (refers to Figure 1)	UTM Coordinates		Year(s) and Seasons of Data Collection[2]
			Easting[1]	Northing[1]	
Brothers/Hadden Watershed – Higher Gradient System					
Water Quality	15 m upstream of Capilano Pacific Trail pedestrian bridge at Clyde Ave, 35 m downstream of Clyde Ave bridge to Capilano Care Centre	BRO1	490503	5463976	2016 (dry and wet season)
Flow	Beneath and at downstream edge of the Keith Rd bridge, west of Keith Pl	Brothers/Hadden Hydrometric Station	490753	5464242	2012–ongoing
Benthic Invertebrates	15 m upstream of Capilano Pacific Trail pedestrian bridge at Clyde Ave, 25 m upstream of Clyde bridge to Capilano Care Centre	BRO1	490503	5463976	2016
East Vinson Watershed – Piped System					
Water Quality	Storm sewer manhole in NW corner of Ambleside Park west of tennis courts near SE corner of Marine Dr and 13th St	VINE2	488979	5463855	2016 (dry and wet season)
West Vinson Watershed – Higher Gradient/Piped System					
Water Quality	Storm sewer manhole in sidewalk on SW corner of intersection of Marine Dr and 14th St in front of Vancity	VINW1	488769	5463912	2016 (dry and wet season)
Flow	Storm sewer manhole in sidewalk on SW corner of intersection of Marine Dr and 14th St in front of Vancity	Vinson West Hydrometric Station	488769	5463912	2012–ongoing
Benthic Invertebrates	40 m downstream of Haywood Ave footbridge, between 15th and 16th St	VINW3	488555	5464520	2016

Notes:
[1]UTM Zone 10U

ISMP Monitoring and Analysis in 2016

As part of ISMP development, KWL completed collecting, analyzing, and reporting on baseline water quality, benthic invertebrate, and flow monitoring data according to MAMF protocols in 2016. This includes:

- Water quality monitoring at the Brothers/Hadden, West Vinson, and East Vinson monitoring sites in the dry (completed in August and September 2016) and wet seasons (completed in November and December 2016);
- Benthic invertebrate sampling in the Brothers/Hadden and West Vinson watersheds (completed in September 2016); and
- Analysis of flow data and derivation of the MAMF flow monitoring performance indicators from the two active sites located downstream of all major tributaries in the Brothers and West Vinson catchments (Brothers/Hadden and West Vinson) from 2012 to present.

To supplement the MAMF sampling, KWL also collected additional dry season water quality in situ and grab sampling at additional locations in the watersheds in 2016. The purpose of this sampling was to identify potential sources of water quality issues for further investigation and follow-up as part of adaptive management.

Key Findings

The 2016 water quality monitoring has had the following key findings:

- Mean low flow summer water temperatures in West Vinson Creek were above 16°C, the top end of the optimal range for streams with rearing coho salmon and/or resident cutthroat trout. Water temperatures in Brothers Creek were approaching this threshold. Water temperatures in East Vinson Creek were also high but are of less concern because this catchment is not known to support salmonid species.
- Mean dry season dissolved oxygen levels were approaching levels of concern in all three catchments but are still above levels recommended for early salmonid life stages (eggs and alevin).
- Mean dry season conductivity was above levels of concern in West Vinson Creek, and approaching levels of concern in Brothers Creek and East Vinson Creek.
- Dry season *E. coli* and fecal coliform levels (geometric means of 5 samples in 30 days) exceeded guidelines for primary contact recreation in West Vinson and Brothers Creek, though were below levels for secondary contact recreation.
- Of the five metals that are tracked by the MAMF, mean dry season total copper approached levels of concern in West Vinson Creek.

The one-time in-situ and grab sampling at a wider number of sites had the following additional key findings:

- Hadden Creek downstream of the Capilano Golf & Country Club (Site HAD2) exceeded provincial water temperature guidelines for streams with rearing coho in mid-August.
- West Brothers Creek downstream of Crestwell Dr (Site BROW6) was found to have elevated turbidity and detergent odours.
- An outfall on the left bank of Brothers Creek just upstream of Taylor Way (Site BRO6) had levels of dissolved oxygen, pH, and conductivity approaching levels of concern.

- Conductivity levels are of concern at several of the in-situ monitoring sites in Brothers and West Vinson Creeks (BROW3, BROW5, BROE1, VINW1, VINW3, VINW4, and VINW5).

Complete results of the 2016 monitoring programs are included in Appendix C.

Proposed Monitoring Program

Table 8-4 summarizes the proposed monitoring program that should be implemented for the Vinson, Brothers, and Hadden Creeks ISMP moving forward. The program includes both existing and newly proposed components. To implement the program, the District should:

- Conduct MAMF water quality and benthic invertebrate water quality monitoring every five years at a minimum (every three years recommended);
- Continue existing continuous hydrometric and rainfall monitoring;
- Conduct annual erosion monitoring of high priority sites such as on Brothers Creek within the Hollyburn Country Club and on Hadden Creek downstream of the Capilano Golf and Country Club;
- Track implementation of on-lot mitigation measures and habitat enhancement projects in a GIS database;
- Conduct desktop monitoring of changes in total impervious area (TIA) and riparian forest integrity (RFI) from aerial photos and GIS-based analysis (this could be implemented on a District-wide basis for all of the District's ISMPs); and
- The District should also support West Vancouver Streamkeeper Society to continue their spawner, fry, and continuous temperature monitoring.

Table 8-4: Proposed Monitoring Program for Vinson, Brothers, and Hadden Creeks ISMP

Program Component	Method	Monitoring Location(s)	Monitoring Frequency	Recommended Implementation Approach
MAMF Water Quality Monitoring	5 samples in 30 days in dry and wet seasons as per MAMF	3 sites: Brothers East Vinson West Vinson	Every 5 years at a minimum, every 3 years recommended	Establish rotating District-wide monitoring program
Flow Monitoring	Hydrometric stations	5 sites: Brothers/Hadden Brothers North Hadden South Vinson South Vinson North	Ongoing – 15 minute intervals	Continue as part of existing District-wide program; focus on 2 sites for analysis
Rainfall (Component of Hydrologic Monitoring)	Rainfall gauge	West Vancouver Municipal Hall	Ongoing – 5 minute intervals	Continue as part of existing District-wide program
Benthic Invertebrate Monitoring	Fall sampling (three replicates in 30 m reach) as per MAMF	2 sites: Brothers West Vinson	Every five years at a minimum, every 3 years recommended	Establish rotating District-wide monitoring program
Erosion Monitoring	Regular field inspections as part of other creek works	All major creeks (as assessed in ISMP)	Compile data every 5 years	Continue as part of existing District-wide program
On-lot Mitigation Adoption by Parcel	Create and update inventory on District's GIS	Whole watershed	Ongoing	Update inventory as part of building permit close-out
Total Impervious Area (TIA)Assessments	GIS-based analysis of impervious surfaces on typical land uses in the watersheds	Whole watershed	Every 5 years	Incorporate fields in cadastral GIS and populate with measured or extrapolated TIA
Riparian Forest Integrity (RFI) Assessments	GIS-based analysis of orthophotos	Whole watershed	Every 5 years	Consider as part of existing District-wide program ISMPs
Fish Passage Barrier Assessments	Create and update inventory on District's GIS	Whole watershed	Ongoing	Update inventory as projects are completed
Salmon Spawner Surveys	No., species, date, and locations of spawners	Throughout Brothers/Hadden watershed	Annually	Continued by West Vancouver Streamkeeper Society
Continuous Temperature Monitoring	Instream temperature probes	4 sites: Upper Brothers Lower Brothers Upper Hadden Lower Hadden	Ongoing – 15 minute intervals	Continued by West Vancouver Streamkeeper Society

8.3 Adaptive Management Plan

Maintaining and enhancing the ecological health of a watershed is best achieved through adaptive management. Monitoring allows assessment of progress towards the plan's goals and reporting to decision-makers, stakeholders, and the public. Using an adaptive management approach for ISMP implementation allows for regular feedback on the effectiveness of measures recommended in the ISMP such that informed decisions can be made about future measures based on whether watershed goals are being achieved. In cases where existing measures are not achieving desired results, changes can be made to improve their effectiveness, or new measures can be taken. Adaptive management is also recommended to ensure improvements in watershed health are achieved in the most cost-effective manner.

Within the MAMF, measures taken to mitigate the impacts of land development on watershed health are defined as Adaptive Management Practices (AMPs). These include measures under a variety of functional categories such as source controls, runoff detention and infiltration facilities, runoff pollution control, runoff treatment, outreach and education, and mitigation of construction impacts. The iterative process of carefully collecting, analyzing, and interpreting data will allow for the effectiveness of these AMPs to be assessed, and if not achieving the desired results, to change measures or to target different priority areas. The process requires proper planning but also flexibility as stormwater management practices and knowledge evolve over time and new technologies are become accessible.

The basis for adaptive management is long-term monitoring of the indicators listed in the proposed monitoring plan described above. If the monitoring results indicate issues in aquatic health, previously implemented AMPs should be re-evaluated or new, more appropriate AMPs should be implemented to mitigate the problem. Analysis of monitoring data should occur on a regular basis. The indicators selected in the monitoring program do not all have to move in a particular direction to show improvement or degradation in watershed health. The full suite of indicators should be reviewed in regular cycles to:

- Note changes or trends in particular indicators;
- Evaluate possible causes of those changes;
- Determine if changes in the indicators represent an impact;
- Evaluate if observed changes are expected or unforeseen; and
- Review the goals, elements, and implementation plan of the ISMP to assess if changes should be made to the plan to remain on track and achieve the overall stormwater goals over the implementation timeline for the ISMP.

The collection of data and its full review (listed above) for the watershed health indicators should be conducted once every five years (four full reviews during the 20-year expected implementation timeline). After the implementation period is complete, monitoring should continue once every five years.

Municipality-Wide Adaptive Management Plan

As recommended in the MAMF, rather than following an adaptive management plan for each ISMP, it is recommended that municipalities prepare a single Adaptive Management Plan on a municipality-wide basis. As the District of West Vancouver will have soon completed all required ISMPs for its watersheds and has several District-wide monitoring programs and datasets, the District is in an excellent position to develop such as a plan. This District-wide Adaptive Management Plan can be used to prioritize among both watersheds and issues, identify and address the highest priority issues first, and ensure the efficient utilization of District resources.

It is also recommended that the results of the additional dry season in situ and grab sampling be used to further guide the adaptive management process in these watersheds.

Adaptive Management for the First Five Years

The primary focus for adaptive management for the first five years after completion of the ISMP will be to:

- Set up tracking systems in accordance with Table 3 for metrics that are not currently tracked
- Further investigate concerns and issues identified in 2016 monitoring and baseline analysis
- Evaluate trends of metrics at the end of five years and assess whether results indicate that:
  - Trends are in the desired directions,
  - Issues and concerns have been mitigated or improved, and
  - Revised mitigation or management approaches are needed.

The review and evaluation of trends and issues at the end of the first five years will set the priorities for the next five years of monitoring, review of data, and adaptation of programs and policies.

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Author: Lmorgan

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District of West Vancouver
Vinson, Brothers, and Hadden Creeks ISMP

Project No. 409-073

Date March, 2017

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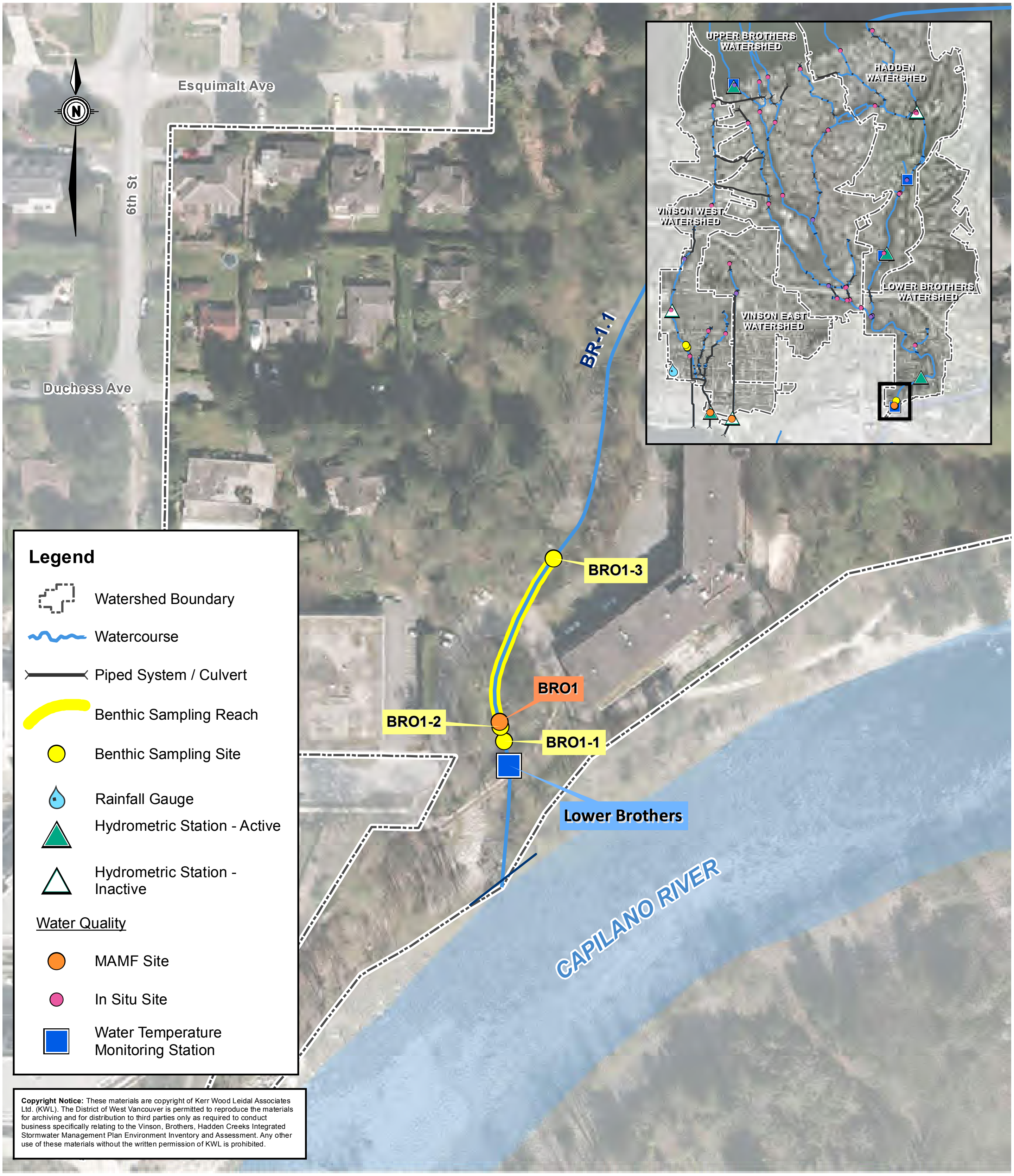
Monitoring Site Locations

Figure 8-1



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Vinson, Brothers, and Hadden Creeks ISMP

Project No.	Date
409-073	March 2017

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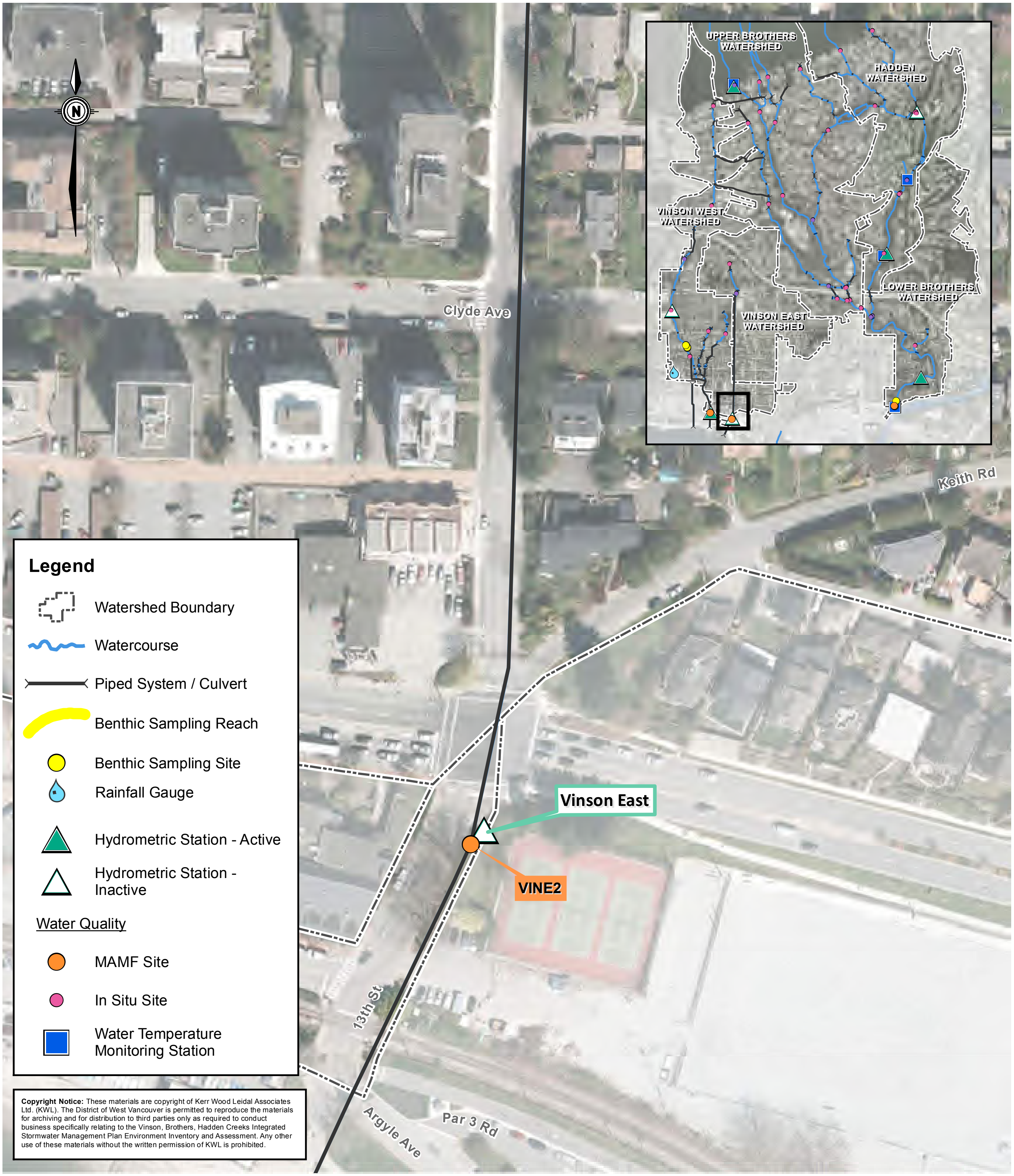
Brothers/Hadden Watershed - MAMF Water Quality and Benthic Invertebrate Monitoring Sites

Figure 8-2



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Vinson, Brothers, and Hadden Creeks ISMP

Project No.	Date
409-073	March 2017

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East Vinson Watershed - MAMF Water Quality Monitoring Sites

Figure 8-3

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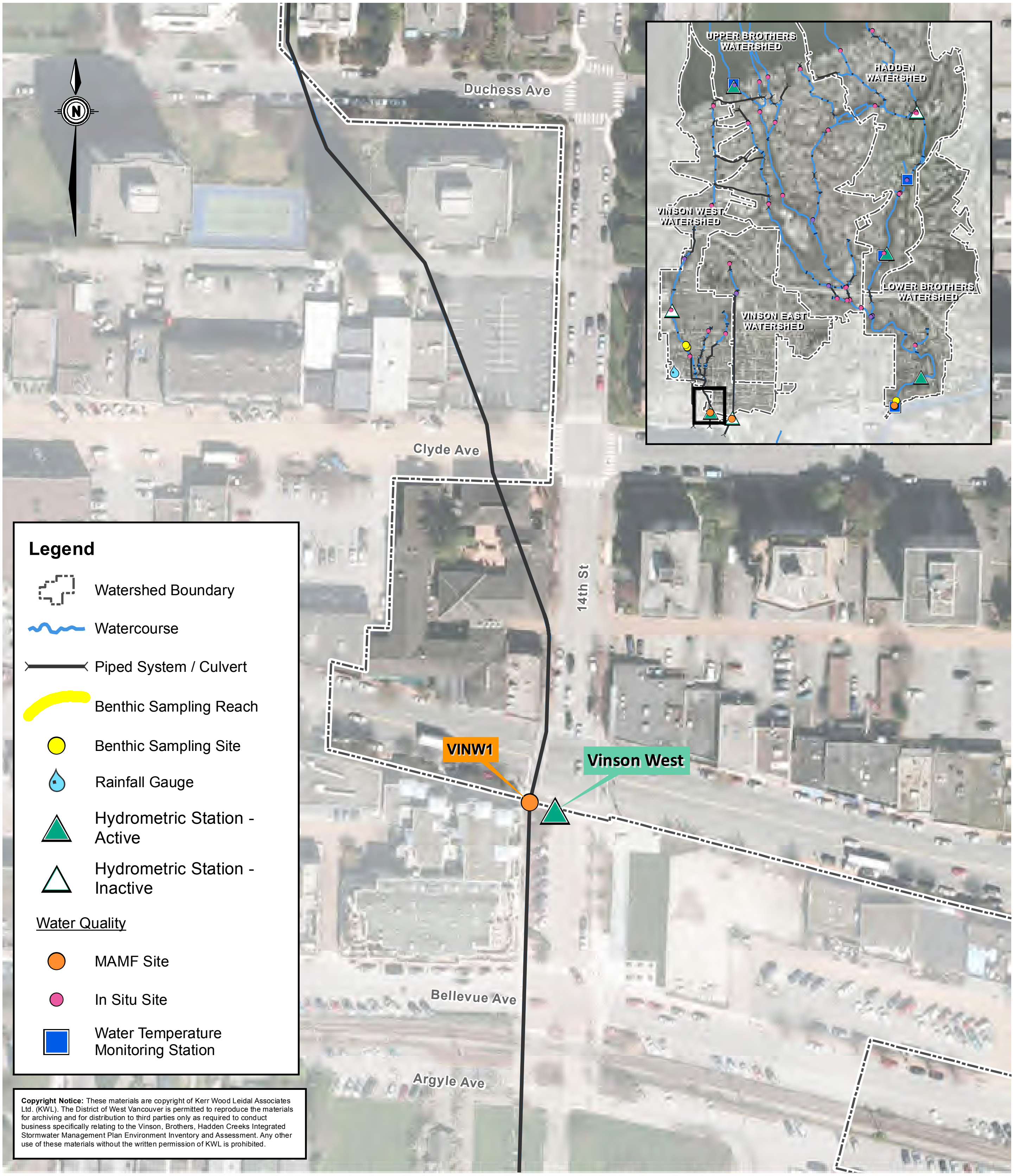

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Vinson, Brothers, and Hadden Creeks ISMP

Project No.	Date
409-073	March 2017

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West Vinson Watershed - MAMF Water Quality and Flow Monitoring Sites

Figure 8-4

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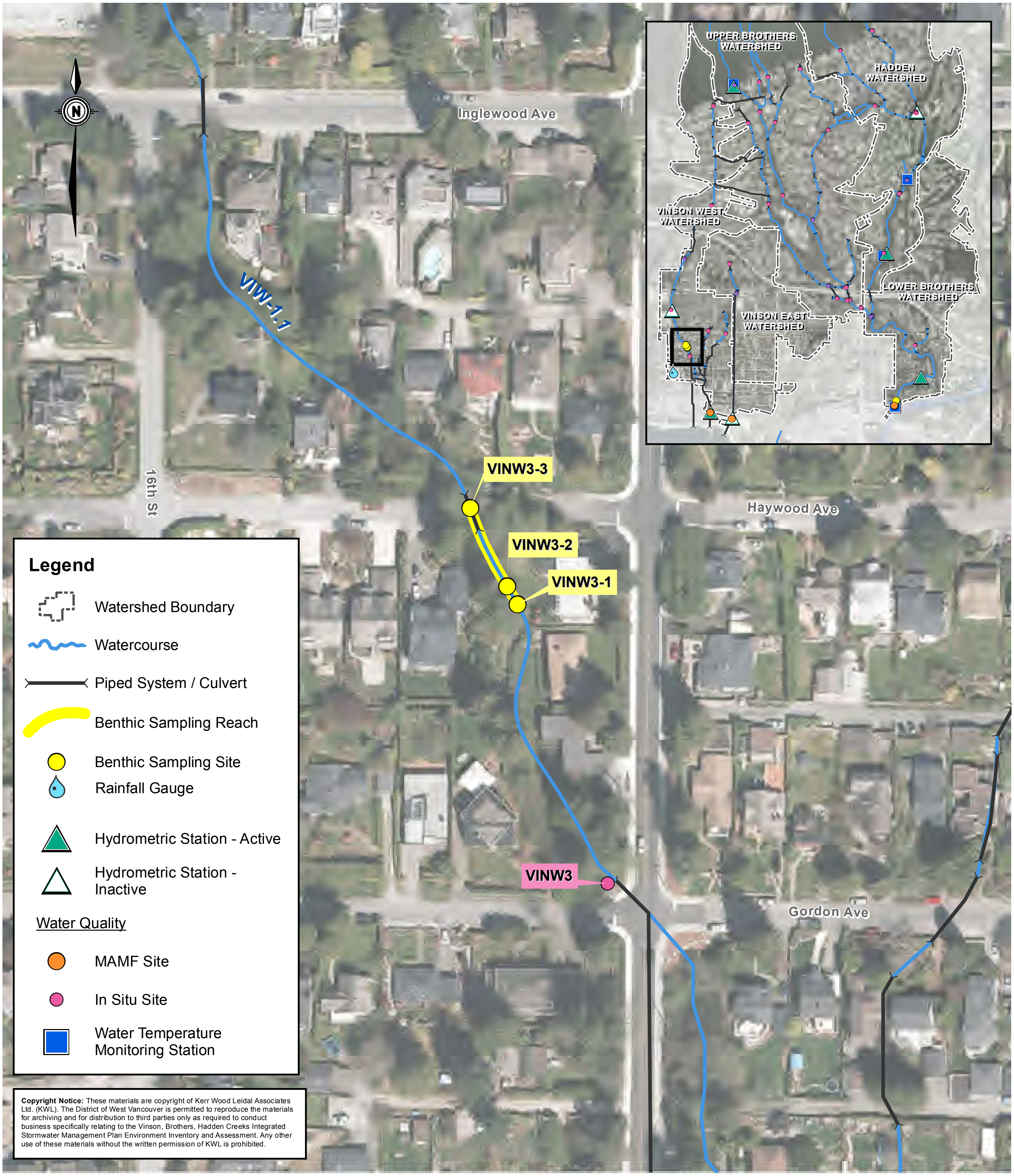

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Project No.	Date
409-073	March 2017

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West Vinson Watershed - MAMF Benthic Invertebrate Monitoring Sites

Figure 8-5

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Author: Lmorgan

9. Recommendations from the ISMP

The following are recommendations resulting from the ISMP study and process for Vinson, Brothers, and Hadden Creeks ISMP. These recommendations refer to elements that are discussed in detail in this report and its appendices. Based on this work, it is recommended that the District:

Task	Recommendation	District Department
1	Adopt and implement the proposed mitigation for anticipated watershed re-development of single family residential lots by formalizing and implementing the *District of West Vancouver Single Family Re-development Lot Rainwater Management Guidelines (KWL, 2015)* including recommended changes, as discussed in Section 7.1.	Planning and Land Development
2	Adopt and implement the proposed mitigation criteria for all non-single-family-residential land uses within the watersheds, as discussed in Section 7.1.	Planning and Land Development
3	Pursue and work with streamkeepers and private property owners to enable environmental compensation and enhancement projects as recommended in Section 7.2.	Engineering
4	Continue to work with stakeholders such as the West Vancouver Streamkeepers and pursue opportunities for public engagement and involvement in watershed health stewardship and enhancement as discussed in Section 7.3.	Engineering and Communications
5	Pursue bylaw and policy changes and enhancements to enable and support protection of watershed health, sustainable re-development, community involvement, and public safety, as discussed in Section 7.4.	Engineering and Planning
6	Develop a schedule and plan for pursuing upgrade of under-capacity in-stream culverts, focusing on the highest priority structures (Priority 1, then 2, etc.) as discussed in Section 7.5 and in Appendix E.	Engineering
7	Plan for further study of potential flood risks due to inadequate capacity of the existing creek cross-sections to determine whether further mitigation may be required, as discussed in Section 7.5.	Engineering
8	Assess current funding sources relative to recommended capital items and evaluate whether additional funding sources, as discussed in Section 8.1, or approaches will benefit implementation of capital projects.	Engineering
9	Continue monitoring of watershed health metrics in accordance with the Metro Vancouver Monitoring and Adaptive Management Framework (MAMF) and with recommendations as discussed in Section 8.2.	Engineering
10	Develop a schedule for reviewing and assessing monitoring data to evaluate whether implementation approaches may need to be revised, as discussed in Section 8.3.	Engineering

Report Submission

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

This document is a copy of the sealed and signed hard copy original retained on file. The content of the electronically transmitted document can be confirmed by referring to the filed original.

Laurel Morgan, M.Sc., P.Eng. Project Manager	Luke Warkentin, BIT Junior Biologist

Reviewed by:

David Zabil, M.A.Sc., P.Eng. Technical Reviewer	Patrick Lilley, M.S., R.P.Bio. Senior Biologist

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of DISTRICT OF WEST VANCOUVER for the Vinson, Brothers, and Hadden Creeks ISMP. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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Revision History

Revision #	Date	Status	Revision	Author
0	October 2017	Final	Final Report	LM
A	March 2017	Draft	Draft issued for District review	LM

OQM | Organizational Quality Management Program

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Appendix A

Stakeholder Consultation Program

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Stakeholder Consultation Strategy

Overview

The Brothers, Vinson and Hadden Creeks Integrated Stormwater Management Pan (ISMP) is guided by the District of West Vancouver (DWV), its departments and staff. KWL is collaborating with District staff and key internal stakeholders to develop the ISMP. This Stakeholder Consultation Strategy provides a framework and details of the consultation process to integrate internal District needs and policies with external needs and values from key external stakeholders and the public. This strategy will guide the process of understanding balancing competing needs and values in the watersheds, such as for development and watershed health, and public access and environmental protection.

As defined in the DWV's *Draft Community Outreach and Engagement Policy (2016)*, key external stakeholders and the public will be **informed** through the ISMP planning process with limited **consultation**. The policy recommends consultation when "…staff have prepared a draft plan, project, and policy with options for input by the community and/or stakeholder." The goal of community consultation is to receive input and feedback on specific items in a plan, to identify project's strength and weaknesses, and identify any unforeseen impact/consequences. The role of the community is to provide input as requested.

Stakeholder Groups

The stakeholders for this project include members from five groups.

Internal Collaboration/Consultation:

1. DWV Project Team: Jenn Moller, Andy Kwan, Sandra Bicego
2. Other DWV Departments and Staff - will include representatives from:

- Engineering and Environmental Services (The project team)
- Planning (2 staff, to be determined): staff with high level knowledge of Official Community Plan (OCP) and staff with detailed knowledge about Environmental Development Permits (EDPs).
- Parks (1 staff, to be determined)
- Land Development : Andrew Vander Helm, Environmental Protection Officer
- Communication : Kristi Merilees, Manager Community Relation

External Consultation:

3. Key Community Stakeholders (Streamkeepers, etc)
4. Interested Public
5. Government Agencies

Internal Consultation

Communication with the District is divided into two streams: 1) DWV Project Team 2) Other DWV Departments and Staff. KWL will be working closely with the DWV Project Team as laid out in the proposal. The project team (KWL and DWV) will be consulting key staff and representatives from various DWV departments. The objectives of consultation with the staff are to:

- Hear various departments' perspective on key issues and priorities, watershed vision, and potential solutions.
- Solicit information about other District initiatives and opportunities for achieving multiple benefits, and ensure ISMP recommendations build on and fit into existing municipal systems.
- Obtain review comments on project deliverables: Watershed Vision, Stage 3 Interim Report, and Draft Report.

Internal consultation will primarily take place at two meetings:

- Task 2.2: Vision Development with Internal Stakeholders.
- Task O2.2: Formal Stakeholder Meeting to Discuss Stage 3 Interim Report

District staff can provide additional input through commenting on key project deliverables, as desired, however unless a specific need for additional staff input is identified, only the DWV Project Team comments are required for moving forward with key deliverables.

Note: It is assumed that DWV Project Team will share (distribute internally) key project deliverables (that are not covered at the meetings) with appropriate internal stakeholders, solicit feedback as needed, resolve any conflicting comments, and provide KWL with one set of collated comments on key documents including: Progress Memos, Draft Vision Statement, and Draft Reports.

External Consultation

External consultation is divided into three streams: 1) Key community Stakeholders 2) Interested Public and 3) Government Agencies.

Key Community Stakeholders

Key community stakeholders include, at the outset, the West Vancouver Streamkeepers, and the Squamish Nation, at different levels. These key groups have valuable insight, and knowledge on watershed values as well as issues and constraints. Key community stakeholders will be notified of the ISMP and invited to participate in the public open house. They will also be the subject of more targeted consultation than the general public.

The proposed interactions with each stakeholder group follows:

Key Community Stakeholders	Proposed Interactions
West Vancouver Streamkeepers	KWL Biologist Patrick Lilley and West Vancouver Streamkeepers representative Bill McAllister coordinate interactions. KWL met with Streamkeepers shortly after project kickoff (Stage 1). KWL has received stream temperature monitoring data (4 years of monitoring at 4 locations) and spawning habitat survey data. KWL will have informal phone calls/email exchanges with Streamkeepers (Stage 2 and Stage 3) as needed. The streamkeepers will be invited to an informal stakeholder meeting with KWL and the DWV Project Team at a midpoint in the project, likely in stage 3 during or subsequent to development of the stage 3 alternatives. This meeting will be an opportunity for streamkeepers to provide feedback on the Vision and alternatives and provide input to the development of solutions. Key deliverables will be sent to streamkeepers for comment, including Vision, Stage 3 alternatives, Stage 3 recommendations, and others as determined by the DWV Project Team. DWV will solicit feedback from the streamkeepers on the draft report.
Squamish Nation	The DWV Project Team will notify the Squamish Nation of the project, and a contact person for the Sqamish Nation should be identified to send project communications to. The Squamish Nation representative will be invited to the public open house and invited to provide feedback similar to residents within the watersheds. The Squamish Nation is not part of the watershed area, but Squamish Nation land is located near the mouth of the Capilano River and the Burrard Inlet, which are receiving waters for the discharges from the study creeks.
Potential Other Stakeholders	At this time, no other key stakeholders for this project have been identified. If additional key stakeholders are identified during the course of the study, they will be provided direct notification of the stages and results of the project as determined by the DWV Project Team.

Interested Public

Members of the public will be notified about the ISMP through a post card mail-out and will be given a chance to provide input into the plan via the website after the development of the project Vision and at a Public Open House scheduled after the development of Stage 3 Alternatives. A webpage will be created for the ISMP and will be updated throughout the project so that interested members of the public as well as other stakeholder can stay informed. Major public consultation activities are:

- Set up a webpage with basic project information and comment form. Update the website with notices about major milestones and deliverables.
- Mail out ISMP notification: design an information post card for the ISMP to notify residents and businesses of project and direct them to the project website.
- Mail out Public Open House notification: design an information post card to invite the public to the open house.

- Open House: This will be the keystone of the public consultation process. The open house will provide the opportunity for the public to learn about stage 3 findings and recommendations and provide feedback.

Note: It is assumed that the DWV will carry out the mail out, build the project website and host the open house. KWL will be providing content and direction for these activities.

Government Agencies

Key government agencies include Departments of Fisheries and Ocean, BC Ministry of Environment, BC Parks, and Metro Vancouver. They will be invited to the public open house and offered the opportunity to read and comment on the draft report, if desired. Recent experience on other ISMPs indicates that the government agencies have little involvement in current ISMPs, however government involvement is a key premise of the ISMP process as developed in the ISMP template and the government agencies will be provided the opportunity to participate in this ISMP, whether or not they choose to do so.

Stakeholder Consultation Summary

The following table summarizes the prosed stakeholder activities, assumptions, and expected outcomes.

Activity	Targeted Stakeholders, Descriptions	Outcome
Project Kickoff Meeting	KWL + DWV Project Team	ID project approach & success factors.
Informal Stage 1 Meeting	KWL + WV Streamkeepers	ID communication plan, available resources, issues & priorities.
Stage 1 Progress Memo	DWV Project Team Key findings from Stage 1 progress memo will be shared on project website (public).	DWV provides KWL with feedback. Stage 1 findings are shared with all stakeholders via web.
Visioning Workshop	KWL + DWV Internal Stakeholders (Project Team and DWV Departments)	KWL develops draft vision following the workshop.
Project Website	Accessed by all stakeholders. KWL creates content & DWV creates and administers website for duration of project.	Keeps the public and all stakeholders informed.
Post Card Mail out (Notification of ISMP)	Notify the Public (Watersheds Residents) of ISMP.	Notifies the public of ISMP.
Stage 2 Progress Memo and Visioning Draft Document	DWV Internal Stakeholders + Key Community Stakeholders Final Vision Document will be shared on project website (public).	All key stakeholders provide KWL with feedback. KWL finalizes vison. Vision is public via web.
Stage 3 Interim Report Alternatives	DWV Internal Stakeholders	KWL distributes report to internal DWV stakeholders for feedback.

Activity	Targeted Stakeholders, Descriptions	Outcome
Informal Key Stakeholder Consultation Meeting	Streamkeepers and Squamish Nation representative Vision and Stage 3 Alternatives will be discussed and input sought for solutions	Key stakeholders provide input for development of solutions.
Stage 3 Internal Stakeholder Meeting + Prep for Open House	DWV Internal Stakeholders (Project Team and DWV Departments)	DWV internal stakeholders provide KWL with feedback. Team agrees on content of public open house.
Post Card Mail-out/Open House Invitations	Notify the Public (Watersheds Residents) of Open House. Email invitations to Community Stakeholders and Agencies.	All stakeholders are notified of the open house.
Open House	All stakeholders	Public & Community Stakeholders provide feedback on alternatives.
Stage 3 Progress Memo	DWV Project Team Key findings from Stage 3 progress memo will be shared on project website.	DWV provides KWL with feedback. Stage 3 findings are shared with all stakeholders via web.
Stage 4- Draft Report	DWV Internal Stakeholders + Key Community Stakeholders	KWL distributes report to key stakeholders for feedback.
Stage 4- ISMP Draft Report Review Meeting	DWV Internal Stakeholders	Assumption: DWV collates comment from internal and external stakeholders and provides KWL with one set of comments.
Final Report	DWV Internal Stakeholders + Key Community Stakeholders Interested Agencies Upload to project website	Final ISMP is distributed to all interested parties and is public via web.

