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REPORT

Ministry of Transportation and Infrastructure

Powell River Regional District
Drainage Study
Electoral Areas A, B & C




March 2018

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF
Signature
Date MARCH 23, 2018 08-18-002

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1 Introduction

1.1 SCOPE OF WORK

The BC Ministry of Transportation and Infrastructure (MOTI), in cooperation with the Powell River Regional District (PRRD), engaged Associated Engineering (AE) to undertake a high-level drainage study for Electoral Areas A, B, and C within the PRRD.

The need for the project is triggered by recent and ongoing flooding and erosion issues, and their impacts on property and the linear drainage system (typically ditches and culverts along MOTI roads). Lack of consideration of drainage during land development, and modifications to the natural drainage pathways have contributed to increased occurrences of problems throughout the region. If not addressed, these issues are anticipated to intensify with further land development and the effects of climate change.

Tetra Tech EBA completed a Landslide and Fluvial Hazards Study for Electoral Areas B and C in 2015. One of the recommendations from that study was for the PRRD to “develop a comprehensive plan for drainage control and stormwater management in coordination with other key stakeholders. One of the key outcomes of this plan would be to develop maintenance and rehabilitation protocols for local watercourses, ditches, and culverts.”

This drainage study is intended to be the initial step towards developing a comprehensive drainage plan, which may take the form of a regional Integrated Stormwater Management Plan (ISMP), or one or more Master Drainage Plans (MDP). The objectives of this study are to conduct a high-level review of the drainage system and reported concerns from stakeholders to improve the understanding of the key issues related to stormwater management, and how they may be mitigated. Throughout this study, we have applied ISMP principles related to responsible stormwater management, within the specific physiographic, climatic, and regulatory context of the PRRD study area.

Based on our understanding of the study area, successful management of drainage requires participation from three primary groups within the regional district:

- MOTI is responsible for much of the drainage system, via ditches and culverts along roads they have built or maintain. This system is needed to convey high flows safely to various discharge points and protect road infrastructure from drainage/flooding issues.
- The PRRD is the regulatory body responsible for managing land development in such a way that it does not adversely impact the watersheds and drainage systems throughout the region.
- The landowners are responsible for their own on-lot drainage, and maintaining their local drainage systems. Their land use and development decisions directly influence runoff characteristics and so influence the condition of the watershed and drainage system considerably.

This unique joint responsibility between these three stakeholders is critical, and is discussed in detail throughout the report.

1.2 STUDY AREA

This study was commissioned to cover the mainland of Electoral Areas A, B, and C, with a focus on MOTI infrastructure from Saltery Bay west to Lund. Areas under the jurisdiction of the City of Powell River and Tla'amin First Nation lands are excluded from the study, as are the two MOTI roads originating on the arms of Powell Lake (Olsen Lake Road, and Allen Road). The study area is shown in Map 1-1.

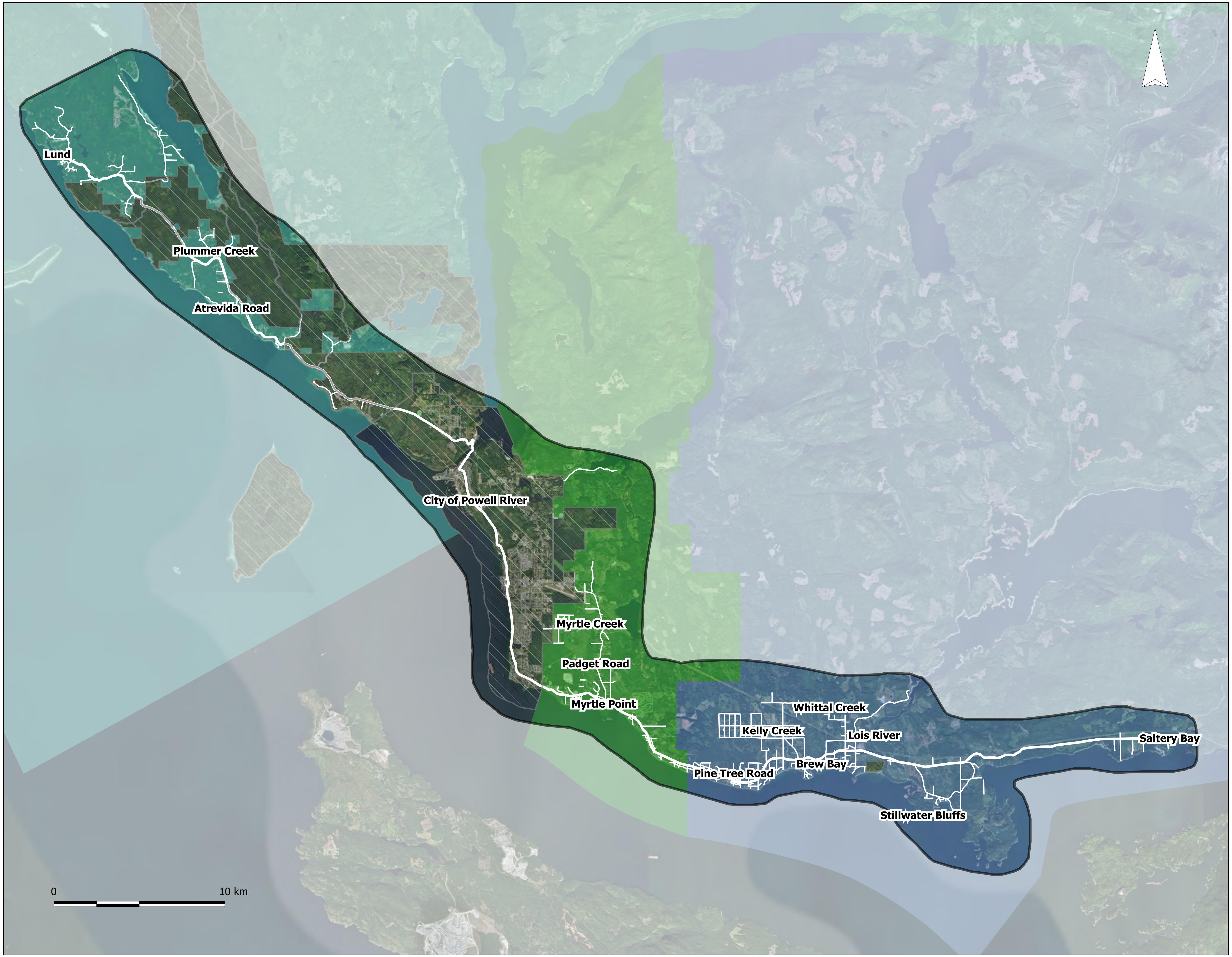
MOTI's road and culvert inventory indicates there are over 1200 culverts and 200 km of roads within the study area. The current study scope and the resolution of available data precludes a comprehensive review of each ditch and culvert within the study area. Thus, the study focuses on identifying and evaluating areas with potentially high risk of impacts in the future due to land use changes or climate change.

1.3 OBJECTIVES

Two primary objectives of the study set by the Ministry and the PRRD are as follows:

- Conduct a high-level drainage study to identify current drainage issues, potential future risks due to land use change, and to recommend measures to mitigate public safety risks from flooding.
- Develop recommendations for policies and bylaws that the PRRD could bring forward to mitigate impacts from development on stormwater and enhance the existing system for the better.

The current drainage study represents the first steps towards addressing existing issues, and improving stormwater management planning to mitigate future drainage issues related to ongoing land development and climate change.



LEGEND

ELECTORAL AREA A
ELECTORAL AREA B
ELECTORAL AREA C
MAJOR ROADS
STUDY AREA
EXCLUDED FROM STUDY

SCALE:	AS SHOWN		
PROJECT NO.	2017-2096	INITIAL	DATE
DRAWN		JS	17-01-15
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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POWELL RIVER REGIONAL DISTRICT DRAINAGE STUDY

STUDY AREA OVERVIEW

DRAWING NUMBER	REV. NO.	SHEET
MAP 1-1		

Map File: P:\20172096\00_PRRD_Drainage\Working_Dwgs\010_GIS\map_prrd_master_20170115_nv.map

2 Background Review of Site Conditions

2.1 GENERAL CONDITIONS

In the developed watersheds throughout the PRRD, stormwater runoff is collected in roadside ditches and directed to either coastal or stream discharge points via driveway and road culverts. The PRRD has no mapping of ditch systems or stormwater infrastructure so most of our information was gathered from the field reconnaissance and subsequent interpretation of orthoimagery. Information on culverts and roads was obtained from MOTI databases. Culvert data included location, material, size, and a few other minor details on fish sensitivity and culvert type. Culvert inverts were not available in the data.

Most of our data on topography and natural drainage features was taken from province wide BC Terrain Resource Inventory Mapping (TRIM) mapping which is of too low resolution (1:20,000) to resolve minor ditches and flow paths. Numerous streams, many of which are unnamed, and a few larger rivers run through the area. The most notable watercourses include Kelly Creek, Lang Creek, Lois River, and Myrtle Creek.

Provincial mapping provided rough watershed delineation throughout the study area. Watersheds fall into two distinct types. In stream-based watersheds, runoff is collected and routed downstream by a main drainage channel. In coastal-based watersheds, runoff is collected in multiple poorly defined drainage paths that drain directly to the ocean, or water travels as seepage flow to the ocean.

Based on information from the Geological Survey of Canada, we found surficial geology to be mainly thin deposits of till, marine sediments, and colluvium overlaying shallow bedrock on steep slopes. These conditions may limit opportunities to effectively infiltrate stormwater throughout the study area.

2.2 LAND USE

Land use mapping and information was obtained from three Official Community Plans (OCPs) produced by the PRRD:

- Electoral Area A OCP, Schedule A to Bylaw No. 500, 2015 (Adopted December 16, 2015)
- Electoral Area B OCP, Bylaw No. 465, 2012 (Adopted March 28, 2013)
- Electoral Area C OCP, Bylaw No. 467, 2012 (Adopted April 25, 2013)

These OCPs provide details on the community vision and goals, general policies and objectives, land use designations and descriptions, infrastructure, environment, economic development, first nations, and implementation of the bylaw.

2.2.1 Existing Land Use

Land use within Electoral Areas A, B, and C vary, but generally fall into the same categories. The three primary land use categories and their relationship to stormwater management are described below.

Resource Development

The PRRD has designated large areas of land for natural resource development including logging, aggregate/mineral extraction, fishing, and hydropower. In relation to the present drainage study, logging is the most relevant given the scale over which it has occurred historically, and its influence on watershed runoff characteristics. Cut blocks and second-growth forests are visible in many upstream reaches of watersheds throughout the PRRD. Forest harvesting activities generally increase runoff and surface erosion, which directly impact the downstream drainage system and aquatic habitat within natural watercourses.

Residential

Single-family residential housing makes up the majority of development in the PRRD. The OCP for the three Electoral Areas categorize residential land use based on the relative density of housing. Housing density ranges from rural residential, in which houses are spread out randomly with minimal impacts on surrounding forests, to denser developments in which lots are side by side. The denser the development, the more impact the development has on runoff and the hydrological response to a rainstorm. Runoff from precipitation along hard surfaces quickly flows to the closest outlet across roadways and through ditches, as opposed to infiltrating into the ground surface or being attenuated in natural soils and vegetation. An increase in impervious coverage can lead to increased peak flows as well as greater runoff volumes.

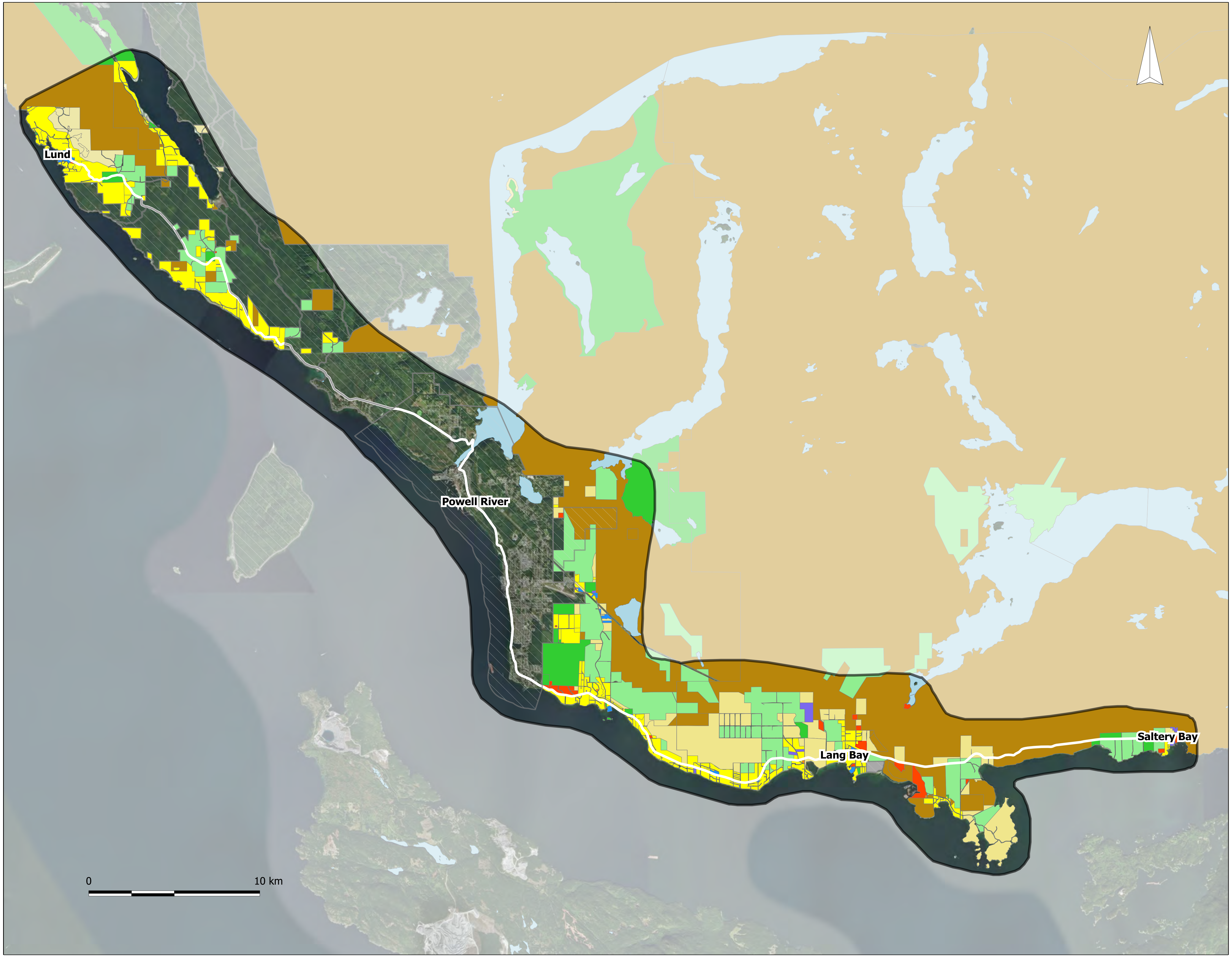
Community Centres

Community centres where people and amenities are concentrated such as Lund, Myrtle Point, Brew Bay, Saltery Bay and Lang Bay are some of the more densely developed areas in the study area. The primary land uses in these centres are single and multi family residential, commercial, industrial, and institutional (schools and churches). The concentration of development in these communities means that the cumulative effects of higher impervious area result in more pronounced impacts to the downstream drainage systems than areas where development is more dispersed.

Map 2-1, shows the existing land uses based on the OCPs. Throughout the study area, land use is mainly residential and rural residential of varied densities. The densest development is found along the coast, near community centres, and along Highway 101, and becomes more dispersed moving inland. Commercial and industrial development is scattered throughout the study area, often near the community centres. Further inland, historic and current logging development makes up the majority of land cover.

2.2.2 Future Land Use

The PRRD's OCPs do not have future zoning maps of the area, but do identify infill areas for development and a "Community Vision" map in the case of Electoral Areas B and C. We reproduced PRRD's infill mapping of "vacant residential land with residential infill potential" in Map 2-2. In general, the community vision maps largely reflect the current development in terms of distribution of residential, resource, and rural areas with a trend towards minor expansion of the developed areas over time.



LEGEND

LAND USE DESIGNATION

- PARK
- AGRICULTURAL
- RURAL RESIDENTIAL
- RESIDENTIAL
- MULTI-FAMILY RESIDENTIAL
- COMMERCIAL
- INDUSTRIAL
- RESOURCE
- INSTITUTIONAL

- LAKE
- HIGHWAY 101
- STUDY AREA
- EXCLUDED FROM STUDY

SCALE:	AS SHOWN		
PROJECT NO.	2017-2096	INITIAL	DATE
DRAWN		JS	17-01-15
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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DRAINAGE STUDY

EXISTING LAND USE

DRAWING NUMBER	REV. NO.	SHEET
MAP 2-1		

Map File: P:\20172096\00_PRRD_Drainage\Working_Dwgs\010_GIS\map_prrd_master_20170115_nv.map

LEGEND

FUTURE INFILL AREAS

- ELECTORAL AREA A
- ELECTORAL AREA B
- ELECTORAL AREA C
- HIGHWAY 101
- STUDY AREA
- EXCLUDED FROM STUDY

Note: Future infill areas are defined as "vacant residential land with residential infill potential" by PRRD's Official Community Plans.

SCALE:	AS SHOWN		
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POWELL RIVER REGIONAL DISTRICT DRAINAGE STUDY

FUTURE INFILL AREAS

DRAWING NUMBER	REV. NO.	SHEET
MAP 2-2		

Map File: P:\20172096\00_PRRD_Drainage\Working_Dwgs\010_GIS\map_prrd_master_20170115_nv.map

In addition to the infill mapping, the existing mapping shows areas that are zoned as if they were developed, but are currently undeveloped. We expect these areas will be developed in the future. Some of the existing land use descriptions include details on densification within each zone as well.

During ongoing development of watersheds, houses tend to get bigger and the area of impervious surfaces for patios, driveways, sheds, and other features tend to increase. The population studies discussed in the OCP indicated that it is possible the number of residents will increase moving forward which would lead to a higher demand for housing. We expect all of these factors will increase the amount of development in the area, in turn leading to more impervious surfaces and altered flow paths, which will increase the impact to stormwater runoff in the long term.

3 Field Review and Stakeholder Input

3.1 INPUT FROM RESIDENTS

To consult residents from the PRRD on stormwater management, we and the team at the PRRD and MOTI completed the following:

- Hosted an online survey during the fall of 2017 and provided information on the PRRD main page about the study.
- Held a public open house in Powell River on November 22, 2017, where we gained in-person feedback from residents.
- Produced a magazine article in the Powell River Peak advertising the study and open house.

The objectives of the consultation were primarily to identify issues not obvious from our high-level field review and learn what concerns residents have regarding the local drainage systems. Secondly, we wanted to learn what level of understanding residents have on the connection between land use practices, the drainage system, local watersheds, and their role in maintaining infrastructure and improving stormwater management. We also used the online survey and open house to educate residents about opportunities they may have to help improve the drainage system in their areas.

We received 30 responses from the survey, two thirds of which were completed online, and the rest at the open house. Approximately 30 visitors attended the open house. The detailed results of the survey are presented in Appendix B. More than half of the responses on the survey were from residents living in electoral area C, with the other portion equally distributed between areas A and B. Most are full time residents who own property.

In general, residents felt that their main priority for watershed function is to provide drinking water and water for domestic/agricultural uses. Their other priorities for watersheds, in order of importance, were to support a diversity of wildlife, provide a habitat for fish, and provide recreational opportunities.

Figure 3-1 shows the distribution of observations residents have made of the drainage system.

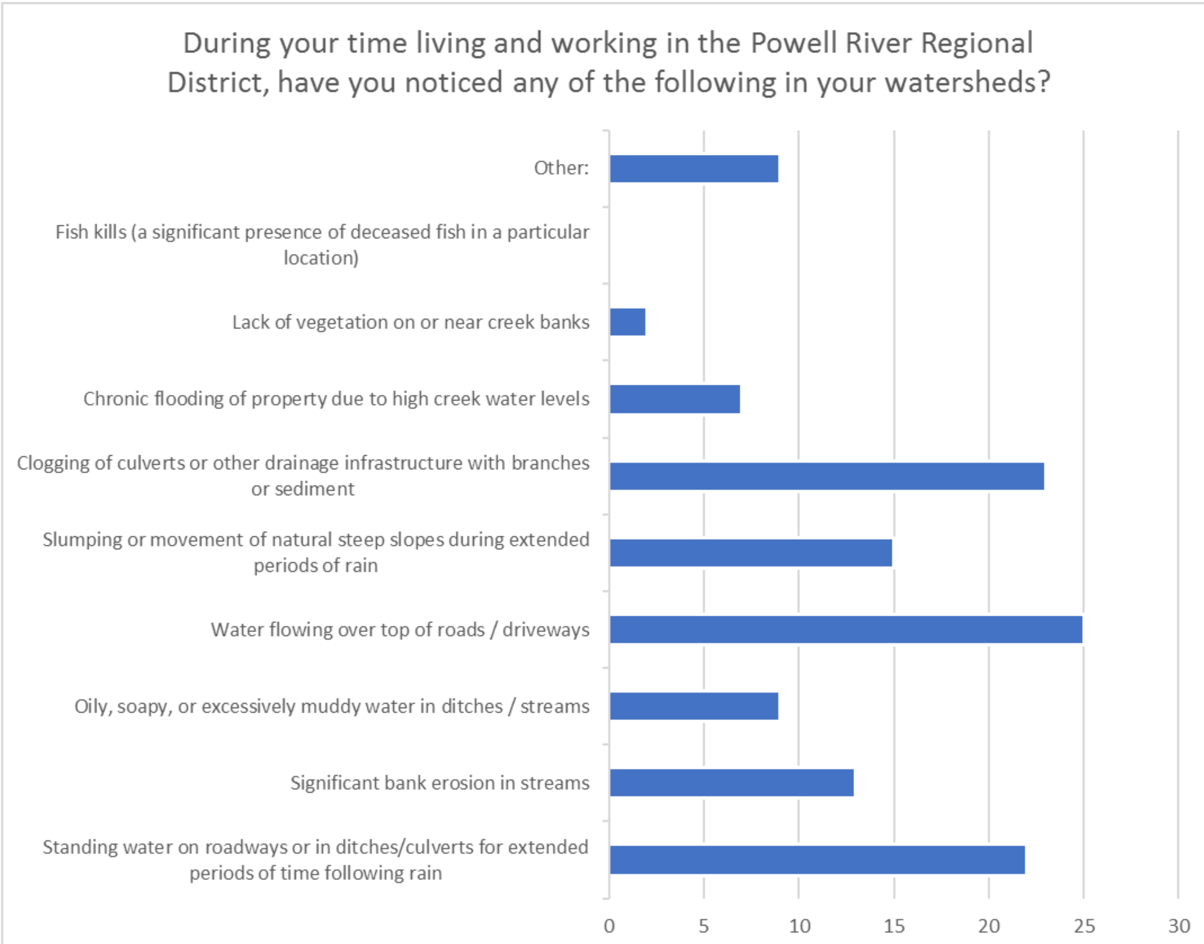

Figure 3-1
Observations of the Drainage System

Drainage issues identified by respondents and through our field review are noted on Map 3-1, with watersheds colour coded by issue type. From reviewing these results, we can see that standing water/flowing water on roadways and clogging of culverts and other drainage infrastructure are some of the main issues in the PRRD. Slumping of steep slopes is a prominent issue in many of the watersheds as well. However, given that a large portion of responses were from people in the Pine Tree Watershed, it is possible other issues have gone unreported in other watersheds, or some issues have been overstated, but further information would be needed to confirm this.

As part of the survey, we asked residents to describe their willingness to voluntarily implement various types of stormwater management features on their own lots. Figure 3-2 shows the results.

LEGEND

ISSUE NOTED BY RESIDENT

LANDSLIDE HAZARD AREA NOTED IN OCP

WATERSHEDS CODED BY ISSUE TYPE

FLOODING ISSUE

LANDSLIDE ISSUE

BOTH

HIGHWAY 101

STUDY AREA

EXCLUDED FROM STUDY

SCALE:	AS SHOWN		
PROJECT NO.	2017-2096	INITIAL	DATE
DRAWN		JS	17-01-15
DESIGNED			
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APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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POWELL RIVER REGIONAL DISTRICT DRAINAGE STUDY

AREAS WITH KNOWN ISSUES

DRAWING NUMBER	REV. NO.	SHEET
MAP 3-1		

Map File: P:\20172096\00_PRRD_Drainage\Working_Dwgs\010_GIS\map_prrd_master_20170115_nv.map

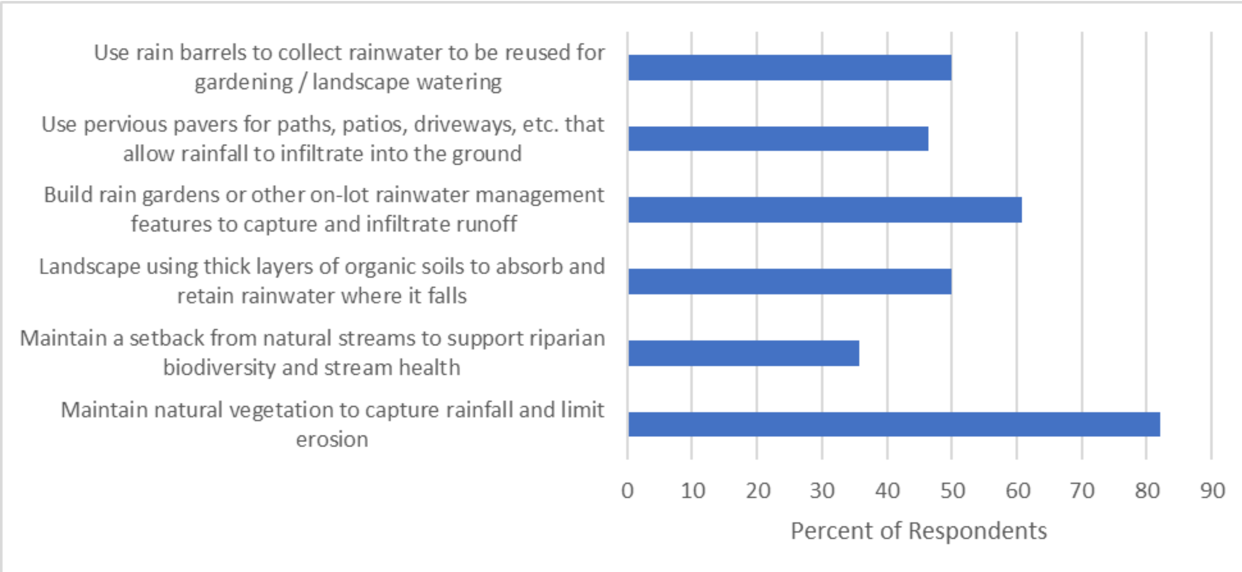


Figure 3-2
Respondent Willingness to Voluntarily Implement On-Lot Stormwater Management Features

In general, many residents have expressed willingness to participate more actively in on-lot stormwater management. Most seem willing to maintain natural vegetation on their properties which is one of the most simple and effective methods of source control.