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Appendix B
Engineering Inventory and Survey

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Appendix B – Engineering Field Inventory

Contents

Tables

Appendix B – Engineering Field Inventory

B Engineering Field Inventory

B.1 Engineering Field Inventory

KWL undertook an engineering field inventory between November 2015 and February 2016. The scope of work covered Brothers Creek, Hadden Creek, and Vinson Creek.

The purpose of the inventory was to supplement the District of West Vancouver's existing geographic information system (GIS) database by locating, photographing and assessing the following features along each stream:

- Culverts;
- Hydraulic structures and stormwater outfalls;
- Bridges;
- Significant deposition in channel;
- Significant bank or channel erosion sites;
- Bank protection; and
- Channel obstructions.

The terms left and right in this report refer to the left and right side of the creek channel when looking downstream.

Equipment

Features and observations were positioned and recorded using an Apple iPad or iPhone with mapping grade GPS receiver and ArcGIS Online field data collection software.

All inventory features were photographed with the iPad or iPhone's digital camera. Photographs were cross referenced to the GPS position and other observations within the field data collection software.

Coordinate System

The coordinate system used for this survey is Universal Transverse Mercator (UTM) Zone 10 North, North American Datum of 1983.

Appendix B – Engineering Field Inventory

Data Structure

The photographs and GPS positions associated with each feature were combined with additional field observations and measurements to produce a fully cross referenced database. The data collection structure used for this project is summarized below:

Culvert

Material	(CMP, concrete, PVC, etc.)
Diameter	(mm)
Shape	(round, box, etc.)
Headwall	(type)
Headwall Condition	(good, fair, damaged)
Barrier/Trash Rack	(yes/no)
Debris Present	(yes/no)
Maintenance Required	(yes/no)
Maintenance	(type)
Condition	(good, fair, damaged)
Comment	(additional notes or comments)

Outfall

Bank	(left bank, mid-channel, right bank)
Diameter	(mm)
Material	(CMP, concrete, PVC, etc.)
Condition	(good, fair, damaged)
Energy Dissipation	(type)
Headwall	(type)
Headwall Condition	(good, fair, damaged)
Outlet Drop	(from invert of culvert down to creek bed)
Sediment Depth	(from invert of culvert up to creek bed)
Comment	(additional notes or comments)

Bridge

Type	(road, footbridge, or driveway)
Low Chord	(from bottom chord of bridge to creek bed)
Comment	(additional notes or comments)

Erosion

Location	(left bank, right bank, or both banks)
Hazard	(low, moderate, high)
Consequence	(low, moderate, high)
Length	(along direction of flow)
Height	(height of eroding bank, or depth of eroded channel)
Comment	(additional notes or comments)

Deposition

Location	(left bank, mid-channel, right bank)
Length	(along direction of flow)
Width	(across channel)
Vegetated	(yes/no)
Comment	(additional notes or comments)

Appendix B – Engineering Field Inventory

Bank Protection

Location	(left bank, mid-channel, right bank)
Type	(riprap, wall, gabions, etc.)
Nominal Rock Size	(in mm)
Left Bank Length	(along direction of flow)
Right Bank Length	(along direction of flow)
Left Bank Height	(vertically from creek bed to top of bank protection)
Left Bank Height	(vertically from creek bed to top of bank protection)
Condition	(good, fair, poor)
Comment	(additional notes or comments)

Channel Obstruction

Type	(boulder, LWD, anthropogenic, other)
Vertical distance	(Vertical distance between obstruction and creek)
Sedimentation	(yes/no)
Stability	(low, moderate, high)
Fish Passage Obstacle	(weir, waterfall, etc.)
Comment	(additional notes or comments)

Confluence

Bank	(bank on mainstem stream from which tributary stream enters)
Comment	(additional notes or comments)

Observed Sites

Orthophotos and GIS data showing storm water collection systems, outfalls, streams and road crossing locations were provided by the City and used as background information to plan and carry out field investigations.

GIS layers were created for obstructions, erosion, bridges, culverts and outfalls observed during the field inspection.

The erosion GIS layer contains the locations of observed erosion sites, the severity of the erosion, the length, width, and height of the erosion, and comments or observations of the erosion and causes. See Table B-1 and Figures 3-1 to 3-4 in the main body of the report.

The obstructions GIS layer contains the type of obstruction, the location of the obstruction, whether the obstruction is a hydraulic barrier in the stream and comments or observations for each obstruction. See Table B-2 and Figures 3-5 and 3-6.

The culverts, bridges, and outfalls GIS layers contain the location, material, condition and comments on the condition of the structures. These are summarized in Tables B-3 to B-5 and Figures 3-7 to 3-10.

Appendix B – Engineering Field Inventory

Table B-1: Field Inventory - Observed Erosion Sites

OBJECT ID	LOCATION	HAZARD	CONSEQUENCE	LENGTH	HEIGHT	COMMENT	CreationDate
1	RIGHT BANK	HIGH (>1.2m)	LOW (>10m)	20m	9m	Old failure with exposed earth 30 sq m. Blackberry surrounding.	2016-02-02 19:43
2	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	20m	10m	Above floodplain some vegetation growing on it. Looks somewhat stable but property above.	2016-02-02 21:50
3	LEFT BANK	HIGH (>1.2m)	HIGH (<5m)	2m	4m	Shallow gully in bank up to top of bank forming. House at top of bank	2016-02-02 22:16
4	RIGHT BANK	HIGH (>1.2m)	MODERATE (5-10m)	4m	8m	Mature tree came down from top of bank. Soil washed away to bedrock. Appears to be close to road (10m approx.) but unsure as can't access top of bank. Bedrock bank of channel likely protects from further erosion. Bank further protected by concrete.	2016-02-04 17:25
5	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	10m	1.2m		2016-02-04 18:47
6	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	10m	1.5m	Tributary eroding around culvert, created new channel to left of culvert (concrete, 600mm)	2016-02-09 17:22
7	RIGHT BANK	HIGH (>1.2m)	HIGH (<5m)	4m	4m	Some Lamium growth, so somewhat stable but moderate amount of bare soil. Not of immediate concern. Deck at top of bank. Steep slope.	2016-02-09 17:47
8	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	5m	.5m	Scours from eddy at culvert outfall undercutting bank.	2016-02-09 18:05
9	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	10m	1.2m	Both banks of tributary are eroding. Right bank covered in icy with house at top of bank less than 5 m from stream. Some bank protection in place just upstream of erosion to protect house but yard still vulnerable.	2016-02-09 18:12
10	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	15m	2m	Gabion bank protection toppling into stream	2016-02-10 19:19
12	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	15m	2m	Gabion bank protection toppling into stream. Upstream gabions supporting stacked rock are disintegrated	2016-02-10 19:20
13	LEFT BANK	HIGH (>1.2m)	HIGH (<5m)	20m	8m	Power line pole at the top of the site. Steep with some ivy.	2016-02-10 19:48
14	RIGHT BANK	HIGH (>1.2m)	LOW (>10m)	10m	3m	Bank erosion. No property nvolved.	2016-02-10 19:52
15	RIGHT BANK	HIGH (>1.2m)	LOW (>10m)	40m	20m	Large bank failure has put trees in creek. Potentially shifted Cree to left.	2016-02-10 20:12
16	RIGHT BANK	HIGH (>1.2m)	LOW (>10m)	20m	4m	Power lines at top of slope but set back 10 m	2016-02-10 21:11
17	RIGHT BANK	HIGH (>1.2m)	LOW (>10m)	30m	10m	Buildings somewhat near top of bank. Forested up top but slope has failed.	2016-02-10 21:16
18	RIGHT BANK	HIGH (>1.2m)	LOW (>10m)	30m	15m	Stretch of stream near property at top of bank with lots of bank erosion/failure.	2016-02-10 21:27
19	LEFT BANK	LOW (<0.3m)	MODERATE (5-10m)	10m	.5m	Landowner mentioned erosion but it doesn't look significant yet.	2016-02-23 21:14
20	RIGHT BANK	HIGH (>1.2m)	MODERATE (5-10m)	6m	1.6m	In behind retaining wall at mouth of culvert undercutting bank. Undercut is 1 meters deep. Could cause failure of slope above of 3 m and into property.	2016-02-23 21:33
21	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	1m	1m	Erosion behind headwall of cvt	2016-02-23 21:39
22	LEFT BANK	LOW (<0.3m)	LOW (>10m)	10m	1m	Undercutting of bank	2016-02-24 22:20
23	RIGHT BANK	HIGH (>1.2m)	MODERATE (5-10m)	7m	5m	Underneath property (yard), slope has given way.	2016-02-24 23:10
24	RIGHT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	10m	1.2m	Banks being undermined on bend in river	2016-02-25 19:28
25	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	6m	1m	Outside of curve, bank is eroding 5 m down from culvert. No property of concern, just evidence of flashiness.	2016-02-26 1:04
26	LEFT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	4m	2m	Grouted rock bank protection failing. Ineffective plywood bank protection. 0.3 m from erosion to 2 m tall grouted rock wall, 6 m to house	2016-02-26 17:20

Appendix B – Engineering Field Inventory

Table B-2: Field Inventory Observed Obstruction Sites

OBJECTID	TYPE	VERTICAL_DISTANCE	SEDIMENTATION	STABILITY	COMMENT	CreationDate
1	LWD	0			New tree fall 40 cm diameter	2016-02-02 20:05
2	LWD	1		HIGH	1 m above stream cedar log spanning creek. Not an obstruction at present.	2016-02-02 21:45
3	LWD	1	NO	MODERATE	Large log jammed behind sewer box.	2016-02-02 22:56
4	LWD	1	NO	MODERATE	Tree fall not recent across channel	2016-02-02 23:01
5	LWD	1	NO	HIGH	Two downed trees within 10m. Ds tree is a live cedar	2016-02-04 16:32
6	LWD	1	NO	HIGH	2 downed trees within 10m. Ds tree is a live cedar 1 m above bankfull	2016-02-04 16:39
7	LWD	1		HIGH	Cedar across stream not currently obstruction. Debris could build behind it.	2016-02-04 16:41
8	LWD	0	YES	MODERATE	Tree across stream with gravel cobble buildup behind	2016-02-04 19:16
9	LWD	1	NO	MODERATE	Two trees down within 20m	2016-02-04 20:37
10	LWD	1	YES	MODERATE	Debris jam. Few large pieces of would with smaller debris caught in it. Some sediment (gravel, fines) upstream. Water flowing under down middle. During high flows water flows around to left bank creating new channel.	2016-02-04 20:48
11	LWD	1	YES	HIGH	Lwd jam with lb deposit fines gravel	2016-02-04 20:55
12	LWD	1			Several jams with gravel fines deposits	2016-02-04 21:09
13	LWD	1	NO	HIGH	Two logs down	2016-02-04 21:25
14	LWD	1	NO	HIGH	Tree across stream	2016-02-04 22:45
15	ANTHROPOGENIC	1		HIGH	Chainlink fence across stream with .5 m clearance.	2016-02-09 22:17
16	ANTHROPOGENIC	0			Concrete admired pipe across creek with grouted rock wall supporting	2016-02-23 21:41
17	ANTHROPOGENIC	1			Chain link fence	2016-02-23 22:17
18	ANTHROPOGENIC	0				2016-02-23 23:20
19	LWD	1		MODERATE	Blowdown of alder and big lead maple across stream. Lots of debris.	2016-02-24 23:35
20	ANTHROPOGENIC	1			Wood fence	2016-02-24 23:36
21	ANTHROPOGENIC	1			Fence across stream could catch debris	2016-02-25 17:01
22	ANTHROPOGENIC	0			2 Fences. Within 10 m	2016-02-25 21:08

Appendix B – Engineering Field Inventory

Table B-3: Field Invetory - Observed Culvert Sites

OBJECT ID	COMMENTS	HEADWALL_TYPE	DEBRIS_RACK	CONDITION	CULVERT_ID	UP_INVERT	DWN_INVERT	CUL_SHAPE	HEIGHT	WIDTH_DIAMETER	MATERIAL	SIDE_SLOPE	Shape_Length	POST_SURVEY_NOTE_LTW
1					308								38.98532778	Surveyed by survey team
2		Rock stack US DS	No	FAIR	307	30.7689991	29.08600044	CIRCULAR	0	600	CONCRETE		22.48273358	Surveyed by survey team
3		Rockstack DS upstream was not accessed		FAIR	310		35.59999847	CIRCULAR	35.59999847	500	CONCRETE		9.127530668	Surveyed by survey team
4	Time consuming survey, how critical?				311								12.05319877	Surveyed by survey team
5	Upstream end was inaccessible to quick survey only invert was surveyed and this using taped distances. Private pond was built next to creek likely gets water from creek but no inlet found.	Conc/Rock hwall	No	FAIR	314	38.97399902	38.64599991	CIRCULAR	0	500	CONCRETE		17.18492316	Surveyed by survey team
6	Not located, survey access would likely be difficult.				316								28.58106167	Surveyed by survey team
7		Concreted rockstack u/s d/s	No	FAIR	319	50.20100021	47.2879982	CIRCULAR	0	500	CONCRETE		15.37233022	Surveyed by survey team
8	Fairly overgrown u/s	Conc/Rock hwall	No	FAIR	318	51.4640007	50.2159996	CIRCULAR	0.100000001	900	CONCRETE		15.4975107	Surveyed by survey team
9					465								16.46081525	Surveyed by survey team
10	750 trash rack over flow pipe in place	Conc u/s rockstack and conc d/s	Yes	FAIR	470	81.97000122	81.33999634	CIRCULAR	0.5	900	CONCRETE		17.2682408	Surveyed by survey team
11	Lower of two culverts see KWL013	Concrete Rockstack u/s d/s	No	GOOD	474	102.3349991	100.8570023	CIRCULAR	0	750	CONCRETE		16.25266173	Surveyed by survey team
12	Creek here is in a 1200 flume entering a 1200 culvert, hard to confirm diam. But I'm reasonably certain. A 600 cmp joins the flow just upstream of the 1200 with a .2m drop. Wire trash rack. Outlet is a 900 conc, in rockstack wall.	Conc u/s	Yes	FAIR	490	147.6719971	122.7350006	CIRCULAR	0	900	CONCRETE		265.0119894	Surveyed by survey team
13					491								31.91568881	Surveyed by survey team
14		Rock us and ds	No	FAIR	407	81.33599854	81.18199921	CIRCULAR		1050	CONCRETE		14.93383609	Surveyed by survey team
15		Conc us and rsw ds	Yes	FAIR	408	85.50099945	85.16799927	CIRCULAR	0.150000006	1050	CONCRETE		12.9016824	Surveyed by survey team
16		Conc u/s, none d/s	No	FAIR	391	356.4450073	355.5690002	CIRCULAR	0	1200	CONCRETE		11.67969563	Surveyed by survey team
17		Rock u/s, none d/s	No	FAIR	388	325.8909912	325.5549927	CIRCULAR	0.600000024	1200	CONCRETE		14.29333423	Surveyed by survey team
18		Rock with conc u/s and d/s	No	FAIR	384	297.526001	296.1669922	CIRCULAR	0.600000024	1350	CONCRETE		15.44512942	Surveyed by survey team
19	Trash rack hz and wooden. I KNOW from a sv I did 5 years ago with other company that there is an u/s crk where shown but all current flow is coming s.ward along road edge in flume	Conc blk u/s, none d/s	Yes	FAIR	396	340.2980042	336.3900146	CIRCULAR	0	750	CONCRETE		19.52199798	Surveyed by survey team
20	Debris rack ~1/3 backed up with leaf litter	Rock with conc u/s, none d/s	Yes	FAIR	394	330.5570068	329.3829956	CIRCULAR	0	750	CONCRETE		47.60191461	Surveyed by survey team
21	Downstream concrete lining is deteriorating	Rockstack US and concrete lined DS	No	FAIR	393	284.8080139	282.2590027	CIRCULAR	0	750	CONCRETE		11.70637063	Surveyed by survey team
22	Several large serious debris racks US of inlet	Rockstack with conc us. Creek bank ds	Yes	FAIR	385	250.3630066	250.572998	CIRCULAR	3	900	CONCRETE		20.0076343	Surveyed by survey team
23		Asph junk u/s boulder stack d/s	No	FAIR	431	255.4049988	253.2030029	CIRCULAR	0.800000012	750	CONCRETE		23.61646489	Surveyed by survey team
24	3200w x 2300h	Concrete both sides	No	FAIR	434	252.5679932	250.5579987	RECTANGLE_CLOSED	2		CONCRETE		12.72094242	Surveyed by survey team
25	700 inlet pipe above 900 inlet in case of blockage 1.1m higher inv	Rockstack with conc. Both ends	No	FAIR	435	286.277	284.327	CIRCULAR		900	CONCRETE		16.10643157	Surveyed by survey team
26	Yard waste/branches/leaves partially blocking u/s culvert	None	No	FAIR	437	258.4119873	257.5360107	CIRCULAR	0.600000024	750	CONCRETE		33.04227707	Surveyed by survey team
27		Concrete U/S none D/S	Yes	FAIR	500	328.978	325.363	CIRCULAR	0	900	CONCRETE		43.4376171	Surveyed by survey team
28	In the wrong place. See kwl006				443								166.3588053	Surveyed by survey team
29	D/s inv not accessible. Inv is ~5.5m u/s of crk-cl and higher by ~ 1.0m. D/s inv is approx	Rock u/s, Rock with conc d/s	No	FAIR	440	270.5950012	267.8999939	CIRCULAR	0	750	CONCRETE		26.27706881	Surveyed by survey team
30	US end concrete base is being scoured and chipped away causing standing. Waves to form, may caus debris to catch	Rockstack with concrete base us ds	No	FAIR	371	215.9660034	214.5939941	CIRCULAR	0	1350	CONCRETE		18.71696145	Surveyed by survey team
31		Rockstack/conc us/ds	No	GOOD	372	198.8880005	196.3220062	CIRCULAR	0.300000012	1350	CONCRETE		32.59407722	Surveyed by survey team
32	Inlet is obscured by leaves/veg, could easily plug	Rockstack head walls	No	GOOD	501	356.476	354.329	CIRCULAR	200	750	CONCRETE		28.92162265	Surveyed by survey team
33	Upstream is rock/conc lined and walled channel. Rebar is exposed in us end of culvert	Conc wall ds	No	FAIR	375	205.7489929	200.227005	CIRCULAR	0.5	1050	CONCRETE		53.09024633	Surveyed by survey team
34	DS end would be very time consuming to survey, looks like at least a 2m drop from road. Hard to confirm	Conc rockstack	No	FAIR	373	244.8919983		CIRCULAR		900	CONCRETE		15.27826558	Surveyed by survey team
35	2 large conc culverts. R: 2400x1540 L 2000x1700	Concrete. Large	No	FAIR	450	339.145	335.929	RECTANGLE_CLOSED			CONCRETE		35.43968489	Surveyed by survey team
36		Conc/rockstack hwalls	No	FAIR	376	239.9550018	238.9880066	CIRCULAR	0.200000003	1350	CONCRETE		16.74527944	Surveyed by survey team
37		Rockstack w concrete us/ds	No	FAIR	377	249.2409973	247.7279968	CIRCULAR	0.5	1500	CONCRETE		26.11110096	Surveyed by survey team
38	Due to local construction access is impeded				379								14.1846786	Surveyed by survey team
39	North east resident dumping garden waste into creek.	Rockstack conc and earth us/ds	No	FAIR	380	280.6960144	279.8710022	CIRCULAR	1	1350	CONCRETE		14.19796141	Surveyed by survey team
40		Rockstack hwall us ds	No	FAIR	381	237.5330048	236.3070068	CIRCULAR	0.300000012	1050	CONCRETE		19.01312967	Surveyed by survey team
41	U/s Invert is below a long drop from pipe ID KWL016 inside a manhole	N/a	No		469	69.32299805							1319.484916	Surveyed by survey team

Appendix B – Engineering Field Inventory

Table B-3: Field Invetory - Observed Culvert Sites

OBJECT ID	COMMENTS	HEADWALL_TYPE	DEBRIS_RACK	CONDITION	CULVERT_ID	UP_INVERT	DWN_INVERT	CUL_SHAPE	HEIGHT	WIDTH_DIAMETER	MATERIAL	SIDE_SLOPE	Shape_Length	POST_SURVEY_NOTE_LTW
42	Doubled parking curb sections at angle to flow alternating sides as baffles throughout culvert. Exposed rebar at DS outlet	Concrete box culvert with wingwalls	No	FAIR	356	66.13400269	62.14400101	RECTANGLE_CLOSED	0.400000006		CONCRETE		108.0342275	Surveyed by survey team
43	Concrete box culvert from 1972 - 2.25h by 3.5w. Slight pool at outlet	Concrete us/ds	No	FAIR	402	66.90799713	64.25499725	RECTANGLE_CLOSED	0		CONCRETE		103.3506137	Surveyed by survey team
44		Rock conc u/s d/s	Yes	FAIR	471	75.73600006	75.11199951	CIRCULAR	1.200000048	750	CONCRETE		18.02186119	Surveyed by survey team
45	2.0m high x 3.0m wide. Conc baffles in culv. 250mm WM inside culv on east side. Fish ladder enter from west (Wildwood).	Conc	No	FAIR	405	70.04699707	68.72899628	RECTANGLE_CLOSED	0.200000003		CONCRETE		23.62443347	Surveyed by survey team
46	HDPE pipe. Looks quite new but squished/oval shape. 0.66m high x 0.95m wide. Creek is ~1.3m wide constrained by ~0.5m high conc walls. HDPE pipe lines old larger CMP	Conc	No	GOOD	404	74.90599823	74.46600342	CIRCULAR	0.200000003		PVC		21.30270926	Surveyed by survey team
47	Old pipe starting under a deck this appears to be the highest culvert on this trib.	Concrete and Rock d/s u/s	Yes	FAIR	476	105.0100021	94.99299622	CIRCULAR	0.600000024	750	CONCRETE		49.48558218	Surveyed by survey team
48	SEE PHOTOS, LONG DROP AT OUTLET WITH FISH LADDER. INVERTS MEASURED WITH A ROD FROM ROAD ELEVATION. There is a nearby 1750 CMP culvert that provides overflow capacity ??	CONCRETE	No	FAIR	361	91.35		CIRCULAR	1	1800	CONCRETE		39.24544611	Surveyed by survey team
49		Conc	No	FAIR	411	140.5939941	140.0180054	CIRCULAR	0	1200	CONCRETE		19.5353509	Surveyed by survey team
50	900 cmp inlet in rockstack/sandbag head wall (newish) 1200 conc outlet (older)	Rockstack	No	GOOD	414	179.4600067	175.8339996	CIRCULAR	0.100000001	900	CSP		36.88700022	Surveyed by survey team
51	Old rotten wooden trash rack, no longer functions well. Two 400 diam. In/outlets at upstream side, unknown function.	Rockstack both ends. Ivy u/s	Yes	FAIR	493	196.7140045	194.4980011	CIRCULAR	0.150000006	750	CONCRETE		24.67522253	Surveyed by survey team
52		Rock with a little conc	No	FAIR	415	162.4019928	159.9320068	CIRCULAR	0.300000012	1200	CONCRETE		20.165585	Surveyed by survey team
53	3m wide 2m tall box culvert w/ wingwalls. Outlet falls onto Rock tongue into pool	Conc	No	FAIR	417			RECTANGLE_CLOSED	0.300000012		CONCRETE		24.68759085	Surveyed by survey team
54	D/s of outlet creek is constrained to a concrete/cobble channel see photos/survey	Creek banks u/s cobble/conc d/s	No	GOOD	416	188.1790009	186.2899933	CIRCULAR	0	1200	CONCRETE	1	24.53279408	Surveyed by survey team
55	2.25m high 2.45m wide box culvert w/ baffles .05m high us .3high ds 2.5m apart o/c brand new	New conc keyed into old us. Rkstack ds	No	GOOD	365	149.0500031	145.5	RECTANGLE_CLOSED			CONCRETE		20.80473995	Surveyed by survey team
56	0.25m drop culv to flume, 2.0m drop flume to crk. Hz trash rack. Flume listing at w/side centre. Original wood culv under flume end.	U/s Rock with little conc, none d/s	Yes	FAIR	423	203.5670013	203.0540009	CIRCULAR	0.25	750	CONCRETE		34.21839559	Surveyed by survey team
57	Old partially destroyed weir u/s of inlet, see survey. Left bank downstream has gabion Rock basket protection	Rockstack u\s native slope d/s	No	FAIR	425	212.6430054	210.75	CIRCULAR	0.400000006	900	CONCRETE	2	20.41213047	Surveyed by survey team
58	Large conc hwall with major trash rack, currently partially blocked with vegetation debris. Hard to measure exact culvert size based on trash rack, 1200 is the best estimate	Concrete U/s	Yes	GOOD	306	30.56100082		CIRCULAR	0	1200	CONCRETE		816.1022373	Surveyed by survey team
59	Debris rack only rests on the head wall, not attached	Rockstack	Yes	FAIR	290	12.07699966		CIRCULAR		1000	CONCRETE		21.11221296	Surveyed by survey team
60	OUTLET IS IN A MANHOLE JUST UPSTREAM OF A CONCRETE/ROCK LINED CHANNEL. OUTLET SURVEY BY TAPED DISTANCES	Conc inlet, DGMH pipe outlet	No	FAIR	293	21.37299919	14.855	CIRCULAR	0.5	750	CONCRETE		63.47377493	Surveyed by survey team
61	Outlet is damaged 500 CMP, SURVEYED BY TAPED DISTANCES	Rockstack concrete US earth DS	No	FAIR	297	22.61199951	18.7	CIRCULAR		500	CONCRETE		60.45063574	Surveyed by survey team
62		Rockstack/conc us DS	No	FAIR	298	22.51799965	21.68000031	CIRCULAR	1.399999976	750	CONCRETE		17.13056595	Surveyed by survey team
63	Inlet may be undersized as the culverts upstream are 600diam. Outlet is 500 diam	Conc rockstack	Yes	FAIR	304	28.18799973	25.76300049	CIRCULAR	0	450	CONCRETE		43.33018816	Surveyed by survey team
64	Not a culvert				302								53.40689084	Surveyed by survey team
65	MH at mid node inv is 173.813. Trash rack is old rusty metal, there is a bridge u/s and d/s	Rock with conc u/s and d/s	Yes	FAIR	492	180.6719971	172.1670074	CIRCULAR	0.200000003	900	CONCRETE		17.0990834	Surveyed by survey team
66	Skipped, private difficult access, small trib				Kwl001								37.41800584	Surveyed by survey team
67	Skipped, private difficult access, small trib				KWL002								27.15060613	Surveyed by survey team
68	Skipped, private access/small trib				KWL003								25.57278298	Surveyed by survey team
69	2200H X 3400W	Concrete	No	FAIR	KWL004	307.466	304.054	RECTANGLE_CLOSED	0.3	0	CONCRETE		23.01947862	Surveyed by survey team
70		Concrete block u/s	No	FAIR	KWL005	304.872	300.938	CIRCULAR	0.3	900	CONCRETE		19.84620551	Surveyed by survey team
71	Outlet inside manhole	Rock stack at inlet with wooden trashrack	Yes	FAIR	KWL006	335.281	313.484	CIRCULAR	1.5	400	CONCRETE		163.4168642	Surveyed by survey team
72		Manhole u/s rockstack d/s	No	GOOD	Kwl007	311.581	309.223	CIRCULAR	0	900	CONCRETE		22.0197437	Surveyed by survey team

Appendix B – Engineering Field Inventory

Table B-3: Field Invetory - Observed Culvert Sites

OBJECT ID	COMMENTS	HEADWALL_TYPE	DEBRIS_RACK	CONDITION	CULVERT_ID	UP_INVERT	DWN_INVERT	CUL_SHAPE	HEIGHT	WIDTH_DIAMETER	MATERIAL	SIDE_SLOPE	Shape_Length	POST_SURVEY_NOTE_LTW
73	Inlet covered in ivy, potential plugging hazard	Overgrown. Concrete?	No	FAIR	KWL008	286.214	284.789	CIRCULAR		900	CONCRETE		24.17683679	Surveyed by survey team
74		None above, rockstack below	No	FAIR	KWL009	271.861	269.849	CIRCULAR	2	1100	CONCRETE		24.31083443	Surveyed by survey team
75	Hear falling water in pipe. Large drop?	Conc with large rocks embedded	No	FAIR	Kwl1000	365.6369934	361.519989	CIRCULAR	0	600	CONCRETE		44.12480203	Surveyed by survey team
76	Boulder crk-top u/s.	Conc u/s, rocks with conc holding together d/s	Yes	FAIR	Kwl1001	332.4790039	330.7149963	CIRCULAR	0	600	CONCRETE		22.64983848	Surveyed by survey team
77		None	No	FAIR	Kwl1002	315.7319946	314.7600098	CIRCULAR	1	600	CONCRETE		14.71109968	Surveyed by survey team
78	Height on d/s inv is negative. The pipe sits lower than creek bed (rough concrete)	Rock u/s and d/s	No	FAIR	Kwl1003	299.7049866	298.3919983	CIRCULAR	0.150000006	600	CONCRETE		12.39893894	Surveyed by survey team
79	D/s. Rsw is more of just a wall holding road/bank along PL instead of hwall	Rock u/s, rsw d/s	No	FAIR	Kwl1004	290.6289978	289.2709961	CIRCULAR	0.200000003	750	CONCRETE		12.02395922	Surveyed by survey team
80	U/s inv is a 2.5m offset, not accessible otherwise. U/s side smells like chlorine!?! Someone dumping pool? Trash rack on u/s side is ~1/3 backed up with sediment and leaves. D/s resident had severe water levels fall 2014 1' from top of wall	U/s conc, d/s conc with rocks embedded	Yes	FAIR	Kwl1005	228.7960052	226.7899933	CIRCULAR	0.349999994	750	CONCRETE		21.50238707	Surveyed by survey team
81	Skipped due to access difficulty				Kwl010								17.16325869	Surveyed by survey team
82	Culvert exits the east wall of the headwalls and must have a 90deg bend	Concrete u/s rockstack d/s	Yes	FAIR	KWL011	227.9609985	225.6360016	CIRCULAR	0	750	CONCRETE		16.57830436	Surveyed by survey team
83		Rock stack u/s d/s gabion stack on the left bank	No	FAIR	KWL012	198.0200043	196.3359985	CIRCULAR	0.200000003	1050	CONCRETE		21.1136851	Surveyed by survey team
84	Bridge. 1200 across crk 1500 across bridge bottom. 1.5m wide bridge deck. .8m from bot chord to crk bot												6.205086805	Surveyed by survey team
85	See wv 474 this is the higher culvert of 2	Conc rockstack both sides	No	GOOD	KWL013	103.4580002	102.0930023	CIRCULAR	1.100000024	600	CONCRETE		16.86435256	Surveyed by survey team
86	Aluminum foot bridge, 10m long deck, 3m wide creek 3m from bot. Chord to crk cl. Deck 1 m wide												10.39179623	Surveyed by survey team
87	Homemade debris rack. inlet is directly under the fence	Concrete/Rock headwall, u/s d/s	Yes	FAIR	KWL013	52.266	50.968	CIRCULAR	0.3	500	CONCRETE		24.97770431	Surveyed by survey team
88		Concrete d/s conc/rock u/s	No	FAIR	KWL014	54.143	53.697	CIRCULAR	0.2	500	CONCRETE		7.970786342	Surveyed by survey team
89	Only able to find the outlet	nat ground around outlet		FAIR	KWL015		55.011	CIRCULAR	0.3	500	CONCRETE		7.771012846	Surveyed by survey team
90	3 X 600 corrugated plastic pipe concreted under a low bridge deck	Rock/conc under a bridge deck	No	GOOD	KWL016	72.3769989	72.29599762	CIRCULAR	0	600	PVC	0	4.817346516	Surveyed by survey team
91	Connects to mh	Rock/conc u/s mh d/s large t-rack	Yes	FAIR	KWL017	71.76399994	71.03199768	CIRCULAR	0.699999988	750	CONCRETE		13.11929648	Surveyed by survey team
92	Start of creek	Rock stack headwall	No	FAIR	KWL018	63.3769989	62.31700134	CIRCULAR	0.150000006	400	CONCRETE		10.76303505	Surveyed by survey team
93	Badly pluged at US end, no inlet was visible but pooling water makes location apparent. DS end last 3-4 pipe segments are pulling apart, about 10cm. US inlet ele is from creek toe elevation but was not visible and may be incorrect		Yes	POOR	KWL019	53	51.36199951	CIRCULAR	0.300000012	900	CONCRETE		14.69762674	Surveyed by survey team
94	Approximate pipe location from basic field review. Better info would require time and further investigation	Rockstack with conc US DS	Yes	FAIR	KWL020	542.7579956	30.57600021	CIRCULAR	0.300000012	900	CONCRETE		170.1686798	Surveyed by survey team
95	Outlet is a 1.5 m drop over a rockstack tail race	Rockstack us/ds	No	FAIR	KWL021	35.3370018	32.65100098	CIRCULAR	1.5	600	CONCRETE		30.00397406	Surveyed by survey team
96	Upstream see notes, DS LIKELY TIES INTO 750 DS	Earth	No	FAIR	KWL022	18.5		CIRCULAR		500	CONCRETE		42.09908304	Surveyed by survey team
97	Trash rack is narrow and debris are getting around the sides, particularly when the main rack is covered with debris. DS ele.is a visual offset as surveying the invert was difficult/dangerous.	Rockstack/conc w/ conc block at us earth DS	Yes	FAIR	KWL024	276.5169983	274.4719849	CIRCULAR	0.300000012	1100	CONCRETE		12.87429638	Surveyed by survey team
98	All survey completed by taped measurements in the field, somewhat rough, I have to confirm the diameter too	Rockstack and conc US/DS	No	FAIR	KWL050	27.194	26.194	CIRCULAR		900	CONCRETE		10.05766758	Surveyed by survey team
99	Footbridge in park. 3.8m long deck, 1.2m across, .5m from bot chord to creek bot. 2.6m channel bottom width												4.693616399	Surveyed by survey team
100	KWL500	Rsw us and ds	No	FAIR	KWL500	72.65000153	71.58999634	CIRCULAR	0	900	CSP		36.49984349	Surveyed by survey team
101	3m wide 2.25 tall box culvert, half meter smaller than upstream culvert crossing highway. Bolted down log baffles approx 3m intervals.	Concrete box w/ wing walls	No	FAIR	KWL501	60.47299957	59.5909996	RECTANGLE_CLOSED	0.100000001		CONCRETE		22.01136331	Surveyed by survey team
102													21.00192736	Surveyed by survey team
103													75.96729525	Surveyed by survey team
104													20.64728105	Surveyed by survey team
105													33.27295938	Surveyed by survey team
106				GOOD									15.39081329	Surveyed by biology team
107	1 m above main culvert left bank												8.41717989	Surveyed by biology team
108	Under golf cart road												3.506843517	Surveyed by biology team
109	8% slope, ~17m long. No baffles, perched 0.4m above pool surface. 0.8m plunge pool. Possible fish barrier			GOOD									19.62293522	Surveyed by biology team

Appendix B – Engineering Field Inventory

Table B-3: Field Invetory - Observed Culvert Sites

OBJECT ID	COMMENTS	HEADWALL_TYPE	DEBRIS_RACK	CONDITION	CULVERT_ID	UP_INVERT	DWN_INVERT	CUL_SHAPE	HEIGHT	WIDTH_DIAMETER	MATERIAL	SIDE_SLOPE	Shape_Length	POST_SURVEY_NOTE_LTW
110				GOOD									5.592060555	Surveyed by biology team
111	Blocked intake in bank protection connected to bridge footing. Not part of main channel												20.75172411	Surveyed by biology team
112	Barrier												13.06808798	Surveyed by biology team
113	Driveway												21.70811976	Surveyed by biology team
114	Driveway												18.84258765	Surveyed by biology team
115	Driveway												10.53530643	Surveyed by biology team
116	Carries segment BR-6.1												12.89242826	Surveyed by biology team
117	Conveys trib to BR-6.1												16.25125283	Surveyed by biology team
118													15.25169383	Surveyed by biology team
119	Driveway												15.52396515	Surveyed by biology team
120	Driveway												21.79661531	Surveyed by biology team
121	Stream enters pipe - 150mm												37.18253649	Surveyed by biology team
122	750mm concrete culvert with trash rack. Additional 500 mm concrete culvert on top. Good condition. Small piece near head wall has broken possibly allowing water in behind head wall. 30cm hole in rock wall. Should be repaired.												21.04984991	Surveyed by biology team
123													23.58302038	Surveyed by biology team
124	450 mm, concrete, good condition.												10.15503388	Surveyed by biology team
125	400 mm steel corrugated culvert, little rusty. Good condition.												9.985646381	Surveyed by biology team
126													22.6901334	Surveyed by biology team
127	Possible fish barrier at cvt invert. 1 m fall onto cement. Grating above.												91.50892275	Surveyed by biology team
128	Possible fish barrier. No plunge pool. Exvert discharges onto cobble and roots. Cascade section ds.												39.18046697	Surveyed by biology team
129	Could not find invert												16.60397886	Surveyed by biology team

Appendix B – Engineering Field Inventory

Table B-4: Field Inventory - Observed Bridge Sites

OBJECT ID	TYPE	LOW_CHORD (m)	COMMENT	CreationDate
1	FOOTBRIDGE	4	Clear span bridge	2016-02-02 17:57
2	ROAD	3.2	Rip rap protection of footings, 2*400 metal pipes suspended from bridge, drainage pipes on right bank *4, 80 mm wide metal at base, likely drain bridge apron	2016-02-02 18:16
3	FOOTBRIDGE	3	Wooden, clear span bridge, arch footbridge, railings rotting	2016-02-02 18:42
4	ROAD	12	Clear span bridge with rip rap and geotextile cloth bank protection for rbank footing	2016-02-02 20:12
5	ROAD	13	Clear span	2016-02-02 21:31
6	ROAD	7	Clear span a inglewood with rip rap armoring	2016-02-03 0:15
7	DRIVEWAY	3.5	Clear span bridge driveway to property with new decor. Concrete protection on footings	2016-02-04 17:07
8	FOOTBRIDGE	1	To residence	2016-02-04 18:31
9	FOOTBRIDGE	2		2016-02-09 18:38
10	FOOTBRIDGE	1.6	Golf cart bridge	2016-02-09 18:47
11	FOOTBRIDGE	2		2016-02-09 21:53
12	FOOTBRIDGE	1		2016-02-09 22:02
13	FOOTBRIDGE	1.5		2016-02-09 22:09
14	FOOTBRIDGE	1.5		2016-02-09 22:12
15	FOOTBRIDGE	1.5	With steel pipe underneath	2016-02-09 22:19
16	FOOTBRIDGE	1.2		2016-02-09 22:21
17	FOOTBRIDGE	1		2016-02-09 22:26
18	DRIVEWAY	2	Wood beam, single lane, good condition.	2016-02-10 0:05
19	DRIVEWAY	2.5		2016-02-10 0:07
20		10	Footing reinforced with concrete which is being undercut ds of bridge	2016-02-10 0:14
21	ROAD	10	Clear span at millstream rd	2016-02-23 19:07
22	FOOTBRIDGE	0.4		2016-02-23 21:45
23	FOOTBRIDGE	1	3 bridges in 50 m with 1 m clearance.	2016-02-23 22:04
24	FOOTBRIDGE			2016-02-23 22:07
25	FOOTBRIDGE	2.5		2016-02-23 23:13
26	FOOTBRIDGE		2 footbridges within 50 m	2016-02-23 23:21
27	FOOTBRIDGE		Two bridges within 50m	2016-02-24 16:51
28	FOOTBRIDGE	1		2016-02-24 17:30
29	FOOTBRIDGE	0	With steel grate below	2016-02-24 17:51
30	FOOTBRIDGE		5 bridges within 150 m	2016-02-24 18:06
31	FOOTBRIDGE			2016-02-24 18:19