When asked about the OCP objectives, most respondents prioritized protecting the natural environment and rural lifestyle, followed by: providing appropriate and affordable infrastructure services; protecting the natural beauty and environmental qualities of the area; protecting the foreshore/public access; and retaining public access to other natural areas.

Overall, based on the residents' survey responses and comments during the open house, several common themes emerged:

- Residents want better drainage infrastructure in the area; some willingness exists to help pay for a planned system.
- Residents are generally receptive to voluntarily implementing on-lot rainwater management, but some further education and support is needed to make this happen.
- Residents acknowledge the need for drainage infrastructure (ditches/culverts) to be regularly maintained; however, there is a lot of uncertainty of who is responsible for this maintenance (homeowners, the PRRD, or the Ministry).
- Some would like to see consequences for people who modify the drainage system without approval.

- Residents feel the Ministry and PRRD need to take more responsibility to maintain the drainage system.
- Many residents feel forestry companies are not doing enough to mitigate impacts of harvesting on downstream drainage.
- Some residents would like to see more regulation put in place and zoning/development bylaws put in place.
- Impacts from stormwater flooding and poor drainage are fairly common, with many residents who are aware of issues, or have been directly impacted.
- Several residents are aware that climate change and land use changes could increase runoff volume.

3.2 FIELD RECONNAISSANCE

AE completed two site visits during the assignment to supplement the desktop study. The first visit was conducted during the last week of August, and the next during the third week in November. During these visits, we made observations of the drainage system throughout each electoral area. Given the scale of the study area, our site visits focused on areas with significant development, and areas where stakeholders had reported drainage issues. Our findings are summarized below:

- The drainage system mostly consists of open ditches, which intercept hillslope and road runoff. The collected runoff is conveyed through privately owned driveway and MOTI culverts, which direct flows either to natural watercourses or larger ditches that discharge to the ocean.
- Many of the culverts in the system appear to be smaller than the minimum recommended sizes in MOTI's Supplement to TAC Hydraulics Chapter (400 mm), and in some locations, culverts are smaller than those upstream on the same drainage path.
- Some ditches are not well-maintained, with heavy vegetation, debris, or erosion issues.
- Many culverts are partly or fully blocked by debris or sediment, have damaged inlets/outlets, show evidence of scour, and/or are otherwise in poor condition. These culverts tend to get blocked during major rain events, and can contribute to flooding.
- In some of the coastal watersheds, the roadside ditches along the highway intercept multiple small drainages and combine them. This results in roadside ditches and culverts that appear to be undersized for the discharge they need to convey during design events.
- In some cases, roadside ditches appear to be undersized, discontinuous, or are not present at all.
- In some locations where drainage is directed from ditches down coastal bluffs to outfall locations on the beaches, extensive erosion is occurring because of inadequate erosion protection.

Example photos of these observations are included in Appendix A.

4 Drainage System Evaluation

4.1 ASSESSMENT OVERVIEW

A detailed evaluation of the hydraulic performance of the drainage system is beyond the scope of the current study, given the size of the study area and the limited data that is available.

Instead, we evaluated the potential changes in land use based on the PRRD's OCP, to identify the areas most likely to undergo land use changes that would influence hydrology. This screening-level assessment helps to focus attention on those areas where changes in land use are most likely to cause adverse impacts to the drainage system in the future, and where mitigation efforts and further study could focus on.

Climate change will also have a significant impact on precipitation in the area, and we completed an overview level assessment to quantify this impact.

We also conducted a more detailed study of the Kelly Creek watershed, including creating a hydrologic model of the pre-development (natural), post-development (current), and future projected conditions, including the effects of climate change on rainfall. The Kelly Creek watershed was selected as the case study area because of our on-site observations of the effects of the upland development on the creek (including evidence of creek erosion, changes in sediment characteristics, and potentially undersized culvert crossings). The intent of the hydrologic modelling is to demonstrate how this type of development modifies creek flows, and how projected climate change impacts exacerbate this modification.

4.2 CHANGES IN RUNOFF CHARACTERISTICS

Runoff in a watershed is directly impacted by upstream land cover. In a natural, undisturbed forest, very little direct surface runoff occurs during most rainfall events. When forest cover is removed and replaced by an impervious surface (concrete, asphalt), or a grass lawn or field, the hydrologic response changes.

In the PRRD, the gradual change in land use from natural forest to its present form (residential development, road infrastructure, concentrated community centres, and logging) has changed the hydrologic regime of the study area.

Prior to development, numerous small drainages and shallow subsurface pathways would carry excess precipitation (i.e. rainfall not captured by the tree canopy, in forest depressions, or infiltrated into the soil) to natural discharge points, such as creeks or seepage faces. Development throughout the study area altered the surface characteristics, increasing the proportion of impervious areas, and with forest cleared for agriculture, land development, and timber harvesting, which in turn influences runoff magnitude and timing.

In the future, continued activity in the watershed and climate change will increase runoff and further strain the drainage system if steps are not taken to address these potential impacts.

4.2.1 Impact of Land Use on Existing Runoff Conditions

To better understand the changes in hydrology across the study area, we assessed the impact of development on runoff, and how this may change in the future.

The Rational Method is commonly used to estimate design flows for sizing drainage infrastructure, and is a recommended method within MOTI's *Supplement to TAC Geometric Design Guide – Hydraulics Chapter (2007).* The method uses three variables: watershed area, rainfall intensity, and a runoff coefficient. Land use changes can cause both the watershed area and the runoff coefficient to change, and climate change can modify the rainfall intensity. We will discuss the impact of climate change in Section 4.2.3.

To evaluate where land use changes have likely had the greatest impacts, and where the greatest risk of future impacts exist, we used the Rational Method runoff coefficient as an indicator. By reviewing how the runoff coefficient is distributed throughout the study area and might change in the future, we can identify the watersheds in the study area where focused attention is warranted.

As the land use mapping is not directly indicative of actual current land use and consequently runoff response, we instead reviewed the ortho imagery and created five new categories of varied land cover to reflect development in terms of runoff response. We assigned runoff coefficients to each category, as shown in Table 4-1.

Table 4-1
Runoff Coefficient based on Land Cover

Land Cover Category	Definition	Runoff Coefficient
Undeveloped	Areas with no changes from original pre-development conditions	0.1
Sparse Residential	Areas with houses spaced irregularly through an otherwise undeveloped area	0.2
Resource Development	Areas impacted by logging, either cut blocks or new growth	0.25
Residential/Modified	Areas with housing developments, agriculture, or other modifications from forested conditions	0.4
Dense Residential/Impervious	Areas with a significant number of houses, roads, infrastructure, or development	0.5

We selected reasonably representative values of runoff fractions, that incrementally increase from the natural conditions based on development type. We note these values are typically lower than the values recommended in the MOTI Supplement to TAC Guidelines. The runoff coefficients in the guidelines are normally higher to provide conservative values of design flows, which are more appropriate for sizing drainage infrastructure.

See Map 4-1 for the resulting distribution of these new land cover categories for the present day.

When comparing locations of the flooding, drainage, and erosion observations listed in Section 3 with the change in runoff conditions from pre- to post-developed time based on our high-level land cover mapping, we can begin to see how land use changes have impacted runoff (Table 4-2).

Table 4-2
Observation of Drainage Issues Compared to Change in Runoff Conditions

Watershed Name	Standing Water on Roadway	Water Flowing Over Roadway	Clogging of Culverts/Infrastructure	Bank Erosion in Streams	Chronic Flooding	Muddy/Soapy/Oily Water in Streams/Ditches	Slumping of steep slopes	Change in Runoff Coefficient (From pre- to post-development)
Pine Tree Watershed	x	x	x	x	x		x	+150-400%
Kelly Creek Watershed			x	x				+150-300%
Okeover Arm Watershed	x	x	x	x	x	x	x	+100-150%
Lund Watershed	x	x				x	x	+100-300%
Atrevida Road Watershed	x	x	x				x	+100-300%
Stillwater Bluffs Watershed	x	x	x		x			+100-300%
Myrtle Creek Area Watersheds (Including Stevenson Road)	x	x	x	x		x	x	+150-400%
Brew Bay Watershed	x	x	x					+300-400%
Whittal Creek Watershed		x	x			x		+100-150%
Lang Bay Watersheds	x	x	x			x		+150-400%
Saltery Bay Area Watersheds							x	+100-150%

In addition to the reported issues in the study area, we expect many instances of flooding and erosion may have gone unreported. We expect other areas are vulnerable to flooding and erosion events based on the current runoff conditions in their respective watersheds. For example, a possible 100-300% increase in runoff near Plummer Creek and Craig Road could lead to erosion or flooding issues downstream in the minor creek below these areas. Watersheds at risk to drainage issues due to runoff changes are illustrated in Map 4-2.

4.2.2 Impact of Land Use on Future Runoff Conditions

To investigate how runoff conditions might change in the future, we reviewed the infill mapping, current zoning in relation to actual development, and details from the OCPs regarding future densification. We then mapped these expected changes in runoff over the study area, illustrated in Map 4-3.

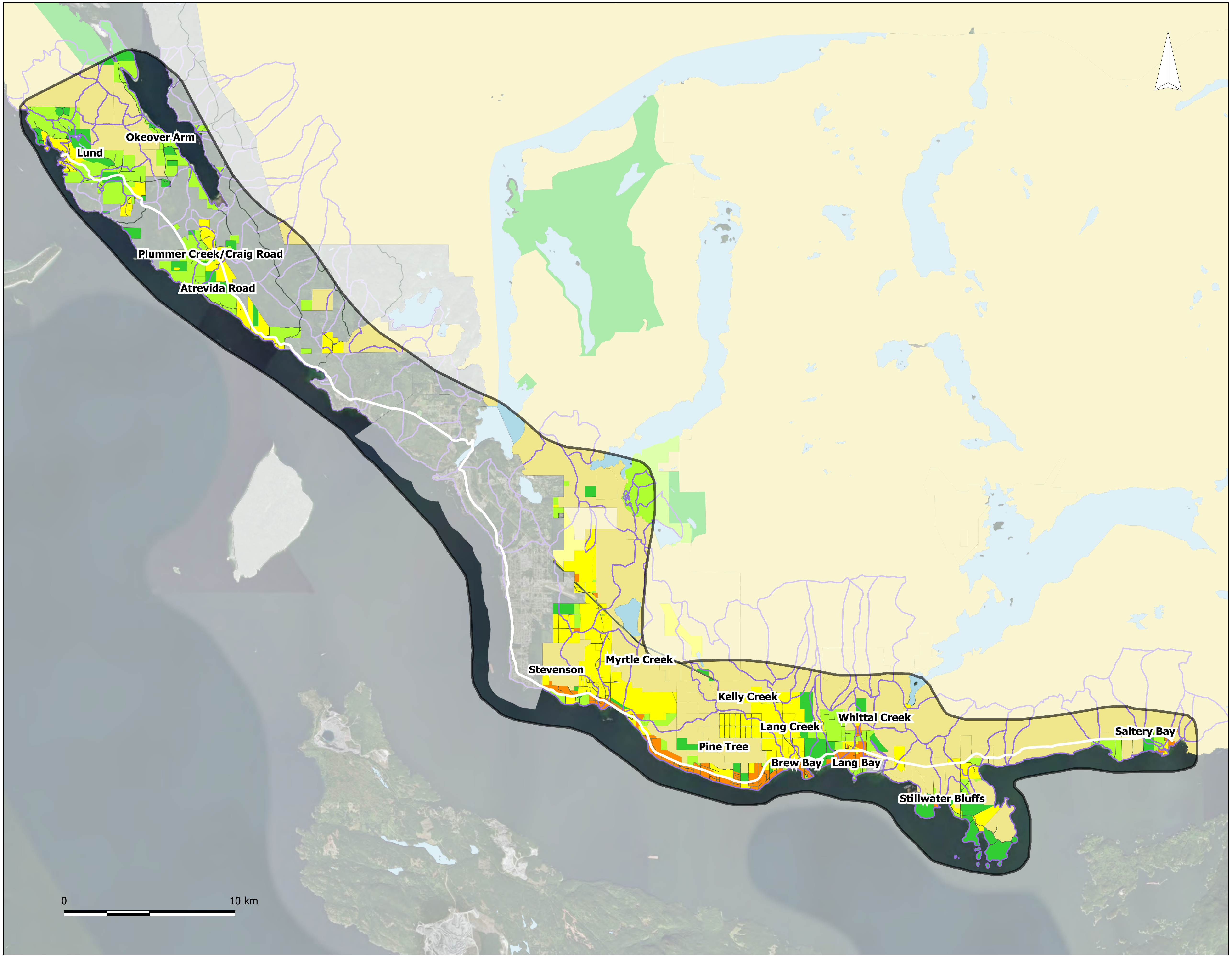
When assessing future impacts on runoff, we can see that numerous watersheds may experience increases in runoff due to further densification and residential, commercial, or resource development. We can also expect that issues in the watersheds already identified from the existing mapping will persist if unmitigated. Watersheds with the potential for a significant increase in runoff from existing conditions include the following:

- Saltery Bay
- Stillwater Bluffs
- Lang Bay
- Whittal Creek
- Lang Creek
- Lund and Surrounding Watersheds
- Okeover Arm Watersheds
- Plummer Creek/Craig Road
- Atrevida Road
- Pine Tree

Additionally, as development progresses further inland, we expect changes in runoff will be most pronounced along the current fringes of development.

4.2.3 Impact of Climate Change on Rainfall

In coastal BC, climate change is impacting rainfall patterns, resulting in an increase in the number of storm events on an annual basis, and an increase in the intensity of rainfall during storms. Overall, these changes to rainfall will lead to greater total volumes of runoff, as well as higher flow rates overland and in channels. We need to anticipate these impacts when planning for stormwater management to ensure that drainage systems are designed considering this new reality.