Appendix B – Engineering Field Inventory

Table B-4: Field Inventory - Observed Bridge Sites

OBJECT ID	TYPE	LOW_CHORD (m)	COMMENT	CreationDate
32	DRIVEWAY	1.5		2016-02-24 21:16
33	FOOTBRIDGE	.5		2016-02-24 21:45
34	FOOTBRIDGE	1.25		2016-02-24 21:48
35	FOOTBRIDGE	1		2016-02-24 22:22
36	FOOTBRIDGE	0.75		2016-02-24 22:40
37	DRIVEWAY	.6		2016-02-24 22:43
38	DRIVEWAY	1	With 150mm pipe underneath	2016-02-24 22:47
39	FOOTBRIDGE			2016-02-24 23:22
40	FOOTBRIDGE	3		2016-02-25 17:08
41	FOOTBRIDGE	3		2016-02-25 19:07
42	FOOTBRIDGE	0.8		2016-02-25 19:17
43	FOOTBRIDGE	0.6		2016-02-25 19:21
44	FOOTBRIDGE	1.6	Footing in creek	2016-02-25 19:30
45	FOOTBRIDGE			2016-02-25 19:34
46	FOOTBRIDGE		Three	2016-02-25 19:38
47	FOOTBRIDGE	1		2016-02-25 20:03
48	FOOTBRIDGE			2016-02-25 21:13
49	FOOTBRIDGE			2016-02-25 21:43
50	FOOTBRIDGE			2016-02-25 22:47
51	FOOTBRIDGE			2016-02-25 22:50
52	FOOTBRIDGE			2016-02-25 22:58
53	FOOTBRIDGE			2016-02-25 23:20
54	FOOTBRIDGE			2016-02-26 0:41
55	FOOTBRIDGE		Three	2016-02-26 17:24
56	FOOTBRIDGE			2016-02-26 17:38
57	FOOTBRIDGE			2016-02-26 17:57
58	FOOTBRIDGE			2016-02-26 20:21
59	FOOTBRIDGE			2016-02-26 20:38
60	FOOTBRIDGE			2016-02-26 20:44

Appendix B – Engineering Field Inventory

Table B-5: Field Inventory - Observed Outfall Sites

OBJECT ID	Bank	Diameter	Height	Shape_1	Material	Condition	Eng_Disipation	Eng_Dis_Type	Headwall	HeadWall_Condi	Outfall_Drop	Sediment_Depth	Comment	CreationDate
1	RIGHT BANK	300	2	Round	PVC	GOOD	YES	RIPRAP	CONCRETE	GOOD	0.05	0	Top mounted flapgate. Roots growing in between fitting and pipe at headwall.	2016-02-02 17:49
2	RIGHT BANK	80	0.5	Round	STEEL	GOOD	YES	CONCRETE	CONCRETE	GOOD	0.3	0	4 outfalls draining bridge, spaced along footing. Possibly mirrored on left bank but not visible due to rip rap	2016-02-02 18:27
3	RIGHT BANK	75	0.5	Round	PVC	GOOD	NO		NONE		0.5	0	Small PVC pipe out from bank	2016-02-02 19:40
4	RIGHT BANK	75	5	Round	PVC	GOOD	NO		NONE		0.5	0	Onto slope above floodplain from residential unit. Slope lacking vegetation, some Lamium.	2016-02-02 19:45
5	RIGHT BANK	100	8	Round	HDEP	GOOD	NO	NONE	NONE		50	0	2 corrugated plastic tubes from residence yard. 2 m apart.	2016-02-02 19:48
6	RIGHT BANK	200	15	Round	PVC	GOOD	NO		NONE		1.5	0		2016-02-02 21:12
7	RIGHT BANK	300	14	Round		GOOD	NO		NONE		15	0	Outfall at level of Keith road, draining down to creek in unmapped watercourse. Blackberry obscuring outlet, unknown material.	2016-02-02 21:13
8	RIGHT BANK	150	20	Round	PVC	GOOD	NO		NONE		0.75	0	On south side of Keith road crossing from under road.	2016-02-02 21:16
9	LEFT BANK	100	6	Round	PVC	GOOD	NO		NONE		1	0	Water flowing at time of survey	2016-02-02 21:38
10	LEFT BANK		4									0	Cannot see or access outfall. High flows and scour of bank to bedrock	2016-02-02 21:59
11	LEFT BANK	100	2	Round	PVC	POOR	NO		NONE		1	0	Pipe from top of bank broken by lwd fall	2016-02-02 22:09
12	LEFT BANK	100	1	Round	PVC	FAIR	NO		NONE		0.3	0	3 outfall pipes draining onto floodplain 4 m from creek	2016-02-02 22:12
13	LEFT BANK	100	0.5	Round	STEEL	FAIR	YES	CONCRETE	CONCRETE	FAIR	0	0	Two steel pipes flowing into concrete chamber that connects to 30m long concrete pipe/berm continuous with creek.	2016-02-02 22:23
14	LEFT BANK	100	3	Round	PVC	GOOD	NO		NONE		0.3	0		2016-02-02 22:29
15	LEFT BANK	100	1	Round	HDEP	GOOD	NO		NONE		0.01	0	Drainage tile	2016-02-02 23:20
16	RIGHT BANK	100	2	Round	PVC	GOOD	NO	NONE	NONE		0.2	0		2016-02-02 23:22
17	RIGHT BANK	200	2	Round	PVC	FAIR	NO		NONE		0.4	0		2016-02-02 23:23
18	LEFT BANK	50	3	Round	HDEP	GOOD	YES	CONCRETE	NONE		2	0	Below outfall is concrete sewer pipe from bank connected with underwater pipe	2016-02-02 23:36
19	LEFT BANK	100	3	Round	PVC	GOOD	NO	NONE	NONE		1	0	Onto bedrock bank	2016-02-02 23:40
20	LEFT BANK	600	2	Round	CONCRETE	GOOD	YES	RIPRAP	RIPRAP	GOOD	0.3	0	Under bridge	2016-02-03 0:18
21	RIGHT BANK	150	6	Round	PVC	GOOD	NO		NONE		2	0	Likely road runoff. Just on downstream side of bridge.	2016-02-03 0:19
22	RIGHT BANK	800	2	Round	CONCRETE	GOOD	YES	RIPRAP	CONCRETE	GOOD	0.7	0	From bridge footing on both sides	2016-02-03 0:28
23	LEFT BANK	150	0.1	Round		GOOD	NO		NONE		0.1	0	Corrugated black plastic coming from top of ravine between houses.	2016-02-03 0:48
24	LEFT BANK	150	4	Round	PVC	GOOD	NO		NONE		4	0		2016-02-03 0:48
25	LEFT BANK	100	0.1	Round	PVC	GOOD	NO		NONE		0	0	Flows into WVS sewer box, new fitting recent installation	2016-02-03 0:51
26	RIGHT BANK	150	5	Round	PVC	GOOD	NO		NONE		0	0	Just upstream of bridge.	2016-02-03 1:01
27	LEFT BANK	300	10	Round	CONCRETE	FAIR	NO		NONE		0.5	0	End of pipe cracked, falls onto bedrock. Some erosion down the slope to the bedrock as water from pipe moves down steep slope to creek.	2016-02-04 16:38
28	RIGHT BANK	75	4	Round	PVC	GOOD	NO		NONE		0	0	Small with trickle of water. Coming from under house.	2016-02-04 16:58
29	RIGHT BANK	150	5	Round	PVC	GOOD	NO		NONE		0.3	0	Coming out of bridge on upstream side. Some small erosion down bank to creek.	2016-02-04 17:07
30	LEFT BANK	100	0	Round	PVC	GOOD	NO		NONE		0	0		2016-02-04 18:08
31	RIGHT BANK	150	0.1	Round	PVC	GOOD	NO		NONE		0.1	0	Coming from residences. Very small flow coming out.	2016-02-04 19:02
32	RIGHT BANK	150	0.3	Round	PVC	GOOD	NO		NONE		0.3	0	From residences. Overhangs creek where bank has likely eroded away 1.5m. Some silt fencing in stream.	2016-02-04 19:14
33	LEFT BANK	200	1.5	Round	STEEL	GOOD	NO		NONE		1.5	0		2016-02-04 19:17
34	LEFT BANK	600	6	Round	PVC	GOOD	YES	ROCK & GRAVEL	RIPRAP	GOOD	2	0	Two pipes from under Stevens dr	2016-02-04 21:55
35	RIGHT BANK	250	5	Round	PVC	GOOD	NO		NONE		0	0	No flow.	2016-02-04 22:02
36	RIGHT BANK	150	4	Round	PVC	GOOD	YES	ROCK & GRAVEL	ROCK & GRAVE	GOOD	0	0	2 pipes From under Stevens dr	2016-02-04 22:04
37	RIGHT BANK	200	6	Round	CONCRETE	FAIR	NO	NONE	ROCK & CONCR	GOOD	0	0	Quite plugged with debris at entrance. Half visible. Considerable flow. Main source of flow into Haden from this tributary.	2016-02-04 22:07

Appendix B – Engineering Field Inventory

Table B-5: Field Inventory - Observed Outfall Sites

OBJECT ID	Bank	Diameter	Height	Shape_1	Material	Condition	Eng_Disipation	Eng_Dis_Type	Headwall	HeadWall_Condi	Outfall_Drop	Sediment_Depth	Comment	CreationDate
38	LEFT BANK	200	1.5	Round	PVC	FAIR	NO		NONE		1.5	0	Pipe seems to be in good condition but water is coming out from around pipe where it exits the ground.	2016-02-04 22:23
39	RIGHT BANK	200	0.2	Round		GOOD	NO		NONE		0.1	0	From residences. Unknown material. No flow.	2016-02-04 22:51
40	RIGHT BANK	150	2	Round	PVC	GOOD	NO		NONE		0.1	0	From driveway runoff.	2016-02-04 23:17
41	LEFT BANK	300	1.2	Round	HDEP	FAIR	YES	ROCK & GRAVEL	NONE		0.4	0	Crack at joint	2016-02-09 17:55
42	LEFT BANK	750	0	Round	STEEL	FAIR	NO		RIPRAP		0	0	Turbid grey black water with styrofoam in it.	2016-02-10 17:41
43	RIGHT BANK	800	0	Round	CONCRETE	GOOD	NO		ROCK & CONCR	GOOD	0	0	Turbidity coming from outfall - grey, black water. Gravel deposits at mouth of outfall.	2016-02-10 18:05
44	LEFT BANK		12	Round	STEEL	GOOD	YES	ROCK & GRAVEL	NONE		2	0.06	Discharging brown turbid water	2016-02-10 19:50
45	RIGHT BANK	400	2	Round	STEEL	FAIR	NO		NONE		0.75	0	Coming from top of bank	2016-02-10 20:38
46	RIGHT BANK	800	0.2	Round	CONCRETE	FAIR	NO		RIPRAP	GOOD	0.2	0		2016-02-23 18:43
47	LEFT BANK	500	0.75	Round	CONCRETE	GOOD	NO		ROCK & CONCR	GOOD	0	0	Significant flow	2016-02-23 22:00
48												0	End of Vinson creek east. Between high and low tide.	2016-02-25 18:01
49		400		Round	CONCRETE	GOOD						0	Trickle of water coming out. 10 m west of main outfall.	2016-02-25 21:45
50		500		Round	CONCRETE	GOOD						0	Main outfall. Iron coloured stain on rocks.	2016-02-25 21:48
51		1250		Round	CONCRETE	GOOD	NO		RIPRAP	GOOD		0	Outfall at low tide still half submerged. Encrusted with barnacles and blue mussels. Riprap protection around.	2016-02-25 22:01
52		1250		Round	CONCRETE	GOOD	YES	CONCRETE				0	Spills onto concrete apron, part of which (right side) has been broken off. Rip rap protects rest of pipe. Encrusted with barnacles and mussels and some seaweed.	2016-02-25 22:13
53		1200		Round	CONCRETE	GOOD						0	From lake	2016-02-25 22:48

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Appendix C

Environmental Inventory and Assessment

Appendix C – Environmental Inventory and Assessment

Contents

Figures at end of Section

Tables

Appendices

Appendix C – Environmental Inventory and Assessment

C Environmental Inventory and Assessment

C.1 Introduction

This Appendix describes the methods and results for the environmental inventory and assessment undertaken in February and March 2016 as part of the first phase of development of the Vinson, Brothers, and Hadden Creeks Integrated Stormwater Management Plan (ISMP). The ISMP is being developed by Kerr Wood Leidal Associates (KWL) for the District of West Vancouver. The work program included assessments on the following topics for the study area:

- Aquatic species and habitats, identifying:
  - Presence and distribution of fish species;
  - Presence and quality of fish habitat, especially for spawning and rearing salmonids;
  - Presence of barriers to fish passage;
  - Key areas of concern (e.g., habitat degradation, erosion);
  - Previously undertaken fish habitat enhancement projects; and
  - Future potential restoration and enhancement opportunities.
- Riparian and overall forest cover in the watersheds, including calculations of Riparian Forest Integrity for sub-catchments (RFI);
- Terrestrial species and wildlife habitat, including species at risk and invasive species; and
- Available water quality and benthic invertebrate data, and ongoing monitoring programs.

The purpose of the assessments were to: (1) to assess status and trends in watershed conditions and the overall health of the Vinson, Brothers, and Hadden catchments; (2) to identify priority environmental issues to be addressed in the ISMP; and (3) to identify environmental enhancement opportunities within the study area. Depending on the assessment, the work included collation and review of existing information, field inventories, and data summarization and analysis.

Study Area

The study area is composed of three major subcatchments/watersheds:

Brothers Creek is a tributary to the Capilano River and is the largest catchment in the ISMP study area at 5.63 km^2. Its headwaters are on the southeast side of Hollyburn Ridge, and its confluence with the Capilano River is 160 m upstream of the Marine Drive bridge. Included in the Brothers Creek watershed are West Brothers Creek, an unnamed tributary running beside Westcot Elementary School, and Macbeth Creek.

Hadden Creek is a tributary of Brothers Creek and it drains a 2.7 km^2 area. Their confluence is 90 m east of Taylor Way and south of Highway 1 between Highway 1 and Inglewood Ave.

The **Vinson watershed** borders Brothers Creek watershed to the west, and consists of East and West Vinson Creeks. It has an area of approximately 3.7 km^2. These two creeks flow into Burrard Inlet at the west end of Ambleside Park.

Appendix C – Environmental Inventory and Assessment

Sources of Data

The following inventory and assessment for the three watersheds is a synthesis of publicly available government and consultant data, previous habitat assessments, data from stewardship groups, and the results of a new field inventory completed as part of the ISMP. Key sources of data and information included:

- District of West Vancouver orthographic photographs and GIS data (DWV 2015);
- EcoCAT: The Ecological Reports Catalogue (MOE 2016a), including multiple reports;
- Fisheries Inventories Information System (MOE 2016b);
- BC Conservation Data Centre (MOE 2016c);
- West Vancouver Streamkeeper Society (WVSS) survey reports, personal communications, and water quality monitoring data (WVSS 2014, WVSS 2015 pers. comm., WVSS 2016 pers. comm.);
- Pacific Streamkeepers Federation watershed profiles (PSKF 2002, PSKF 2003a, PSKF 2003b); and
- A biophysical inventory of Brothers, Hadden, and Vinson Creeks conducted by KWL in February 2016.

C.2 Aquatic Species and Habitat

Fish Presence and Distribution

Brothers Creek

Brothers Creek supports 10 species of fish, including four species of anadromous salmon and two species of trout (Table C-1). Historical escapement numbers for salmon returning to Brothers Creek over ten years are shown in Table C-2 (MOE 2016b). Figure C-1 shows the distribution of fish species in the three watersheds based on background information and field survey.

From 1984–1991, Brothers Creek was stocked with Steelhead sourced from the Capilano River, and, in 1984, with Cutthroat Trout from the Capilano River (MOE 2016b). Currently WVSS operates the Nelson Creek hatchery, receiving Chum, Coho, and Pink stock from Tenderfoot, Capilano, Seymour, and Alouette hatcheries. They release the salmon fry and smolts into creeks across West Vancouver including West Brothers Creek. WVSS also conduct visual surveys for fry in the spring to document the location and approximate number of fry in the streams of West Vancouver since 2011 (WVSS 2013) The areas they survey correspond to reaches BR-1.1, BR-2.1, BR-4.1, BR-4.2, HA-1.1, HA-1.2, and HA-1.3 in this report. These surveys help determine the success of spawning salmon and the development of wild fry before the release of hatchery fry.

Appendix C – Environmental Inventory and Assessment

Table C-1: Known Fish Species Present in Brothers Creek

Species code	Common name	Scientific name	Notes	Source
CO	Coho Salmon	*Oncorhynchus kisutch*	Spawners observed from 2006-2015, rearing fry sampled during electrofishing training and salvaged in tributary during culvert replacement	MOE 2016b, VIU 2008, ISL Engineering and Land Services 2013, WVSS 2015
CM	Chum Salmon	*Oncorhynchus keta*	Spawners observed from 2006-2015, rearing fry sampled during electrofishing training	MOE 2016b, VIU 2008, WVSS 2015
CH	Chinook Salmon	*Oncorhynchus tshawytscha*	Spawners observed from 2010-2015, numbers two orders of magnitude greater in 2014 than in other years	MOE 2016b, WVSS 2015
PK	Pink Salmon	*Oncorhynchus gorbuscha*	Spawners observed in 2009, 2011, 2013, and 2015	MOE 2016b, WVSS 2015
ST	Steelhead	*Oncorhynchus mykiss*		MOE 2016b
RB	Rainbow Trout	*Oncorhynchus mykiss*	Rearing fry sampled during electrofishing training.	MOE 2016b, VIU 2008, MOE 1980
CT	Cutthroat Trout	*Oncorhynchus clarki* (formerly *Salmo clarki*)	Rearing fry salvaged during culvert replacement in tributary.	ISL Engineering and Land Services 2013
CAL	Coastrange Sculpin	*Cottus aleuticus*	Migrating juveniles sampled during electrofishing training.	MOE 2016b, VIU 2008
CAS	Prickly Sculpin	*Cottus asper*	Migrating juveniles sampled during electrofishing training.	MOE 2016b, VIU 2008
TSB	Threespine Stickleback	*Gasterosteus aculeatus*	Sampled during electrofishing training.	VIU 2011

Since 2006, WVSS has collected information on the number and location of returning salmon every fall for watersheds in West Vancouver. In 2015, volunteers counted 319 Chum, 95 Coho, 2 Chinook, and 1226 Pink Salmon returning to Brothers Creek to spawn (WVSS 2015). Pink salmon return in odd years and the number of returns has been increasing in recent years. WVSS counted 88 pink salmon in 2011 and 232 in 2013. Chinook had unusually high returns to Brothers Creek in 2014, with 103 adults counted in that year compared to 3–4 per year from 2010–2012. This was possibly due to the high turbidity levels in the Capilano River in 2014. High turbidity may have influenced adults that would otherwise spawn in the Capilano River to swim into Brothers Creek (WVSS 2015).

Table C-2: Summary of Historical Spawner Escapement in Brothers Creek

Species	Date Range	Mean	Max
Chum	1985-1994	25	93
Coho	1985-1994	92	253
Chinook	1988-1997	80	130
Pink	1985-1993	25	27

Appendix C – Environmental Inventory and Assessment

Adult salmon returning to Brothers Creek have been observed spawning in the following areas (downstream to upstream) based on Streamkeeper surveys (WVSS 2016 pers. comm.):

- Below the Clyde Ave bridge;
- Large pool upstream of the Clyde Ave bridge;
- Under the Keith Road bridge;
- Downstream and upstream of the Inglewood Ave bridge;
- Opposite 620 Inglewood Ave (private residence);
- Upstream of Taylor Way beside 1305 Taylor Way (Synagogue / Jewish Community Centre); and
- Pools downstream and upstream of Wildwood Lane.

Salmon also swim west into Burly Creek (reach BR-6.1) below Highway 1, and it is unknown how far salmon swim upstream on West Brothers Creek above Wildwood Lane (WVSS 2016 pers. comm.). Resident Cutthroat Trout are found on Brothers Creek above Cross Creek Road (DFO 1999).

Hadden Creek

Hadden Creek provides habitat for Coho, Chum, Chinook, and Pink Salmon, as well as Cutthroat Trout.

Table C-3: Known Fish Species Present in Hadden Creek

Species Code	Common Name	Scientific Name	Notes	Source
CO	Coho Salmon	*Oncorhynchus kisutch*	Collected in fish salvage during construction in 2006 and 2007, spawners observed in 2006-2014	MOE 2016b, Coast River Environmental Services 2006, Sartori Environmental Services 2007, WVSS 2014
CM	Chum Salmon	*Oncorhynchus keta*	Spawners observed in 2006-2015	WVSS 2015
CH	Chinook Salmon	*Oncorhynchus tshawytscha*	Spawners observed in 2006-2015	WVSS 2015
PK	Pink Salmon	*Oncorhynchus gorbuscha*	Spawners observed in 2015, 2013, and 2011	WVSS 2015
CT	Cutthroat Trout	*Oncorhynchus clarki* (formerly *Salmo clarki*)		MOE 2016b, Coast River Environmental Services 2006, DFO 1997

In 2014, 56 Chum, 69 Coho, and 102 Chinook returned to Hadden Creek (WFSK 2014). Coho and Chinook traveled farther up Hadden than in previous years (WVSS 2014). Chinook returns in Hadden creek in 2014 were two orders of magnitude higher than the previous four years (102 in 2014, one in 2012, and one in 2010) possible due to heavy sedimentation in the Capilano River in 2014 (WFSK 2014).

Appendix C – Environmental Inventory and Assessment

West and East Vinson Creek

The Vinson watershed has records of Cutthroat Trout. Multiple barriers at the mouth of Vinson and extensive habitat alteration can explain the absence of salmon from this watershed. There are no recorded salmon returns to East or West Vinson Creeks in the recent past (all piped systems at ocean).

Table C-4: Known Fish Species Present in Vinson Creek

Species Code	Common Name	Scientific Name	Source	Notes
CT	Cutthroat trout	*Oncorhynchus clarki* (formerly *Salmo clarki*)	PSKF 2003b, WVSS 2016 pers. comm.	

Biophysical Survey

KWL biologists carried out a field inventory of Brothers, Hadden, and Vinson Creeks in January and February of 2016. The inventory covered up to the 365 m development boundary. This work focused on assessing fish habitat values in the three creeks, including:

- Physical channel measurements and morphology;
- Substrate composition;
- Spawning habitat based on substrate composition;
- Rearing habitat based on instream cover, large woody debris (LWD), and pools;
- Potential fish barriers;
- Existing fish habitat enhancements;
- Points of concern for fish and aquatic habitat (habitat degradation, outfalls, etc.);
- Condition of the riparian zone;
- Presence of invasive plants; and
- Potential locations for future habitat enhancements.

The survey was based on the Stream Inventory Standards and Procedures section of *Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures* (Resource Inventory Committee 2001) with a simplified sampling design and a segment-by-segment approach. Reaches were defined as stretches of stream between major changes, such as large roads and highways, major culverts, and land use changes. Each reach was divided into segments to capture more fine scale variation in the streams. Fish sampling was not within the scope of this project.

Aquatic Habitat Values

Brothers Creek provides extensive aquatic habitat for spawning and rearing salmon, trout, and other aquatic organisms (Figure C-2). Downstream of Highway 1, it has an average bankfull width of 10.1 m. See Table C-5 for stream physical traits and Table C-6 for fish habitat parameters. The substrates in the lower reaches are dominated by gravels and cobbles, providing excellent spawning habitat for salmon. Brothers Creek provides moderate rearing habitat throughout the lower reaches downstream of Highway 1 and excellent rearing habitat in West Brothers Creek and the mainstem upstream of Highway 1 in the heavily forested segments within the Hollyburn Country Club. Upstream of King Georges Way, the quality of aquatic habitat decreases due to small channel size, lack of riparian vegetation, and frequent encroachments from development, structures, landscaping, and clearing.

Appendix C – Environmental Inventory and Assessment

Table C-5: Stream Physical Traits

Segment #	Channel Dimensions				Substrate					Instream cover %
	Average bankfull width (m)	Average wetted width (m)	% bedrock	% boulder	% cobble	% gravel	% fines	% organics	% embed-dedness	
Brothers Creek										
BR-1.1	9.4	8	5	25	50	15	5	0	10	5
BR-1.2	9	7	10	20	40	25	5	0	10	10
BR-1.3	8.5	7	5	10	30	40	15	0	15	15
BR-1.4	13.5	12	0	5	40	55	0	0	5	5
BR-2.1	9	8	0	10	30	40	10	0	10	10
BR-2.2	14	12	0	40	40	15	5	0	5	15
BR-2.3	14	12	15	40	30	15	0	0	2	10
BR-3.1	13	10	20	30	30	20	0	0	5	10
BR-3.2	5	3.5	80	10	5	5	0	0	0	10
BR-3.3	4.5	3.5	50	30	15	5	0	0	0	5
BR-3.4	5	4	55	30	10	5	0	0	0	5
BR-4.1	1	1	20	0	30	30	10	0	10	5
BR-4.2	3	2	0	15	30	40	5	0	10	15
BR-4.3	4	2.5	0	30	30	30	10	0	15	20
BR-4.4	2	1.8	0	5	25	60	10	0	8	10
BR-4.5	3	1.8	0	5	30	65	5	0	5	15
BR-4.6	1.5	1	63	30	2	3	2	0	0	5
BR-5.1	2.6	2	20	30	30	20	0	0	2	15
BR-5.2	2.5	2	5	10	40	45	0	0	2	5
BR-5.3	1.5	1.2	0	5	40	45	5	0	5	8
BR-6.1	2.5	2	0	5	35	50	10	0	12	10
BR-7.1	1.3	1	0	5	10	75	10	0	15	8
Macbeth Creek										
MA-1.1	2.6	2	0	5	20	65	10	0	8	8
Hadden Creek										
HA-1.1	4.5	4	0	5	45	35	15	0	15	10
HA-1.2	4.5	3.5	0	10	30	50	10	0	15	15
HA-1.3	5.5	4.5	0	35	35	20	10	0	15	15
HA-2.1	6	4	0	15	40	30	15	0	15	30
HA-2.2	1.5	1.5	1	9	50	30	10	0	15	5
HA-2.3	2.6	2.3	0	0	10	50	40	0	12	15
HA-3.1	2	1.75	5	10	25	40	20	0	10	5
HA-3.2	3	1.5	30	30	25	15	0	0	10	10
HA-4.1	2.6	2	10	10	40	35	5	0	3	5
HA-4.2	2	1.8	20	20	30	30	0	0	3	8
Vinson Creek East										
VIE-1.1	3	2	0	5	10	50	35	0	20	5
VIE-1.2	2	1	0	1	30	35	35	4	25	10
Vinson Creek West										
VIW-1.1	2	1.5	0	5	25	45	25	0	15	15
VIW-2.1	1.5	1.2	0	10	40	45	5	0	4	5
VIW-2.1	2.3	2	0	15	40	40	5	0	3	8
VIW-2.1	1	0.75	5	0	10	30	50	5	30	5
VIW-2.2	1	0.8	0	15	45	40	0	0	2	5
VIW-3.2	2	0.5	0	5	10	40	40	5	15	1
VIW-4.1	1.5	1.5	0	5	20	65	10	0	8	4

Appendix C – Environmental Inventory and Assessment

Table C-6: Fish Habitat Parameters

Segment number	Channel morphology	RFI	Fish presence*	Spawning gravel	Spawning type	Rearing habitat
Brothers Creek						
BR-1.1	Riffle-pool	64.9%	Anadromous (CO, PK, CH, CM)	Extensive	Anadromous salmon	Moderate
BR-1.2	Riffle-pool	82.0%	Anadromous (CO, PK, CH, CM)	Extensive	Anadromous salmon	Moderate
BR-1.3	Riffle-pool	74.3%	Anadromous (CO, PK, CH, CM)	Extensive	Anadromous salmon	Moderate
BR-1.4	Riffle-pool	44.2%	Anadromous (CO, PK, CH, CM)	Extensive	Anadromous salmon	Moderate
BR-2.1	Riffle-pool	45.6%	Anadromous (CO, PK, CM)	Extensive	Anadromous salmon	Moderate
BR-2.2	Cascade-pool	82.7%	Anadromous (CO)	Extensive	Anadromous salmon	Abundant
BR-2.3	Cascade-pool	84.2%	Anadromous (CO)	Extensive	Anadromous salmon	Moderate
BR-3.1	Cascade-pool	68.2%	Resident	Little	Anadromous salmon	Moderate
BR-3.2	Cascade-pool	82.3%	Resident	Little	Anadromous salmon	Little
BR-3.3	Cascade-pool	31.0%	Resident	Little	Anadromous salmon	Little
BR-3.4	Cascade-pool	47.5%	Resident	Little	Trout/char	Little
BR-5.1	Cascade-pool	49.7%	Anadromous (CO)	Extensive	Anadromous salmon	Moderate
BR-5.2	Cascade-pool	24.3%	Resident	Little	Trout/char	Little
BR-5.3	Riffle-pool	13.6%	Resident	Little	Trout/char	Little
BR-6.1	Riffle-pool	42.0%	Anadromous (CO, PK, CM)	Extensive	Both	Moderate
BR-7.1	Riffle-pool	37.8%	Anadromous (CO)	Extensive	Both	Little
Macbeth Creek (tributary to Brothers Creek)						
MA-1.1	Riffle-pool	42.2%	Anadromous (CO, PK, CH, CM)	Extensive	Both	Moderate

Appendix C – Environmental Inventory and Assessment

Segment number	Channel morphology	RFI	Fish presence*	Spawning gravel	Spawning type	Rearing habitat
West Brothers Creek						
BR-4.1	Riffle	29.9%	Anadromous (CO, PK, CM)	Extensive	Anadromous salmon	None
BR-4.2	Riffle-pool	48.0%	Anadromous (CO, PK, CM)	Extensive	Anadromous salmon	Moderate
BR-4.2	Riffle-pool	48.0%	Resident	Extensive	Anadromous salmon	Moderate
BR-4.3	Cascade-pool	83.5%	Resident	Extensive	Anadromous salmon	Abundant
BR-4.4	Riffle-pool	49.1%	Resident	Extensive	Both	Moderate
BR-4.5	Riffle-pool	68.1%	Resident	Extensive	Both	Moderate
BR-4.6	Step-pool	38.4%	None	None	NA	None
Hadden Creek						
HA-1.1	Riffle-pool	54.9%	Anadromous (CO, PK, CH, CM)	Extensive	Anadromous salmon	Moderate
HA-1.2	Riffle-pool	55.1%	Anadromous (CO, PK, CH)	Extensive	Anadromous salmon	Moderate
HA-1.3	Cascade-pool	93.3%	Anadromous (CO)	Extensive	Anadromous salmon	Moderate
HA-2.1	Riffle-pool	41.0%	Anadromous (CO)	Extensive	Anadromous salmon	Moderate
HA-2.2	Riffle-pool	16.0%	Resident	Little	Anadromous salmon	Little
HA-2.3	Riffle-pool	74.0%	Resident	Extensive	Trout/char	Abundant
HA-3.1	Cascade-pool	26.0%	Resident	Extensive	Anadromous salmon	Little
HA-3.2	Cascade-pool	15.3%	Resident	Little	Both	Little
HA-4.1	Riffle-pool	31.8%	None	Little	Trout/char	Little
HA-4.2	Riffle-pool	26.6%	None	Little	Trout/char	Little
Vinson Creek West						
VIW-1.1	Riffle-pool	36.0%	Resident	Extensive	Both	Little
VIW-1.2	Riffle-pool	34.0%	Resident	Extensive	Anadromous salmon	Little
VIW-2.1	Cascade-pool	16.3%	Unknown	Little	Trout/char	Little

Appendix C – Environmental Inventory and Assessment

Segment number	Channel morphology	RFI	Fish presence*	Spawning gravel	Spawning type	Rearing habitat
VIW-2.2	Cascade-pool	17.9%	Unknown	Little	Trout/char	Little
VIW-3.1	Riffle-pool	15.2%	None	Little	Trout/char	None
VIW-3.2	Riffle-pool	67.7%	None	Little	Trout/char	None
VIW-4.1	Riffle-pool	13.4%	None	Little	Trout/char	None
Vinson Creek East						
VIE-1.1	Riffle-pool	35.1%	Unknown	Extensive	Both	None
VIE-1.2	Riffle-pool	44.7%	Unknown	Extensive	Both	Little
*Fish presence based on historical records (EcoCat), West Vancouver Streamkeepers Surveys and personal communications, and field assessment of habitat and barriers.						

Appendix C – Environmental Inventory and Assessment

Several ponds within the watershed provide aquatic habitat. There is one inline pond (9200 m²) on a tributary of Brothers Creek approximately 1 km upstream of the southern boundary of Cypress Provincial Park. There is also one small pond (1800 m²) that is approximately 50 m from the creek within Cypress Provincial Park. The west portion of Elveden Lake, located north of Groveland Rd, also drains into Brothers Creek. Elveden Lake provides wildlife habitat for waterfowl, amphibians, aquatic insects, and potentially for resident fish.

Hadden Creek also provides extensive aquatic habitat for spawning and rearing salmon, trout, and other aquatic organisms. The lower reach of Hadden has an average bankfull width of 4.8 m. Hadden Creek has extensive spawning gravels from its confluence with Brothers Creek upstream to the Capilano Golf and Country Club, and a stretch from within the golf course upstream to Kenwood Rd. There is high quality fish habitat between Stevens Dr and Hadden Dr (segment HA-1.3). In this section, natural processes like abundant wood debris recruitment, sediment deposition, and formation of side channels and scour pools have created complex habitat. Segment HA-2.3 is a forested section in the northern portion of the golf course which contains high quality rearing habitat. This section also has habitat complexity, with side channels, abundant large woody debris, and pools.

There are two small inline ponds (1000 m² each) within Hadden Creek in the Capilano Golf & Country Club. The east portion of Elveden Lake (7000 m²) also drains into Hadden Creek. The lake provides wildlife habitat for waterfowl, amphibians, aquatic insects, and potentially for resident fish.

Overall, the **Vinson watershed** (East and West) provides poor fish habitat due to extensive piped sections, culverts, channelization, and lack of riparian vegetation. Bankfull width is on average 1.8 m. Approximately 80% of East Vinson Creek has beenpiped and buried underground starting at Burrard Inlet, and West Vinson Creek has a 600 m piped section that also starts at its mouth although the creek has more open channel sections upstream. Although there are suitable spawning gravels, there is little to no quality rearing habitat in the Vinson watershed.

Barriers to Fish Migration

KWL biologists found seven definite barriers and eight potential barriers to fish passage in the Brothers Creek catchment (Figure C-3). There were four definite and four potential barriers in the Hadden Creek catchment. The Vinson Creek catchment contained four definite barriers and one potential barrier.

In the **Brothers Creek** mainstem, upstream passage of spawners is limited by a culvert at Cross Creek Dr. On the tributary that runs beside Wescot Elementary School, salmon have access up to just downstream of the culvert that runs underneath the sports field.

In **West Brothers Creek**, Coho use the fish ladder between 890 and 920 Wildwood Lane to pass upstream of Wildwood Lane (WVSS 2015 pers. comm.), but another culvert near 921 Wildwood lane is a potential barrier.

In **Macbeth Creek**, spawners are limited by a wire mesh hatch built below a fence between two residences, 40 m upstream of Inglewood Ave. The hatch has a hinge and can be opened to allow fish passage, but it is unknown if the landownder operates it.

In **Hadden Creek**, spawners can pass the Hadden Dr culvert but are currently blocked by a perched culvert below Pond 5 at the Capilano Golf & Country Club. Chum have been recorded upstream of the Alaska steeppass fishway at Stevens Dr (WVSS 2012).

In the **Vinson watershed**, the piped sections from the mouths of East Vinson Creek (1300 m long) and West Vinson Creek (600 m long) are barriers to anadromous species. Resident Cutthroat Trout are blocked by the culvert under Highway 1 (invert covered in 2 cm mesh) and several barriers upstream of Highway 1. There are over 40 culverts in the Vinson watershed overall.

Appendix C – Environmental Inventory and Assessment

Table C-7: Barriers to Fish Migration

Segment	Location	Barrier type	Description	Barrier to fish passage?
Brothers Creek				
BR-2.3	50 m upstream of confluence with east branch tributary. East of Hollyburn Country Club	Chute-cascade	4 m tall, 10 m long, Chute on right side of channel, cascade on left, with log jam upstream	Potential
BR-2.3	130 m upstream of confluence with east branch tributary. East of Hollyburn Country Club	Chute-cascades	2 m high, 4 m long	Potential
Between BR-2.3 and BR-3.1	**At Cross Creek Rd**	**Culvert**	**20 m long, 20% slope with steeper, bedrock approach**	**Yes**
BR-3.1	170 m upstream of Cross Creek Rd	Log jam	1.8 m fall	Potential
BR-3.1	80 m downstream of Burnside Rd	Chute-cascade	2.5 high, 15 long, 25% slope	Potential
Between BR-3.1 and BR-3.2	**At Burnside Rd**	**Culvert**	**2 m drop onto boulders, no immediate plunge pool**	**Yes**
BR-3.2	40 m upstream of Burnside Rd	Chute-cascade	5 m high, 5 m long, bedrock	Potential
BR-3.2	**220 m upstream of Burnside Rd**	**Falls**	**5 m high, vertical**	**Yes**
BR-5.1	At Cross Creek Rd/ Eyremound Dr	Culvert	1 m perch over cobble. Plunge pool is 1 m deep but is 2.5 m downstream from exvert	Potential
BR-5.1	**Between Cross Creek Rd and Eyremount Dr in back yard**	**Fall**	**3 m constructed fall**	**Yes**
Between BR-5.1 and BR-5.2	**At Eyremount Dr**	**Culvert**	**Culvert bends up at 100% angle, creating a velocity barrier**	**Yes**
BR-7.1	At Wescot Elementary School field	Culvert	80 m culvert underneath school field, with fence at invert. Likely a barrier to spawners, potential barrier to resident fish	Potential
Macbeth Creek (tributary to Brothers Creek)				
MA-1.1	40 m upstream of Macbeth Crescent, in back yard	Fall	1.5 m high, 0.5 m plunge pool	Potential

Appendix C – Environmental Inventory and Assessment

Segment	Location	Barrier type	Description	Barrier to fish passage?
MA-1.1	**40 m upstream of Inglewood Ave**	**Fence**	**Wire grating fence with wooden frame projecting below property fence to bottom of stream, with trapdoor**	**Yes**
West Brothers Creek				
BR-4.2	At Wildwood Lane, near 921 Wildwood Lane	Culvert	Culvert has steel pipe grate at invert	Potential (WVSK 2016 pers com)
BR-4.5	**At Burnside Rd and step-pool section of Chartwell Park downstream of Burnside Rd**	**Culvert and downstream step-pool section**	**2m perch discharges onto boulders with subsurface flow, with steep step-pools downstream**	**Yes**
Hadden Creek				
Between HA-2.1 and HA-2.2	**Downstream of Capilano Golf and Country Club golf course south pond**	**Culvert**	**1.2 m perch with 1 m plunge pool. DWV, Capilano Golf and Country Clun, West Vancouver Streamkeepers, and Sartori are working on replacement design.**	**Yes**
HA-2.2	Downstream of pond within Capilano Golf and country club	Culvert under golf cart bridge	10% slope for 10 m, 0.7 m plunge pool, perched 0.45 m. Invert has 0.55 m wooden wall at tail of pond that spills onto concrete with no plunge pool.	Potential for resident fish
HA-3.1	At Robin Hood Rd	Culvert/spillway	1.5 m falls with plunge pool, with shallow spillway and culvert upstream	Potential for resident fish
HA-3.1	Between Kenwood Rd and Robin Hood Rd	Falls	1 m high falls created by wall made of concrete sandbags, protecting rusting 200 mm pipe crossing stream	Potential for resident fish
HA-4.1	**At Southborough Dr**	**Culvert**	**1.5 high perch, discharges onto boulders, plunge pool not directly under exvert**	**Yes**
Between HA-4.1 and HA-4.2	**At Hawstead Pl**	**Culvert**	**3 m high perch**	**Yes**
HA-4.2	**50 m downstream of St Andrews Rd**	**Chute-cascade**	**10 m high, 100% slope**	**Yes**
HA-4.2	40 m upstream of St Andrews Rd	Falls	1.5 m high	Potential

Appendix C – Environmental Inventory and Assessment

Segment	Location	Barrier type	Description	Barrier to fish passage?
Vinson Creek West				
Downstream of VIW-1.1	**Mouth of stream to Fulton Ave**	**Culvert/underground segment**	**600 m of underground stream**	**Yes**
Between VIW-1.2 and VIW-2.1	**Highway 1**	**Culvert**	**90 m long, invert has 2 cm mesh size steel grating**	**Yes**
VIW-2.1	Camwell Dr	Culvert	Steel grate across culvert invert	Potential
VIW-2.1	**Just upstream of Whitby Rd**	**Falls**	**Just upstream of culvert invert**	**Yes**
Between VIW-2.1 and VIW-2.2	**Chippendale Rd**	**Culvert**	**Perched 1.8 m, discharges onto cobble, no plunge pool**	**Yes**
Vinson Creek East				
Downstream of VIE-1.1	**Mouth of stream to Lawson Ave**	**Culvert/underground segment**	**1300 m of underground stream**	**Yes**
Note: Obvious fish barriers are in bold				

Appendix C – Environmental Inventory and Assessment

Previous Enhancement Projects

Through consultation with West Vancouver Streamkeeper Society and the field inventory, KWL identified the following previous enhancement projects in the study area:

Brothers Creek

- 1997-1998: Fishway installed at Wildwood Lane, fish ladder on West Brothers Creek upstream of confluence with Brothers Creek mainstem, fish ladder on Westcot Creek tributary, and baffles under Highway 1 (WVSS 2016); juvenile fish ladder on Macbeth Creek (PSKF 2002)
- 1990s: Fish passage enhancements/restoration at Taylor Way during redevelopment (fish couldn't pass Taylor Way prior to this; WVSS 2015 pers. comm.)
- 1980: Removal of concrete apron for sewer line (location unspecified; MOE 2016b)
- 1964: Construction of fishway in culvert under Taylor Way (MOE 2016b)

Hadden Creek

- 2015: Replacement of Hadden Dr culvert with new fish passable concrete box culvert with baffles designed for 200-year event (WVSS 2015 pers. comm.)
- 2005: Installation of Alaska steep-pass fishway on either side of Stevens Dr by British Pacific Properties (WVSS 2015 pers. comm.)
- 1997: Installation of baffles in culvert under Highway 1 (DFO 1999) reported to be very effective (WVSS 2015 pers. comm.); replacement of culvert and slope modification in 13th fairway of Capilano Golf and Country Club

Priority Fish and Aquatic Habitat Issues

Based on the assessment, KWL identified the following priority issues for fish and aquatic habitat (see Figure C-4).

Brothers Creek was classified as endangered in 1997 due to channelization, effective impermeable area covering 10% or greater of the watershed, and effects from urbanization (DFO 1997). Priority issues for fish and aquatic habitat in this watershed are as follows:

- A sanitary sewer line built in the late 1960s runs down Brothers Creek downstream of Highway 1, and includes 20 manholes in the creek and concrete armoured pipes that run within the creek channel and cross in several places. Risks to aquatic habitat include:
    - Potential for damage and leaking sewage; and
    - Potential for obstruction from manholes in channel.
- Culverts block fish passage:
    - Culvert near 921 Wildwood Lane; and
    - Culvert under Westcot Elementary School field.
- Impacts to water quality from stormwater:
    - Two large outfalls just upstream of Taylor Way discharge turbid gray water into the creek during rainfall events; and

  - An outfall within Hollyburn Country Club discharges turbid brown water during rainfall events and causes erosion.

- New clearing of riparian trees and vegetation in West Brothers Creek riparian zone;
- Future development causing increased impervious area, tributary loss, addition of outfalls, erosion, sedimentation, riparian clearing, and channelization/bank alteration (PSKF 2002);
- Low riparian forest cover in east branch of mainstem.

Hadden Creek was classified as endangered in 1997 due to effective impermeable area covering 10% or greater of the watershed, water quality issues, and effects from urbanization (DFO 1997). Priority issues for fish and aquatic habitat in this watershed are as follows:

- Fish passage issues with culverts, especially in golf course;
- Storm drain discharges; and
- Low riparian forest cover in segment HA-2.2 and upstream of Capilano Golf & Country Club.

Vinson Creek was classified as endangered in 1997 due to effective impermeable area covering 10% or greater of the watershed and effects from urbanization (DFO 1997). Priority issues for fish and aquatic habitat in this watershed are as follows:

- Creek is piped and channelized throughout and tributaries have been lost:
  - Mouth of West Vinson Creek is culverted for 600 m;
  - Mouth of East Vinson Creek is culverted for 1300 m;
  - West Vinson has nine culverts above Highway 1, a 265 m culvert under the highway, and 29 culverts downstream of the highway; and
  - East Vinson has three culverts below Highway 1.
- Very low riparian forest cover throughout watershed;
- Possibility of sewer line damage and leakage into creek (PSKF 2003b).

Overall:

The following priority issues exist for all of the watersheds:

- Loss of riparian forest cover and vegetation throughout the watersheds impacting water and habitat quality by increasing temperature, decreasing input of organic matter, large woody debris, and invertebrates, and reducing bank stability;
- Extensive channelization and bank armouring through private properties reducing habitat complexity and limiting natural channel processes that create complexity; and
- Stormwater runoff introducing harmful substances into the water and increasing the rates and volume of runoff during rainfall events.

Appendix C – Environmental Inventory and Assessment

C.3 Riparian and Watershed Forest Cover

Riparian Forest Cover

Riparian Forest Integrity (RFI) values for the study area and invididual subcatchments can be found in Figure C-5. The orthophotos used for calculating RFI and watershed forest cover were taken in 2011. RFI for the overall study area watershed was 57%, with sub-catchments ranging from 72.0% for Upper Brothers to 18.0% for Vinson East (Table C-8). The presence of undeveloped land in the upper watersheds of Upper Brothers and Hadden watersheds partially explains their higher RFI values. The segments with the highest RFI were found on Lower Brothers downstream of Highway 1, on Upper Brothers and West Brothers within the Hollyburn Country Club (BR-2.2 and BR-4.3), and on Hadden Creek between Stevens Dr and Hadden Dr (HA-1.3). The distribution of riparian forest cover and RFI values are shown in Figure C-0-5.

Table C-8: Watershed and Riparian Forest Cover

Section	Total Area (ha)	Watershed forest cover (ha)	Watershed forest cover (%)	Riparian buffer area (ha)	Riparian forest area (ha)	Riparian Forest Integrity (RFI) (%)
Overall Watershed	1218.7	580.3	47.6%	201.2	120.1	57.0%
Lower Brothers	130.4	44.3	34.0%	12.4	8.6	69.9%
Upper Brothers	562.8	370.5	65.8%	104.0	74.9	72.0%
Hadden	268.2	122.8	45.8%	47.1	28.4	60.4%
Vinson East	98.0	11.1	11.3%	9.9	1.8	18.0%
Vinson West	159.2	31.7	19.9%	27.9	6.4	20.8%

Watershed Forest Cover

Overall forest cover within the watershed, including the area above the development boundary, was 47.6% (Table C-9). Upper Brothers had the highest watershed forest cover at 65.8%, with Hadden second highest at 45.8%. The lowest percentages of watershed forest cover were in Vinson East (11.3%) and Vinson West (19.9%).

C.4 Terrestrial Habitat and Species

Terrestrial Vegetation and Habitat

Table C-9 provides details on forest patches greater than two hectares in size within the three watersheds. Larger forest patches are thought to provide significant habitat for terrestrial wildlife.

Larger forest patches provide habitat for terrestrial wildlife, including interior forest habitat, for birds, mammals, reptiles, amphibians, and invertebrates. The largest forested areas in the watersheds are:

- Upper headwater areas of Brothers and Hadden Creeks on Cypress Mountain north of the powerline right-of-way (364.7 ha);

Appendix C – Environmental Inventory and Assessment

- Lower headwater areas of Brothers and Hadden Creeks on Cypress Mountain south of the powerline right-of-way and above the urban development boundary (56.9 ha);

There are several high-value wildlife habitat patches below the 365 m development boundary:

- Mature forest patch between Stevens Dr and Hadden Dr (4.2 ha): consists of second growth forest patch with relatively few invasive plant species, provides high quality habitat for wildlife and a corridor for movement between upper Hadden and lower Brothers riparian areas;
- Riparian forest on segment HA-2.3 (3.5 ha) within Capilano Golf & Country Club, provides a patch of forest
- Forest patch within Hollyburn Country Club provides a 15.3 ha patch of forest
- Forest patch north of Capilano View Cemetery (12.4 ha): doesn't border one of the study's creeks but is continuous with Capilano River riparian forest.
- Riparian corridor of Brothers Creek from confluence with Capilano River to Highway 1: 12.5 ha second growth forest patch providing habitat for wildlife.

Table C-9: Major Forest Patches Greater Than 2 Hectares (Largest to Smallest)

Size (ha)	Catchment(s)	Description	Location
364.7	Upper Brothers and Hadden	Alpine and forested area spanning headwaters	North of development boundary and north of power line right-of-way
56.9	Upper Brothers, Hadden, and Vinson	Forested area spanning headwaters	South of power line right-of-way, north of development boundary
15.3	Upper Brothers	Riparian forest of Brothers Creek mainstem and West Brothers Creek	Within Hollyburn Country Club property
12.4	Lower Brothers	Forest patch	North of Capilano View Cemetery
4.6	Lower Brothers and Hadden	Riparian forest patch	North of Inglewood Ave to Highway 1
4.4	Lower Brothers	Riparian forest patch	Between Keith Rd and Inglewood Ave
3.5	Lower Brothers	Riparian forest patch	From confluence with Capilano River to Keith Rd
4.2	Hadden	Riparian forest patch	Between Stevens Dr and Hadden Dr
3.5	Hadden	Within Capilano Golf & Country Club	Riparian forest patch
2.7	Hadden	At north end of Capilano Golf & Country Club	Riparian and non-riparian forest patch
2.5	Lower Brothers	Along south side of Highway 1, south of the highway and west of Taylor Way	Riparian and non-riparian forest patch
2.2	Hadden	Between Highway 1 and Stevens Dr	Riparian forest patch

Appendix C – Environmental Inventory and Assessment

Invasive Plant Species

Invasive plant species were frequently encountered during the biophysical inventory and are widely distributed. KWL identified nine major invasive plant species in the study area (Figure C-6, Table C-10). The highest priority species for management is giant hogweed (*Heracleum mantegazzianum*), due to its toxicity to humans and animals. Contact with the plant's sap can cause burns, blistering and scarring. Sap contact to the eyes can lead to blindness. Giant hogweed was found in the Brothers and Hadden watersheds, mainly in the upper study area. For specific UTM locations of giant hogweed, refer to Table C-10. Knotweed (*Fallopia* sp.) was found throughout the three watersheds. This species can damage roads, sidewalks, and other infrastructure, and has negative impacts on native plants and wildlife. Himalayan blackberry (*Rubus armeniacus*) and English ivy (*Hedera helix*) are ubiquitous throughout the study area. Both of these species can have detrimental effects on native vegetation.

Table C-10: Invasive Plants Species Present in Watershed

Common Name	Scientific Name	Distribution in Watershed	Notes	Hogweed Locations (Easting/Northing, UTM Zone 10U)
Himalayan blackberry	*Rubus armeniacus*	Ubiquitous		-
Knotweed sp.	*Fallopia* sp.	39 patches, scattered	Noxious weed, hazard to building integrity and humans.	-
Giant hogweed	*Heracleum mantegazzianum*	9 patches/individual plants in upper Brothers and Hadden watersheds	Toxic, hazardous to humans and animals. Action required to control spread throughout watershed.	490133/5465230 489780/5465803 489166/5466523 490267/5466959 490243/5466975 490141/5467074 490702/5466866 490668/5466950 489682/5465226*
Cherry-laurel	*Prunus laurocerasus*	Common		-
Spurge-laurel	*Daphne laureola*	Common		-
English ivy	*Hedera helix*	Ubiquitous		-
Common perwinkle	*Vinca minor*	Common		-
Yellow archangel	*Lamium galeobdolon*	Common		-
Reed canarygrass	*Phalaris arundinacea*	Relatively low, mainly in Capilano Golf & Country Club		-

*reported upstream by landowner, not confirmed

Appendix C – Environmental Inventory and Assessment

Wildlife

Species at Risk

There are five species at risk that are present or potentially present in the study area (Table C-11). Coastal Tailed Frog (*Ascaphus truei*) are present in Brothers Creek. In 2011, thirteen tadpoles and one adult were sampled upstream of Millstream Rd, with a density of 0.25 tadpoles/m² (Golder Associates 2012). Coastal Tailed Frog are blue-listed in BC and are a Species of Special Concern on Schedule 1 of the *Species at Risk Act*. Theyare a Priority 1 Species under the BC Conservation Framework (BCCDC 2014).

There is a small pond just upstream of Burrard Inlet in Ambleside Park on the western edge of the Par 3 Golf Course. The pond is considered as part of the Vinson Creek drainage in iMapBC but is considered as part of Swáy'wey Creek (Pound Creek) in District of West Vancouver GIS data. There are records of Green Heron (*Butorides virescens*) active nesting with fledglings in all years from 2003 to 2008, except 2005. The nest was in a Scots pine (*Pinus sylvestris*). The herons did not return in 2009 or 2010 (BCCDC 2014).

Table C-11: Species at Risk Known or With Potential to be Present in Vinson, Brothers, and Hadden Watersheds

Common Name	Scientific Name	Conservation Status					Status and Habitat in Watershed	Ref.
		Provincial	COSEWIC	BC list	*SARA*	Global		
Fish								
Coastal Cutthroat Trout	*Oncorhynchus clarkii clarkii*	S3S4 (2004)	None	Blue	None	G4T4 (1997)	Present in Capilano River and possibly in watershed	MOE 2016B, MOE 2005
Amphibians and Reptiles								
Coastal Tailed Frog	*Ascaphus truei*	S3S4 (2010)	SC (2011)	Blue	1-SC (2003)	G4 (2004)	Sampled in Brothers Creek in 2011	Golder 2012
Northern Red-legged Frog	*Rana aurora*	S3S4 (2010)	SC (2015)	Blue	1-SC	G4 (2008)	Found in nearby watersheds	BCCDC 2014
Birds								
Great Blue Heron	*Ardea herodias fannini*	S2S3B, S4N (2009)	SC (2008)	Blue	None	G5T4 (1997)	Hunts in watershed, does not overwinter, landowner observed in Capilano Golf and Country Club hunting in ponds	PSKF 2003, survey
Green Heron	*Butorides virescens*	S3S4B (2015)	None	Blue	None	G5 (1996)	Active nesting from 2003–2004 and 2006–2008 in watershed	BCCDC 2014

Appendix C – Environmental Inventory and Assessment

Other Wildlife

KWL biologists observed 14 species of wildlife during the biophysical survey (Table C-12). During the survey, wildlife trees were noted in lower Hadden watershed (3), alonglower Brothers creek (2), and along in West Brothers Creek; however, wildlife trees were not comprehensively mapped. Other wildlife present known to be present in the Brothers Creek watershed are Black Bear (*Ursus americanus*), River Otter (*Lontra canadensis*), Belted Kingfisher (*Megaceryle alcyon*), Ensatina (*Ensatina eschscholtzii*), and Western Red-backed Salamander (*Plethodon vehiculum*) (PSKF 2002).

Table C-12: Wildlife Species Observed During Biophysical Survey in February 2016

Common Name	Scientific Name	Location(s)	Comments
American Dipper	*Cinclus mexicanus*	Brothers and Hadden Creeks	Sighted at multiple locations on lower Brothers Creek and Hadden Creek
Common Merganser	*Mergus merganser*	Brothers Creek	Sighted
Great Blue Heron	*Ardea herodias*	Brothers Creek	Sighted
Kestrel or Merlin	*Falco sparverius* or *Falco columbarius*	Hadden Creek	Sighted at 608 King George Way, within 20 m of Hadden Creek
Mallard	*Anas platyrhynchos*	Elveden Lake West	Sighted 5 pairs
Bufflehead	*Bucephala albeola*	Elveden Lake West	Sighted 1 pair
Anna's Hummingbird	*Calypte anna*	Brothers Creek	Sighted
Varied Thrush	*Ixoreus naevius*	Brothers Creek and Vinson Creek	Sighted pair at Brothers, single at Vinson
Bald Eagle	*Haliaeetus leucocephalus*	Vinson Creek catchment	Sighted
Black-capped Chickadee	*Poecile atricapillus*	Hadden	Sighted
Northwestern Crow	*Corvus caurinus*	Various	Sighted
Pacific Wren	*Troglodytes pacificus*	Various throughout riparian	Heard
Beaver	*Castor canadensis*	Hadden Creek	Landowner observation in October 2015
Coyote	*Canis latrans*	Unmapped tributary to Brothers east of Wescot School	Sighted in riparian upstream of Southborough Dr
North American River Otter	*Lontra canadensis*	Hadden Creek, in Capilano Golf and Country Club	Landowner observation
American Bullfrog	*Lithobates catesbeianus*	Hadden Creek in Capilano Golf and Country Club ponds, Elveden Lakes	Landowner observation, WVSS pers. comm. 2016

Appendix C – Environmental Inventory and Assessment

Values to Protect

The forest patches below the 365 m development boundary in the above Terrestrial Vegetation and Habitat section are of high value and should be protected and enhanced (e.g. remove invasive plants) if appropriate.

C.5 Water Quality and Benthic Invertebrate Monitoring

West Vancouver Streamkeeper Society Monitoring

West Vancouver Streamkeeper Society has run the following water quality and benthic invertebrate monitoring programs:

- Water temperature monitoring at four sites (Graph C-1): automatic temperature loggers recording every 10 minutes from April 2011 to April 2015 and every 60 minutes from April 2015 to January 2016. The four sites are:
    - Upper Brothers is upstream of Millstream Rd above the development boundary;
    - Lower Brothers: at Clyde Ave just upstream from the confluence with the Capilano River;
    - Upper Hadden: just downstream of the culvert at the outlet of Capilano Golf and Country Club pond 5; and
    - Lower Hadden: below Stevens Dr culvert (approximately 800 m downstream of upper Hadden site).
- Benthic invertebrate sampling

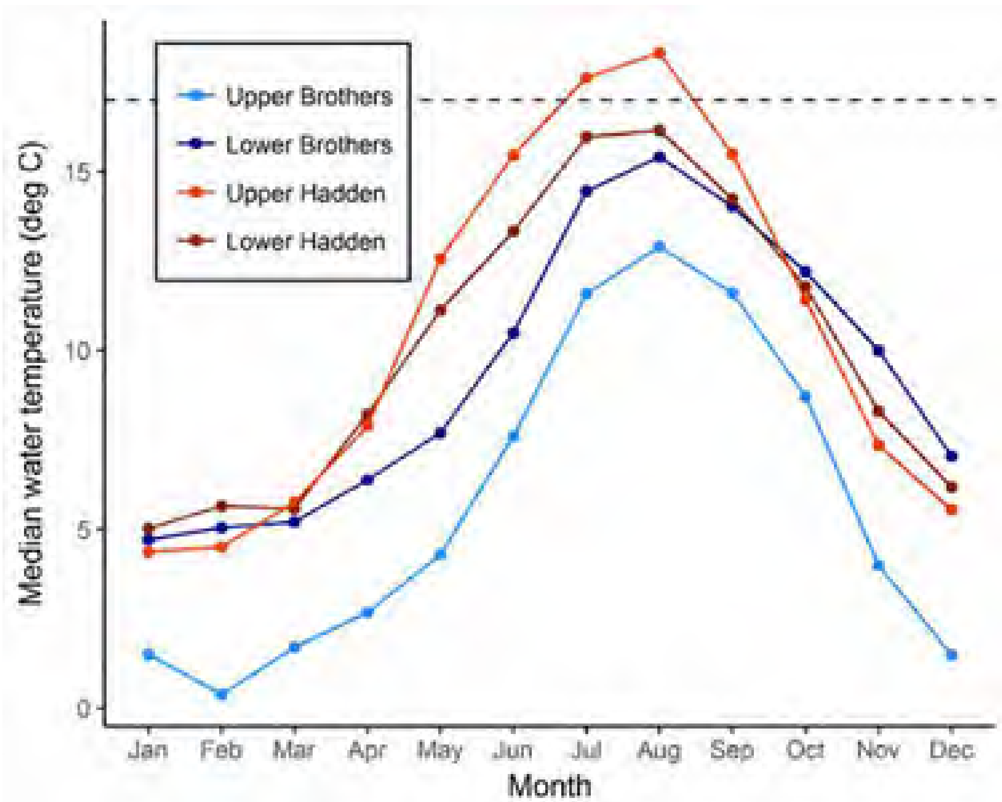
KWL analyzed the water temperature data collected by West Vancouver Streamkeepers Society volunteers and found the following key findings (see Graph C-1):

- Water temperatures in Brothers Creek show a typical pattern in which the water is colder at the upstream monitoring site as the creek leaves the forested section upstream of the study area.
- After travelling through the developed area of the watershed, the water temperature is consistently higher throughout the year.
- The coldest water temperatures in the watershed were in Upper Brothers Creek from December to March.
- Hadden Creek shows an atypical pattern: the water in Upper Hadden, just south of the Capilano Golf and Country Club, is warmer than the water downstream from May to September. This is likely due to solar heating of the large ponds within the golf course.
- The warmest monthly median water temperatures were recorded in July and August in Upper Hadden Creek. In both of these months, the monthly median temperature exceeded the 17°C maximum recommended temperature for streams with rearing Coho Salmon based on the BC Water Quality Guidelines for Temperature (MOE 2016d).

Water temperatures were likely elevated in Upper Hadden Creek because of land use and a lack of riparian forest cover upstream. This monitoring site is just downstream of the Capilano Golf and Country Club. Only 16% of the riparian zone of segment HA-2.2 is forested (just upstream of the temperature logger, within the golf course), compared to 60.4% of Hadden Creek overall. In addition,

Appendix C – Environmental Inventory and Assessment

there are two ponds in segment HA-2.2, where direct sunlight warms the water that flows downstream. Upstream of the golf course, reaches HA-3 and HA-4 also have low percentages of riparian forest cover (15-31%). In contrast, segment HA-1.3 (between the Upper and Lower Hadden temperature monitoring stations) has 93% forest cover in its riparian zone. This cover likely allows for the water to cool as it flows downstream.



Graph C-1: Monthly Median Water Temperature at Four Monitoring Stations from 2011-2016.[1]

Water Quality Concerns Based on Background Information

The inventory and assessment identified the following concerns for water quality in the different watersheds:

Overall

- Water quality impacts of stormwater runoff: Outfalls and non-point source runoff may be detrimental to water quality, especially around Highway 1 and Taylor Way

[1] The dashed line indicates 17°C, the maximum recommended water temperature for streams with rearing Coho Salmon based on BC Water Quality Guidelines for Temperature (MOE 2016).

Appendix C – Environmental Inventory and Assessment

Brothers Creek

- There is a risk of water contamination from potential breakages where sewer lines cross Brothers Creek

Hadden Creek

- Warm water temperatures possibly influenced by land use, lack of forest cover, and ponds within Capilano Golf and Country Club
- Identified as having significant water quality issues, potentially from temperature and/or water chemistry (DFO 1997)

Vinson Creek

- Channelized sections may contain reduced benthic communities due to high water velocities during storm events
- Very low forest cover suggests high water temperature

Monitoring and Adaptive Management Framework (MAMF) Monitoring

KWL carried out MAMF water quality and benthic invertebrate monitoring in 2016 during the wet and dry seasons at three sites (Figure C-7). One-time grab sampling was also carried out at an additional eight sites. Detailed methodology and results of this monitoring can be found in the *2016 Watershed Monitoring in the Vinson, Brothers, and Hadden Creek Watersheds Draft Report*.

In-Situ Water Quality Rapid Assessment

To provide a broad assessment of how water quality conditions vary within the study area, a one-time in-situ water quality survey was undertaken during low flow conditions on September 28, 2016. A total of 40 sites were visited: 20 sites in the Brothers Creek catchment, 10 in the Vinson Creek catchment and 10 in the Hadden Creek catchment (Figure C-7). Two of the 40 sites visited (one site each in the Vinson and Hadden Creek catchment) were found to be dry and not sampled. In-situ water quality parameters (dissolved oxygen, pH, water temperature, conductivity, turbidity, total dissolved solids, salinity, oxygen reduction potential) were measured in the field using a YSI 6920 water quality multiparameter sonde (YSI 6920).

Results of the in-situ water quality survey are summarized in Table C-13. Complete results for each catchment are provided in Appendix C-ii. Results were assessed according to water quality priority indicator categories in Metro Vancouver's *Monitoring and Adaptive Management Framework Water Quality Evaluation System* (MAMF). Although caution should be taken in comparing one-time sampling results to guidelines intended for arithmetic and geometric means, the values are a useful screening tool to assess the general distribution of water quality conditions and potential sources of water quality degradation.

Appendix C – Environmental Inventory and Assessment

Table C-13: In Situ Water Quality Measurements for the Vinson, Brothers, and Hadden Creek Catchments

Catchment	Water quality parameters														
	Dissolved oxygen (mg/L)			pH			Water Temperature (ºC)			Conductivity (mS/cm)			Turbidity (NTU)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Vinson Creek (n =9)	10.13	9.74	10.60	7.74	7.33	7.98	14.14	12.66	15.92	0.152	0.093	0.199	4.6	0.4	17.2
Brothers Creek (n=20)	10.17	6.88	11.03	7.26	6.00	7.94	12.86	10.45	15.44	0.087	0.011	0.178	1.1	0.0	12.0
Hadden Creek (n=3)	10.13	9.67	10.57	7.21	6.36	7.79	13.39	11.74	15.47	0.079	0.011	0.134	0.5	0.0	1.0
Catchment Total (n=38)	10.15	6.88	11.03	7.36	6.00	7.98	13.29	10.45	15.92	0.101	0.011	0.199	1.8	0.0	17.2

* For each sub-catchment , n represents the number of sites where in situ water quality measurements were taken.
** Two sites were dry and are not included in the total count.
*** Green = Good, Yellow = Satisfactory, Red = Needs Attention

Appendix C – Environmental Inventory and Assessment

Under the MAMF, the interpretation of the water quality priority indicator categories is as follows:

- Good Priority Indicator = suggests that water quality for this parameter, at least at the current monitoring location, is good. Based on this, no further monitoring for this parameter is required in the drainage system for 5 years. No adaptive management is required based on this monitoring.
- Satisfactory Priority Indicator = suggests that water quality is either closely approaching a level of concern for this parameter or is already in non-attainment with provincial water quality guidelines. The level of the parameter result (relative to water quality guidelines and/or objectives) and the incidence of additional priority indicators of concern should be considered in development of the city-wide Adaptive Management Plan. Consideration should be given to supplemental water quality monitoring and/or adaptive management actions.
- Needs Attention Priority Indicator = suggests that water quality is in non-attainment with provincial water quality guidelines. The level of the parameter result and the incidence of additional priority indicators of concern should be considered as part of the city-wide Adaptive Management Plan. Supplemental water quality monitoring and/or adaptive management actions are recommended.

Under the MAMF, water temperature, dissolved oxygen, and turbidity are primary indicators. Conductivity and pH are secondary indicators, and provide supporting information for interpretation of priority indicators and for identification of the source of an impact. See Metro Vancouver (2014) for more details.

Key findings from the water quality monitoring include:

- Mean conductivity levels for each catchment fell into the MAMF's "satisfactory" category for all three catchments. Eight sites located near the top of the Brothers and Hadden Creek catchments had conductivity values situated in the "good" category. This indicates there is likely some impact from non-point source pollution downstream of the developed areas in all catchments.
- Dissolved oxygen was at least "satisfactory" at all sites, suggesting dissolved oxygen levels are approaching a level of concern. One site near the base of the Brothers Creek catchment fell in the "good" category.
- Temperatures ate all sites were in the MAMF's "good" category, with no sites exceeding the 16°C dry season threshold for fish health.
- Turbidity levels were mostly within the MAMF's "good" category with a few exceptions. Only four of the 38 sampled sites exceeded 5.0 NTU and were categorized as "satisfactory".
- pH levels were less than 6.5 at six locations in the Brothers and Hadden Creek catchments, situating them in the MAMF's "satisfactory" category. All other sites were in the "good" category. As the six "satisfactory" sites are all located at the top of the catchments above where significant development has occurred, it is likely the low pH levels are due to natural factors.

As the assessment was based on single measurements from each site, further monitoring is recommended for sites flagged as having potential issues to assess whether measurements represent long-term conditions at each site.

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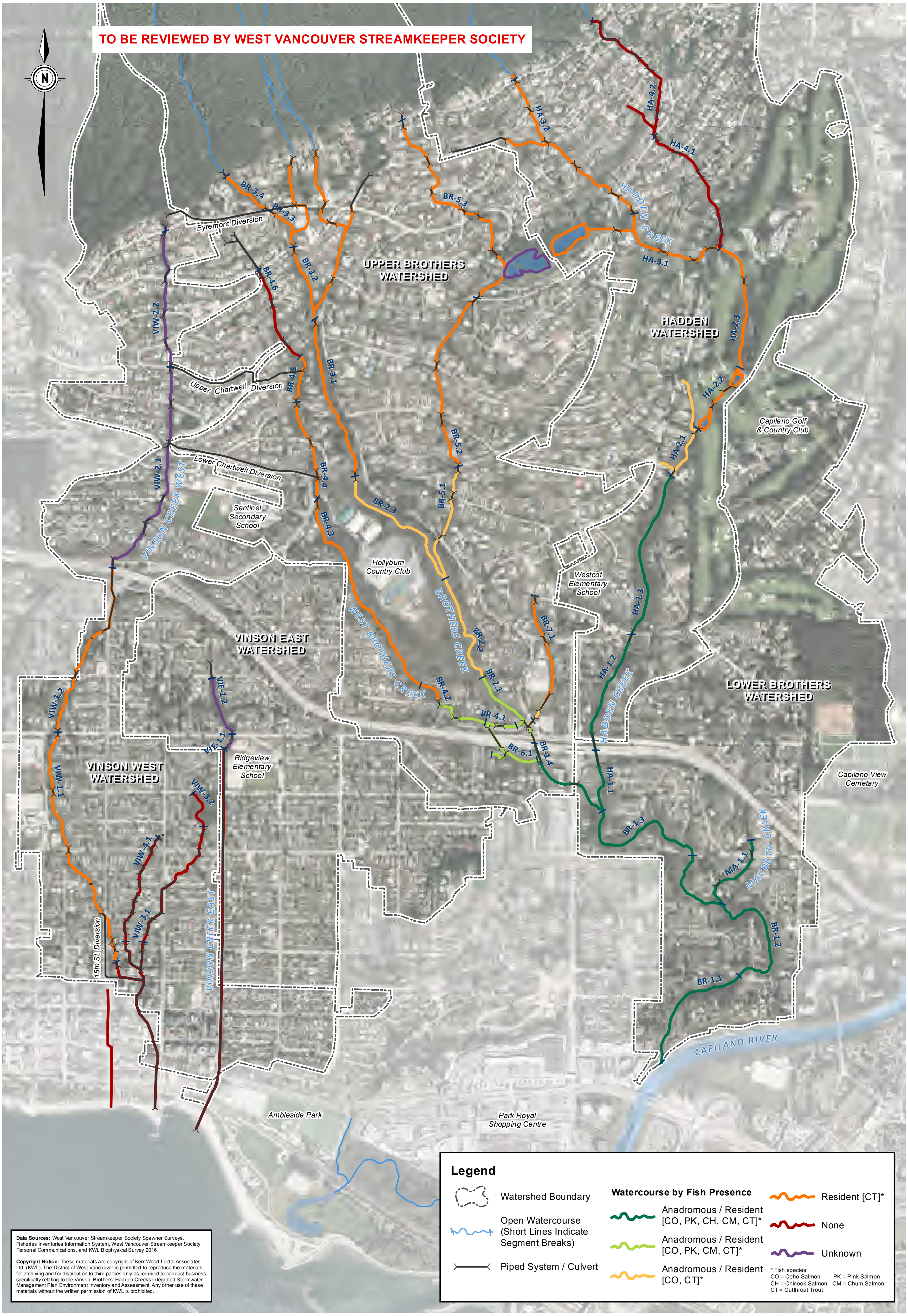

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consulting engineers

District of West Vancouver
Vinson, Brothers, Hadden Creeks ISMP

Project No.	Date
409-073	June, 2016

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Fish Distributions

Figure C-1

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Salmonid Spawning and Rearing Habitat

Figure C-2

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Project No.	Date
409-073	June, 2016

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Barriers to Fish Migration

Figure C-3

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Project No. 409-073

Date August, 2016

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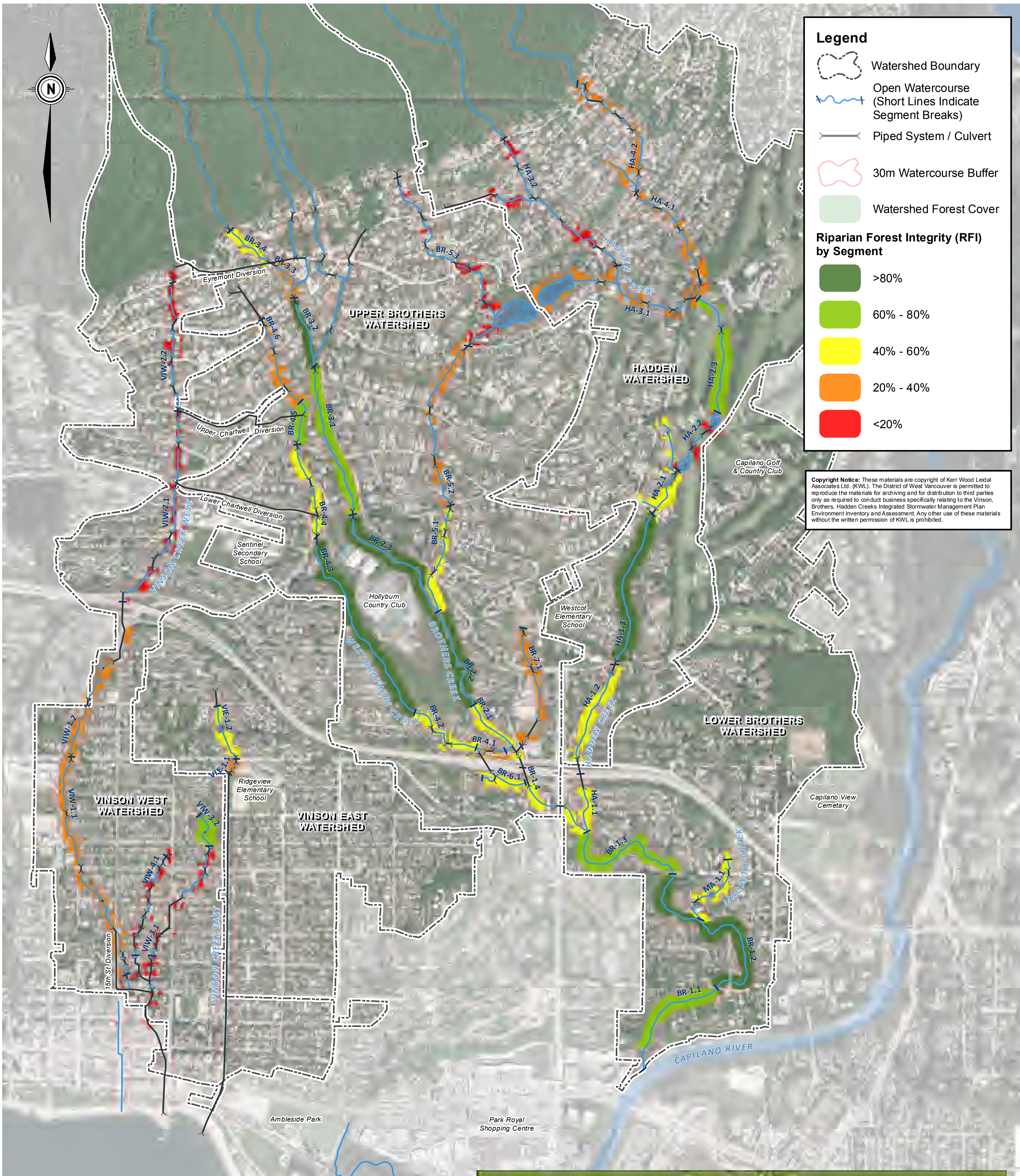
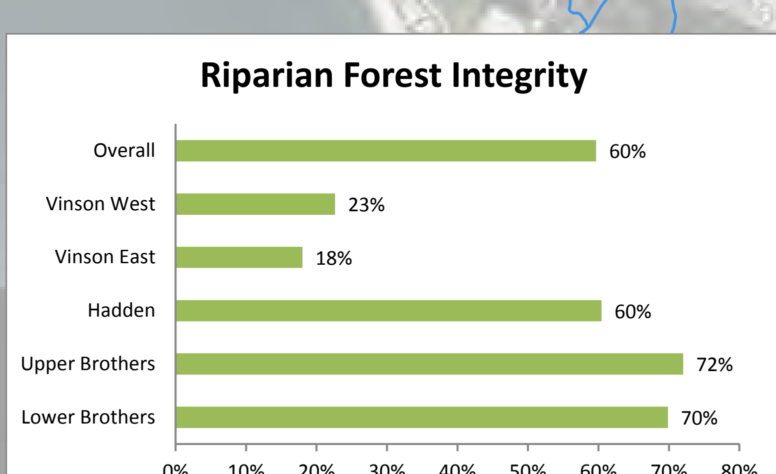
Enhancement Opportunities / Priority Environmental Points of Concern

Figure C-4





Riparian Forest Integrity			
Catchment	Total forested riparian area (ha)	Total riparian area (ha)	Riparian Forest Integrity (%)
Lower Brothers	8	12	70%
Upper Brothers*	75	104	72%
Hadden*	28	47	60%
Vinson East	2	10	18%
Vinson West*	9	39	23%
Overall	120	201	60%

Watershed Forest Cover			
Catchment	Total forested area (ha)	Total area (ha)	% Forested area
Lower Brothers	44	130	34%
Upper Brothers*	373	563	66%
Hadden*	123	268	46%
Vinson East	11	96	11%
Vinson West*	32	159	20%
Overall	580	1219	48%

* Includes areas above urban containment boundary.