LEGEND

LAND COVER

- DENSE RESIDENTIAL/ IMPERVIOUS
- RESIDENTIAL/MODIFIED
- RESOURCE DEVELOPMENT
- SPARSE RESIDENTIAL
- UNDEVELOPED
- LAKE
- WATERSHED
- HIGHWAY 101
- STUDY AREA
- EXCLUDED FROM STUDY

SCALE:	AS SHOWN		
PROJECT NO.	2017-2096	INITIAL	DATE
DRAWN		JS	17-01-15
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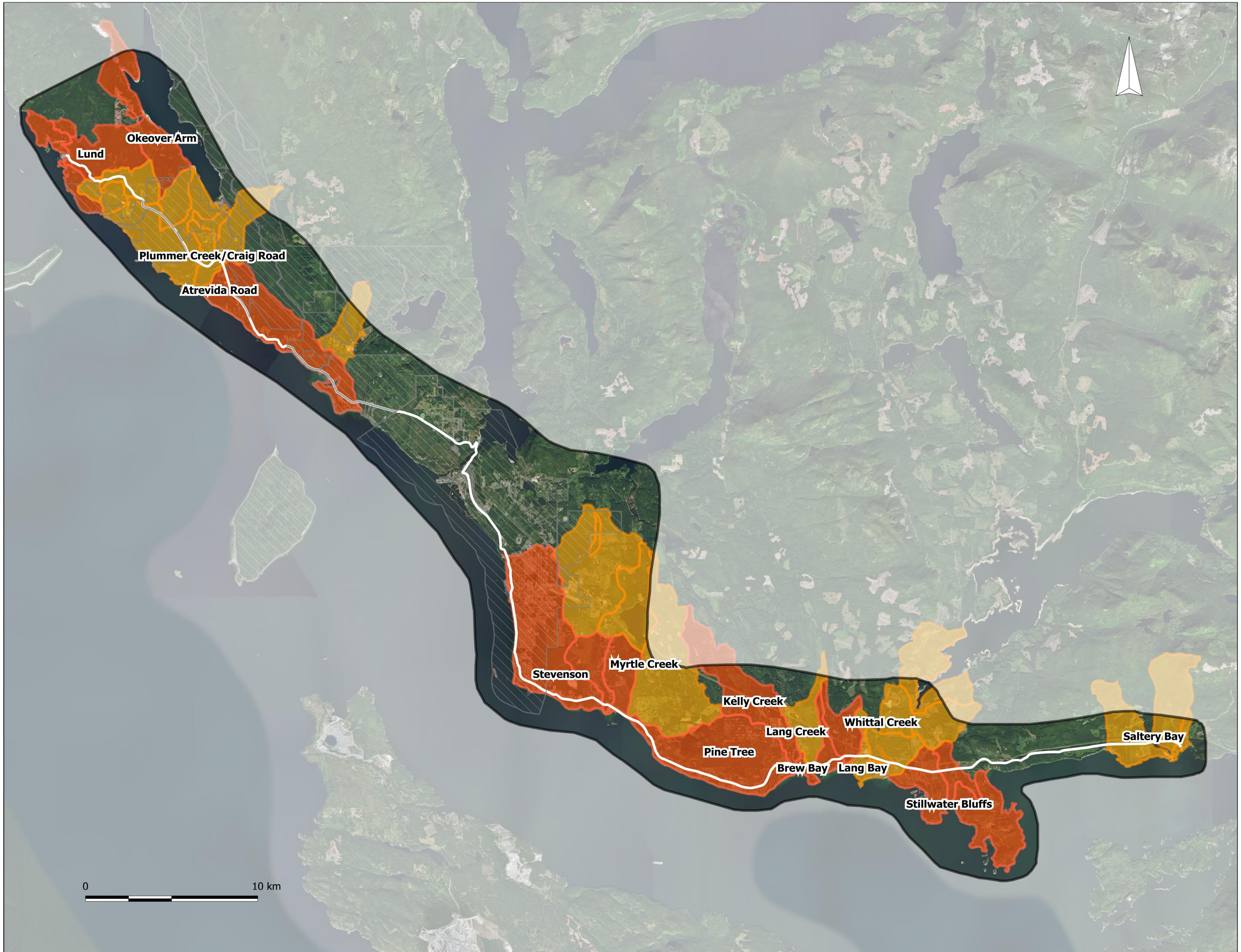
POWELL RIVER REGIONAL DISTRICT DRAINAGE STUDY

DISTRIBUTION OF LAND COVER

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-1		

Map File: P:\20172096\00_PRRD_Drainage\Working_Dwgs\010_GIS\map_prrd_master_20170115_nv.map



LEGEND

AT RISK WATERSHEDS

WATERSHED WITH OBSERVED ISSUE

WATERSHED WITH POTENTIAL FOR ISSUES

HIGHWAY 101

STUDY AREA

EXCLUDED FROM STUDY

SCALE:	AS SHOWN		
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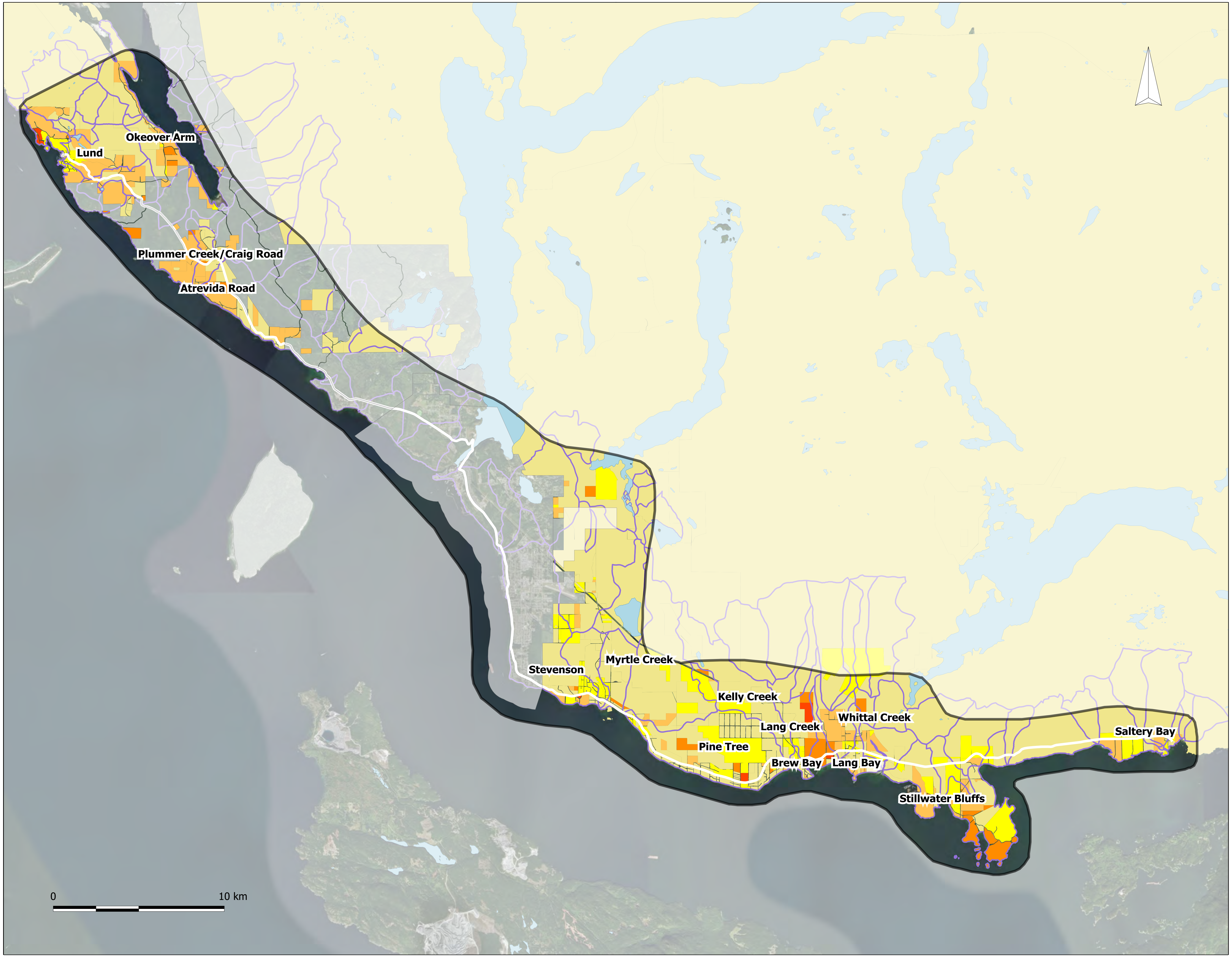
POWELL RIVER REGIONAL DISTRICT DRAINAGE STUDY

WATERSHED AT RISK TO DRAINAGE ISSUES

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-2		

Map File: P:\20172096\00_PRRD_Drainage\Working_Dwgs\010_GIS\map_prrd_master_20170115_nv.map



LEGEND

INCREASE IN RUNOFF FROM EXISTING TO FUTURE

- 0-25%
- 25-60%
- 60-150%
- 150-300%
- 300-400%

- LAKE
- WATERSHED
- HIGHWAY 101
- STUDY AREA
- EXCLUDED FROM STUDY

SCALE:	AS SHOWN		
PROJECT NO.	2017-2096	INITIAL	DATE
DRAWN		JS	17-01-15
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

British Columbia Ministry of Transportation and Infrastructure

POWELL RIVER REGIONAL DISTRICT DRAINAGE STUDY

FUTURE INCREASE IN RUNOFF POTENTIAL

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-3		

Map File: P:\20172096\00_PRRD_Drainage\Working_Dwgs\010_GIS\map_prrd_master_20170115_nv.map

To estimate future rainfall intensities, the University of Western Ontario (UWO) has developed an online tool which modifies historic Intensity-Duration-Frequency rainfall (IDF) curves from local Environment Canada rain gauges based on the outputs from global circulation models under various greenhouse gas emission scenarios. Based on the information from the rain gauge and IDF curve at the Powell River Airport, this tool suggests that the PRRD could expect rainfall intensities to increase by 30% or more over the next 50 years.

Consequently, even if no additional land use changes were to occur, the existing drainage system would be strained because of climate change effects alone, and the frequency of flooding issues noted by residents will likely increase.

New or retrofitted drainage infrastructure should be designed with this increase in rainfall in mind to ensure extreme precipitation events are conveyed safely through communities without damaging infrastructure, the ecosystem, or risking public safety. When designing infrastructure, it is prudent to assume a 30% increase in rainfall intensity. It is important to note that UWO's tool is an oversimplified way to measure the impacts from climate change, and has been recently shown to underestimate changes, compared with more robust statistical methods. Nonetheless, it provides an estimate of the possible changes and is appropriate for informing this level of analysis.

4.3 KELLY CREEK HYDROLOGIC / HYDRAULIC ASSESSMENT

We created a simplified hydrologic / hydraulic model of the Kelly Creek watershed to illustrate how runoff response can be impacted by development and climate change. We used PCSWMM, a hydrologic and hydraulic modelling software, to create a model of the main stem of the creek and subcatchments draining directly to the creek.

4.3.1 Model Development

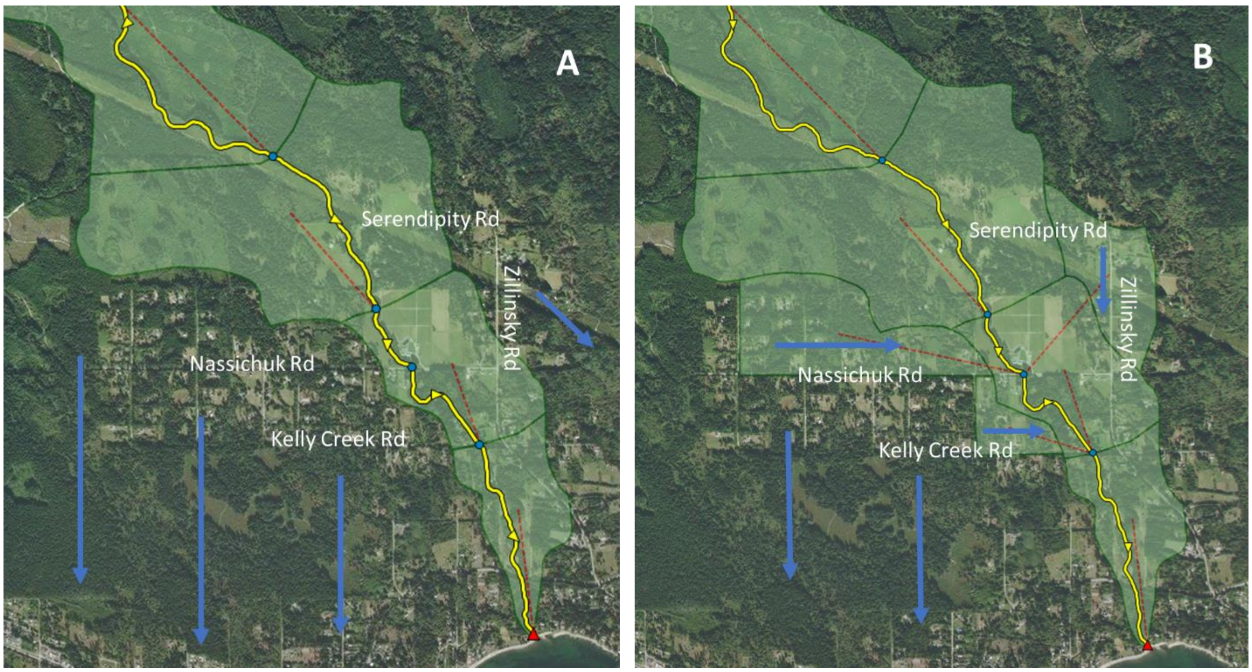
We created three separate models of the Kelly Creek system to represent the pre-development, post-development (existing), and future land use conditions. The model is intended to provide insight into the relative changes in runoff between these three cases.