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Vinson, Brothers, Hadden Creeks ISMP

Project No. 409-073

Date June, 2016

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Riparian and Watershed Forest Cover

Figure C-5

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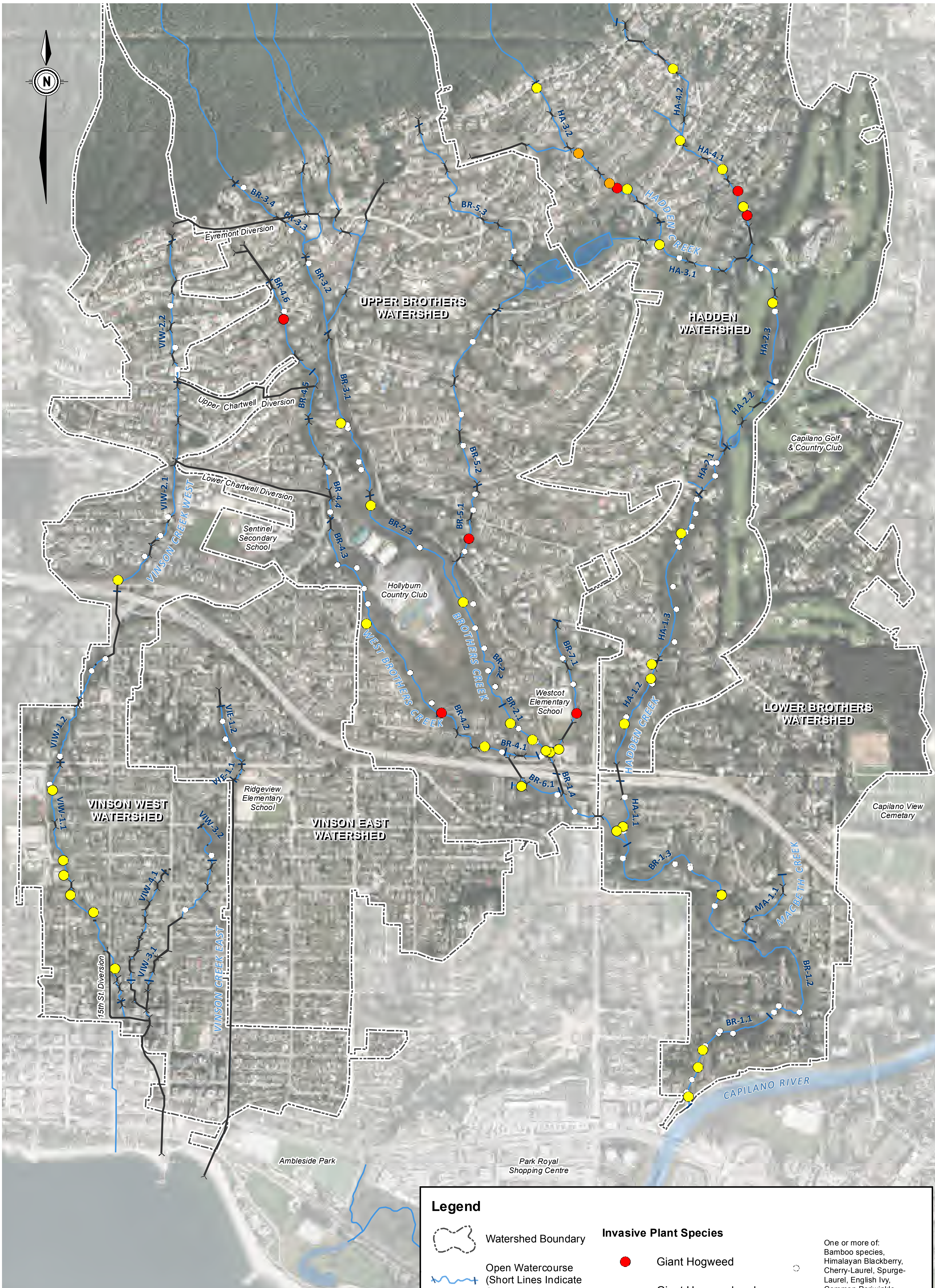

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High Priority / Dangerous Invasive Plant Species

Figure C-6

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KERR WOOD LEIDAL
consulting engineers

District of West Vancouver
Vinson, Brothers, and Hadden Creeks ISMP

Project No.	Date
409-073	December, 2016

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Monitoring Site Locations

Figure C-7

Appendix C – Environmental Inventory and Assessment

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Appendix C-i

Stream Reach Photographs and Summaries

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-1.1**

February 2, 2016 Between confluence with Capilano River and Keith Rd

Photo A-1: Looking Upstream

Photo A-2: Looking Downstream

Photo A-3: Typical Riffle

Photo A-4: Typical Substrate Conditions

Wetted width:	8 m	Instream cover:	5%	Spawning gravel:	Extensive
Bankfull width:	9.4 m	LWD:	Few	Rearing habitat:	Moderate

General comments: High quality habitat but lacking large woody debris (LWD); naturally functioning channel processes. Consistent riparian area tree size and structure throughout, substrate dominated

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-1.2**

February 2, 2016 Between Keith Rd and Inglewood Ave

Photo A-5: Looking Upstream

Photo A-6: Looking Downstream

Photo A-7: Typical Riffle

Photo A-8: Typical Substrate Conditions

Wetted width:	7 m	Instream cover:	10%	Spawning gravel:	Extensive
Bankfull width:	9 m	LWD:	Few	Rearing habitat:	Moderate

General comments: Deep ravine lower down, frequent out-falls, concrete manholes for sewer access every 100 m, concrete sewer pipes in stream, generally good fish habitat, little LWD, abundant English ivy and other invasive plants.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-1.3**

February 4, 2016 Confluence with Hadden Creek to Inglewood Ave

Photo A-9: Looking Upstream

Photo A-10: Looking Downstream

Photo A-11: Typical Riffle

Photo A-12: Typical Substrate Conditions

Wetted width:	7 m	Instream cover:	15%	Spawning gravel:	Extensive
Bankfull width:	8.5 m	LWD:	Few	Rearing habitat:	Moderate

General comments: Generally good fish habitat, lacking abundant LWD. Confined along ~50% of length by steep bedrock banks. Remnants of small dam with diversion reach and aqueduct. Mid-section with frequent bank armouring. Some large trees on the right bank, midway along the segment. More accumulation of fines than downstream segments BR-1.1 and BR-1.2.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-1.4**

February 10, 2016 From the confluence of with Hadden Creek to Highway 1 culvert

Photo A-13: Looking Upstream

Photo A-14: Looking Downstream

Photo A-15: Typical Riffle

Photo A-16: Typical Substrate Conditions

Wetted width:	12 m	Instream cover:	5%	Spawning gravel:	Extensive
Bankfull width:	13.5 m	LWD:	Few	Rearing habitat:	Moderate

General comments: Intersected by Taylor way culvert. Good spawning gravels throughout with low embeddedness. Concern with two culverts just west of Taylor way discharging gray turbid water into Brothers Creek.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-2.1**

February 10, 2016 From Highway 1 culvert to significant gradient change

Photo A-17: Looking Upstream

Photo A-18: Looking Downstream

Photo A-19: Typical Riffle

Photo A-20: Typical Substrate Conditions

Wetted width:	8 m	Instream cover:	10%	Spawning gravel:	Extensive
Bankfull width:	9 m	LWD:	Few	Rearing habitat:	Moderate

General comments: Good fish habitat with abundant spawning gravel. Narrow riparian band. Little cover and LWD. Bank protection throughout segment.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-2.2**

February 10, 2016 Upstream of the gradient change to the confluence with the east branch tributary, generally between Cross Creek Rd and Highway 1

Photo A-21: Looking Upstream

Photo A-22: Looking Downstream

Photo A-23: Typical Riffle

Photo A-24: Typical Substrate Conditions

Wetted width:	12 m	Instream cover:	15%	Spawning gravel:	Extensive
Bankfull width:	14 m	LWD:	Abundant	Rearing habitat:	Abundant

General comments: High quality fish habitat with frequent pools and LWD input from forest. Some erosion of banks but low risk to property damage.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-2.3**

February 10, 2016 Downstream of Cross Creek Rd to the confluence with the east branch tributary

Photo A-25: Looking Upstream

Photo A-26: Looking Downstream

Photo A-27: Typical Riffle

Photo A-28: Typical Substrate Conditions

Wetted width:	12 m	Instream cover:	10%	Spawning gravel:	Abundant
Bankfull width:	14 m	LWD:	Abundant	Rearing habitat:	Moderate

General comments: Cascade pool segment with potential fish barriers throughout. Mature riparian. Several large erosion points.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-3.1**

February 10, 2016 Upstream of Cross Creek Rd to Burnside Rd

Photo A-29: Looking Upstream

Photo A-30: Looking Downstream

Photo A-31: Typical Riffle

Photo A-32: Typical Substrate Conditions

Wetted width:	10 m	Instream cover:	10%	Spawning gravel:	Little
Bankfull width:	13 m	LWD:	Abundant	Rearing habitat:	Moderate

General comments: Abundant cascades and several significant fish barriers. Frequent pools and LWD. Possible resident fish presence, unlikely anadromous salmon.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-3.2**

February 23, 2016 Between Burnside Rd and Crestwell Rd

Photo A-33: Looking Upstream

Photo A-34: Looking Downstream

No photo

Photo A-35: Typical Riffle

Photo A-36: Typical Substrate Conditions

Wetted width:	3.5 m	Instream cover:	10%	Spawning gravel:	Little
Bankfull width:	5 m	LWD:	Few	Rearing habitat:	Little

General comments: Bedrock canyon segment with frequent chute-cascades and several falls, one 4 m tall. Fish impassable segment.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-3.3**

February 23, 2016 Between Crestwell Rd to Eyremount Rd

Photo A-37: Looking Upstream

Photo A-38: Looking Downstream

Photo A-39: Typical Riffle

Photo A-40: Typical Substrate Conditions

Wetted width:	3.5 m	Instream cover:	5%	Spawning gravel:	Little
Bankfull width:	4.5 m	LWD:	Few	Rearing habitat:	Little

General comments: Encroachment increases upstream of canyon section. Loss of riparian trees throughout. Not accessible to anadromous fish. Frequent cascades.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-3.4**

February 23, 2016 Between Eyremount Dr and Millstream Rd


Photo A-41: Looking Upstream


Photo A-42: Looking Downstream


Photo A-43: Typical Riffle


Photo A-44: Typical Substrate Conditions

Wetted width:	4 m	Instream cover:	5%	Spawning gravel:	Little
Bankfull width:	5 m	LWD:	Few	Rearing habitat:	Little

General comments: More intact riparian forest and less encroachment than downstream segment. Cascades throughout.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-4.1**

February 24, 2016 From confluence with Brothers Creek to the end of channelized segment

Photo A-45: Looking Upstream

Photo A-46: Looking Downstream

Photo A-47: Typical Riffle

Photo A-48: Typical Substrate Conditions

Wetted width:	1 m	Instream cover:	5%	Spawning gravel:	Extensive
Bankfull width:	1 m	LWD:	None	Rearing habitat:	None

General comments: Poor fish habitat. Mostly channelized with grouted rock bottom. Some spawning gravels retained, but no rearing habitat.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-4.2**

February 24, 2016 From channelized section to forested area

Photo A-49: Looking Upstream

Photo A-50: Looking Downstream

Photo A-51: Typical Riffle

Photo A-52: Typical Substrate Conditions

Wetted width:	2 m	Instream cover:	15%	Spawning gravel:	Extensive
Bankfull width:	3 m	LWD:	None	Rearing habitat:	Moderate

General comments: Landowner at upstream end says stream has been stable for 30 years. Really nice spawning habitat in lower reach of segment. Landowners mentioned lots of salmon fry and herons in summer. Stream modified with bank protect in many locations. Riparian area heavily impacted.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-4.3**

February 24, 2016 Forested section upstream to Cross Creek Dr

Photo A-53: Looking Upstream

Photo A-54: Looking Downstream

Photo A-55: Typical Riffle

Photo A-56: Typical Substrate Conditions

Wetted width:	2.5 m	Instream cover:	20%	Spawning gravel:	Extensive
Bankfull width:	4 m	LWD:	Abundant	Rearing habitat:	Abundant

General comments: Wide ravine with excellent habitat. Abundant LWD in stream, complex channel with islands, LWD creating debris jams and deep pools. Decadent alder forest with lots of blowdown. Not many conifers. Lots of English Ivy.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-4.4**

February 24, 2016 Upstream of Cross Creek Dr to Chartwell Pl

Photo A-57: Looking Upstream

Photo A-58: Looking Downstream

Photo A-59: Typical Riffle

Photo A-60: Typical Substrate Conditions

Wetted width:	1.8 m	Instream cover:	10%	Spawning gravel:	Extensive
Bankfull width:	2 m	LWD:	Few	Rearing habitat:	Moderate

General comments: Some sections with relatively intact riparian forest. Others in backyards with active shrub and tree removal including salmonberry on river banks and 30 cm cedars within 4 m of stream. Invasive species throughout. One large gabion wall.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-4.5**

February 25, 2016 Upstream of Chartwell Pl to the downstream extent of step-pool segment within Chartwell Park

Photo A-61: Looking Upstream

Photo A-62: Looking Downstream

Photo A-63: Typical Riffle

Photo A-64: Typical Substrate Conditions

Wetted width:	1.8 m	Instream cover:	15%	Spawning gravel:	Extensive
Bankfull width:	3 m	LWD:	Abundnat	Rearing habitat:	Moderate

General comments: Highest quality wildlife habitat on west brothers creek reach 4 and comparable to highest values in watershed. Relatively intact riparian forest with some mature cedars. Abundant LWD in stream. Spawning and rearing habitat moderate because of infrequent pools and downstream barriers. To protect.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-4.6**

February 25, 2016 Step-pool segment of Chartwell Park, downstream of Burnside Rd

Photo A-65: Looking Upstream

Photo A-66: Looking Downstream

Photo A-67: Typical Riffle

Photo A-68: Typical Substrate Conditions

Wetted width:	1 m	Instream cover:	5%	Spawning gravel:	None
Bankfull width:	1.5 m	LWD:	Few	Rearing habitat:	None

General comments: Step pool canyon section mainly bedrock and boulder. Rapid gradient change from downstream segment. Fish barrier

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-5.1**

February 23, 2016 Tributary of Brothers Creek from confluence just downstream of Highland Dr to Eyremount Dr


Photo A-69: Looking Upstream


Photo A-70: Looking Downstream


Photo A-71: Typical Riffle


Photo A-72: Typical Substrate Conditions

Wetted width:	2 m	Instream cover:	15%	Spawning gravel:	Extensive
Bankfull width:	2.6 m	LWD:	Few	Rearing habitat:	Moderate

General comments: Tributary of Brothers Creek with potential fish barrier above confluence with Brothers creek. Narrow~5-10 m riparian.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-5.2**

February 23, 2016 Upstream of Eyremount Dr to Groveland Rd

Photo A-73: Looking Upstream

Photo A-74: Looking Downstream

Photo A-75: Typical Riffle

Photo A-76: Typical Substrate Conditions

Wetted width:	2 m	Instream cover:	5%	Spawning gravel:	Little
Bankfull width:	2.5 m	LWD:	Little	Rearing habitat:	Little

General comments: High level of encroachment through segment. Falls constructed and several barrier culverts alter gradient to create flat areas separated by barriers. Low riparian forest cover. Flat areas have more gravel.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-5.3**

February 24, 2016 Upstream of Groveland Dr to Millstream Rd

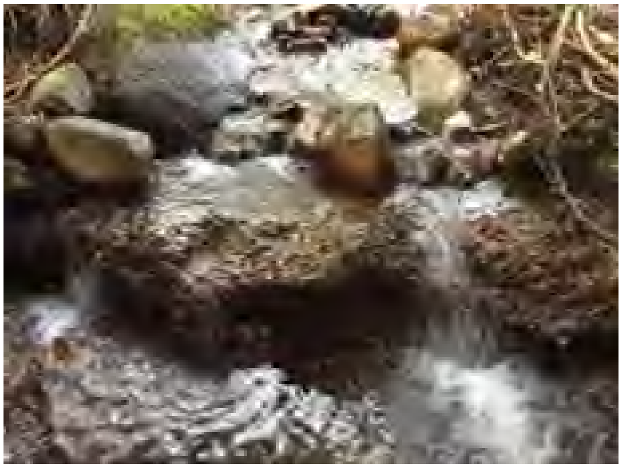

Photo A-77: Looking Upstream

Photo A-78: Looking Downstream

No photo

Photo A-79: Typical Riffle

Photo A-80: Typical Substrate Conditions

Wetted width:	1.2 m	Instream cover:	8%	Spawning gravel:	Little
Bankfull width:	1.5 m	LWD:	Few	Rearing habitat:	Little

General comments: Section has much encroachment and lack of riparian trees especially around Elvedeen lake west. Gradient increases from 2 to 5 percent at Eyremount dr culvert upstream of Elvedeen lake. Freq invasive plants and bank protection throughout. Most grouted rock in yards. Riparian note: Significant stretches with only grass.

Appendix C-i: Stream Reach Photographs and Summaries

Brothers Creek **Segment: BR-6.1**

February 24, 2016 Unmapped tributary to Brothers Creek with confluence just downstream of Highway 1

Photo A-81: Looking Upstream

Photo A-82: Looking Downstream

Photo A-83: Typical Riffle

Photo A-84: Typical Substrate Conditions

Wetted width:	2 m	Instream cover:	10%	Spawning gravel:	Extensive
Bankfull width:	2.5 m	LWD:	Few	Rearing habitat:	Moderate

General comments: Unmapped tributary to Brothers creek. Streamkeepers reported salmon here in fall 2015. High quality spawning habitat. Moderate rearing habitat due to few pools and LWD cover.

Appendix C-i: Stream Reach Photographs and Summaries

Macbeth Creek (tributary to Brothers Creek) **Segment: MA-1.1**

February 26, 2016 Tributary to Brothers Creek with confluence below Macbeth Cres

Photo A-85: Looking Upstream

Photo A-86: Looking Downstream

Photo A-87: Typical Riffle

Photo A-88: Typical Substrate Conditions

Wetted width:	2 m	Instream cover:	8%	Spawning gravel:	Extensive
Bankfull width:	2.6 m	LWD:	Few	Rearing habitat:	Moderate

General comments: Unmapped trib to brothers creek with confluence downstream of Inglewood. Moderate to good fish habitat with abundant spawning habitat. Active erosion and bank protection failure downstream of good spawning gravels. Some encroachment from back yards

Appendix C-i: Stream Reach Photographs and Summaries

Hadden Creek **Segment: HA-1.1**

February 4, 2016 Between Highway 1 and confluence with Brothers Creek

Photo A-89: Looking Upstream

Photo A-90: Looking Downstream

Photo A-91: Typical Riffle

Photo A-92: Typical Substrate Conditions

Wetted width:	4 m	Instream cover:	10%	Spawning gravel:	Extensive
Bankfull width:	4.5 m	LWD:	Few	Rearing habitat:	Moderate

General comments: Abundant invasive plants, no bedrock, fish habitat lacks much LWD. Encroachment from yards especially right bank.

Appendix C-i: Stream Reach Photographs and Summaries

Hadden Creek **Segment: HA-1.2**

February 4, 2016 Between Highway 1 and Stevens Rd

Photo A-93: Looking Upstream

Photo A-94: Looking Downstream

Photo A-95: Typical Riffle

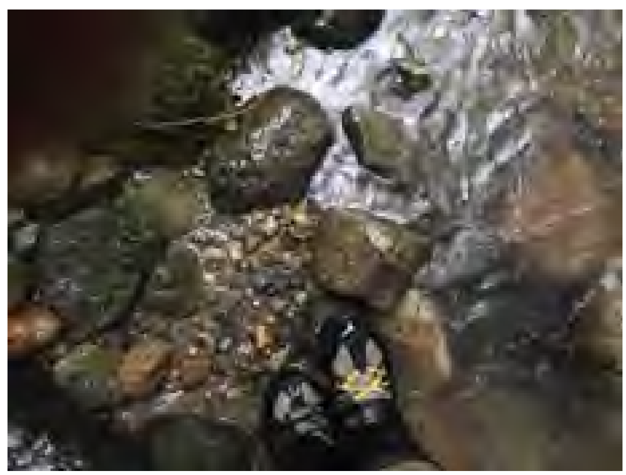

Photo A-96: Typical Substrate Conditions

Wetted width:	3.5 m	Instream cover:	15%	Spawning gravel:	Extensive
Bankfull width:	4.5 m	LWD:	Few	Rearing habitat:	Moderate

General comments: Not much complexity through segment. Moderate fish habitat quality. Upper half of segment has wider riparian corridor. Houses in lower half encroaching and have channelized some of the stream. Lots of overhanging vegetation. Dominated by overhanging vegetation. Very little LWD, not much habitat complexity.

Appendix C-i: Stream Reach Photographs and Summaries

Hadden Creek **Segment: HA-1.3**

February 4, 2016 Between Stevens Dr and Hadden Dr


Photo A-97: Looking Upstream


Photo A-98: Looking Downstream


Photo A-99: Typical Riffle


Photo A-100: Typical Substrate Conditions

Wetted width:	4.5 m	Instream cover:	15%	Spawning gravel:	Extensive
Bankfull width:	5.5 m	LWD:	Abundant	Rearing habitat:	Moderate

General comments: High quality fish habitat with relatively undisturbed riparian and banks and abundant LWD in stream. Cascades throughout, likely high quality habitat for sculpins, juvenile Coho and Rainbow Trout. Second growth forest with relatively undisturbed vegetation and banks. High wildlife habitat value in this area of catchment.

Appendix C-i: Stream Reach Photographs and Summaries

Hadden Creek **Segment: HA-2.1**

February 9, 2016 From Hadden Dr to Capilano Golf and Country Club

Photo A-101: Looking Upstream

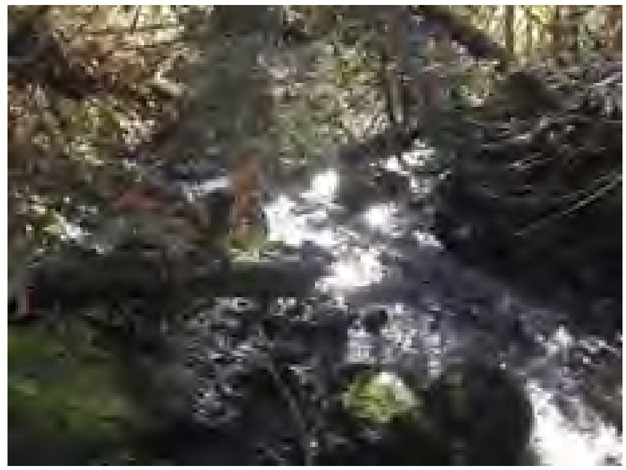

Photo A-102: Looking Downstream

Photo A-103: Typical Riffle

Photo A-104: Typical Substrate Conditions

Wetted width:	4 m	Instream cover:	30%	Spawning gravel:	Extensive
Bankfull width:	6 m	LWD:	Abundant	Rearing habitat:	Moderate

General comments: Excellent fish habitat. Lots of LWD and cover from overhanging vegetation. Floodplain well vegetated, good channel complexity (mid-channel island), English ivy common. Lots of overhanging vegetation. Large second growth conifers, red alder and some bigleaf maple.

Appendix C-i: Stream Reach Photographs and Summaries

Hadden Creek **Segment: HA-2.2**

February 9, 2016 Within Capilano Golf and Country Club, from downstream end of south pond to upstream end of north pond

Photo A-105: Looking Upstream

Photo A-106: Looking Downstream

Photo A-107: Typical Riffle

Photo A-108: Typical Substrate Conditions

Wetted width:	1.5 m	Instream cover:	5%	Spawning gravel:	Little
Bankfull width:	1.5 m	LWD:	None	Rearing habitat:	Little

General comments: Low quality fish habitat. Channelized with no cover, little rearing habitat. Lots of cobble but little spawning gravel. Almost no cover. Golf course manicured lawn to edge of bank. No native riparian vegetation.

Appendix C-i: Stream Reach Photographs and Summaries

Hadden Creek **Segment: HA-2.3**

February 9, 2016 Forested stretch within Capilano Golf and Country Club upstream of north pond.

Photo A-109: Looking Upstream

Photo A-110: Looking Downstream

Photo A-111: Typical Riffle

Photo A-112: Typical Substrate Conditions

Wetted width:	2.3 m	Instream cover:	15%	Spawning gravel:	Extensive
Bankfull width:	2.6 m	LWD:	Abundant	Rearing habitat:	Abundant

General comments: Existing forested riparian segment with golf course upstream and downstream. Abundant LWD and gravels with one 50m side channel. Likely habitat for resident fishes due to downstream fish barrier at golf course pool outlet. Side channel has deep pools and plentiful cover. High quality rearing habitat. 60 m of the segment is directly bordered by golf course green.

Appendix C-i: Stream Reach Photographs and Summaries

Hadden Creek **Segment: HA-3.1**

February 9, 2016 Between Southborough Dr to Kenwood Dr

Photo A-113: Looking Upstream

Photo A-114: Looking Downstream

Photo A-115: Typical Riffle

Photo A-116: Typical Substrate Conditions

Wetted width:	1.75 m	Instream cover:	5%	Spawning gravel:	Extensive
Bankfull width:	2 m	LWD:	None	Rearing habitat:	Little

General comments: Poor fish habitat. Some good pools at the ends of cascades, but little rearing habitat due to channelization. Riparian area is heavily impacted by residences with ornamental plants. Little cover. Very little cover. Mostly channelized with hardened walls. Mostly encroached by lawns with ornamental plants. Many trees removed.

Appendix C-i: Stream Reach Photographs and Summaries

Hadden Creek **Segment: HA-3.2**

February 24, 2016 Upstream from Kenwood Dr to survey boundary upstream of Millstream Rd


Photo A-117: Looking Upstream


Photo A-118: Looking Downstream


Photo A-119: Typical Riffle


Photo A-120: Typical Substrate Conditions

Wetted width:	1.5 m	Instream cover:	10%	Spawning gravel:	Little
Bankfull width:	3 m	LWD:	Few	Rearing habitat:	Little

General comments: Overall poor fish habitat. Significant fish barriers at culverts exist, as well as in stream structures and Steep chutes and falls. Channelized with little riparian vegetation for significant stretches. Heavily modified. Maybe few areas allow for moderate small fish habitat. Some stretches of very dense overhanging vegetation. Very few forested sections. Lots of encroachment with yards and ornamentals dominating. Significant numbers of invasive species, including giant hogweed and Japanese knotweed.

Appendix C-i: Stream Reach Photographs and Summaries

Hadden Creek **Segment: HA-4.1**

February 24, 2016 East branch of Hadden Creek from its confluence with the mainstem upstream to St. Andrews Rd

Photo A-121: Looking Upstream

Photo A-122: Looking Downstream

Photo A-123: Typical Riffle

Photo A-124: Typical Substrate Conditions

Wetted width:	2 m	Instream cover:	5%	Spawning gravel:	Little
Bankfull width:	2.6 m	LWD:	Few	Rearing habitat:	Little

General comments: Segment has extensive encroachment esp downstream section. More natural section upstream with more intact riparian veg. Invasives throughout and 60 m stretch of grouted rock ds. Giant hogweed and several patches of knotweed. New construction with ineffective silt fences and using flex mse walls

Appendix C-i: Stream Reach Photographs and Summaries

Hadden Creek **Segment: HA-4.2**

February 24, 2016 Upstream of St. Andrews Rd to the survey boundary upstream of Millstream Rd

Photo A-125: Looking Upstream

Photo A-126: Looking Downstream

Photo A-127: Typical Riffle

Photo A-128: Typical Substrate Conditions

Wetted width:	1.8 m	Instream cover:	8%	Spawning gravel:	Little
Bankfull width:	2 m	LWD:	Few	Rearing habitat:	Little

General comments: Significant encroachment up to 150 m stretches. Transition from downstream riffle pool to upstream cascade pool morphology just downstream of greenwood Rd culvert. Several fish barriers present. Marginal fish habitat due to multiple barriers, high level of encroachment and little channel complexity. Few pools, mostly at culverts. 100 m stretches with no riparian forest

Appendix C-i: Stream Reach Photographs and Summaries

Vinson Creek West **Segment: VIW-1.1**

February 25, 2016 Upstream of Esquimalt Ave to Mathers Ave

Photo A-129: Looking Upstream

Photo A-130: Looking Downstream

Photo A-131: Typical Riffle

Photo A-132: Typical Substrate Conditions

Wetted width:	1.5 m	Instream cover:	15%	Spawning gravel:	Extensive
Bankfull width:	2 m	LWD:	Few	Rearing habitat:	Little

General comments: Rial rim vegetation has varied widely through segment due to backyards, ornamentals and invasives. Many properties have cleared vegetation to the bank.

Appendix C-i: Stream Reach Photographs and Summaries

Vinson Creek West **Segment: VIW-1.2**

February 25, 2016 Between Mathers Ave and Highway 1

Photo A-133: Looking Upstream

Photo A-134: Looking Downstream

Photo A-135: Typical Riffle

No photo

Photo A-136: Typical Substrate Conditions

Wetted width:	2 m	Instream cover:	8%	Spawning gravel:	Extensive
Bankfull width:	2.3 m	LWD:	Few	Rearing habitat:	Little

General comments: Moderate fish habitat due to little LWD and low cover. Few deep pools. Several mature conifers in yards. Abundant patches of ivy at least 60 sq m. Frequent clearing and encroachment. Abundant ivy

Appendix C-i: Stream Reach Photographs and Summaries

Vinson Creek West **Segment: VIW-2.1**

February 25, 2016 Upstream of Highway 1 to Chippendale Rd


Photo A-137: Looking Upstream


Photo A-138: Looking Downstream


Photo A-139: Typical Riffle


Photo A-140: Typical Substrate Conditions

Wetted width:	1.2 m	Instream cover:	5%	Spawning gravel:	Little
Bankfull width:	1.5 m	LWD:	Few	Rearing habitat:	Little

General comments: Frequent encroachment and invasive species. downstream extent to Hwy 1 has 60 m concrete channel. Marginal fish habitat. Frequent bank armouring

Appendix C-i: Stream Reach Photographs and Summaries

Vinson Creek West **Segment: VIW-2.2**

February 25, 2016 Upstream of Chippendale Rd to survey boundary just upstream of Chartwell Dr

Photo A-141: Looking Upstream

Photo A-142: Looking Downstream

Photo A-143: Typical Riffle

Photo A-144: Typical Substrate Conditions

Wetted width:	0.8 m	Instream cover:	5%	Spawning gravel:	Little
Bankfull width:	1 m	LWD:	Few	Rearing habitat:	Little

General comments: Frequent culverts and invasive plants. Marginal fish habitat. Very few pools or LWD.

Appendix C-i: Stream Reach Photographs and Summaries

Vinson Creek West **Segment: VIW-3.1**

February 25, 2016 Farthest east tributary of West Vinson Creek, upstream of Fulton Ave to south border of Chatwin Park


Photo A-145: Looking Upstream


Photo A-146: Looking Downstream


Photo A-147: Typical Riffle


Photo A-148: Typical Substrate Conditions

Wetted width:	0.75 m	Instream cover:	5%	Spawning gravel:	Little
Bankfull width:	1 m	LWD:	None	Rearing habitat:	None

General comments: More sedimentation and organics above culvert. Poor habitat, heavily modified channel and riparian area. Low flows through summer. Heavily modified. Encroached by lawns and gardens.

Appendix C-i: Stream Reach Photographs and Summaries

Vinson Creek West **Segment: VIW-3.2**

February 25, 2016 Within Chatwin Park

Photo A-149: Looking Upstream

Photo A-150: Looking Downstream

Photo A-151: Typical Riffle

Photo A-152: Typical Substrate Conditions

Wetted width:	0.5	Instream cover:	1%	Spawning gravel:	Little
Bankfull width:	1.5	LWD:	Few	Rearing habitat:	None

General comments: Low gradient with small gravel and fines. Most natural channel in VIW-3. Almost no cover for fish but good canopy cover. Undergrowth severely impacted by park goers. Almost bare.

Appendix C-i: Stream Reach Photographs and Summaries

Vinson Creek West **Segment: VIW-4.1**

February 25, 2016 Middle tributary to Vinson Creek West, upstream of underground section at Fulton Ave

Photo A-153: Looking Upstream

Photo A-154: Looking Downstream

Photo A-155: Typical Riffle

Photo A-156: Typical Substrate Conditions

Wetted width:	1.5 m	Instream cover:	4%	Spawning gravel:	Little
Bankfull width:	1.5 m	LWD:	None	Rearing habitat:	None

General comments: Heavily modified segment that runs through residential area. Over 60% is channelized between bank protection or in culverts. Poor fish habitat. Riparian zone is mainly yards.

Appendix C-i: Stream Reach Photographs and Summaries

Vinson Creek East **Segment: VIE-1.1**

February 25, 2016 Upstream of 13th Ave to Mathers St

Photo A-157: Looking Upstream

Photo A-158: Looking Downstream

Photo A-159: Typical Riffle

Photo A-160: Typical Substrate Conditions

Wetted width:	2 m	Instream cover:	5%	Spawning gravel:	Extensive
Bankfull width:	3 m	LWD:	None	Rearing habitat:	None

General comments: Poor fish habitat - shallow, little cover. Good gravel. Very little riparian vegetation. In playground.

Appendix C-i: Stream Reach Photographs and Summaries

Vinson Creek East **Segment: VIE-1.2**

February 25, 2016 Upstream of Mathers Ave

Photo A-161: Looking Upstream

Photo A-162: Looking Downstream

Photo A-163: Typical Riffle

Photo A-164: Typical Substrate Conditions

Wetted width:	1 m	Instream cover:	10%	Spawning gravel:	Extensive
Bankfull width:	2 m	LWD:	Few	Rearing habitat:	Little

General comments: Poor to moderate fish habitat. Shallow, with little cover. Good canopy cover but little riparian vegetation. Substrate dominated by gravel and cobble. Basically no wood. Much of understory not well vegetated.