We adjusted the percent of impervious coverage to represent the changes to land cover in each scenario, based on our assessment of runoff conditions in Section 4.2.

Using IDF data from the Powell River Airport gauge, we modelled the 2-year return period, 24-hour SCS Type 1A storm for all three scenarios. The SCS (US Soil Conservation Service) Type 1A storm is a rainfall distribution used to represent typical precipitation events for coastal watersheds. This is a relatively common event which has a 50% chance of occurring any given year.

For the future scenario, we assumed climate change would cause rainfall volume to increase by 30% (See Section 4.2.3 for explanation).

In the pre-development scenario, only the original Kelly Creek watershed contributes drainage to the creek. In the other scenarios, we added three smaller subcatchments. We expect runoff from the area above Nassichuk Road and Kelly Creek Road would previously have drained directly to the coast given the topography in this area, but now appears to be collected in roadside ditches and directed to Kelly Creek (Figure 4-1). In addition, drainage from the northern section of Zillinsky Road, as well as Serendipity Road also appears to have been redirected into the Kelly Creek Watershed. These additional subcatchments increase the area of the total watershed by approximately 15% from pre-development to post-development conditions. This increase in watershed area further increases creek flow.



*Blue arrows denote general flow direction.

Figure 4-1
Change in Drainage Area and Direction of the Kelly Creek Watershed between (A) Pre-Development and (B) Post-Development Conditions

We confirmed these catchment boundaries through limited ground truthin the field, and large-scale topography mapping. It is possible the actual drainage paths vary from our assumptions, but this modelling exercise still provides us information on the impact of land use on runoff response.

4.3.2 Model Results

Figure 4-2 demonstrates how flows in Kelly Creek differ between pre-development, post-development (current), and future conditions, and how the discharge relates to the precipitation.

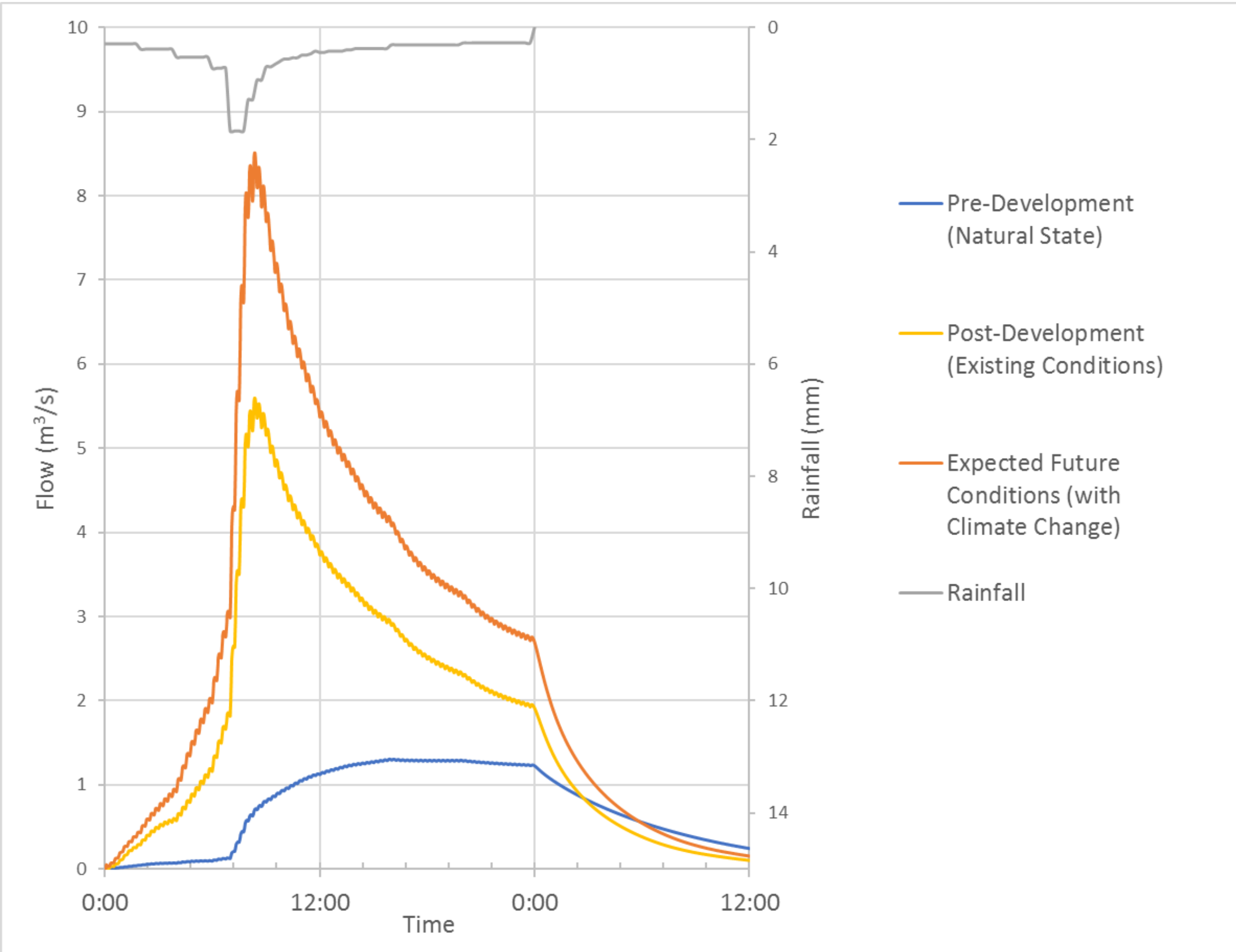


Figure 4-2
Model Results for Kelly Creek Models to Illustrate Relative Differences between Scenario Hydrographs

The following observations can be made based on the results presented in Figure 4-2:

- For the pre-development scenario, the peak of the hydrograph lags the peak of the rainfall event by approximately 6 hours. This reflects the typical delayed runoff response from a forested watershed, where most of the rainfall is intercepted by tree cover, forest floor depressions, or is infiltrated into the ground and flow paths are slower to concentrate runoff.
- For the post-development (existing) and future cases, the hydrograph in Kelly Creek peaks almost immediately following the peak of the rainfall event. This reflects the increased efficiency of the altered drainage system.
- The increased impervious coverage in the post-development scenario causes the runoff peak to be nearly 5 times that of the pre-development scenario.

- There is a significant increase in runoff volume (represented by the total area under each curve) for both the post-development and future scenarios when compared to the pre-development scenario. Therefore, the loss of pervious area decreases the volume of precipitation that could recharge local groundwater.
- For the future scenario, land use change and increased precipitation due to climate change contributes to a greater peak flow and runoff volume.
- The observed erosion in Kelly Creek is likely due to this increase in peak flow and volume caused by an increase in surface runoff on modified land cover, and additional watershed area. In the future scenario, this problem would worsen with climate change and natural densification if not properly mitigated.

These results demonstrate how peak flows and runoff volumes relate to land use and climate change. Increases to runoff such as those shown above can contribute to increased flooding, erosion, and landslide hazards when unmitigated. Appropriate stormwater management planning is needed to prevent similar impacts from occurring and mitigate existing issues.

4.4 IMPACTS DUE TO HIGHWAY 101

The Sunshine Coast Highway (Highway 101) transects the majority of the watersheds in the study area, causing numerous flow paths to be altered. Precipitation that would otherwise drain to the coast via minor shallow channels, or as shallow subsurface flow appears to be intercepted by highway ditches throughout the study area. This intercepted flow is then collected and concentrated in progressively larger ditches towards a single outfall point. Rather than constructing a single culvert for each minor topographic low, it is common practice to collect these minor drainages and route them through fewer large culverts. In the Pine Tree coastal watershed, this appears to have occurred. Multiple small drainages are collected by the highway ditches and discharged over the coastal bluff at a few points. This results in concentrated flows in the ditches that appears to be contributing to some of the identified drainage issues downstream of the highway.

5 Stormwater Management in Practices in BC and the PRRD

5.1 INTEGRATED STORMWATER MANAGEMENT PLANNING AND TARGETS

Integrated stormwater management planning takes a more comprehensive approach to stormwater management with the goal of enhancing the overall health of a watershed by including infrastructure, local ecosystems, and land use in a broader plan. In particular, this integrated approach dictates that measures should be implemented in developed watersheds to mimic the undeveloped hydrological conditions, to the extent possible. In stormwater planning, not only the extreme flooding events should be considered, but also the more frequently occurring rain events. The Stormwater Planning Guidebook for BC (Ministry of Environment, 2002) recommends dividing the range of precipitation events into three tiers. The guidebook suggests different means of managing the type of rainfall in each tier to better mimic the natural hydrologic regime.

The Guidebook uses the Mean Annual Rainfall (MAR) as a reference to define the tiers, where the MAR is defined as the rainfall event that occurs once per year, on average. Table 5-1 provides an overview of the tiers as defined in the Stormwater Planning Guidebook.

Table 5-1
Overview of Stormwater Guidebook Rainfall Tiers

Event Type	Rainfall Description	Relation to MAR	Preferred Management Strategy
Tier A	Typical rainfall events	50% of MAR	Attempt to infiltrate or capture up to this rainfall amount at the source.
Tier B	Heavy, but still common, rainfall events (erosion-causing events)	50% MAR to MAR	Detain and release these events at a rate which approximates the response from an undeveloped watershed.
Tier C	Extreme rainfall events	> MAR	Safely convey these extreme events through stormwater infrastructure and natural watercourses.

(Stormwater Planning Guidebook for BC)

Historic stormwater management had focused on conveying the extreme (Tier C) events only. However, it is now well accepted that the more common rainfall events must be properly accounted for.

These goals can be achieved in a variety of ways including promoting infiltration, removing impervious surfaces, implementing community detention ponds, and upgrading infrastructure to manage large events. For the PRRD specifically, the three tiers could be managed as follows:

- **Tier A:** Residents of the PRRD are responsible for managing the stormwater on their lots, by limiting the amount of impervious coverage or implementing rain gardens or other low impact development options. The PRRD can help facilitate this by providing education and support to residents for implementing these on-lot management strategies.
- **Tier B:** The PRRD is responsible for land use planning to help limit impervious coverage, and developing neighbourhood-scale detention options in high density areas. The Ministry could also assist in installation and design of small detention systems.
- **Tier C:** The Ministry and PRRD is responsible for ensuring adequate capacity of high flow events in ditches and culverts, and ensuring the maintenance of this infrastructure for future events.

5.2 INVESTIGATION INTO NEIGHBOURING MUNICIPALITIES

In general, the drainage issues the PRRD is facing are not unique. Land use planning and stormwater management are understood to be linked, and municipalities and regional districts have come up with strategies on how to address this.

The following sections provide a review of some of the policies and bylaws nearby districts and municipalities have implemented that support stormwater management. This provides some insight into the types of regulations the PRRD could consider putting in place.

5.2.1 Sunshine Coast Regional District

The Sunshine Coast Regional District (SCRD) has a similar regulatory position and relationship with MOTI as does the PRRD. We list relevant policies and bylaws the SCRD has for stormwater management below.

Official Community Plans: The Egmont and Pender Harbour community plan has detailed wording on stormwater management. In general, the plan supports integrated stormwater management and has some practical recommendations, summarized below:

- Amend zoning bylaws to include provisions limiting percent impervious coverage and encouraging infiltration / retention.
- Establish a protocol with MOTI regarding requirements for site-specific drainage plans to minimize the impact of stormwater at the time of subdivision development, both on the site and on properties downstream.
- Amend the Subdivision and Servicing Bylaw to ensure that developments requiring building permit or subdivision applications meet on-site and off-site stormwater management criteria (for large developments).
- During rezoning, require the retention of native trees and vegetation.
- Revegetate developed areas using Naturescape BC Guidelines.

Zoning Bylaws: Regulates allowable development in the SCRD, limits the amount of impervious coverage on a lot, and limits development adjacent to waterbodies.

Development Cost Charges Bylaw: Allows the SCRD to impose cost charges on anyone who obtains approval for a subdivision or a building permit. This could be used as a mechanism to obtain funding for stormwater management projects.

5.2.2 City of Powell River

The City of Powell River has a more established network of storm mains, catch basins, manholes, detention facilities, and open channels. The policies that are already effective in the City of Powell River would be useful for the PRRD to reference when implementing their own policies.

Liquid Waste Management Plan: This plan deals primarily with treatment and discharge of sanitary waste but also addresses stormwater runoff management. In particular, the plan addresses source controls and their role in preventing excess runoff from flowing to watercourses. The plan requires creation of Master Drainage Plans to promote infiltration, develop a monitoring program, and develop a stormwater bylaw with enforceable regulations. The plan also provides provisions for including stormwater management in a subdivision control bylaw to implement approval procedures necessary to apply for a development permit. Funding is allocated to these items through the operations and maintenance budget of the City as well as capital funding.

Infrastructure Design and Construction Bylaw: Requires developers to provide drainage collection and disposal, a plan for drainage and erosion control works, and facilities for drainage detention. It also includes supplementary conditions and variations to the Master Municipal Construction Documents (MMCD) documents relating to drainage infrastructure construction.

Stormwater Asset Management Plan: This plan describes the operation, maintenance, and replacement of stormwater infrastructure assets throughout their full life cycle and covers construction of new assets. It also establishes levels of service for this infrastructure with performance measurements and establishes future demands to the system.

Development Cost Charges Bylaw: Provides details on cost charges to provide money to fund capital costs of infrastructure including stormwater drainage. This bylaw also provides provisions for reducing charges if an owner implements onsite stormwater management that reduces the burden on the City's system.