Appendix C-ii

Vinson, Brothers, and Hadden Creeks One-time Water Quality Sampling Results

September 28, 2016

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Vinson, Brothers, and Hadden Creeks One-time Water Quality Sampling Results - September 28, 2016

Site*	Easting	Northing	Location	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)**	pH	Water Temperature °C	Conductivity (mS/cm)	Conductivity (mS/cm^{C})	Turbidity (NTU)	Total Dissolved Solids (TDS)**	Salinity**	Oxygen Reduction Potential (ORP)**
Brothers Creek Catchment													
BRO1			15 m d/s of regular BRO1 site, under pedestrian bridge.	11.03	103.7	7.80	12.58	0.089	0.116	0.0	0.076	0.05	156.3
BRO3	488999	5466989	10m u/s of Millstream Rd Bridge.	10.80	96.6	6.15	10.45	0.011	0.015	0.0	0.010	0.01	224.0
BRO4	489731	5465730	D/s of Highland Dr culvert across from 865 Highland Dr.	10.32	100.8	7.94	14.19	0.117	0.147	1.5	0.096	0.07	178.5
BRO5	490188	5464895	U/s of Taylor Way, u/s of outfall on left bank. Near Montesorri School.	10.33	97.5	7.31	12.49	0.074	0.097	0.0	0.063	0.05	182.9
BRO6	490188	5464895	D/s of outfall on left bank, u/s of Taylor Way.	6.88	64.9	6.47	12.73	0.107	0.140	1.4	0.090	0.06	100.5
BRO7	490049	5465073	30 m u/s of Hwy 1 on-ramp, 10 m d/s of Wildwood Lane Bridge over Brothers Creek.	10.65	101.1	7.43	12.99	0.052	0.068	0.0	0.044	0.03	190.2
BRO8	489461	5465970	U/s of culvert under Cross Creek Drive near Hollyburn Club	10.77	100.2	7.54	12.13	0.033	0.044	0.0	0.029	0.02	145.2
BRO9	489247	5466735	U/s side fo Crestwell Rd, just west of 1357 Crestwell Rd	10.80	98.4	7.44	11.22	0.018	0.024	0.0	0.016	0.01	171.3
BRO10	489220	5467003	Next Creek east of BRO3, d/s of Millstream Rd, at 1151-1153 Millstream Rd	10.24	95.1	6.28	12.04	0.017	0.023	0.0	0.015	0.01	164.4
BRO11	489297	5467059	U/s side of Millstream Rd, just west of 1143 Millstream Rd	10.17	93.4	6.00	11.60	0.013	0.018	0.0	0.012	0.01	198.7
BRO12	489873	5466564	Corner of Eyremont Dr. and Hillside Rd. Just south of 1110 Hillside Road, NE corner of intersection	9.42	90.8	7.15	13.68	0.078	0.099	0.2	0.065	0.05	86.3
BRO13	489617	5467143	At 1129 Henlow Road, d/s side of road	9.68	91.4	6.42	12.79	0.027	0.036	0.3	0.023	0.02	238.9
BRO14	489377	5466624	U/s side of Groveland Court, at 1125 Groveland Court	10.36	97.8	7.00	12.76	0.054	0.071	0.0	0.046	0.03	210.1
BROW1	489887	5465097	30 m u/s of grab sample location and 30m u/s of diversion under Hwy 1	10.35	98.9	7.71	13.25	0.142	0.183	0.1	0.119	0.09	
BROW2	490094	546497	At mouth of culvert entering Brothers Creek, just d/s of Hwy 1 off ramp	10.69	100.7	7.56	12.65	0.104	0.137	0.4	0.089	0.07	117.9
BROW3	490077	5464967	In channel 10 m u/s of culvert on Brothers West leading to Brothers Creek, south of Hwy 1.	10.52	99.7	7.78	12.89	0.167	0.217	0.2	0.141	0.10	103.8
BROW4	489979	5464983	820 Mathers Ave, at culvert entering creek on right bank, just south of Hwy 1.	9.18	88.8	7.01	13.76	0.140	0.179	3.4	0.116	0.08	37.6
BROW5	489323	5465882	U/s of culvert at Cross Creek Drive	10.35	99.6	7.85	13.60	0.176	0.227	0.6	0.146	0.11	114.4
BROW6	489137	5466636	D/s side of Crestwell Rd, at 1435 Chartwell Dr	9.51	95.2	7.38	15.44	0.103	0.126	12.0	0.082	0.06	166.8
BROE1	490049	5465073	In fish ladder beside Brothers Creek, just d/s of BRO7	10.48	101.4	7.89	13.88	0.178	0.227	1.4	0.147	0.11	192.7
MAC1	490691	5464554	5 m u/s of culvert under Macbeth Creek (440 Macbeth Crescent)	10.53	99.5	7.49	12.82	0.074	0.096	0.4	0.063	0.04	112.1
Vinson Creek Catchment													
VINE2	488978	5463852	Manhole at SE corner of Marine Drive and 13th Street	10.05	101.7	7.91	15.92	0.151	0.183	17.2	0.119	0.09	164.4
VINE3	489019	5465035	10m d/s of culvert at Mathers Ave, east of 13th St at Ridgeway School	10.14	99.4	7.58	14.43	0.098	0.120	13.4	0.098	0.07	90.4
VINE4	488953	5465312	U/s side of Ottawa Ave at entrance to culvert on property (1335 Ottawa Ave)	9.88	97.2	7.63	14.58	0.140	0.174	0.4	0.113	0.08	139.7
VINW1	488773	5463905	Manhole at SW concern of Marine Drive and 14th Street in front of VanCity	10.49	102.0	7.73	14.09	0.171	0.216	5.2	0.140	0.10	188.1
VINW3	488592	5464442	Gordon Ave and 15th St, just above diversion	10.60	100.8	7.98	13.06	0.189	0.244	1.2	0.159	0.12	140.9
VINW4	488405	5464872	U/s side of King's Ave at corner of 17th Street	10.26	98.6	7.90	13.53	0.199	0.254	0.4	0.165	0.12	154.2
VINW5	488774	5465849	D/s of culvert under Camelot Road, at 1402 Camelot Road	9.94	96.7	7.77	14.05	0.181	0.228	0.5	0.149	0.11	124.6
VINW6	488791	5466779	Top of Vinson West Creek at Chartwell Drive, near intersection with Eyremont Drive near 1575 Chartwell Drive										
VINW7	488754	5464679	At property just upstream of Inglewood Drive, just west of 14th Street	10.11	100.2	7.85	14.95	0.145	0.179	0.4	0.116	0.09	165.7
VINW8	488916	5464651	At property on south of Inglewood Drive, b/w 14th and 13th Streets	9.74	92.1	7.33	12.66	0.093	0.122	2.7	0.079	0.06	60.6
Hadden Creek Catchment													
HAD3	490408	5465421	U/s of Stevens Drive at top of fish ladder, at Hadden South Hydrometric Station	10.42	99.6	7.79	13.33	0.102	0.132	0.5	0.086	0.06	210.7
HAD4	490557	5465976	U/s of culvert under Hadden Drive	10.11	98.6	7.69	14.22	0.104	0.131	1.0	0.085	0.06	180.0
HAD5	490699	5406743	D/s of confluence with Hadden East, ~40m d/s of culvert of Southborough Drive	10.29	98.6	7.53	13.43	0.092	0.118	0.5	0.077	0.06	160.0
HAD6	490555	5465978	In tributary few meters u/s of confluence with Hadden Creek on u/s side of Hadden	9.67	96.9	7.70	15.47	0.134	0.164	1.0	0.106	0.08	174.1
HADW1	490699	5466743	D/s of Southborough Dr at tailout of pool, u/s of confluence with Hadden East, abo	10.23	98.1	7.11	13.46	0.080	0.103	0.4	0.067	0.05	209.2
HADW2	490323	5466792	At 825 Kenwood Rd, corner of Kenwood and Elveden Row, u/s of Kenwood										
HADW3	489982	5467335	U/s of Millstream Rd, at 1065 Millstream Road	10.57	97.5	6.36	11.74	0.011	0.014	0.0	0.009	0.01	239.9
HADE1	490699	5466743	Just u/s of confluence with Hadden Creek mainstem below Southborough Drive	10.31	98.9	7.67	13.46	0.119	0.153	0.7	0.099	0.07	176.0
HADE2	490289	5467484	D/s side of Craighorn Rd/Millstream Rd. Near 590 Craighorn Rd	9.89	93.1	6.60	12.62	0.039	0.051	0.2	0.033	0.02	235.3

* See Figure X for sampling site locations.
** Dissolved oxygen (%), total dissolved solids, salinity and oxygen reduction potential do not have MAMF thresholds.
*** Green = Good, Yellow = Satisfactory, Red = Needs Attention

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Appendix D
Modelling

Appendix D – Hydrologic and Hydraulic Modelling

Contents

Figures at end of Section

Tables

Appendix D – Hydrologic and Hydraulic Modelling

D Hydrologic and Hydraulic Modelling

D.1 Introduction

This appendix outlines the development of the detailed hydrologic and hydraulic model of the Vinson, Brothers, and Hadden Creeks watersheds. The appendix includes:

- Description of the detailed hydrologic and hydraulic model development using the District's GIS database and surveyed information;
- Calibration and validation of the hydrologic model to ensure accurate predictions of watershed rainfall-runoff response; and
- Description of the design storms used to assess the major system infrastructure under existing, future, and climate change conditions.

The results of the major system capacity analysis are presented in Appendix E.

D.2 Rainfall and Flow Monitoring Data Collection

Rainfall Data

Table D-1 below summarizes rainfall monitoring stations in the vicinity of the study area.

Table D-1: Rainfall Stations for Model Calibration

Station	Location	Elevation	Operated By
VW14	District of West Vancouver Municipal Hall	41 m	Metro Vancouver
District Works Yard	Cypress Bowl Road, near Upper Levels Highway	200 m	District of West Vancouver
VW51	Capilano Golf and Country Club	201 m	Metro Vancouver
Bonnymuir	North of Bonnymuir Drive and Bonnymuir Place	~270 m	District of West Vancouver
Cypress Ranger Station	Cypress Bowl Road, near Cypress Mountain Ski Area	930 m	District of West Vancouver

Recorded storm events at Cypress Ranger Station and District of West Vancouver Municipal Hall (VW14) were used for calibration. These stations were selected for their consistency of record and proximity to the study area. VW14 rainfall data was applied to catchments from 0 – 100 m elevation, and scaled by a factor of 1.45 and applied to catchments from 100 – 400 m elevation. Cypress Ranger Station rainfall data was applied to catchments greater than 400 m in elevation.

Appendix D – Hydrologic and Hydraulic Modelling

Flow Monitoring

The study area contains several flow monitoring gauges that have been in operation and recording data since 2012. These are summarized in the Table D-2 below and shown in Figure D-1.

Table D-2: Hydrometric Monitoring Stations for Model Calibration

Flow Gauge	Start Date	End Date
Brothers North	08/06/2012	Present
Hadden North	09/06/2012	01/06/2015
Hadden South	08/06/2012	Present
Brothers Hadden[1]	08/06/2012	Present
Vinson North	09/06/2012	Present
Vinson West	13/05/2012	Present
Vinson East[1]	01/05/2012	31/12/2013
1. Gauge not used for calibration		

The Brothers Creek gauge below the confluence with Hadden was not used for calibration as it was found that the gauge may be significantly under-reporting flows; the Vinson East gauge was not used due to inconsistencies in its flow record.

D.3 Percentage Impervious

The existing land use total impervious percentages used in the model were based on the BC Assessment Land Use Codes, a 2011 orthophoto, and cadastral data provided by the District. Lots were grouped into more general land use types and then total impervious percentages were calculated by averaging the impervious percentage of several sample lots. Figure D-2 shows the total impervious area for the catchments under existing land use. These values are summarized by general land use type in Table D-3 below.

For the future land use, total impervious percentages of most residential zones were increased due to tendency for redevelopment to encompass larger housing footprints. A 2014 update to land use regulations permitted the addition of “detached secondary suites” in much of the study areas. Although not yet prevalent, addition of secondary suites could become part of the re-development pattern.

The District is currently undergoing an OCP review process. As part of the process, land use changes are being considered for areas currently considered town centres, Ambleside and Marine Drive, and important corridors such as Taylor Way. Changes being considered in these areas include:

- Infill (mid-rise development) in Ambleside Apartment Area. Infill (conversion of single family to duplexes) and addition of low-rise development (townhouses) in single family neighbourhoods adjacent to Ambleside Town Centre.
- Expansion of existing boundary of Ambleside Town Centre to allow additional multi-family and mid-rise residential development.
- High-rise development along Marine Drive (south Brothers) and Park Royal Shopping Centre.
- Shift from single family to ground oriented housing (townhouses, low-rise buildings, and care facilities) in the Taylor Way Corridor (between the Highway and Clyde Avenue).

Appendix D – Hydrologic and Hydraulic Modelling

Land use in the study area for the future scenario is shown in Figure D-3. Total impervious area assigned to each land use type is summarized in Table D-3. Figure D-4 shows the increase in percentage impervious area from existing to future land use scenarios.

Table D-3: Land Use Impervious Percentages

Land Use	Total Existing Impervious Percentage[1]	Total Future Impervious Percentage
Single Family British Properties	60	75
Single Family British Properties South	50	65
Single Family	45	60
Single Family Riparian	20	30
High Rise	75	75
Duplex	80	80
Row Housing	45	85
Institutional	60	60
Commercial	95	95
Park	10	10
Undeveloped Greenfield	5	N/A[2]
Forested/Alpine	0	0
Easement	5	5
ROW	70	70

1. Based on District of West Vancouver's 2011 Orthophoto, BC Assessment Land Use Codes, and cadastral data
2. Included in the future Single Family categories.

D.4 PCSWMM Model Development

Model Network

The model conduits are made up of the Vinson, Brothers, and Hadden Creeks main stems and their major tributaries, and the culverts that convey the flow in these creeks. The model also includes three piped systems diverting flow from the Vinson Creek main stem to Brothers Creek. Nodes in the model consist of manholes, intakes, outfalls, storage, and junctions on the main stems and their tributaries.

Culverts contained in the District's GIS database were surveyed prior to model development. Some culverts could not be located or had access issues, in which case missing attribute information was supplied by the District, or filled in according to the following procedure:

- Culverts with missing geometry were given diameters large enough to convey the design storm peak flows without surcharging; and
- Missing invert elevations were estimated based on the DEM or linearly interpolated based on nearby entities.

Culverts with missing attribute information are shown in Figure D-5.

Creek cross sections were cut from the DEM and refined based on typical cross sections measured during the field inventory. Channel and conduit roughness values were assigned based on typical values for the various conduit materials.

Appendix D – Hydrologic and Hydraulic Modelling

The drainage system includes:

- 17 km of creeks;
- 7.5 km of pipes/culverts;
- 297 manholes/nodes/junctions; and
- 2 detention facilities.

Figure D-6 shows the Vinson, Brothers, and Hadden Creeks model network.

Model Catchments

The Vinson, Brothers, and Hadden Creeks drainage areas were divided into lot catchments, forested catchments, and road catchments. Data for the lot and road catchments were taken from the District's cadastral land use GIS mapping. The District's GIS storm drainage network was used to pair each parcel/segment of road with the manhole, creek node, junction, or end of a culvert that the parcel/segment of road would be expected to drain to. Forested catchments (above the upper development boundary) were delineated using the District's 2011 GIS contour data and were paired to inflow nodes at the development boundary.

In total, 12 forested catchments, 3,642 lot catchments, and 199 road catchments were created and imported into the PCSWMM model. Catchments were assigned the following attributes:

- Slopes, using digital elevation mapping (DEM) information;
- Existing land use impervious percentage, using the District of West Vancouver's GIS land use assessment information for individual lots; and impervious percentage for future land use scenarios, estimated based on typical redevelopment patterns in the study areas, and input from the District's OCP review process; and
- Groundwater parameters based on provincial soils mapping.

Groundwater and Soil Parameters

The groundwater feature of PCSWMM was used to better estimate the groundwater and interflow portions of the runoff hydrograph. Infiltration rates, soil depths, and soil hydraulic conductivity inputs were based on previously used values and/or typical values for parameters as initial values prior to calibration.

Figure D-7 shows the surficial geology of the Vinson, Brothers, and Hadden Creek Basins that was used to determine soil parameters.

Appendix D – Hydrologic and Hydraulic Modelling

D.5 Model Calibration

Introduction

Recorded storm events at Cypress Ranger Station and District of West Vancouver Municipal Hall (VW14) were used for calibration. A continuous simulation approach was used as opposed to discrete event calibration; this approach ensures that watershed parameters are calibrated across a range of events. The periods modelled for calibration and validation are listed in Table D-4.

Table D-4: Time Periods Modelled for Calibration

Dates (DD/MM/YYYY)	Hydrometric Station	Calibration/Validation
27/11/2013 – 27/04/2014 26/09/2014 – 07/04/2015 01/09/2015 – 20/10/2015	Brothers North	Calibration (Groundwater)
3/9/2014 – 30/12/2014	Hadden North	Calibration (Groundwater)
3/9/2014 – 30/12/2014	Hadden South	Calibration (Runoff)
27/11/2013 – 27/04/2014 26/09/2014 – 07/04/2015 01/09/2015 – 20/10/2015	Vinson North	Validation
27/11/2013 – 27/04/2014 26/09/2014 – 07/04/2015 01/09/2015 – 20/10/2015	Vinson West	Validation

Model calibration involved the adjustment of parameters, within reasonable ranges, until a set of objectives was met. The Vinson, Brothers, and Hadden Creeks model was calibrated to all aspects of the hydrograph (peak flow, volumes, the receding portion of the hydrograph from groundwater). Some differences may be attributed to variation in the rainfall distribution over the catchment.

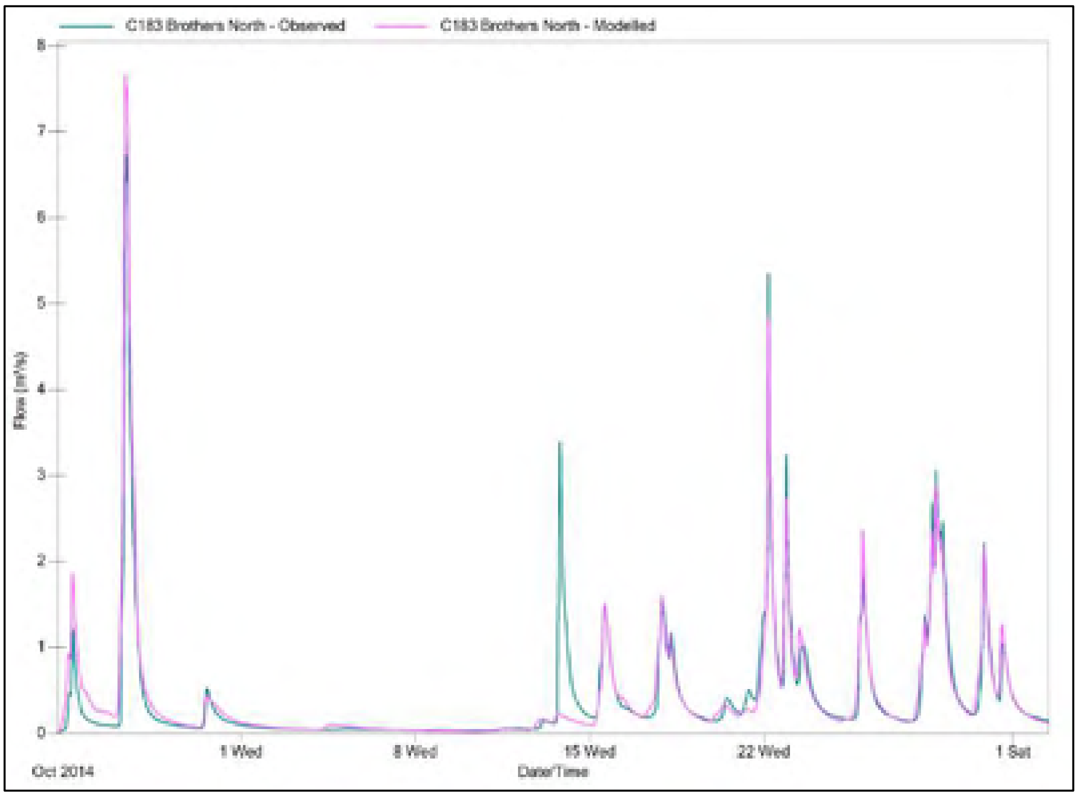
Calibration of Upper Undeveloped Catchments – *Groundwater Calibration*

It was assumed that there would be little to no runoff from the upper forested catchments even during extreme events based on the lack of impervious area and the predominant underlying soil type in the area. Therefore, calibration of the upper undeveloped catchments focused solely on the groundwater parameters.

Appendix D – Hydrologic and Hydraulic Modelling

The Brothers North hydrometric station, located at the Upper Development Boundary, was used for calibration of the upper forested catchments draining to Vinson and Brothers Creeks. The initial groundwater parameters input to the model were a combination of the calibrated parameters from the McDonald-Lawson ISMP XP-SWMM model, and the Mackay / Mosquito ISMP PCSWMM model. Calibration involved iteratively adjusting groundwater parameters to replicate the shape of the observed hydrographs. As shown in the Graph D-1 below, the process yielded a close match between the modelled and observed time series, both in terms of the hydrograph peaks and groundwater tails.

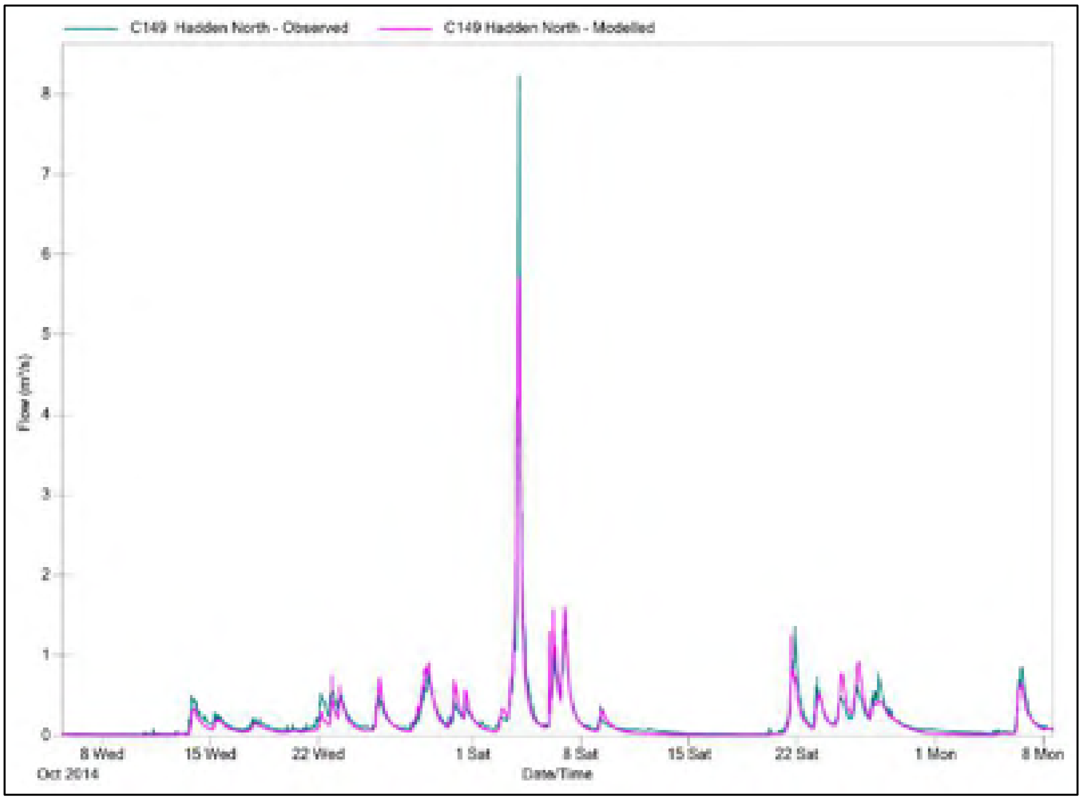
Any significant differences in the flow volumes may be attributed to errors or data gaps in the Cypress Mountain Ranger Station rainfall record.



Graph D-1: Upper Undeveloped Catchments Calibration to Brothers North Hydrometric Station

Appendix D – Hydrologic and Hydraulic Modelling

The Hadden North hydrometric station was used to calibrate the upper forested catchments draining to Hadden Creek and its major tributaries. Initially, the groundwater parameters calibrated to the Brothers North gauge were applied to the catchments; however, flow from the upper Hadden catchments was found to behave differently from Vinson and Brothers, with hydrographs showing much smaller peaks and longer, more drawn-out tails. Groundwater parameters were tweaked until representative hydrographs were achieved, as shown in Graph D-2 below. The difference in peaks between modelled and observed for the largest flow event on November 3, 2014 is not a concern as the observed flow is outside the confidence limits for the rating curve at the Hadden North gauge.



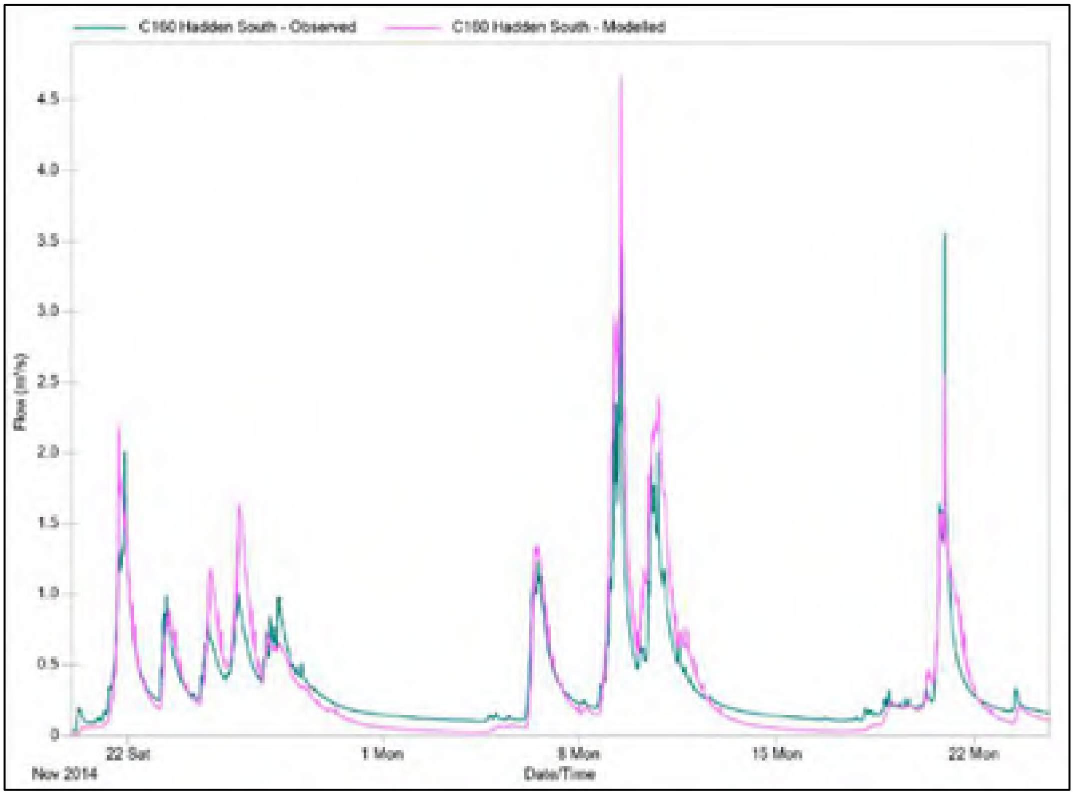
Graph D-2: Upper Undeveloped Catchments Calibration to Hadden North Hydrometric Station

Appendix D – Hydrologic and Hydraulic Modelling

Calibration of Urban Developed Catchments – *Runoff Calibration*

The groundwater parameters determined via calibration of the upper undeveloped catchments were applied to the urban areas. Calibration then focused on runoff from the developed catchments.

The Hadden South gauge was used for calibration of surficial hydrologic parameters within the study area. Infiltration and surficial conductivity were adjusted to match the peaks in the observed flow timeseries, shown in the graph below.



Graph D-3: Urban Developed Catchments Calibration to Hadden South Hydrometric Station

D.6 Design Storms

The calibrated model was used to simulate 2-, 5-, 10-, 100-, and 200-year return period 1-, 2-, 4-, 6-, 12- and 24-hour duration design events and to determine governing peak flows and volumes for each culvert. The design rainfall for the analysis was based on the existing IDF curves for the GVRD West Vancouver Municipal Hall gauge VW14. Design storms were developed based on the Atmospheric Environmental Services (AES) Pacific Coastal distribution; the 30th percentile curve was applied to the short duration storms (1-, 2-, and 4-hours), and the 50th percentile curve was applied to the longer duration storms (6-, 12-, and 24-hours).

Appendix D – Hydrologic and Hydraulic Modelling

Similar to the calibration rainfall, a scale factor of 1.45 was applied to the rainfall depths for elevations between 100 m and 400 m. A scale factor of 1.9 was applied to the rainfall depths for elevations greater than 400 m. The 200-year design storms were created by multiplying the 100-year design storm rainfall depths by 1.15 and adding a snowmelt allowance of 40 mm per day snow water equivalent (SWE) for elevations greater than 400 m. This is consistent with the process used to create rainfall design storms for the McDonald-Lawson ISMP.

It is generally accepted that climate change will increase the intensity of storms of all return periods, particularly for shorter duration events. As the actual increases can only be projected, a generic percentage increase of 10% was applied to all rainfall depths for the modelled climate change scenarios. Table D-5 shows the design storm precipitation totals for all modelled events.

Table D-5: Design Storm Rainfall Depths for Vinson, Brothers, and Hadden Creeks ISMP

Duration	Return Period, No Climate Change					Return Period, Climate Change				
Elevation 0 m - 100 m										
	2-yr	5-yr	10-yr	100-yr	200-yr	2-yr	5-yr	10-yr	100-yr	200-yr
1-hr	12.7	16.8	19.5	27.8	32.0	14.0	18.5	21.4	30.6	35.2
2-hr	18.4	24.3	28.1	40.1	46.1	20.3	26.7	30.9	44.1	50.7
4-hr	26.7	35.1	40.6	57.8	66.4	29.4	38.6	44.6	63.5	73.1
6-hr	33.2	43.5	50.3	71.5	82.2	36.5	47.8	55.3	78.7	90.5
12-hr	48.1	62.8	72.6	103.1	118.5	49.7	65.0	75.1	106.6	122.5
24-hr	69.6	90.8	104.8	148.5	170.8	76.6	99.9	115.3	163.4	187.9
Elevation 100 m - 400 m										
	2-yr	5-yr	10-yr	100-yr	200-yr	2-yr	5-yr	10-yr	100-yr	200-yr
1-hr	18.5	24.4	28.2	40.3	46.4	20.3	26.8	31.1	44.4	51.0
2-hr	26.7	35.2	40.8	58.1	66.8	29.4	38.7	44.8	63.9	73.5
4-hr	38.7	50.9	58.8	83.7	96.3	42.6	55.9	64.7	92.1	105.9
6-hr	48.1	63.1	72.9	103.7	119.3	52.9	69.4	80.2	114.1	131.2
12-hr	69.7	91.1	105.3	149.4	171.8	76.7	100.2	115.8	164.4	189.0
24-hr	101.0	131.7	152.0	215.3	247.6	111.1	144.8	167.2	236.9	272.4
Elevation >400 m										
	2-yr	5-yr	10-yr	100-yr	200-yr	2-yr	5-yr	10-yr	100-yr	200-yr
1-hr	24.2	31.9	37.0	52.8	62.6	26.6	35.1	40.7	58.1	68.7
2-hr	35.0	46.1	53.4	76.2	91.2	38.5	50.7	58.8	83.8	99.9
4-hr	50.8	66.6	77.1	109.7	133.4	55.8	73.3	84.8	120.7	146.0
6-hr	63.0	82.6	95.6	135.9	167.1	69.4	90.9	105.1	149.5	182.7
12-hr	91.3	119.4	137.9	195.8	246.8	100.5	131.4	151.7	215.4	269.4
24-hr	132.3	172.5	199.1	282.2	367.8	145.5	189.8	219.0	310.4	400.3

1. Rainfall depths based on Metro Vancouver's GVRD Gauge VW14 IDF Curves – 1959-1979, 1983-2010 (47 years)

Appendix D – Hydrologic and Hydraulic Modelling

The short duration storm events (<6 hours), typically convective summer storms, were modelled using unsaturated soil conditions. The longer duration storm events (≥6 hours) which typically occur in the winter months when the soil does not have sufficient time to dry out between storm events, were modelled using saturated soil conditions.

D.7 Peak Flow Estimates

Peak flows were compared against a KWL database of calibrated model peak flows for similar creeks to confirm the model is producing expected results. As shown in the table below, 200-year peak flows for existing land use produced at four different locations within the watersheds are in line with estimates for similar creeks.

Table D-6: Unit Peak Flow Comparison

Location	200-Year Unit Peak Flow ($m^3/s/ha$)
Undeveloped Catchments	
Brothers Main / Centre Branch at 1200 ft. contour (240 ha, 0% TIA)	**0.0789**
McDonald West Branch at 1200 ft. contour (69 ha, 0% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0809
Lawson East Branch/Main Branch at 1200 ft. contour (129 ha, 0% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0827
Partially Developed Catchments	
McDonald West Branch at Upper Levels Highway (119 ha, 19% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0372
Hadden Creek at Upper Levels Highway (268 ha, 32% TIA)	**0.0395**
McDonald East Branch at Upper Levels Highway (54 ha, 25% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0536
Brothers Main / Centre Branch at Upper Levels Highway (483 ha, 17% TIA)	**0.0620**
Lawson Creek at Outlet to Burrard Inlet (243 ha, 15% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0716
McDonald Creek at Outlet to Burrard Inlet (374 ha, 17% TIA) - *2004 McDonald and Lawson Creeks ISMP*	0.0719
Mackay Creek at Montroyal Boulevard (307 ha, 16% TIA) - *2016 Mackay and Mosquito Creeks ISMP, Draft*	0.0749
Vinson East Branch at Outlet to Burrard Inlet (97 ha, 53% TIA)	**0.0894**

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Author: tsoh

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Project No.	Date
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Hydrometric and Water Temperature Monitoring Stations

Figure D-1

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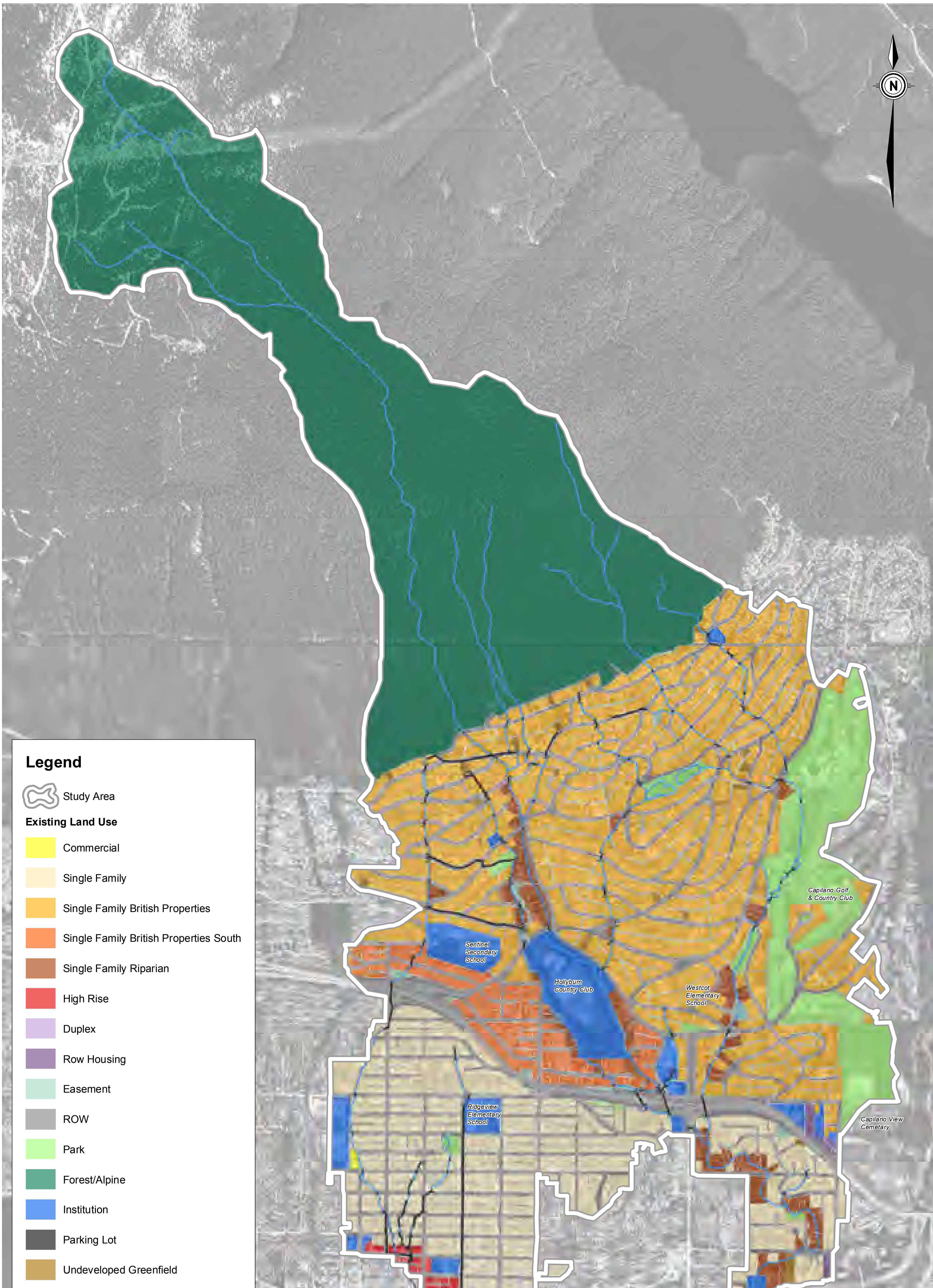

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Existing Land Use

Figure D-2

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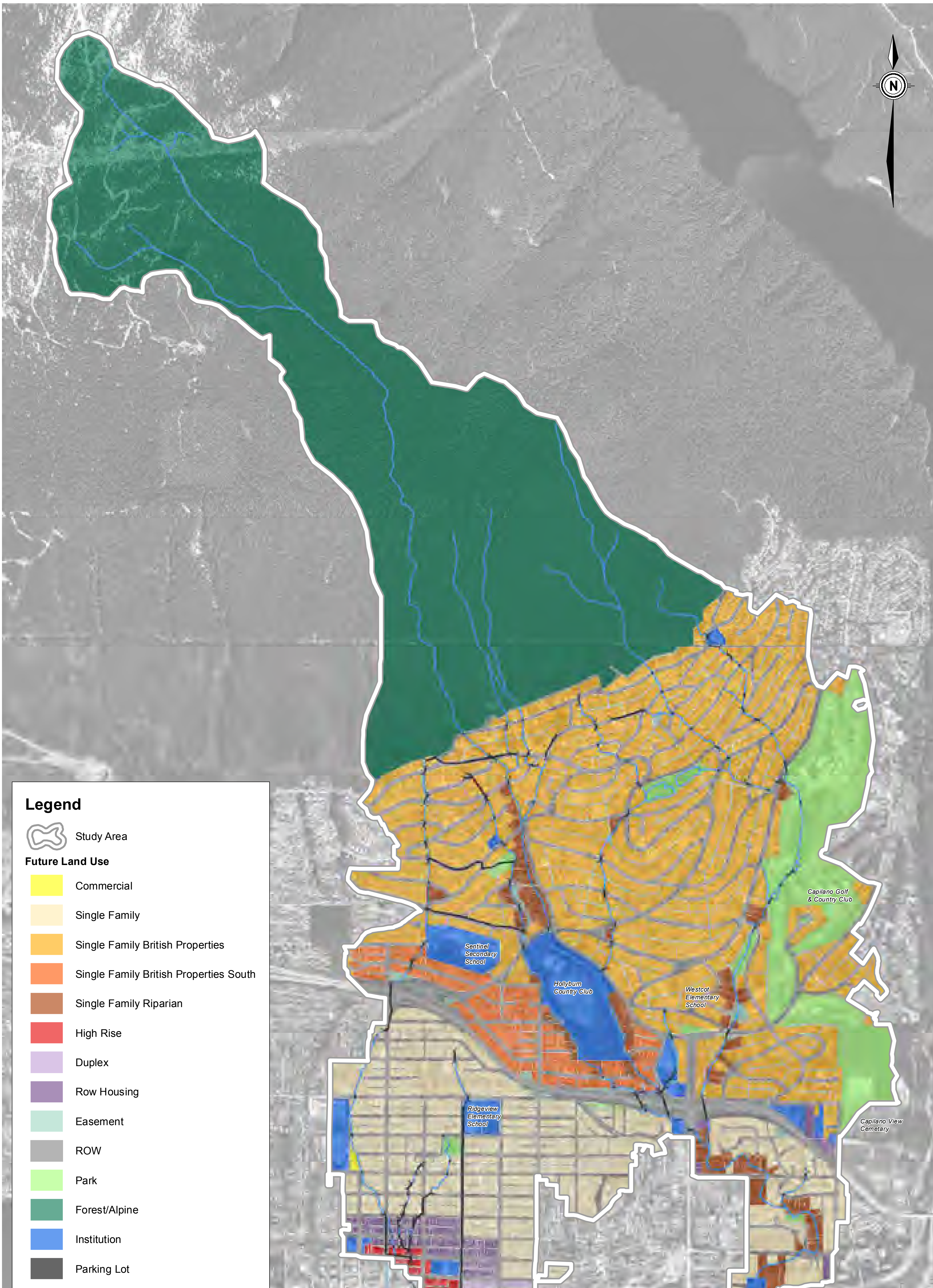

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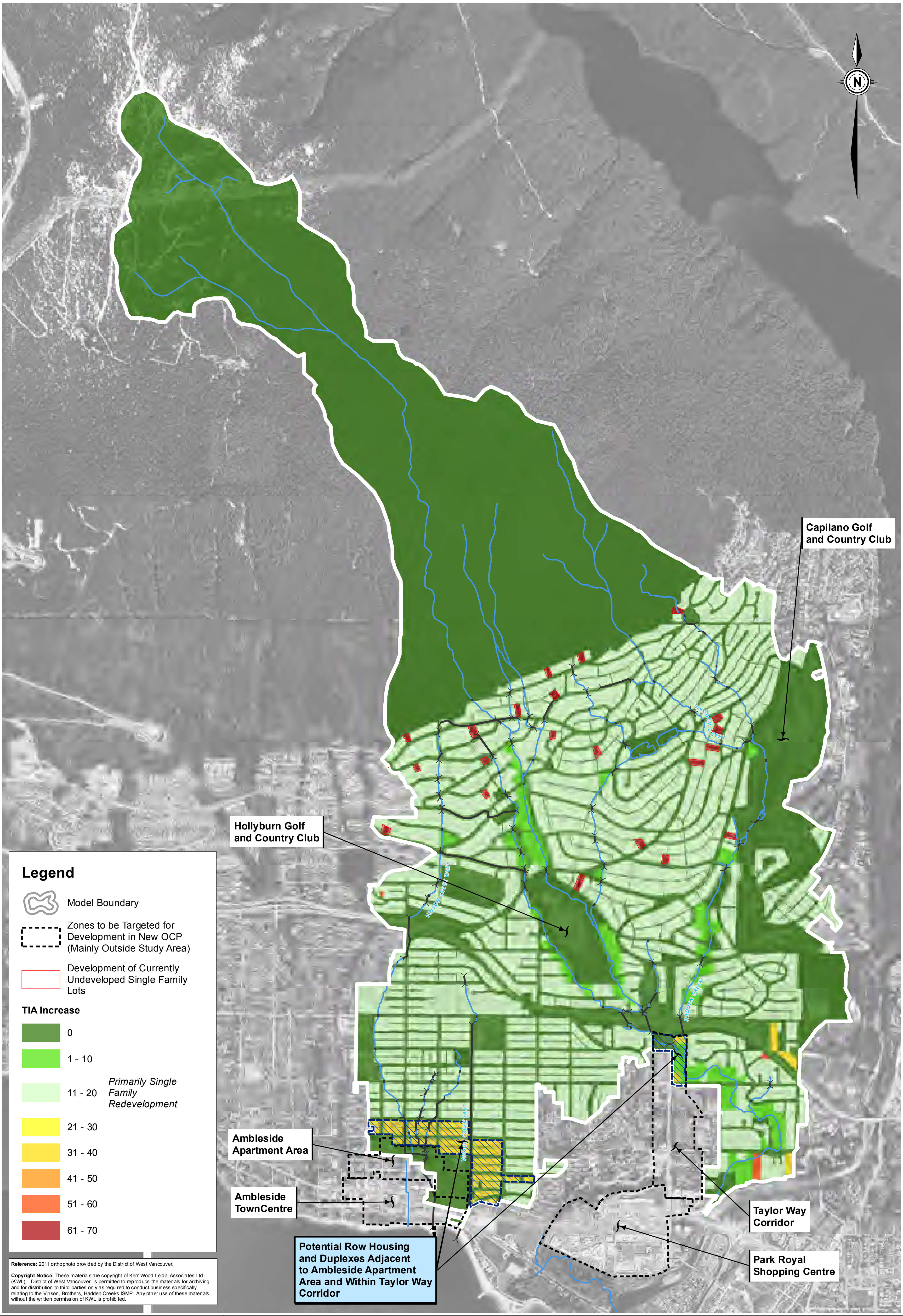
Future Land Use

Figure D-3



Reference: 2011 orthophoto provided by the District of West Vancouver.