Sanitary Sewer and Storm Drain Source Control Bylaw: Prohibits dumping of waste or substances that would damage the storm system or receiving water courses and describes monitoring and sampling of any prohibited substances after the fact.

Storm Sewer Collection System Charge: Establishes connection charges for hooking up to the storm system.

Official Community Plan: Powell River provides general language supporting integrated stormwater management and requiring use of stormwater source controls including the following:

- Requires upland development on the Cranberry Lake shoreline to have source control.
- Lists on-site storm water management as a priority for sustainable land use and development planning to reduce irrigation loads and need for hard stormwater infrastructure.
- Westview Watershed Master Drainage Plan (MDP) is used as a general guide to manage stormwater, other MDPs will be undertaken as required.
- Encourages use of the BC Stormwater Planning Guidebook for stormwater management policies.
- Requires source control in all site designs for rezoning and new subdivisions.
- Encourages minimizing impervious areas on lots to improve infiltration, as well as maintaining natural vegetation.
- Encourages and supports construction of rain gardens, rainwater collection, alternative options for pavement.

5.2.3 District of North Vancouver

The District of North Vancouver (DNV) experiences similar rainfall patterns to the PRRD and has established stormwater management policies. North Vancouver also manages similar landslide hazards to the PRRD and has developed methods for mitigating these hazards through stormwater regulations.

Development Servicing Bylaw: This bylaw describes the amendments to the MMCD design guidelines for stormwater management. More specifically, it describes how to implement integrated stormwater management, goals for drainage management, drainage principles, design criteria, design rain storms, performance targets, analysis methodology, design targets, and construction standards for the storm system.

Sewer Bylaw: Details requirements for connecting to the storm sewer system, provision for work on sewer systems, use of oil and grit interceptors, provisions for establishing connections to the system, capping connections, right of entry to the system, and associated charges and fees.

Official Community Plan: The OCP discusses protection of aquatic ecosystems through stormwater management, promotes low impact development and best practices to protect watersheds from adverse impacts. Stormwater management is intertwined with broader sustainability goals in the document. General text regarding implementation of on site stormwater management and other integrated stormwater goals is promoted throughout the document. The OCP also has detailed information to mitigate slope stability issues through stormwater management. Key items are listed below:

- Buildings in slope stability hazard areas are connected to a centralized storm system.
- Buildings are located away from steep slopes and away from runoff points at the base of slopes, a 10 m minimum setback is enforced.
- Natural vegetation is maintained to the extent possible.
- The District recommends fill or yard trimmings should not be placed at the top off slope or along existing drainage channels.
- Water is diverted away from draining down slopes, ponding is not allowed near slopes.
- Grade lots to drain into streets and away from slopes.
- Paved surfaces are limited.

5.2.4 City of Surrey

The City of Surrey has a well-developed and refined approach to stormwater management. Policies and Bylaws at the City of Surrey include the following:

10-Year Servicing Plan: Establishes a renewal and upgrades timeline and funding for the storm system.

Design Criteria Manual: Details all design considerations for stormwater management including servicing objectives for conveyance systems, rain gauges to use in design and Intensity Duration Frequency curves, storm design methodology, instructions for stormwater modelling, details on design of storm sewer components, open channel flow design considerations, etc.

Integrated Stormwater Management Plans: Surrey has completed ISMPs for all upland catchments across the City providing guidance on stormwater upgrades and performance.

Local Area Service Program: This program allows residents to gather funding amongst property owners in their neighborhood to fund infrastructure improvements which will directly benefit their area. Utility upgrades and extensions are included under this program.

City-Wide Stormwater Flow Monitoring Programs: Provides Surrey with specific streamflow monitoring, water level monitoring, and rainfall gauges.

Rain and Drainage Interactive Simulator: Simulator to help residents visualize and understand how stormwater management and watershed response differs between natural hydrologic conditions, traditional non-sustainable stormwater infrastructure, and integrated stormwater management with current best practices.

Official Community Plan: General text supporting integrated stormwater management including the following:

- Adhering to Metro Vancouver’s Integrated Liquid Waste Resource Management Plan.
- Completing ISMPs for every watershed to inform land use planning.
- Protecting natural watercourses from development.

- Supporting sustainable stormwater management techniques.
- Requiring developers to pay for stormwater extensions.
- Requiring submission of a stormwater management plan for development in a “steep slope hazard area”.

Development Cost Charges: Provides provisions for Surrey to implement development cost charges to provide funds for drainage upgrades for people who obtain approval for a subdivision or building permit.

Land Development and Subdivision: Ensures all development has adequate drainage collection facilities and details which documents should be used for design and construction details.

Erosion and Sediment Control: Regulates what can be discharged into natural watercourses for the protection of the natural environment, including limits on TSS concentration, details on required erosion and sediment control plans to mitigate pollution, and enforcement of these plans.

Stormwater Drainage Regulation and Charges: Regulates use of the stormwater drainage system including charges, and protection of the system and natural watercourses. Some specific clauses include details on floodplain protection, on-site stormwater management requirements, stormwater drainage extensions, service connections, and offences and penalties.

Zoning Bylaw: Stormwater specific clauses include streamside protection requirements, building set backs from streams, and limits to lot coverage.

5.3 CURRENT PRRD STORMWATER REGULATIONS

In general, the PRRD has no bylaws relating to zoning, building permits, or more specific items such as tree cutting. This impacts stormwater management, as these bylaws generally have information related to limiting percent impervious areas, preserving native vegetation, enforcing setbacks from slopes/riparian buffers, specifying allowable runoff release volumes from properties, and regulating housing density.

Currently, there is only brief mention of stormwater management in PRRD’s bylaws for Electoral Areas A, B, and C. The OCP for Electoral Area A is the most recently updated OCP (2015). It mentions that integrated rainwater management planning should be promoted. It recommends property owners minimize impervious surfaces and encourages both property owners and the Ministry to maintain ditches and culverts to meet provincial standards. The OCPs for Electoral Area B and C only mention encouraging responsible storm water management within the resource land category.

In all three OCPs, language exists to establish maximum residential densities by limiting minimum sizes of parcels to help maintain a ‘rural’ feel. This would also indirectly benefit stormwater management by limiting the amount of undeveloped forests that can be cut or covered with impervious surfaces.

The PRRD also has two bylaws specific to conservation of water sources, the Lund Watershed Bylaw and Myrtle Pond Bylaw. Although specific to regulating land use to protect water for drinking, they provide an example of types of regulations PRRD could put in place for managing impervious coverage. The bylaws specify maximum floor areas for accessory buildings, and maximum lot coverage by percentage (in Myrtle Pond's case it was 50% coverage).

5.4 FEASIBILITY FOR NEW REGULATIONS IN THE PRRD

Based on the pre-existing regulations in the PRRD and the range of options for stormwater management described in Section 5.2, the following regulatory improvements would be feasible:

- Strengthening and expanding language in the OCP documents regarding stormwater management and slope hazard mitigation.
- Implementing a zoning bylaw.
- Implementing a tree cutting bylaw preventing removal of some native vegetation.
- Implementing a mechanism for centralized funding similar to the Local Service Area Program at the City of Surrey or a Development Cost Charges bylaw.
- On-site and off-site stormwater management regulations, or a servicing bylaw.

6 Recommendations

6.1 DIVISION OF STORMWATER MANAGEMENT RESPONSIBILITY

Three main parties are responsible for stormwater management in the study area. The MOTI, the PRRD, and the local residents and landowners.

Each of these three parties has a different but crucial role to play in improving stormwater management in the area.

MOTI Role: Infrastructure Development and Maintenance

A1. Draining the highway and other roads built and maintained by MOTI.
A2. Routing drainage intercepted along the length of the roads safely downstream.
A3. Maintaining databases of all MOTI infrastructure (roads, bridges, culverts, ditches).
A4. Ensuring new infrastructure meets MOTI design criteria.
A5. Regularly inspecting and maintaining MOTI infrastructure.
A6. Upgrading MOTI infrastructure which is not performing to an acceptable level of service or has known structural or hydraulic performance deficiencies (regardless of which standards it was designed to).

PRRD Role: Land Use Planning and Regulatory

B1. Implementing and enforcing bylaws, including development standards. Including criteria related to stormwater management in these bylaws such as maximum lot coverage or limits to impervious areas.
B2. Ensuring development is consistent with land use planning and OCPs.
B3. Providing education to the public on watershed management and best practices for on-lot stormwater management.
B4. Building, maintaining, and upgrading drainage infrastructure under PRRD jurisdiction.
B5. Implementation of centralized drainage planning and construction and maintenance of community scale drainage infrastructure.
B6. Defining targets for on-lot stormwater management for new developments (infiltration rates, required detention volume per hectare, release rates from detention ponds).

Property Owner Responsibilities: On-Lot Stormwater Management

C1. Managing runoff from their property to meet PRRD standards once enacted through use of low impact development options:
   a. Limiting impervious areas for new buildings such as garages, sheds, and other hard surfaces such as paved driveways and sidewalks.
   b. Conserving natural vegetation and tree cover (especially on steep slopes).
   c. Using rain barrels.
   d. Directing roof leaders to splash pads and to disperse over lawns or other pervious surfaces.

   e. Using absorbent topsoil (i.e. topsoil amended with compost to improve its absorption and attenuation characteristics).
   f. Constructing landscaping features with rainwater management functions, such as rain gardens or bioswales.
   g. Using alternatives to impervious surfaces (gravel driveways, permeable pavers, paving stones, raised sheds, etc.).

C2. Installing, maintaining, and upgrading drainage infrastructure such as driveway culverts and ditches on their property (i.e. driveway culverts should be minimum 400 mm in diameter).

C3. Educating themselves and their community on the best practices of managing runoff from their property, and how this effects other downstream residents and infrastructure.

Opportunities for Collaboration:

1. Developing ISMPs, drainage plans, or other drainage planning documents for various communities.
2. Developing a stormwater service and associated bylaw.

Given the extent of potential resource development in the upper watersheds across the PRRD study area, it would also be advantageous for the Ministry of Forests, Lands, and Natural Resource Operations (MFLNRO) to be involved in this discussion.

6.2 PRIORITIZED RECOMMENDATIONS

The present drainage study identifies the necessary steps toward improving stormwater management in the PRRD. Our study has indicated that each of the PRRD, MOTI, and property owners have an important role to play in improving stormwater management in the study area.

Table 6-1 lists specific recommendations to advance stormwater management planning in the region.

Table 6-1
Prioritized List of Recommendations

Recommendation	Responsibility	Description
1) Conduct a comprehensive inventory of existing drainage infrastructure.	MOTI and PRRD	The Ministry presently maintains a database of culverts and bridges within the study area. Further inspections and data collection should be undertaken so that more detailed information on asset condition is known. This should include collection of information on the condition, invert elevations, shape, size, and records of the date installed or repaired. Improving the database to include ditching line work could also help to identify locations where the ditching is inadequate. Information on condition will allow for more effective asset management, while collection of invert elevations could support further drainage system evaluation in the future. This is not intended to be a detailed hydrologic

Recommendation	Responsibility	Description
		or hydraulic assessment of each structure but rather a basic inventory of the drainage infrastructure throughout the study area to ensure MOTI records are sufficient to strategically plan renewal efforts.
2) Explicitly define maintenance responsibilities.	MOTI/PRRD	From our discussion with residents, there is significant confusion over who is responsible for the maintenance of ditches and culverts (clearing vegetation and brush from ditches, ensuring driveway culverts are not damaged), and what property owners' responsibilities are. The PRRD and MOTI should explicitly define these responsibilities, and communicate this information to the public.
3) Address coastal bluff erosion due to drainage outfalls.	MOTI/PRRD	Several locations in the study area have been identified as having issues with uncontrolled drainage over an exposed coastal bluff. Two such areas include Reave Road, and Fleury Road. In these areas, serious erosion problems are resulting which could threaten houses and public safety in the future. Addressing these areas through slope stabilization and erosion mitigation should be a priority, and reconfiguring the drainage to safely convey flows down the slopes is important. Similar efforts have been made recently on Random Road and on Stevenson Road. The performance of those installation should be reviewed to determine whether design modifications would result in a more effective design.
4) Develop a public education program on stormwater management.	PRRD/MOTI/ Residents	A significant improvement to drainage conditions can be achieved if property owners and communities take action to improve their on-lot management of stormwater. To do this, the PRRD and MOTI should undertake a comprehensive public education program. This could include open houses, mailouts, and information on the PRRD's website. This program could provide general information on how the drainage system works, expected level of performance, where responsibilities lie, and what property owners can do to improve the conditions. It could also provide resources and support to property owners interested in constructing stormwater source controls, such as rain

Recommendation	Responsibility	Description
		gardens. The PRRD and MOTI can relate these stormwater source controls and their role in improving groundwater recharge back to residents' high priority for maintaining groundwater for domestic/agricultural uses.
5) Conduct hydrologic and hydraulic assessments of the major creek crossings in the study area.	MOTI	To better understand the current hydraulic capacity of culverts on major watercourses beneath the highway, focused hydrologic and hydraulic assessments of these creeks could be undertaken. In Kelly Creek, for example, the accumulation of sediment at the inlet suggests the culvert may not have sufficient capacity. A comprehensive review of the current capacity, as well as an evaluation of the resilience of these crossings to climate change could help to understand the risk of these major culverts washing out during extreme events.
6) Collect LiDAR data for the region.	MOTI/PRRD	The current topographic data (20 m contours) is not sufficient to delineate watersheds to the degree necessary for assessing the hydraulic capacity of the drainage network and to support drainage planning. Additional information is needed to pinpoint locations where the ditches are inadequate, and to assess the resilience of the current system to climate change effects. Given that the drainage system is primarily open channels, LIDAR survey may be an effective way to collect the information necessary for more detailed drainage studies in the future. The LIDAR should be collected during a dry period at high resolution, to maximize its capability of picking up ditch bottoms.
7) Continued drainage and stormwater planning.	PRRD/MOTI/ Residents	The present study represents a first step in improving stormwater management planning in the PRRD. Further work could be undertaken to build upon these findings and set specific stormwater targets and plans. This could be done in the form of regional ISMPs or MDPs. Given the number of reported problems within the Pine Tree watershed, it may be worthwhile to focus on this area first.