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Existing to Future Land Use
Total Impervious Area Increase

Figure D-4

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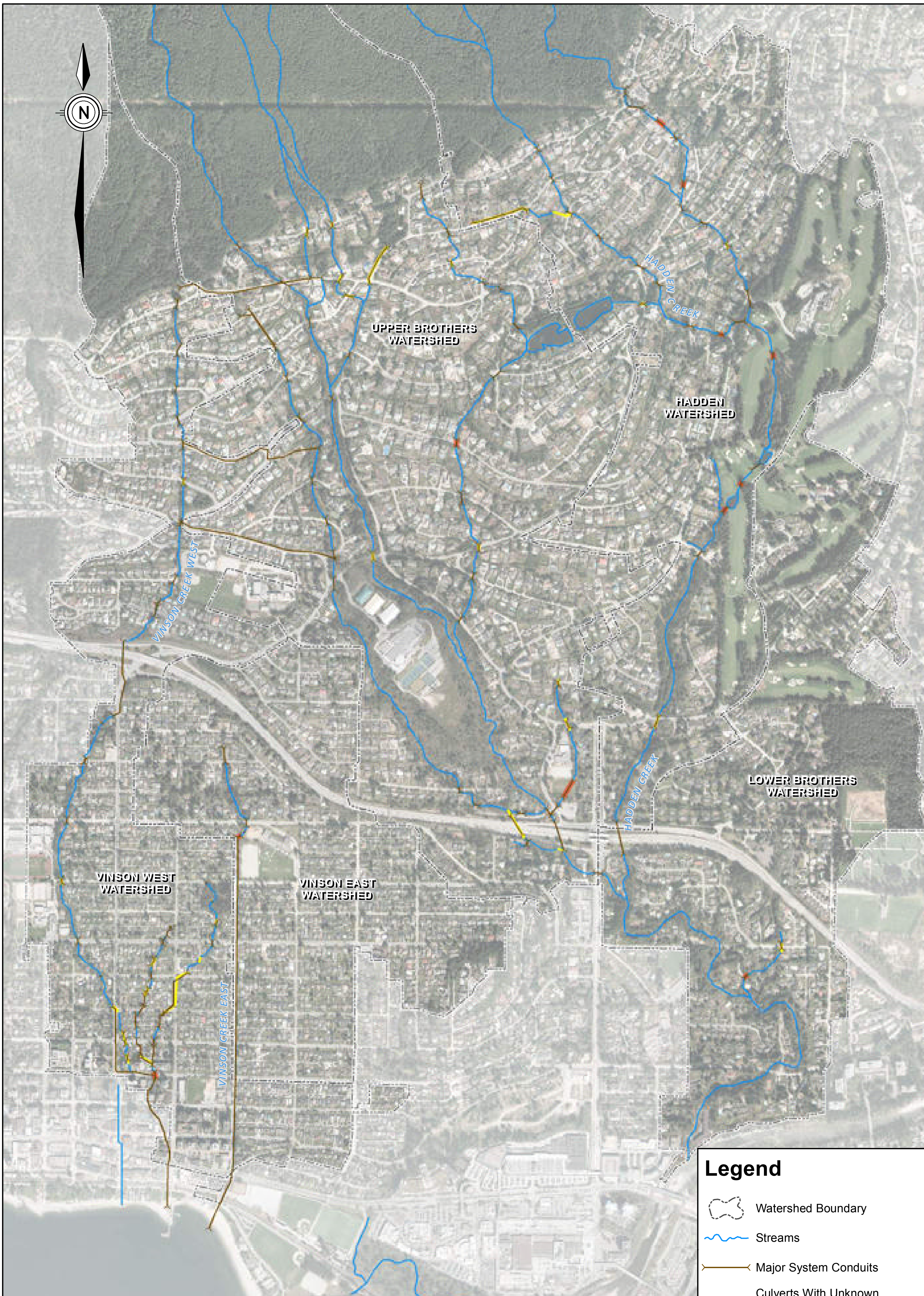

Reference: 2011 orthophoto provided by the District of West Vancouver.

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Culverts with No Data

Figure D-5

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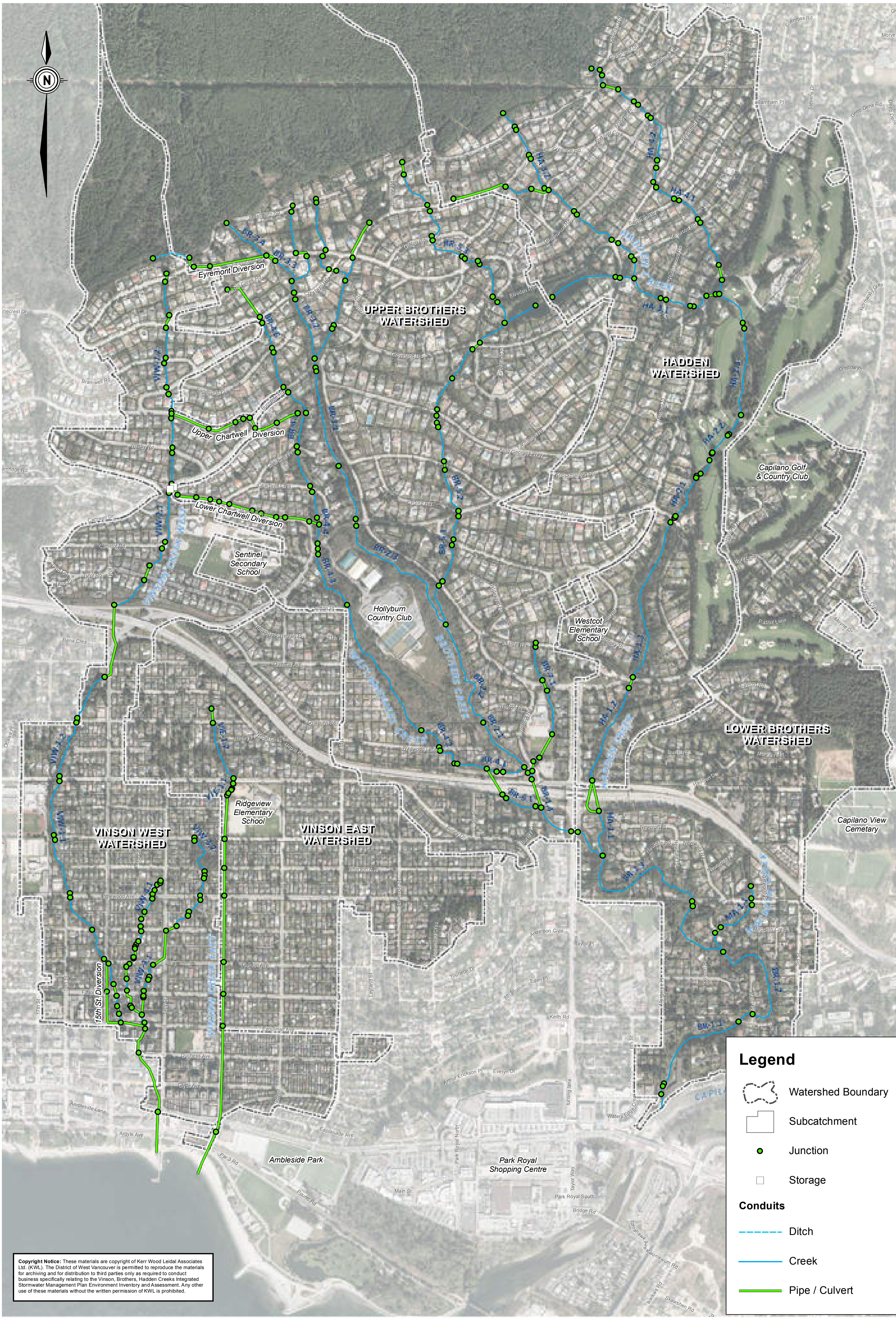

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Modelled Network

Figure D-6

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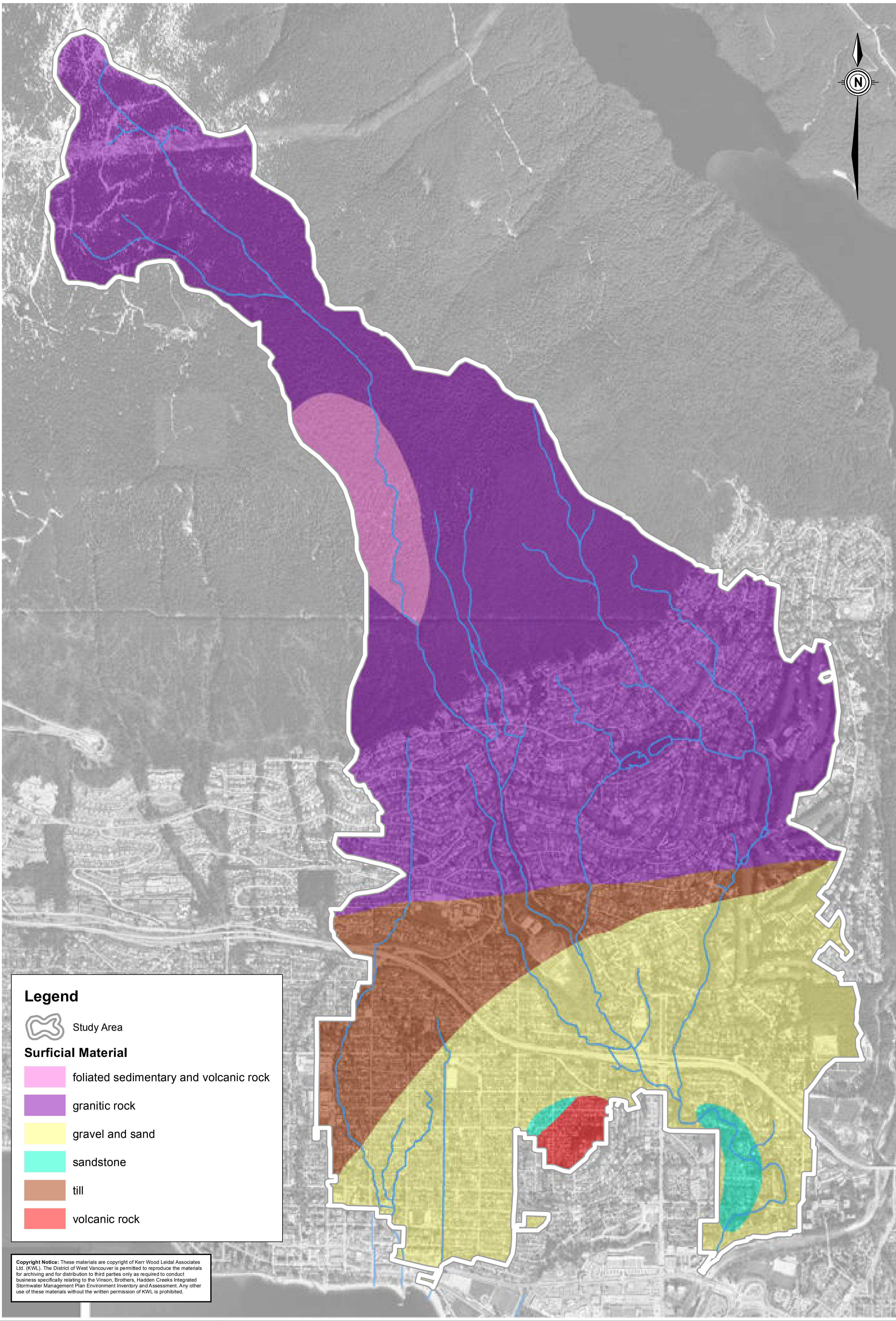

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Soils Map

Figure D-7

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Appendix E
Capital Plan

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Appendix E – Capital Plan

Contents

Tables

Appendix E – Capital Plan

E Capital Plan

E.1 Introduction

This appendix outlines the development of the capital plan for culvert upgrades based on the results of the hydrologic/hydraulic modelling of the Vinson, Brothers, and Hadden Creeks watersheds. The appendix includes:

- Criteria for assessing undersized culverts;
- Description of the criteria for prioritization of upgrades; and
- Cost estimate for the recommended upgrades.

The proposed upgrades are shown by priority of upgrade in Figure 7-2 in the main report.

E.2 Drainage Assessment Criteria

Culverts were assessed based on their ability to pass the 200-year flow without surcharging. Of the 159 major system conduits in the Vinson, Brothers, and Hadden watersheds:

- 108 are undersized for the 200-year existing land use scenario,
- four more are undersized for the future land use scenario, and
- two more conduits are undersized for the future land use with climate change scenario.

Major system conduits that do not have the capacity to pass the 200-year design storm should be upgraded to the required size necessary to pass the 200-year future land use with climate change flows.

E.3 Criteria for Prioritization

Recommended upgrades are prioritized first by existing service level and then by flood potential. Existing service level was determined by modelling the 2-, 5-, 10-, 100-, and 200-year design storms under existing land use. Those conduits unable to pass the 2-, 5-, and 10-year flows are the highest priority for upgrade.

The flood potential was evaluated by modeling overflow weirs to represent the road elevations above the culverts. A culvert is said to “flood” when the modeled water elevation at the upstream end of the culvert exceeds the road elevation. Not all undersized culverts flood over the road for the design event and those that surcharge but do not flood over the road are given a lower priority than those that do flood over the road.

Culvert upgrades were prioritized by the following criteria:

Priority 1a. Culverts that have an existing service level of less than 2 years and result in potential flooding over the road during the 200-year existing land use design event.

Priority 1b. Culverts that have an existing service level of less than 2 years.

Priority 2a. Culverts that have an existing service level of 2 to 5 years and result in potential flooding over the road during the 200-year existing land use design event.

Priority 2b. Culverts that have an existing service level of 2 to 5 years.

Priority 3a.	Culverts that have an existing service level of 5 to 10 years and result in potential flooding over the road during the 200-year existing land use design event.
Priority 3b.	Culverts that have an existing service level of 5 to 10 years.
Priority 4a.	Culverts that have an existing service level of 10 to 100 years and result in potential flooding over the road during the 200-year existing land use design event.
Priority 4b.	Culverts that have an existing service level of 10 to 100 years.
Priority 5.	Culverts that have an existing service level of 100 to 200 years.
Priority 6.	Culverts that have a future service level of less than 200 years, regardless of whether or not surface flooding occurs. These upgrades are recommended as end-of-life or development opportunity upgrades only.

E.4 Cost Estimate

The cost estimates for the proposed capital works are found in Table E-1 along with culvert identification, design peak flow, and recommended sizing. See Figure 7-2 in the main report for the location of the recommended upgrades. The cost estimates are of Class C accuracy, meaning that the general requirements for upgrading including size and approximate depth of excavation, as well as some general site conditions are known. The projects identified have not considered the following factors that may affect construction and costs:

- Relocation of adjacent services (water, hydro, etc.);
- Special permitting requirements (fisheries windows, contaminated sites, etc.);
- Geotechnical issues requiring special construction such as pile-supported piping, buoyancy problems or rock blasting; and
- Critical market shortages of materials.

Surveys and more detailed assessments of proposed capital works should be conducted prior to construction.

As the factors above have not been included in the cost estimates, the following allowances are applied to all projects:

- Markup on Materials – 18%
- Mobilization/Demobilization/Bonding – 9%
- Engineering – 15%
- Contingency – 30%

The prices reflect KWL's recent experience with similar work, and therefore represent the best prediction of actual (2016) costs as of the date prepared. Actual tendered costs will depend on market conditions, location factors, time of year, contractors' workloads, and perceived risk exposure associated with the work and unknown conditions.

Table E-1: Class C Cost Estimates for Recommended Culvert Upgrades

Priority	Existing Level of Service	Conduit ID	Length (m)	Existing Size	Required Upgrade Size	200-Yr FLU w/ Climate Change Peak Flow (m^3/s)	Earthworks ($)	Roadworks ($)	Restoration and Planting ($)	Culvert/ Headwalls ($)	Total Cost ($)	Total Cost with Mark-ups ($)
1a	<2yr	296	40.9	0.15 m ⌀	1.35 m ⌀	2.4	$201,000	$53,000	$47,000	$143,000	$444,000	$804,000
1a	<2yr	292	26.7	0.3 m ⌀	1.35 m ⌀	2.5	$133,000	$34,000	$47,000	$127,000	$341,000	$618,000
1a	<2yr	444	25.6	0.75 m ⌀	1.8 m ⌀	5.4	$128,000	$33,000	$47,000	$131,000	$339,000	$614,000
1a	<2yr	453	24.1	0.75 m ⌀	1.8 m ⌀	5.4	$121,000	$31,000	$47,000	$129,000	$328,000	$594,000
1a	<2yr	460	13.6	0.75 m ⌀	1.8 m ⌀	5.3	$70,000	$17,000	$47,000	$115,000	$249,000	$451,000
											Priority 1a Subtotal	**$3,081,000**
1b	<2yr	385	20.1	0.9 m ⌀	1.8 m ⌀	3.6	$25,000	$12,000	$22,000	$67,000	$126,000	$228,000
											Priority 1b Subtotal	**$228,000**
2a	2yr	347	26.6	0.75 m ⌀	2.4 m ⌀	8.9	$133,000	$34,000	$47,000	$152,000	$366,000	$662,000
2a	2yr	471	18.0	0.75 m ⌀	2.1 m ⌀	6.7	$24,000	$11,000	$22,000	$74,000	$130,000	$236,000
2a	2yr	404	4.8	0.66 m x 0.9 m elliptical (squished circular)	2.4 m ⌀	10.1	$13,000	$6,000	$21,000	$57,000	$96,000	$174,000
2a	2yr	349	22.7	0.9 m ⌀	2.4 m ⌀	8.9	$114,000	$29,000	$47,000	$143,000	$333,000	$603,000
2a	2yr	Kwl1005	21.5	0.75 m ⌀	1.8 m ⌀	5.2	$63,000	$21,000	$35,000	$94,000	$214,000	$387,000
2a	2yr	408	12.9	1.05 m ⌀	2.4 m ⌀	10.3	$31,000	$11,000	$30,000	$80,000	$152,000	$276,000
2a	2yr	407	9.7	1.05 m ⌀	2.4 m ⌀	10.3	$23,000	$7,000	$29,000	$71,000	$130,000	$236,000
2a	2yr	414_1	18.1	0.9 m ⌀	2.1 m ⌀	7.0	$40,000	$15,000	$30,000	$87,000	$172,000	$311,000
2a	2yr	465	16.5	0.9 m ⌀	2.1 m ⌀	7.3	$84,000	$21,000	$47,000	$127,000	$279,000	$505,000
2a	2yr	411	19.5	1.2 m ⌀	2.4 m ⌀	10.9	$39,000	$15,000	$28,000	$91,000	$173,000	$313,000
2a	2yr	393	11.7	0.75 m ⌀	1.5 m ⌀	3.4	$16,000	$7,000	$21,000	$46,000	$90,000	$163,000
2a	2yr	490	265.0	0.9 m ⌀	1.8 m ⌀	4.9	$191,000	$133,000	$18,000	$411,000	$753,000	$1,362,000
2a	2yr	375	53.1	1.05 m ⌀	2.1 m ⌀	6.7	$48,000	$29,000	$19,000	$139,000	$235,000	$426,000
2a	2yr	381	19.6	1.05 m ⌀	2.1 m ⌀	6.9	$21,000	$10,000	$20,000	$74,000	$125,000	$226,000
2a	2yr	438	12.9	1.1 m ⌀	2.1 m ⌀	6.0	$52,000	$14,000	$41,000	$103,000	$210,000	$380,000
2a	2yr	Kwl1000	44.1	0.6 m ⌀	1.05 m ⌀	1.4	$56,000	$28,000	$23,000	$58,000	$165,000	$299,000
											Priority 2a Subtotal	**$6,559,000**
2b	2yr	423	29.7	0.75 m ⌀	2.1 m ⌀	5.8	$58,000	$23,000	$29,000	$107,000	$217,000	$393,000
2b	2yr	470	17.3	0.9 m ⌀	2.1 m ⌀	7.3	$81,000	$21,000	$45,000	$123,000	$270,000	$488,000
2b	2yr	318	15.5	0.9 m ⌀	2.1 m ⌀	6.5	$40,000	$13,000	$32,000	$87,000	$173,000	$312,000
2b	2yr	415	20.2	1.2 m ⌀	2.4 m ⌀	11.0	$133,000	$30,000	$54,000	$161,000	$378,000	$684,000
2b	2yr	437	33.0	0.75 m ⌀	1.5 m ⌀	3.3	$48,000	$22,000	$24,000	$84,000	$179,000	$324,000
2b	2yr	Kwl1003	12.4	0.6 m ⌀	1.35 m ⌀	2.1	$41,000	$12,000	$36,000	$81,000	$170,000	$308,000
2b	2yr	440	26.3	0.75 m ⌀	1.5 m ⌀	3.2	$131,000	$34,000	$47,000	$136,000	$349,000	$631,000
2b	2yr	379	14.2	1.05 m ⌀	2.1 m ⌀	7.0	$53,000	$15,000	$39,000	$102,000	$209,000	$378,000
2b	2yr	493	24.7	0.75 m ⌀	1.35 m ⌀	2.4	$55,000	$21,000	$30,000	$73,000	$178,000	$322,000
2b	2yr	409	39.2	0.6 m ⌀	1.2 m ⌀	1.5	$193,000	$51,000	$47,000	$125,000	$416,000	$752,000
2b	2yr	425	20.4	0.9 m ⌀	1.65 m ⌀	4.1	$121,000	$29,000	$51,000	$135,000	$336,000	$608,000
2b	2yr	455	15.3	0.6 m ⌀	1.2 m ⌀	1.8	$79,000	$20,000	$47,000	$107,000	$252,000	$456,000
2b	2yr	Kwl1001	22.6	0.6 m ⌀	1.05 m ⌀	1.4	$89,000	$26,000	$41,000	$93,000	$249,000	$451,000
2b	2yr	414_2	18.8	1.2 m ⌀	2.1 m ⌀	7.1	$13,000	$7,000	$14,000	$66,000	$100,000	$182,000
											Priority 2b Subtotal	**$6,289,000**
3a	5yr	KWL016	4.8	3 @ 0.6 m ⌀	2 @ 1.35 m ⌀ and 1 @ 1.05 m ⌀	6.7	$13,000	$6,000	$21,000	$61,000	$100,000	$181,000
3a	5yr	405	23.6	2 m x 3 m box	3 @ 3.05 m x 2.44 m box	38.6	$105,000	$29,000	$44,000	$382,000	$559,000	$1,012,000
3a	5yr	417	24.7	2 m x 3 m box	3 @ 2.7 m x 1.5 m box	28.9	$124,000	$32,000	$47,000	$350,000	$552,000	$999,000
											Priority 3a Subtotal	**$2,192,000**
3b	5yr	474 and 474_2	16.3	0.75 m ⌀ and 0.6 m ⌀	2.1 and 1.65 m ⌀	10.5	$70,000	$19,000	$43,000	$136,000	$268,000	$486,000
3b	5yr	419	17.3	1.2 m ⌀	2.4 m ⌀	10.3	$54,000	$17,000	$36,000	$102,000	$208,000	$377,000
3b	5yr	431	23.6	0.75 m ⌀	1.35 m ⌀	2.7	$148,000	$34,000	$53,000	$142,000	$377,000	$683,000
3b	5yr	476	49.5	0.75 m ⌀	1.35 m ⌀	2.2	$138,000	$48,000	$35,000	$112,000	$333,000	$603,000
3b	5yr	Kwl1004	12.0	0.75 m ⌀	1.35 m ⌀	2.4	$33,000	$10,000	$33,000	$62,000	$138,000	$249,000
3b	5yr	555_2	23.0	0.5 m ⌀	0.9 m ⌀	0.7	$115,000	$30,000	$47,000	$105,000	$297,000	$537,000
3b	5yr	KWL011	14.7	0.75 m ⌀	1.35 m ⌀	2.0	$69,000	$18,000	$45,000	$106,000	$237,000	$430,000
3b	5yr	KWL008	24.2	0.9 m ⌀	1.65 m ⌀	3.7	$61,000	$22,000	$33,000	$89,000	$205,000	$370,000
3b	5yr	KWL501	22.0	2.25 m x 3 m box	3 @ 3.05 m x 2.44 m box	39.5	$140,000	$32,000	$53,000	$392,000	$617,000	$1,118,000
3b	5yr	KWL012	21.1	1.05 m ⌀	1.65 m ⌀	4.2	$144,000	$32,000	$55,000	$149,000	$379,000	$686,000
											Priority 3b Subtotal	**$5,539,000**
4a	10yr	C97	43.0	0.5 m ⌀	1.35 m ⌀	2.1	$30,000	$20,000	$16,000	$72,000	$138,000	$251,000
											Priority 4a Subtotal	**$251,000**
4b	10yr	304	43.3	0.45 m ⌀	1.2 m ⌀	1.6	$87,000	$35,000	$29,000	$74,000	$226,000	$409,000
4b	10yr	297	60.5	0.5 m ⌀	1.2 m ⌀	2.0	$63,000	$35,000	$21,000	$73,000	$192,000	$348,000
4b	10yr	310	9.1	0.5 m ⌀	1.2 m ⌀	1.6	$49,000	$5,000	$49,000	$102,000	$205,000	$372,000
4b	10yr	314	17.2	0.5 m ⌀	1.05 m ⌀	1.4	$59,000	$18,000	$38,000	$81,000	$195,000	$353,000
4b	10yr	319	15.4	0.5 m ⌀	1.05 m ⌀	1.0	$20,000	$9,000	$21,000	$37,000	$87,000	$158,000
4b	10yr	307	22.5	0.6 m ⌀	1.2 m ⌀	1.5	$36,000	$15,000	$25,000	$50,000	$126,000	$229,000
4b	10yr	KWL014	8.0	0.5 m ⌀	0.9 m ⌀	0.8	$14,000	$7,000	$18,000	$34,000	$73,000	$132,000

Table E-1: Class C Cost Estimates for Recommended Culvert Upgrades

Priority	Existing Level of Service	Conduit ID	Length (m)	Existing Size	Required Upgrade Size	200-Yr FLU w/ Climate Change Peak Flow (m^3/s)	Earthworks ($)	Roadworks ($)	Restoration and Planting ($)	Culvert/ Headwalls ($)	Total Cost ($)	Total Cost with Mark-ups ($)
4b	10yr	555	23.0	0.75 m ⌀	1.2 m ⌀	1.6	$115,000	$30,000	$47,000	$112,000	$304,000	$550,000
4b	10yr	492	52.5	0.9 m ⌀	1.35 m ⌀	2.4	$159,000	$54,000	$37,000	$129,000	$379,000	$685,000
4b	10yr	KWL005	19.8	0.9 m ⌀	1.5 m ⌀	2.8	$56,000	$19,000	$34,000	$83,000	$192,000	$348,000
4b	10yr	402	103.4	2.25 m x 3.5 m box	3 @ 3.05 x 2.44 m box	39.1	$1,118,000	$203,000	$70,000	$1,411,000	$2,802,000	$5,072,000
4b	10yr	394	55.2	0.75 m ⌀	1.05 m ⌀	1.4	$74,000	$37,000	$24,000	$66,000	$201,000	$363,000
4b	10yr	KWL021	31.6	0.6 m ⌀	1.05 m ⌀	1.4	$25,000	$15,000	$17,000	$43,000	$100,000	$181,000
4b	10yr	361	39.2	1.8 m ⌀	3.05 m ⌀	15.6	$1,101,000	$123,000	$113,000	$554,000	$1,892,000	$3,425,000
4b	10yr	C4	13.5	0.6 m ⌀	1.2 m ⌀	1.5	$70,000	$17,000	$47,000	$105,000	$240,000	$434,000
4b	10yr	KWL009_1	8.6	1.1 m ⌀	1.65 m ⌀	4.1	$19,000	$2,000	$28,000	$58,000	$107,000	$194,000
4b	10yr	316	28.6	0.6 m ⌀	1.05 m ⌀	1.2	$142,000	$37,000	$47,000	$113,000	$339,000	$613,000
4b	10yr	355	142.2	1.5 m ⌀	2.4 m ⌀	8.9	$687,000	$187,000	$47,000	$396,000	$1,317,000	$2,384,000
4b	10yr	500	48.9	0.9 m ⌀	1.35 m ⌀	2.3	$65,000	$32,000	$24,000	$89,000	$210,000	$381,000
4b	10yr	317	13.9	0.45 m ⌀	0.75 m ⌀	0.5	$71,000	$18,000	$47,000	$100,000	$236,000	$427,000
4b	10yr	416	24.5	1.2 m ⌀	1.65 m ⌀	4.4	$72,000	$24,000	$35,000	$95,000	$227,000	$411,000
4b	10yr	388	14.3	1.2 m ⌀	1.65 m ⌀	3.8	$34,000	$12,000	$31,000	$72,000	$148,000	$269,000
4b	10yr	434	12.7	2.3 m x 3.2 m box	2 @ 3.05 m x 2.44 m box	28.6	$42,000	$13,000	$37,000	$176,000	$268,000	$485,000
4b	10yr	391	11.7	1.2 m ⌀	1.65 m ⌀	3.8	$28,000	$9,000	$30,000	$67,000	$135,000	$244,000
4b	10yr	372	32.6	1.35 m ⌀	1.8 m ⌀	5.4	$170,000	$43,000	$48,000	$146,000	$408,000	$738,000
4b	10yr	371	18.7	1.35 m ⌀	1.8 m ⌀	5.5	$53,000	$18,000	$34,000	$89,000	$194,000	$351,000
4b	10yr	C92	8.2	0.75 m ⌀	1.05 m ⌀	7.1	$187,000	$8,000	$107,000	$364,000	$666,000	$1,205,000
4b	10yr	469_2	94.8	0.9 m ⌀	1.35 m ⌀	9.1	$460,000	$124,000	$47,000	$207,000	$838,000	$1,516,000
4b	10yr	469_3	100.5	0.9 m ⌀	1.2 m ⌀	8.9	$487,000	$132,000	$47,000	$171,000	$837,000	$1,515,000
4b	10yr	450	35.4	1.54 m x 2.4 m box	3 @ 2.7 m x 1.5 m box	11.1	$98,000	$34,000	$44,000	$419,000	$595,000	$1,077,000
4b	10yr	450_2	35.4	1.7 m x 2 m box								
4b	10yr	376	16.7	1.35 m ⌀	1.8 m ⌀	4.9	$68,000	$19,000	$42,000	$104,000	$233,000	$421,000
4b	10yr	396	19.5	0.75 m ⌀	1.05 m ⌀	1.1	$22,000	$11,000	$20,000	$38,000	$91,000	$164,000
4b	10yr	KWL500	32.2	0.9 m ⌀	1.35 m ⌀	2.4	$31,000	$17,000	$19,000	$63,000	$131,000	$237,000
4b	10yr	380	14.2	1.35 m ⌀	1.8 m ⌀	4.9	$28,000	$10,000	$27,000	$58,000	$123,000	$222,000
4b	10yr	384	15.4	1.35 m ⌀	1.65 m ⌀	3.9	$49,000	$15,000	$36,000	$86,000	$186,000	$336,000
4b	10yr	KWL009_2	15.7	1.1 m ⌀	1.5 m ⌀	3.0	$48,000	$15,000	$35,000	$88,000	$186,000	$336,000
4b	10yr	377	26.1	1.5 m ⌀	1.8 m ⌀	4.9	$65,000	$23,000	$32,000	$84,000	$205,000	$370,000
											Priority 4b Subtotal	**$26,955,000**
5	100yr	KWL004	23.0	2.2 m x 3.4 m box	2 @ 2.7 m x 1.5 m box	22.4	$291,000	$48,000	$75,000	$365,000	$779,000	$1,410,000
5	100yr	356	108.0	1.4 m x 2.1 m box	2 @ 2.1 m x 1.2 m box	7.3	$772,000	$173,000	$57,000	$570,000	$1,572,000	$2,845,000
5	100yr	315	38.6	0.5 m ⌀	0.9 m ⌀	0.8	$129,000	$41,000	$38,000	$88,000	$298,000	$539,000
5	100yr	C238	9.9	0.4 m ⌀	0.675 m ⌀	0.4	$52,000	$12,000	$47,000	$98,000	$210,000	$379,000
5	100yr	467	10.8	0.4 m ⌀	0.6 m ⌀	0.3	$20,000	$7,000	$25,000	$36,000	$88,000	$159,000
5	100yr	469_6	109.6	1.05 m ⌀	1.5 m ⌀	12.7	$531,000	$144,000	$47,000	$266,000	$988,000	$1,788,000
5	100yr	469_5	110.5	1.05 m ⌀	1.5 m ⌀	12.2	$535,000	$145,000	$47,000	$267,000	$995,000	$1,801,000
5	100yr	469_1	150.4	0.9 m ⌀	1.2 m ⌀	7.0	$727,000	$198,000	$47,000	$208,000	$1,180,000	$2,136,000
5	100yr	469_7	373.2	1.05 m ⌀	1.35 m ⌀	13.2	$1,796,000	$492,000	$47,000	$533,000	$2,868,000	$5,191,000
5	100yr	469_4	228.7	1.05 m ⌀	1.35 m ⌀	11.2	$1,103,000	$301,000	$47,000	$363,000	$1,814,000	$3,283,000
5	100yr	C59_2	94.9	1.05 m ⌀	1.35 m ⌀	6.0	$819,000	$166,000	$63,000	$263,000	$1,311,000	$2,373,000
5	100yr	298	17.1	0.75 m ⌀	1.2 m ⌀	1.5	$34,000	$13,000	$28,000	$52,000	$127,000	$229,000
5	100yr	382	190.0	0.75 m ⌀	1.05 m ⌀	1.1	$917,000	$250,000	$47,000	$212,000	$1,426,000	$2,581,000
5	100yr	293	62.9	0.75 m ⌀	1.2 m ⌀	1.7	$116,000	$50,000	$28,000	$87,000	$281,000	$509,000
5	100yr	383	63.6	0.75 m ⌀	0.9 m ⌀	1.0	$310,000	$83,000	$47,000	$122,000	$563,000	$1,018,000
5	100yr	KWL013	21.0	0.6 m ⌀	0.9 m ⌀	0.8	$24,000	$12,000	$20,000	$36,000	$92,000	$166,000
5	100yr	435	16.1	0.9 m ⌀	1.05 m ⌀	1.4	$72,000	$19,000	$44,000	$96,000	$230,000	$417,000
5	100yr	454	138.4	0.6 m ⌀	0.9 m ⌀	0.6	$670,000	$182,000	$47,000	$154,000	$1,052,000	$1,904,000
5	100yr	410	13.2	0.6 m ⌀	0.75 m ⌀	0.5	$68,000	$17,000	$47,000	$100,000	$232,000	$419,000
5	100yr	290	21.1	1.2 m ⌀	1.5 m ⌀	3.4	$140,000	$31,000	$54,000	$153,000	$379,000	$685,000
											Priority 5 Subtotal	**$29,832,000**
6	200yr	469_9	158.0	1.35 m ⌀	1.65 m ⌀	13.2	$763,000	$208,000	$47,000	$296,000	$1,314,000	$2,378,000
6	200yr	Kwl007	22.0	0.9 m ⌀	1.05 m ⌀	1.3	$81,000	$24,000	$40,000	$89,000	$234,000	$424,000
6	200yr	260	101.8	0.525 m ⌀	0.6 m ⌀	1.1	$493,000	$134,000	$47,000	$116,000	$790,000	$1,431,000
6	200yr	365	20.8	2.25 m x 2.45 m box	3.05 x 2.44 m box	13.7	$380,000	$52,000	$91,000	$375,000	$897,000	$1,624,000
6	200yr	C59_1	92.4	1.2 m ⌀	1.35 m ⌀	9.2	$449,000	$121,000	$47,000	$204,000	$821,000	$1,485,000
6	200yr	C249	18.9	1.05 m ⌀	1.35 m ⌀	2.4	$96,000	$24,000	$47,000	$117,000	$284,000	$514,000
											Priority 6 Subtotal	**$7,856,000**

1. Conduit IDs with underscores are pipes that had to be split in the model. Conduit IDs beginning with C or KWL are conduits that were found during the survey or engineering inventory that were not in the District's GIS database.
2. Grey shading represents end of life upgrades only.
3. Assumed existing diversions will not be upgraded. Downstream infrastructure sized to convey remaining undiverted flows.
4. Where culvert inverts unknown, a depth of 4 m was assumed for cost estimates.
5. Where multiple box culverts have been recommended it may be more cost effective to replace with a bridge depending on site specific constraints.

Appendix F

Mitigation of Future Development

KERR WOOD LEIDAL
consulting engineers

Greater Vancouver
200 - 4185A Still Creek Drive
Burnaby, BC V5C 6G9
T 604 294 2088
F 604 294 2090

Technical Memorandum

DATE: September 12, 2016

TO: Tony Tse, P.Eng., Manager of Development Engineering

FROM: Chris Johnston, P.Eng.

RE: **DISTRICT OF WEST VANCOUVER**
Single Family Redevelopment Lot Rainwater Management Guidelines
Our File 409.050-300

1. Introduction

1.1 Purpose

The purpose of this memorandum is to provide the District of West Vancouver (District) with:

- methodology in assessing the impacts from redevelopment of a single family residential lot;
- design criteria for redevelopment of single family residential lot; and
- design guidance for permit application.

This information is intended to be used as a guide to facilitate submission and evaluation for redevelopment of single-family residential lots. A professional engineer specializing in stormwater management will be required to seal all calculations and drawings for each re-developed lot.

1.2 Limitations

This guide is for single-family residential re-development only. For other land uses, development impacts and rainwater management design are required to be assessed by a Professional Engineer specialized in rainwater or stormwater management using a similar methodology or a different process approved by the District.

This guide applies to a majority of the existing single-family lots in West Vancouver where re-development is proposed. However, in areas of geotechnical concern (i.e. lots next to ravines or geotechnically significant slopes, etc.), a professional geotechnical engineer should be engaged by the applicant to review the applicability of disconnected impervious surfaces to infiltration areas. Also, in areas where an Integrated Stormwater Management Plan (ISMP) has been completed, the ISMP will govern over this document.

2. Rainwater Management Requirements

The basic requirements of this bylaw are listed as follows:

1. Prior to carrying out any development and/or re-development, [the permit applicant] must submit a rainwater management plan for the site and must obtain the District's written approval of the plan.
2. For any development and/or re-development, the rainwater management system must be installed according to the plan and will be inspected by the District prior to approval of permit.
3. The site rainwater management plan should include:
   - A site plan showing the following:
     - Overall site showing lot dimensions and area;
     - **proposed** development including all buildings, patios, decks, driveways, and other impervious surfaces as well as gardens, lawn areas, and undisturbed areas. Areas must be labeled and their footprint area must be calculated and noted in sq.metres;
     - **existing** development including all buildings, patios, decks, driveways, and other impervious surfaces as well as gardens, lawn areas, and undisturbed areas. Areas must be labeled and their footprint area must be calculated in sq.metres. Existing surfaces should be shown by dashed lines;
     - location of the District's storm sewer connection;
     - 1 metre elevation contours and labeling;
     - Property boundaries;
     - General grading and slopes for overland drainage c/w arrows;
     - Upslope interception ditches (if applicable) to protect property from surface runoff (Note: interceptor ditches can't be used to intercept groundwater or interflow); and
     - Proposed drainage facilities including locations of roof leaders, splash pads, storage tanks, rock pits, overflow locations, lawn basins, etc.
   - Area calculation (sq. meters) showing the proposed change in connected impervious area.
   - Calculation of volume (cubic metres) and rate of runoff (cubic metres / second) from the **existing** site (excluding natural forested areas).
   - Calculation of volume and rate of runoff from the **proposed** development on the site (excluding natural forested areas).
   - Storage volume required as shown in Section 4 complete with orifice dimensions and calculation.
   - Description, drawing and sizing of the rainwater source controls to be used.
   - A description of the applicable Operations and Maintenance (O&M) requirements for the rainwater management system in accordance with District's Development Bylaw.
   - The submission must include drawings, calculation notes, graphs, and digital spreadsheets. The submission shall be sealed by a Profession Engineer registered in B.C. and specializing in stormwater management.

3. Rainwater Management Criteria - Single Family Redevelopment

There are two design criteria required under these guidelines to adequately address the re-development of single family lots: Detention Storage and Volumetric Capture. Detention storage applies to the NEW impervious surfaces proposed in the redevelopment plan. Should no new surfaces be planned, no detention storage will be required. Volumetric Capture, on the other hand, applies to ALL impervious surfaces on the redeveloped site.

3.1 Detention Storage Criteria

For redevelopment of single-family residential lots, there shall be no net increase in the rate of rainwater runoff from existing conditions. Under no circumstances shall the runoff exceed existing conditions unless approved by the District. Existing conditions are defined as state of the land prior to any alterations proposed or undertaken as part of a permit application. Existing conditions include mature forest cover, grass/gardens, and impervious and semi-impervious areas.

Redevelopment of a site shall include design to handle any runoff increase above existing conditions during the 10-year return period storm event on-site. Only, the natural, forested areas can be excluded from the runoff calculations in both the existing and proposed development calculations.

All sites shall have a storage facility to assist in attenuating rainwater runoff flows for the 10-year event under six design storm durations ranging from 1-hours to 24-hours. Methodology in sizing of a tank is provided in Section 4 of this document.

3.2 Volume Capture Criteria

In addition to the detention storage criteria, a volumetric “capture” criterion is required. This criteria is required to mitigate against increasing erosion in creeks and watercourses caused by increasing impervious surfaces. It also lessons the damage to the aquatic environment, and improves water quality along the beaches of the District.

Redevelopment of a site shall include the necessary measures to infiltrate or re-use the first 31 mm of rainfall assuming dry conditions. This can also be expressed as treating 75% of the annual rainfall amount. This shall apply to all surfaces: existing and proposed.

Exceptions: In areas of geotechnical concern (i.e. lots next to ravines or geotechnically significant slopes, etc.), a professional geotechnical engineer should be engaged by the applicant to review the applicability of infiltration measures. In these areas, the detention storage requirements will be increased to accommodate a rate-of-discharge release to the storm sewer where the rate-of-discharge is equal to the infiltration rate of the native soil times the lot area.

4. Volume Analysis for Detention Storage

Volume analysis shall be performed using a version of the Rational Method provided in this document. All calculations shall be performed and sealed by the Design Engineer. Selection of runoff coefficients for each surface must be clearly identified.

4.1 Rational Method

The volume of runoff for any given time step on smaller residential properties can be calculated using the formula:

Runoff Volume (cubic metres) = C * R /1000 * A

Where

C = runoff Coefficient (Table 1 below)
R = Rainfall amount over a time interval (mm)
A = Area (sq. m.)

The runoff coefficients are provided below.

Table 1: Runoff Coefficient (C)

Surface	10 Year Runoff Coefficient
Driveway	1.0
Roof	1.0
Patio / Deck / Pool Areas	1.0
Grass (400 mm Topsoil)	.75
Gardens (400+ mm Topsoil)	.75
Natural Woodlands/Mature Forest	.65

Multiple surfaces can be added together by performing the above equation for each surface then adding together to summarize the entire lot area (including undeveloped areas).

Note: the above equation should only be used for single-family residential sites less than 2,500 sq.m in size. The equation will overestimate runoff volume on larger sites.

4.2 Rainfall and Elevation Correction

Rainfall amounts for the runoff calculations are provided in Table 2. These depths are derived from a rainfall Intensity-Duration-Frequency (IDF) curve for the Metro Vancouver's District of West Vancouver Municipal Hall (VW14) rain gauge. Table 2 is valid for site elevations less than 100 m geodetic elevation within the District of West Vancouver.

For higher elevations, an elevation correction factor shall be applied to adjust the rainfall depth to reflect actual conditions. For single family residential lots located in elevations ranging from 100 m to 400 m, a factor of 1.45 shall be applied to the rainfall depths. For higher elevations ranging from 401 m to 950 m, a factor of 1.9 shall be applied to the rainfall depths.

Table 2 lists rainfall amounts for design storms ranging from 1-hour to 24-hours. The storm shapes are based on historic patterns for the District.

By applying the above formula for each rainfall time step, a runoff hydrograph can be created for both the existing development scenario and the re-developed scenario.

4.3 Determination of Storage Volume Required

The Rational Method described above shall be used to calculate the storage volume required to detain excess runoff from the proposed redevelopment. Excess water is defined as the additional peak flow that would be flowing from the site in re-development conditions over existing conditions.

To do this, a detention spreadsheet should be created that calculates the amount of runoff leaving the the site in both existing conditions and proposed re-development conditions. Only, the natural, forested areas can be excluded from the runoff calculations in both the existing and proposed development calculations. The calculations will be performed using a time step approach whereby the flow leaving the site is calculated in 5 to 10 minute time steps.

This can be accomplished in the following manner:

1. Six design storms are provided (see Table 2). Calculate the volume released in each time step for each storm for the existing development scenario (linear interpolation can be used to derive 5-minute rainfall amounts);
2. Determine the maximum 5-minute time step volume released for each storm;
3. Size an orifice and detention tank volume that matches the proposed development release rate to the existing development release rate for each storm within 10%.
4. The release rate of the 10-year, 6-hour storm can not exceed 31.8 L/s/ha under any circumstances;
5. It is acceptable to include an overflow volume in the calculation of a release rate as long as the combined orifice flow and overflow do not exceed the existing develop flow.

This will provide the tank and orifice size.

Existing development and post-development calculations will be performed on the entire site NOT the incremental impervious area difference.

Figure 1 provides an example of what this should look like for the 1-hour storm.

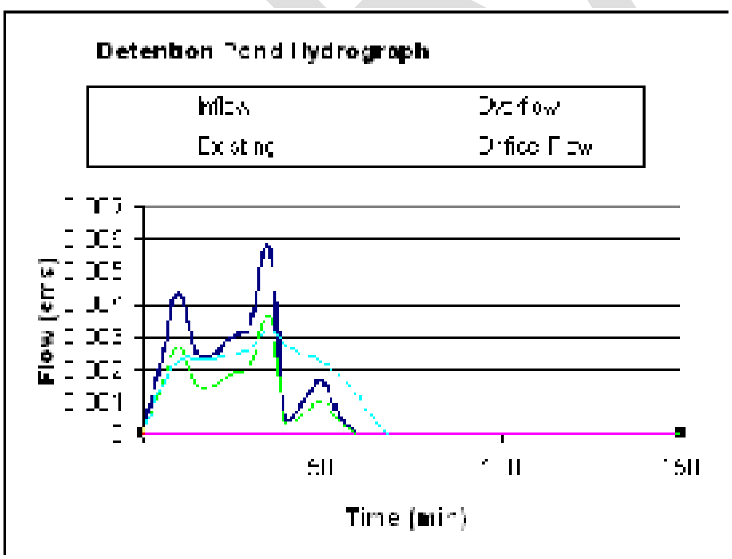


Figure 1

4.4 Orifice Calculation

Release rates using orifices can be calculated using the standard orifice equation as follows:

Release Rate (cms) = 0.6 x Orifice Area (sq.m.) x (19.62 x H (m))$^{0.5}$

Where:

H – the height of water above the orifice centreline

The release rate can then be multiplied by the time step to calculate an allowable release volume.

The minimum size of an orifice will be 10 mm for the detention tank. Actual size will be determined based on an iterative process using the above calculations.

The easiest way to perform the above set of calculations is within a spreadsheet. It should be noted that depending on the dimensions of the storage tank, the designer may wish to add addition time steps through interpolation for greater accuracy.

4.5 Storage Facilities

The Design Engineer shall select one storage facility that can retain rainwater on-site and limit runoff flows to not exceed existing conditions.

The Design Engineer must ensure all rainwater captured on site drains into the storage facility.

The storage facility will have an overflow outlet connected to the District's storm sewer or drainage system. The maximum hydraulic grade line (HGL) of the storage facility will be noted on the drawings along with the minimum building elevation. The minimum building elevation must be above the maximum HGL of the storage facility.

4.6 Outlet Flow Control

The Design Engineer shall ensure outlet flow from the storage facility is controlled to not exceed existing runoff conditions by designing and sizing an orifice outlet to control outflows. The orifice shall be protected in such a way to avoid plugging by floatables and other materials. An access hatch shall be provided to maintain the orifice.

4.7 Perimeter Drains

Perimeter drains shall not be connected to the storage facility. Under no circumstances can the surface collection system be connected to the building footing drain system upstream of the storage facility.

5. Analysis and Methods of Volumetric Capture Criteria

This section provides the background information available to guide the design of the measures required to meet the volumetric capture criteria. The designer is also referred to the supporting documentation: Metro Vancouver Stormwater Source Control Guidelines 2012. Together, these documents form the requirements for achieving the volumetric capture criteria.

5.1 Sizing Methods for Volumetric Capture Criteria

The Stormwater Source Control Guidelines 2012 provides specifications, design details, and sizing criteria for the main capture measures proposed: Pervious Paving, Infiltration Trench and Soakaway, Infiltration Swale System, and Absorbent Landscape.

Sizing for each of the measures is proposed as follows:

- **Pervious Paving:** Pervious Paving surfaces shall include a 0.3m deep rock trench below the sand layer. See Figure 2 for additional design considerations.
- **Infiltration Trench (Rock Trench/Pits):** Rock trenches shall be 1.5m deep and shall not exceed a contributing area to trench footprint area ratio of 20:1. Infiltration trenches shall include an orifice sized to release water at 0.25 L/s/ha of contributing area. See Figure 3 for additional design considerations. Contributing areas should first run overland prior to entering the rock trench.
- **Rain Gardens:** Rain Gardens shall have rock trenches that are 1.5m deep and shall not exceed a contributing area to trench footprint area ratio of 20:1. Infiltration trenches shall include an orifice sized to release water at 0.25 L/s/ha of contributing area. See Figure 4 for additional design considerations. Contributing areas should first run overland prior to entering the rock trench.
- **Absorbent Landscape:** provide 400 mm of top soil (growing medium), and terrace to less than 2% slope. No additional sizing is required. The re-direction of impervious surfaces can be used provided the ratio of impervious surface to absorbent landscape doesn't exceed 2. A lawn basin must be installed at a downslope location to intercept any sheet flow prior to discharge on neighbouring lots. The lawn basin shall be connected to the storage facility.

5.2 Absorbent Landscape

All cleared and landscaped areas not covered with hard surfaces shall have a minimum of 400 mm of top soil and will be terraced as much as possible to maintain vegetated areas of 2% slope or flatter.

Topsoil may be existing growing medium that was removed during construction, stockpiled, and replaced on the site, or it may be imported topsoil. Where topsoil is imported, it must be shown to meet appropriate landscape standards for organic content (see MMCD "Properties for growing medium"), and the other requirements contained in the "Absorbant Landscape" section of the *Stormwater Source Control Guidelines 2012*. Existing and imported topsoil must have a minimum of 3.5 mm/hr infiltration rate.

Where disconnected impervious surfaces are directed to absorbent landscaping, the impervious surface to absorbent landscaping ratio can't exceed 2.

5.3 Forest Areas

The Design Engineer shall make every effort to limit the reduction of forest cover as much as possible. Tree canopies of mature, existing forest trees are valuable for rainwater management on any site. For the purposes of this guideline, it is assumed that natural forested areas meet the volumetric capture target and no further action is required.

Forested areas cannot be used as treatment measures for re-directed impervious areas.

5.4 Driveways – Pervious Paving

If the existing driveway will remain intact and will not be modified in any way, no new measures are required. However, if the driveway surface is increased or the surface is re-constructed, the volumetric capture criteria will apply. Treatment methods could include re-direction of runoff to absorbent landscaping or infiltration trenches or the reconstruction of the driveway using pervious paving techniques together with an infiltration trench if required.

5.5 Roof Leaders and Patios

All roof and patio areas shall be discharged to splash pads (Armtec Product No: SP50603, SP50903, SP51203, or equivalent) and allowed to infiltrate into the ground (absorbent landscape). Where there isn't sufficient area to accomplish this, infiltration trenches or rain gardens shall be used.

The maximum contributing roof area per splash pad is recommended to be 50 sq.m. Absorbant landscaping shall be used to receive the rainwater such that the roof or patio area divided by the absorbant landscape area does not exceed 2.

Splash pads with a minimum length of 600 mm shall be installed at the discharge area of the roof leaders. Water shall then be allowed to flow towards either a lawn or garden with a minimum surface infiltration travel length of 4 meters. The depth of top soil (growing medium) under the travel length shall be 400mm. These areas will be graded to a lawn basin. For larger storm events, the infiltration of the growing medium will be exceeded. Therefore, a lawn basin will be required to intercept all surface runoff from a disconnected roof leader and patio area such that neighbouring properties are not impacted. The lawn basin(s) will be connected directly to a storage facility and clearly shown on the site drawing and other relevant drawings.

An impermeable barrier must be provided between the splash pad area and the building footing drain system. This can be accomplished either by the use lower permeable soil or an appropriate membrane.

No surface runoff shall be allowed to flow on to neighbouring properties. All surface runoff must be intercepted. As well, all trenches, rock pits, and other unground conduits must be appropriately sealed to prevent uncontrolled groundwater or interflow from leaving the subject property at rates that greater than pre-developed rates. This can be accomplished through the use of low permeable trench dams.

In some cases, it may necessary to intercept the roof leader, then daylight the piping away from the building. This shall be deemed acceptable provided the minimum conditions of vegetative length, growing medium depth, and lawn basin requirements noted above are still met.

If the disconnection of roof leaders is not possible in some circumstances, an equivalent infiltration trench (rock pit) can be used provided a sediment sump is located upstream, and the rock pit incorporates an overflow that discharges to the storage facility (see Section 4).

5.6 Infiltration Trenches and Rain Gardens

Direct connection of any surface level impervious surfaces to infiltration trenches (rock pits) and Rain Gardens is prohibited. Water entering an infiltration trench or rain garden must first flow overland through pervious vegetation (minimum travel length 4.0m). Roof water must also flow overland prior to infiltration connection. Where roof water cannot be disconnected due to vegetated areas, a sediment sump shall be used prior to rock pit connection.

Direct connection of surface level impervious surfaces to infiltration trenches and rain gardens is permitted.

Infiltration trenches and rain gardens shall be designed with the following features:

- A minimum 600 mm diameter sump c/w 500 mm (minimum) sediment trap and floatables protection must be installed upstream of the infiltration trench. Floatables protection shall accomplished using a 150mm diameter tee on the outlet connection.
- A perforated drain shall be installed at the top of the rock layer below the growing medium and must connected directly to the storage facility;
- The depth of a rock layer cannot exceed 2 m below the ground surface;
- The minimum depth of a rock layer is 1.5 m;
- Appropriate filter fabric shall be used on the surface of the infiltration trench to prevent migration of fines from the topsoil layer (growing medium) to voids rock material; and,
- Infiltration testing of native sub-surface soil conditions should be carried out in the area of the proposed infiltration trench. **Under no circumstances will an infiltration trench or rain garden be designed or allowed to exfiltrate more than 3.5 mm/hr.** If the testing confirms an infiltration rate greater than 3.5 mm/hr, lower permeable soils should be used to lower exfiltration below 3.5 mm/hr.

Infiltration trenches and rain gardens must be constructed in native material and cannot be bisected by utility trenches or highly permeable soils. In cases where this cannot be avoided, trench dams comprising low permeable material can be used to prevent the trench from exfiltration at rates greater than 3.5 mm/hour.

In some cases blasting of the bedrock may be required to create the construction of the rock layer. Raising the ground elevation with imported fill is also acceptable provided that the fill material does not allow the infiltration to exceed 3.5 mm/hr. This will require a lower permeable fill material.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Chris Johnston, P.Eng.
Stormwater Specialist

Reviewed by:

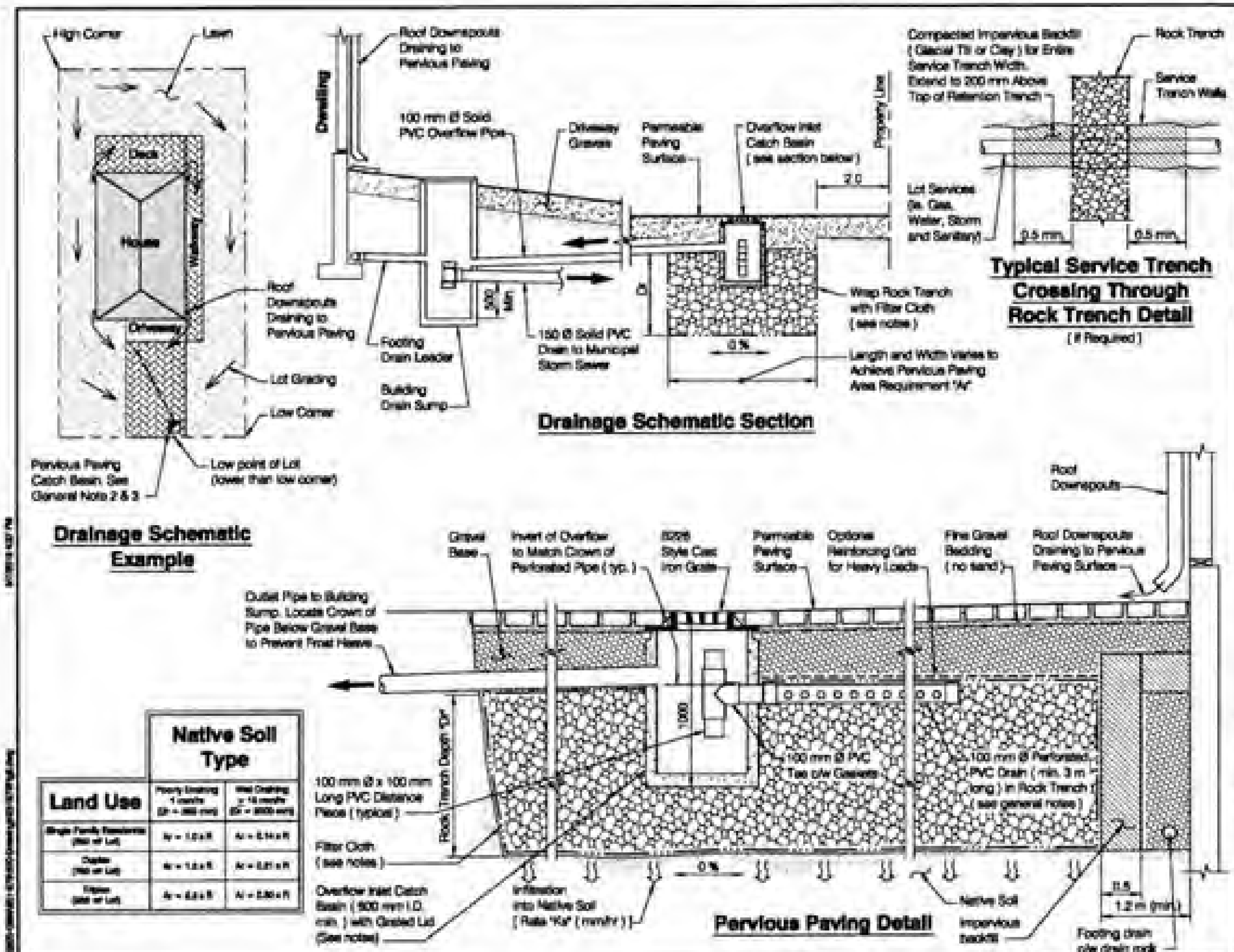
Crystal Campbell, P.Eng.
Technical Review

Attach.

Figure2 – 4
Table 2

Statement of Limitations

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.



Land Use	Native Soil Type	
	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

Metro Vancouver Region Wide Baseline For Onsite Rainwater Management

Pervious Paving Areas:

Pervious Paving Notes:

General Notes:

KERR WOOD LEIDAL consulting engineers

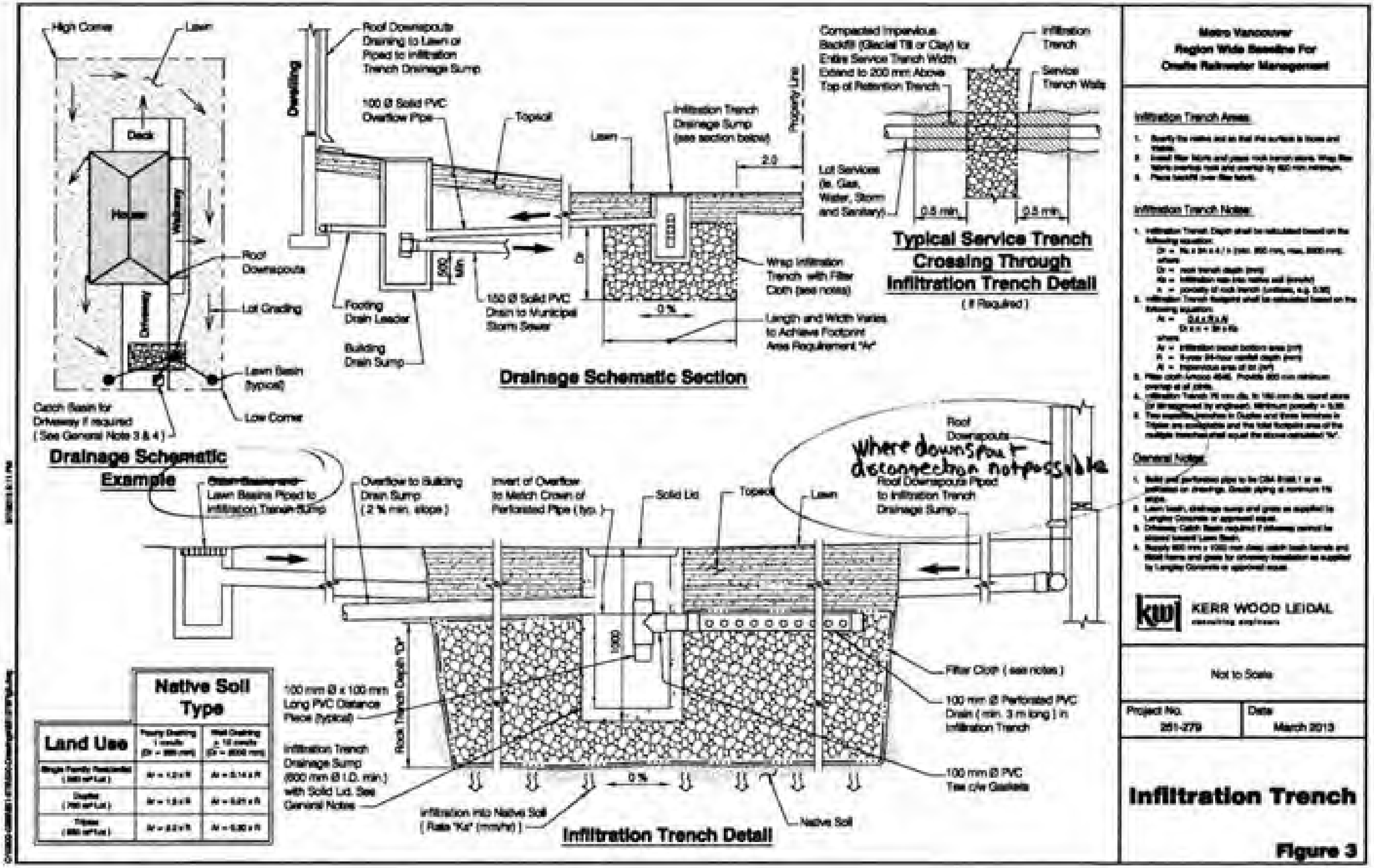
Not to Scale

Project No. 251-279

Date March 2013

Pervious Paving

Figure 2



High Corner
Lawn
Deck
House
Walkway
Driveway
Roof Downspouts
Lot Grading
Lawn Basin (typical)
Low Corner
Catch Basin for Driveway if required (See General Note 3 & 4)
Drainage Schematic Example
Dwelling
Roof Downspouts Draining to Lawn or Piped to Infiltration Trench Drainage Sump
100 Ø Solid PVC Overflow Pipe
Topsoil
Lawn
Infiltration Trench Drainage Sump (see section below)
Property Line
2.0
Footing Drain Leader
Building Drain Sump
150 Ø Solid PVC Drain to Municipal Storm Sewer
Wrap Infiltration Trench with Filter Cloth (see notes)
0 %
Length and Width Varies to Achieve Footprint Area Requirement "Ar"
Drainage Schematic Section
Compacted Impervious Backfill (Glacial Till or Clay) for Entire Service Trench Width. Extend to 200 mm Above Top of Retention Trench
Infiltration Trench
Service Trench Walls
Lot Services (ie. Gas, Water, Storm and Sanitary)
0.5 min.
0.5 min.
Typical Service Trench Crossing Through Infiltration Trench Detail
(If Required)
Lawn Basins Piped to Infiltration Trench Sump
Overflow to Building Drain Sump (2 % min. slope)
Invert of Overflow to Match Crown of Perforated Pipe (typ.)
Solid Lid
Topsoil
Lawn
Roof Downspouts
Roof Downspouts Piped to Infiltration Trench Drainage Sump
Where downspout disconnection not possible
Rock Trench Depth "Dr"
100 mm Ø x 100 mm Long PVC Distance Piece (typical)
Infiltration Trench Drainage Sump (600 mm Ø I.D. min.) with Solid Lid. See General Notes
Infiltration into Native Soil (Rate "Ks" (mm/hr))
0 %
Native Soil
Filter Cloth (see notes)
100 mm Ø Perforated PVC Drain (min. 3 m long) in Infiltration Trench
100 mm Ø PVC Tee c/w Gaskets
Infiltration Trench Detail
Native Soil Type
Land Use
Metro Vancouver
Region Wide Baseline For
Onsite Rainwater Management
Infiltration Trench Areas:
Infiltration Trench Notes:
General Notes:
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Not to Scale
Project No.
251-279
Date
March 2013
Infiltration Trench
Figure 3

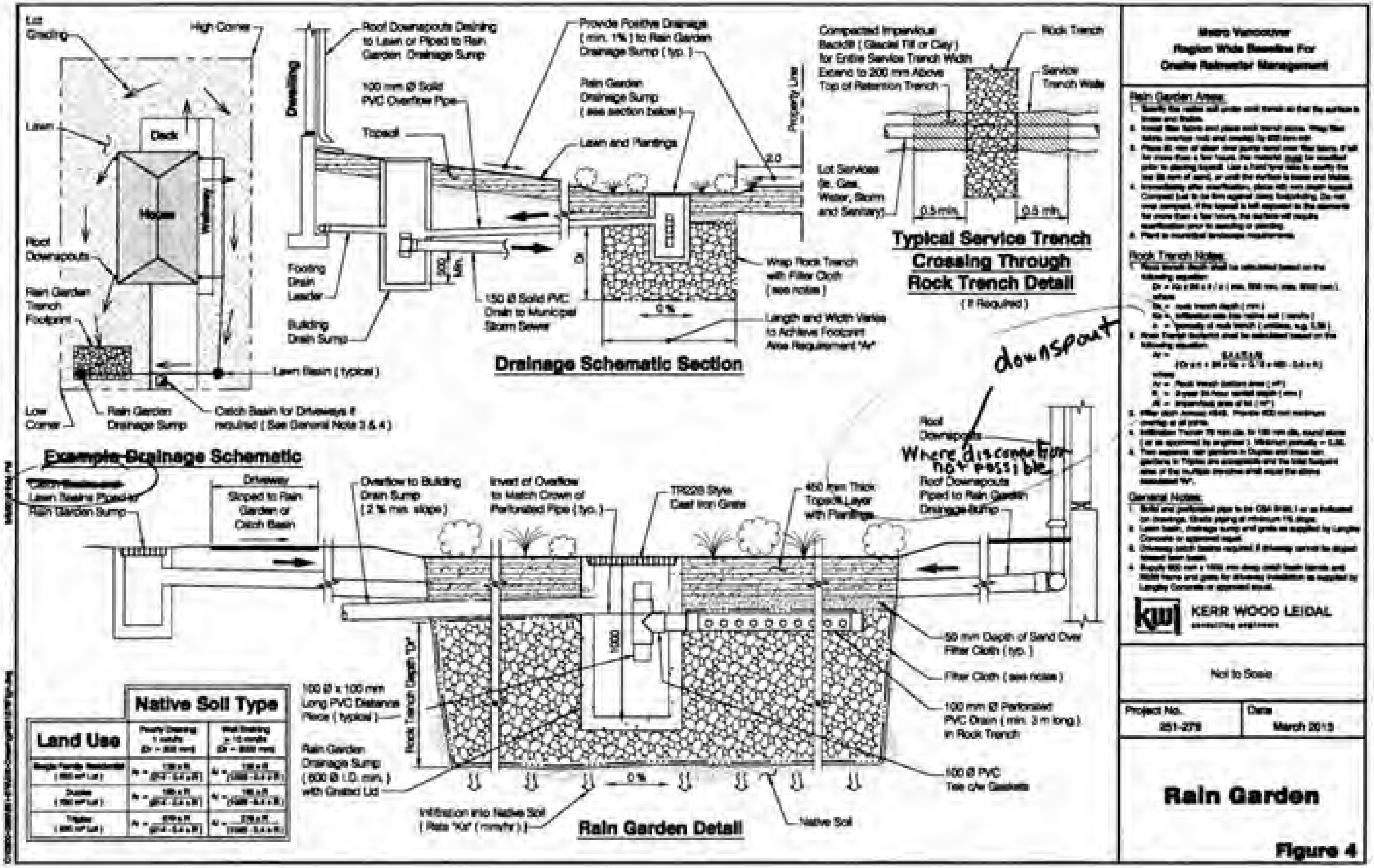
Metro Vancouver
Region Wide Baseline For
Onsite Rainwater Management
Example Drainage Schematic
Lot Grading
High Corner
Lawn
Deck
House
Walkway
Roof Downspouts
Rain Garden Trench Footprint
Lawn Basin (typical)
Low Corner
Rain Garden Drainage Sump
Catch Basin for Driveways if required (See General Note 3 & 4)
Drainage Schematic Section
Dwelling
Roof Downspouts Draining to Lawn or Piped to Rain Garden Drainage Sump
100 mm Ø Solid PVC Overflow Pipe
Topsoil
Footing Drain Leader
Building Drain Sump
150 Ø Solid PVC Drain to Municipal Storm Sewer
Provide Positive Drainage (min. 1%) to Rain Garden Drainage Sump (typ.)
Rain Garden Drainage Sump (see section below)
Lawn and Plantings
Property Line
2.0
Wrap Rock Trench with Filter Cloth (see notes)
0 %
Length and Width Varies to Achieve Footprint Area Requirement "Ar"
Typical Service Trench Crossing Through Rock Trench Detail
(If Required)
Compacted Impervious Backfill (Glacial Till or Clay) for Entire Service Trench Width Extend to 200 mm Above Top of Retention Trench
Rock Trench
Service Trench Width
Lot Services (ie. Gas, Water, Storm and Sanitary)
0.5 min.
0.5 min.
downspout
Where disconnection not possible
Rain Garden Detail
Driveway
Sloped to Rain Garden or Catch Basin
Lawn Basins Piped to Rain Garden Sump
Overflow to Building Drain Sump (2 % min. slope)
Invert of Overflow to Match Crown of Perforated Pipe (typ.)
TR220 Style Cast Iron Grate
450 mm Thick Topsoil Layer with Plantings
Roof Downspouts
Roof Downspouts Piped to Rain Garden Drainage Sump
Rock Trench Depth "D"
100 Ø x 100 mm Long PVC Distance Piece (typical)
Rain Garden Drainage Sump (600 Ø I.D. min.) with Grated Lid
Infiltration into Native Soil (Rate "Ks" (mm/hr))
Native Soil
50 mm Depth of Sand Over Filter Cloth (typ.)
Filter Cloth (see notes)
100 mm Ø Perforated PVC Drain (min. 3 m long) in Rock Trench
100 Ø PVC Tee c/w Gaskets
Native Soil Type
Land Use
Rain Garden Areas:
Rock Trench Notes:
General Notes:
KERR WOOD LEIDAL
consulting engineers
Not to Scale
Project No.
251-279
Date
March 2015
Rain Garden
Figure 4

Table 2
AES Design Storms - West Vancouver Municipal Hall

10-year 1-hour	30% curve	10-year 2-hour	30% curve		10-year 4-hour	30% curve	10-year 6-hour	50% curve	10-year 12-hour	50% curve	10-year 24-hour	50% curve
Time (minutes)	Rain (mm)	Time (minutes)	Rain (mm)		Time (minutes)	Rain (mm)	Time (minutes)	Rain (mm)	Time (minutes)	Rain (mm)	Time (minutes)	Rain (mm)
0	0.000	0	0.000	0.000	0	0.000	0	0.000	0	0.000	0	0.000
5	1.529	10	2.211	1.525	20	2.880	30	2.975	60	4.302	120	6.221
10	3.057	20	4.421	3.049	40	5.760	60	3.471	120	5.019	240	7.258
15	1.720	30	2.487	1.715	60	3.240	90	4.958	180	7.170	360	10.369
20	1.720	40	2.487	1.715	80	3.240	120	2.479	240	3.585	480	5.185
25	2.102	50	3.040	2.096	100	3.960	150	3.471	300	5.019	600	7.258
30	2.293	60	3.316	2.287	120	4.320	180	6.942	360	10.039	720	14.517
35	4.013	70	5.803	4.002	140	7.560	210	4.463	420	6.453	840	9.332
40	0.382	80	0.553	0.381	160	0.720	240	4.958	480	7.170	960	10.369
45	0.764	90	1.105	0.762	180	1.440	270	4.463	540	6.453	1080	9.332
50	1.147	100	1.658	1.143	200	2.160	300	4.463	600	6.453	1200	9.332
55	0.382	110	0.553	0.381	220	0.720	330	3.471	660	5.019	1320	7.258
60	0.000	120	0.000	0.000	240	0.000	360	3.471	720	5.019	1440	7.258