Closure

This report was prepared for the Ministry of Transportation and Infrastructure to provide insight into the sources of drainage related issues in the PRRD and recommend mitigative actions. Collaboration between the PRRD, MOTI, and residents has the potential to greatly improve stormwater management across the regional district.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

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Appendix A - Photos from Field Visits

Photos from Field Visits in August and November of 2017

Lack of ditches at Stevenson Road. Evidence of road erosion.

Filled in ditch on Myrtle Point Road, causing drainage flowing onto down slope properties (8611/8612).

Photos from Field Visits in August and November of 2017

Example of driveway culverts and ditches along Traff Road.

Example of a highway ditch at Stevenson Road.

Photos from Field Visits in August and November of 2017

Eroding bluff at Fleury Road ditch outfall.

Ditch spilling water onto eroded bluff at Fleury.

Photos from Field Visits in August and November of 2017

Discharge eroding the bluff at Reave Road

Full ditch along Stager Road off Stark Road.

Photos from Field Visits in August and November of 2017

Ditch along Reave Road.

Standing water at Arbour Drive.

Photos from Field Visits in August and November of 2017

Flowing ditch on Pine Tree Road. Residents indicated that the flow at the time of the photo was relatively

Creation of new concentrated flow path along rip rap lined channel on Pine Tree Road

Photos from Field Visits in August and November of 2017


Typical unmaintained ditch/culvert outlet.


High flow in ditches along Victory Road.

Photos from Field Visits in August and November of 2017

Build up of sediment and debris at Kelly Creek Culvert under Highway 101 (August 2017).

Winter flows with log blockage at culvert entrance on Kelly Creek (November 2017).

Photos from Field Visits in August and November of 2017

Uncontrolled drainage on Finn Bay Road

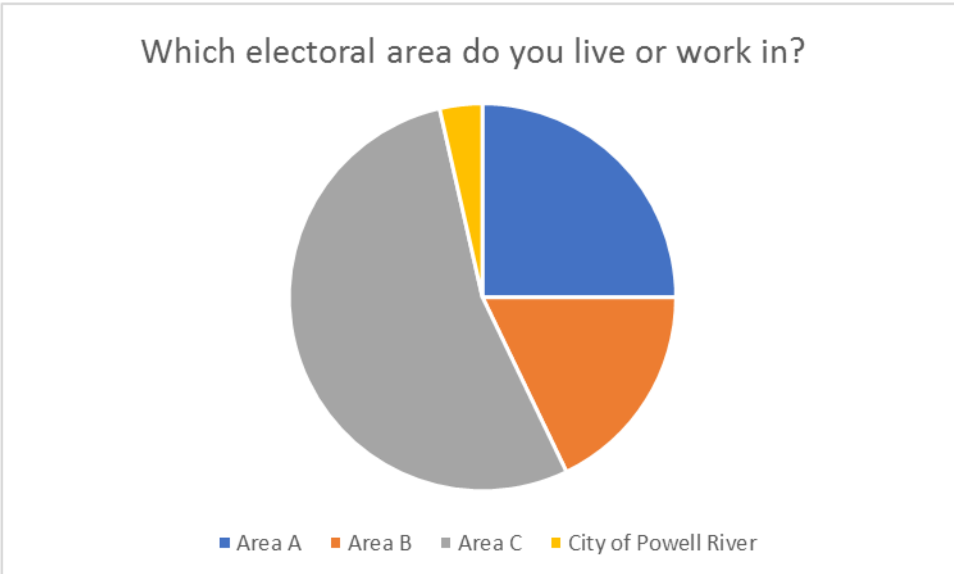
Steep cut with seepage near Atrevida Road.

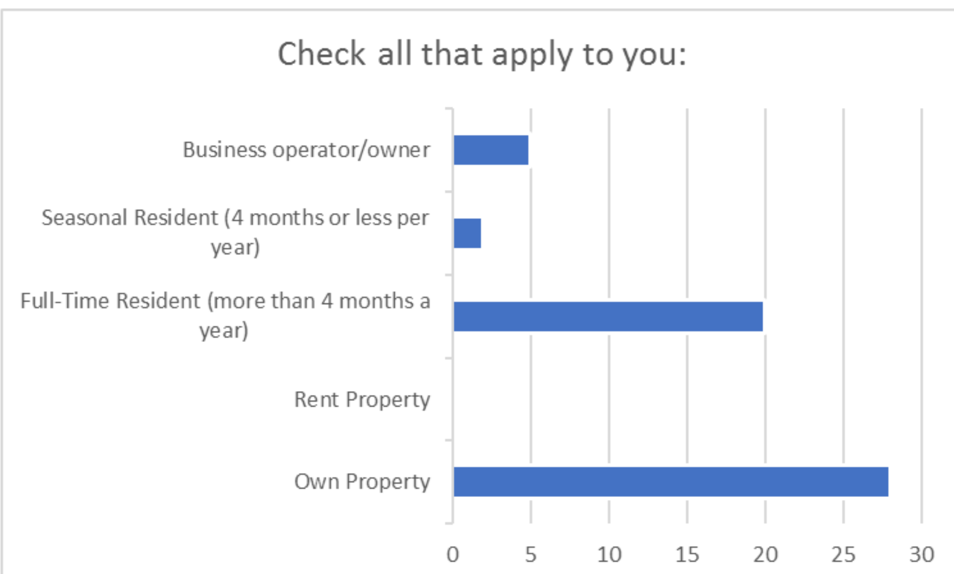
Appendix B - Survey Results

PRRD Drainage Survey Summary

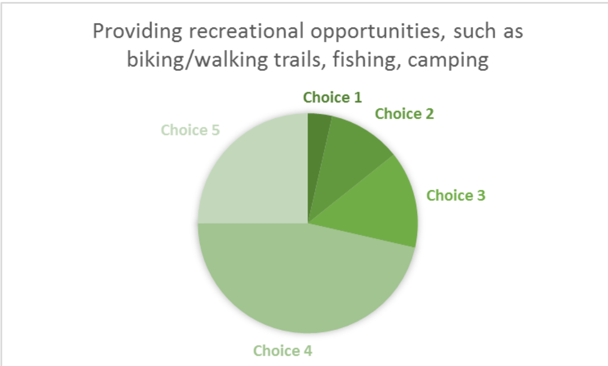
We received 28 complete survey responses and 2 with just comments. The 28 are represented in the graphical answers, the comments are added into the text responses.

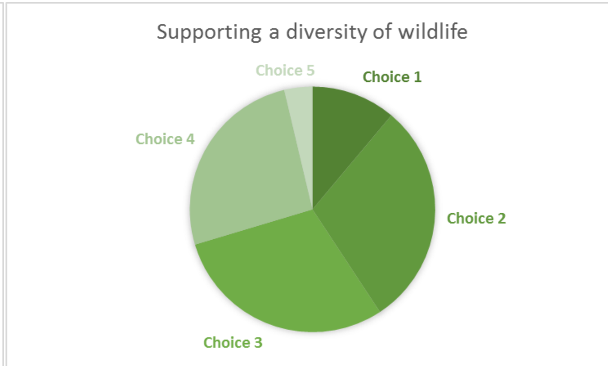
Question 1:

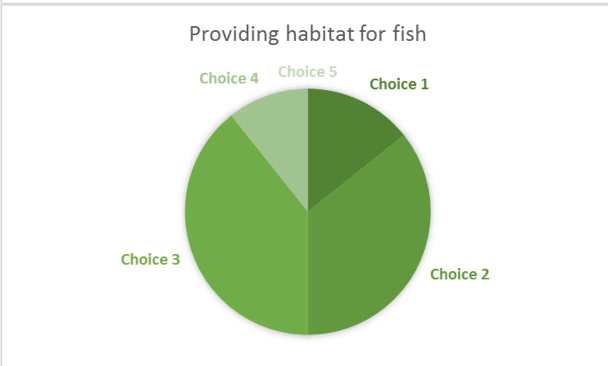


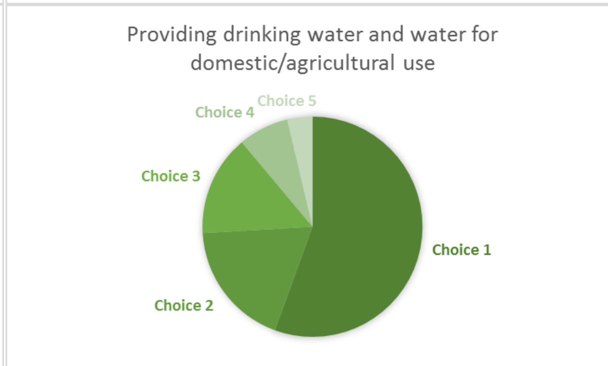


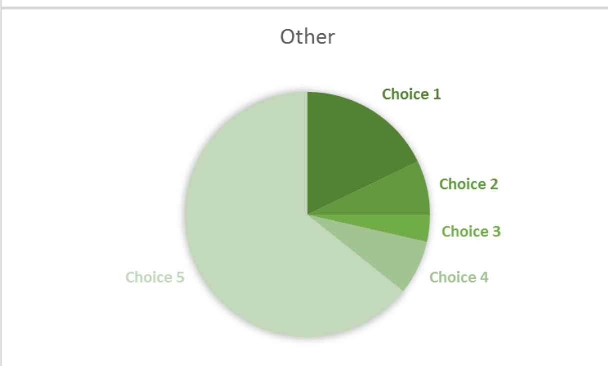
Question 2: Although one function of a watershed is to provide efficient drainage of storm events, it also serves a variety of other purposes. Based on their importance to you, in which order would you choose the following? (1-most important, 5-least important). ***Other was also an option.***









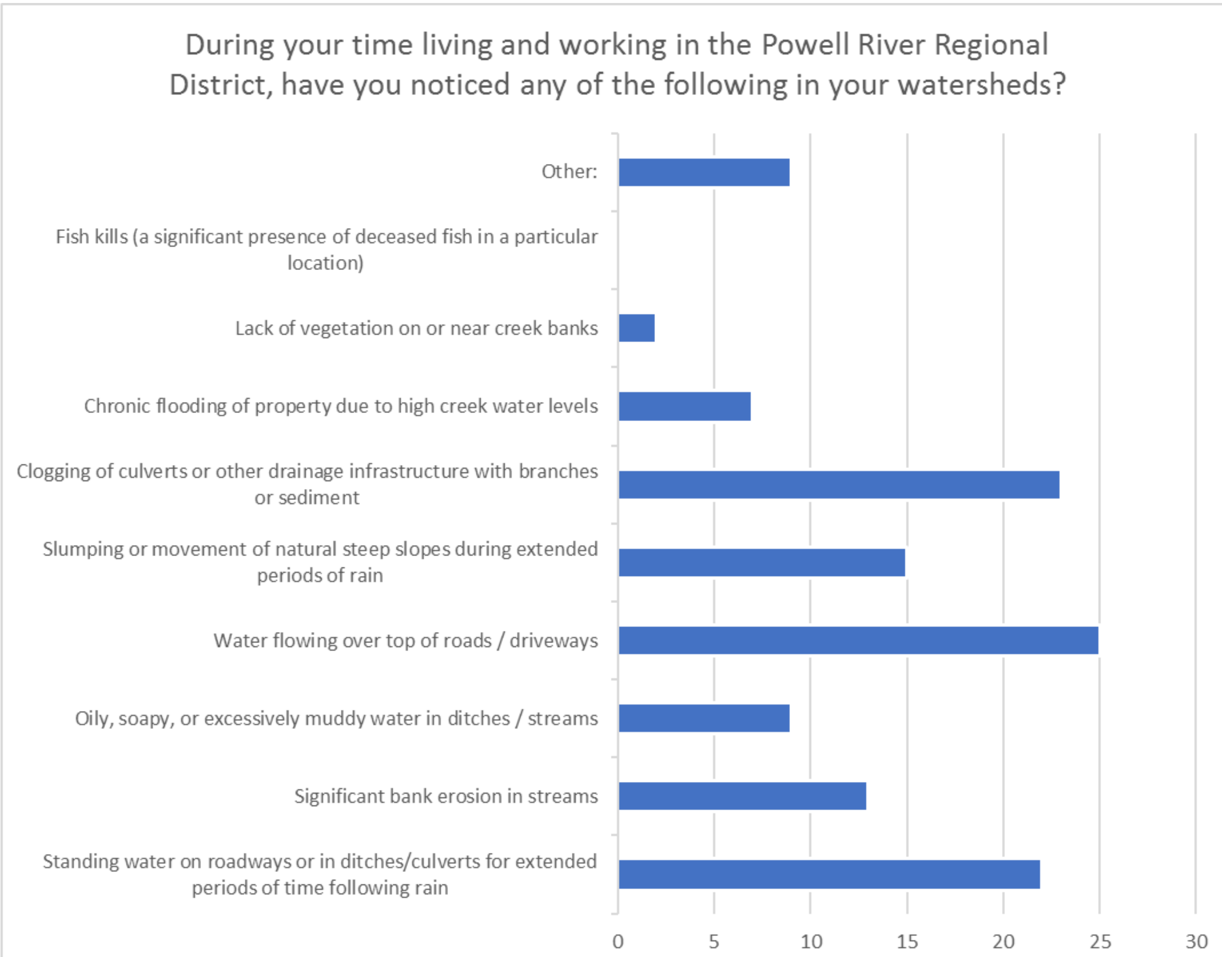


Other:

- Protection of my house and property, access and use of my land.
- All of the above.
- Maintain environment to ensure clean drinking water and uncontaminated gardens. No runoff from roadways and other properties.
- Provide protection for infrastructure, public and private property.
- Stop logging within two miles of the shoreline.
- Ensuring that pollution of the environment does not inadvertently (or deliberately) occur.
- Supporting a healthy community with infrastructure.
- Drainage ditches/culverts correct sizing.

- Environmental stability – prevent road and slope failures (ie. Plugged undersized culverts/insufficient culvert diameters).
- Erosion/flooding.

Question 3:



Other:

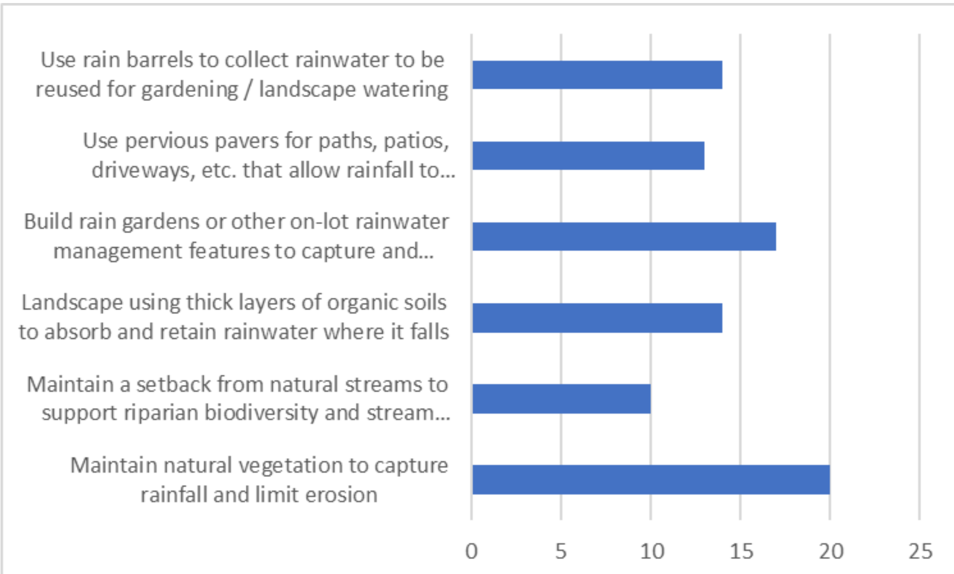
- Flooding of septic fields and basements.
- No ditches where there should be.
- Culvert flooding yard, contaminates well.
- Heavy water flow due to lack of drains on road.
- A lake in my front yard during stormy rainy season.
- Water flowing from ditches into private property.
- Increase in standing water on property.
- Landslide.
- Evidence of water high and over the capacity of the system, potential logging processes up stream will increase the volume of water and increase the problems, need for better policies regarding impacts of land use.

Question 4: Where/when have you noted the items identified above?

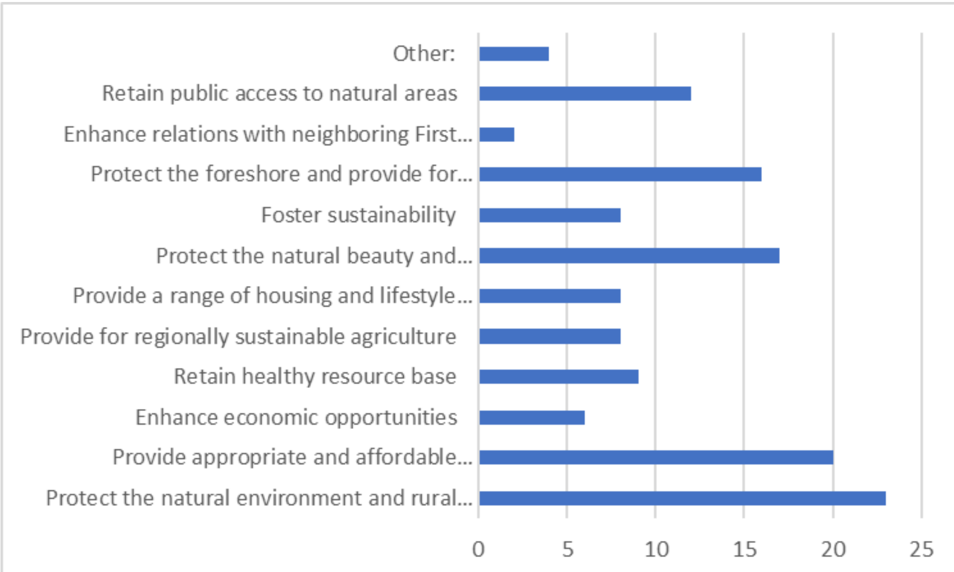
- May 2017 Douglas Bay Rd/Donkersley Rd, Powell River.
- Run-off from Weldwood logging road crossing highway 101. It has no outlet to existing drainage channel so fills the ditch, the runs down and erodes the private driveways.
- Properties at Myrtle Creek.
- Atrevida Road, yearly during the rainy season.
- South side of Patrick Road – water flows from neighbours across the street.
- On the highway/Reave Rd drainage collector ditch, from Stittle Rd to final discharge culvert adjacent to my property. This portion of ditch is not maintained by anyone, and has overflowed across my property at 9421 Stittle Rd. The cascading discharge from this culvert has caused landslides that threaten adjoining properties.
- Corner of Frolander Bay Road/Arbour Drive.
- Water flowing across Longacre Road near the bottom; creates very icy conditions in winter. Areas of Finn Bay Rd flood regularly. Murray Road, just above SunLund mobile home, is being undermined and the bank is eroding to the point that boulders are working their way down the embankment.
- Crowther Road near 10568.
- 6552 Sutherland Ave.., Powell River, B.C.(Wildwood)
- Donkersley Rd and Douglas Bay Rd (water flowing across roads and driveway). Flooding of properties from ditch drainage into private property through most of the 2016/17 rainy season.
- Water flowing over road during heavy rains and standing after heavy rains on the corner just past Theden Forest Products when heading toward Lund. Clogging of culverts with debris on the same stretch of Hwy.
- On Finn Bay Road, Lund, just after turn off from Lund highway, in early December.
- Pine Tree Road and Random Road.
- I have observed the MOTI pipe that drains into the waterfront between my property and our neighbour's become plugged with debris. I have also seen oily substances discharged from that same pipe. I have also seen the beach and waterfront eroded by the condition of this pipe.
- Lamb Road across from 1851 Lamb and just past 1948 Roberts Road. Both problems are due to lack of road maintenance/ditches.
- Ditches along Highway 101, bank below Centennial Dr., highway in front of Oceanside Resort water runs off highway onto property, culvert openings covered with debris along Highway 101.
- Kennedy Rd, Lang Bay. Ditches are there but blocked with vegetation and the water just runs down the road.
- Kristensen Road between Mcleod and Palmer.
- Lower Pine Tree Road and Random Road, Culvert on Hummingbird Lane, and Pine Tree road, Standing water on pine tree place.
- 9449 Stittle Rd.
- Stittle Rd. Mclean, Power Rd- ditch, Hwy 101 and Reeve.
- Highway 101/Victory Road, view street and victory road, ditch and side of albion road at victory, view st. access to beach rd./ditch.
- Lund highway all along.
- Highway 101 north/south/Malaspina road/baggi road/finn bay.

- Marine, pine tree at highway, random at pine tree, the ditch system between highway and sea has been stretched beyond capacity more than once, culverts on individual properties may need upgrading.
- Stevenson road, pine tree, any location where highway culverts discharge.
- 2255 Hwy 101 Road water running into driveway plugging his trench at least 4 times a year.

Question 5: There are several things individual property owners can do to have a positive impact on storm drainage and watershed / stream health. The following is a list of some of these common approaches. If you knew more about them, which of the following would you be interested in doing on your property to help manage runoff?



Question 6: If you could establish priorities when moving towards future development and implementation of the OCP developed by the PRRD, what would be your top 5 priorities? *Total number of times selected as top 1 through 5 priority listed in bar graph.*



Other:

- Freedom to make property improvements and stabilize banks with rock retainers and rock gardens and utilize my acreage sensibly and protect my property from water in all directions.
- Zoning and regulate land use.

Question 7: What if anything would you suggest to enhance drainage conditions or watershed health in the PRRD?

- Be aware and map areas in the regional district with ongoing drainage problems during storm conditions - effectively deal with them by long term solutions re ditching, maintenance of ditches etc.
- Enforcement of set backs from streams - workshops on rainwater management- at cost rain barrels available from City and Regional District.
- Slope ditches properly, with ridiculous poorly executed ditch deepening after the Atrevida road mudslide they now hold standing water all winter and fester mosquitos all spring, Clear vegetation from ditches after hydro tree trimming maintenance, Slope and surface Atrevida road properly toward the ditches.
- Ensure proper and well maintained drainage ditches along roads.
- (1) Define responsibility for maintenance for ALL elements of drainage network, including easement areas; (2) conduct condition assessment of culverts and discharges of the network, and prioritize remedial/replacement work; (3) Ensure that any logging is permitted ONLY after surface runoff issues are evaluated and remediated to handle additional flows.
- Inform homeowners on their rights and responsibilities pertaining to drainage. Take a stronger approach to those who make inconsiderate changes to drainage systems without permission.

- Insist that Ministry of Highways spend the money to keep the infrastructure up to date and well maintained.
- Require logging to provide connection to storm or ditches and/or make ponds to capture, clear culverts and ditches.
- The PRRD should develop a proper drainage infrastructure in keeping with good environmental practices. This will involve MOTI and it will require MOTI to improve and replace many of the drainage systems that it has installed and which have and continue to affect the natural environment and foreshore.
- Maintenance of roads and ditches would help.
- Run off water from Highway and roads needs to be directed away from landowners property, ie: culverts, ditches, drains, need to be installed.
- Keep ditches cleaned out.
- Clean out drainage ditches and culverts on a regular basis, attention to winter/spring lakes in forest areas uphill of residents.
- Upgrade/maintain drainage infrastructure.
- Coordinate plan between MOTI and district to collect drainage for distribution to the ocean, District to introduce formal zoning and bylaws for development of agricultural and residential properties.
- Regulate land use with zoning, DCC's for infrastructure, hire engineers for a proper storm drain system, build a proper planned sustainable community.
- Correct culvert sizing, reroute incorrect water flow (ditching).
- Salmon habitat restoration- almost always also solves the flash flooding issues.
- Ensure all private land water courses and crossings/structures are included in all studies to ensure complete picture of the entire drainage areas, provide incentives for land owners to properly treat/manage watercourses/drainage on their properties (tax credits?) need to have benefits to landowners, almost impossible and impractical to try and enforce through regulation.
- Need better and updated infrastructure with increased capacity that can manage the volume of water and manage surges, need to better control land use upstream, (like logging) to reduce erosion and runoff downstream.
- Provide proper discharge structure over high banks, control land development to reduce water runoff.
- He would like to pave the edge of the highway, cause the gravel has washed out. He would suggest paving road edge to grass, no ditch on his side of hwy, possible to put a culvert on his side to direct water to opposite side of road which has the ditch. Additionally, he says to pave and edge the hwy 101 from southview road to malaspina road.
- Myrtle point drive 8611-8612- the ditch has been filled in without culverts, it appears to be directing water into our property which in turns will go upon highway 101, don't fill in ditches without notification

Question 8: Do you have any additional comments you would like the authors of this study to know?

- Flooding of septic fields & basements with more frequent and intense storm conditions, now more prevalent with global warming. Contaminated ground water going into the ocean.
- My property on Atrevida was an expensive investment and taxes are huge, the road and culvert maintenance are inadequate, I want to be able to make property improvements and

protect my property from the water both from inland and the ocean without unreasonable restrictions, I invested in this property with its acreage above the road with the freedom to utilize that acreage, I feel strongly about responsibly retaining this freedom!!

- Discharge culvert adjacent to my property is corroding, and downstream embankment is eroding.
- Previously when I met with a highways rep at the office on Alberni St. I asked for info for installing a driveway culvert for a new home. The rep gave me paperwork on current rules but would not look at or advise on the unusual circumstances of the location. I hope this approach has changed.
- On two occasions when trying to drive through the Finn Bay Road "puddle" I have floated two vehicles, significant damage.
- Decades ago, MOTI installed a pipe between our property (7883 Traffe) and our neighbor's. Our neighbor entered into an agreement with MOTI. The former owner of our property did not. The drainage pipe took water from drains along Traffe Road and directed it into the ocean. The drainage pipe was not installed in accordance with the plans (no protective rip rap). The pipe is now damaged and damage is occurring to the beachfront and dangers created.
- Ditches and culverts need to be monitored and maintained regularly to avoid blockage and or runoff situations.
- Interested in helping maintain the storm drainage systems already in place on their property. We recommend logging be restricted to at least 2 miles from the high tide mark or restrict logging in area C.
- Let's get into the 21st century, global warming is a reality and the water must be moved to lower the impact on residents.
- Ensure province provides and maintains arterial and collection drainage, ensure district maintains and talks responsibility for all local drainage.
- The highway at victory road is being undermined, ie: cracks in highway because of right angle turn above highway. (no culvert under highway!)
- Keep climate change in mind.
- Ensure crossing and drainage designs incorporate ongoing climate change implications re numerous high intensity rainfall events (need culverts/bridges to handle the increased peak flows) thank you.
- Since the impact of land use upstream of the residential areas can significantly affect the run-off of storm water, recommend that natural resources be full partner in discussions. Policies needed to protect residential areas, consider region replacing undersized culverts to improve system and look at ways to re-coup the property taxes over time, these might help increase willingness to have improvements done.
- Identify the regional district and MOTI as the responsible parties for causing the majority of bank erosion and flooding along the shoreline.