Associated Environmental

# FINAL REPORT

## Regional District of Central Okanagan

Regional Floodplain Management Plan:
Phase 1




**June 2016**

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June 20, 2016
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Janelle Taylor
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**Re: FINAL REPORT - REGIONAL FLOODPLAIN MANAGEMENT PLAN - PHASE 1**

Dear Ms. Taylor:

Associated Environmental Consultants Inc. is pleased to provide the final report of Phase 1 of the Regional Floodplain Management Plan (RFMP). All comments on the draft report provided by the Regional District of Central Okanagan (RDCO) have been considered and incorporated within the final report.

The final report includes a review of existing information on historic floods and flood mechanisms within the RDCO, identifies and maps flood-prone areas and streams, develops and presents the Preliminary Flood Risk Ratings for the flood-prone areas and streams, and provides recommendations for updates to the RDCO Emergency Flood Plan and for Phase 2 of the Regional Floodplain Management Framework.

Thank you for the opportunity to assist RDCO on the RFMP. Please contact Hugh Hamilton or Drew Lejbak if you have any questions.

Yours truly,
**Associated Environmental Consultants Inc.**

Hugh Hamilton, Ph.D., P.Ag.
Project Manager

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# Executive Summary

## 1 BACKGROUND

The Regional District of Central Okanagan (RDCO) represents one of the fastest growing areas in Canada over the past 20 years and growth is expected to continue. The RDCO is a “waterfront community”, characterized not only by many kilometres of lake shore, but also by numerous watercourses that mostly originate in the upland forested watersheds around the region. This proximity to water means that flooding of developed areas can occur due to a mixture of natural conditions and land use activity. As such, RDCO is committed to proactive management of flood hazards.

As an important step towards region-wide flood hazard management, a three-phase Regional Floodplain Management Framework was outlined for the RDCO by Clarke Geoscience Ltd. (2014). The overall objective of the Regional Floodplain Management Framework (i.e. all three phases) was to develop a better understanding of flood risk within RDCO boundaries such that the likelihood of damage from floods is reduced. The three phases are:

- Phase 1 – Development of a Regional Floodplain Management Plan (RFMP) that identifies flood hazards and establishes the scope and priorities of Phases 2 and 3.
- Phase 2 – Flood Hazard and Risk Assessment.
- Phase 3 – Flood Risk Mitigation Strategies.

In August 2015, RDCO issued a request for proposal (RFP) for the development of the Phase 1 RFMP. Following this, Associated Environmental Consultants Inc. (AE) was retained by the RDCO to complete Phase 1. This document is the Phase 1 RFMP final report completed by AE.

The specific objectives for the Phase 1 RFMP are outlined in Section 1.4 of this report. The intended outcomes for the RFMP are as follows:

1. Reduce flood risk.
2. Improve emergency response by identifying and prioritizing flood-prone areas and by establishing proactive measures to mitigate risk.
3. Increase resilience to climate change by increasing the ability to anticipate, absorb, accommodate and recover from flood events.

## 2 PHASE 1 REGIONAL FLOODPLAIN MANAGEMENT PLAN METHODS

The Phase 1 RFMP included a data collection and stakeholder engagement exercise to collect and collate available information to help formulate the RFMP. The methods used to develop the Phase 1 RFMP included:

- Online and library searches for background, technical, and planning information relevant to flood management in the RDCO.
- Government and stakeholder involvement through a three hour stakeholder workshop that took place at RDCO offices to review available information and confirm the desired scope and format of the Phase 1 RFMP.
- Identification and mapping of flood-prone streams within RDCO.
- A preliminary flood risk screening assessment to assign a Preliminary Flood Risk Rating (PFRR) to the watercourses within the RDCO.

## 3 BIOPHYSICAL, LAND-USE, AND SOCIAL-COMMUNITY CONTEXT

To help provide direction for the context for the Phase 1 RFMP, a summary of biophysical characteristics of the RDCO (including climate, land-use, hydrology, climate change impacts) with relevance on flood hazards was completed. In addition, existing floodplain mapping, flood infrastructure, and historic flood events were summarized.

The key findings from the review of available information are as follows:

- Population within the RDCO is largely concentrated in the valley bottom, with the most desirable property and real estate adjacent to waterbodies and watercourses. As a result, much of the infrastructure is built on alluvial fans and floodplains, which are more susceptible to flooding than upland areas.
- Total precipitation and snowfall are much greater at higher elevations in the Okanagan Valley than in the valley bottoms. The risk of floods in valley bottom is largely driven by precipitation and snowmelt processes at higher elevations.
- Flood mechanisms within the RDCO include rain, rain-on-snow, snowmelt, debris blockages and rapid release of flows, ice jams, dam break, dike breach, sediment accumulation, high lake levels, surge and wave set up, and climate change. A number of these flood mechanisms are influenced by land use, and changes in land use within the upper watersheds, which have the potential of altering these mechanisms to some degree.
- Based on the available climate change research, the magnitude of extreme peak flows is projected to increase and this could cause an increase in flood and natural hazards within the RDCO.
- The B.C. Ministry of Environment (MOE) has mapped the 1:200-year return period floodplain along portions of Mission Creek and the west shore of Okanagan Lake from Peachland to West Kelowna. Floodplain mapping of Mill Creek has also been completed by the City of Kelowna. No other watercourses or waterbodies within the RDCO have had floodplain mapping completed.
- Flood mitigation infrastructure is not widespread within the RDCO, with only five watercourses (Bellevue, Mission, Mill, Trepanier and McDougall Creeks) identified to have any permanent flood infrastructure. Smaller emergency flood protection works have been implemented on watercourses throughout the RDCO, but are not well documented.

There are currently 129 dams within or up-gradient of the RDCO, with the majority located in the headwaters (upper watershed). Of the dams with an assigned consequence rating, 47 are rated as low consequence from a dam breach, 27 are significant, 38 are high, 4 are very high, and one is extreme. Owners of dams which have a consequence classification of high or greater are required to complete a Dam Safety Review (DSR) on a regular basis. DSRs have been completed for most of these dams within the RDCO.

## 4 PRELIMINARY HAZARD AREA IDENTIFICATION AND PRIORITIES

Flood hazard assessments have not been completed for the majority of watercourses and waterbodies within the RDCO boundaries, and only limited floodplain mapping available to date. To aid in identifying areas at risk of flooding and their corresponding consequences, a preliminary flood risk screening procedure was completed to assign an initial flood risk rating to watercourses within the RDCO. This screening approach followed the flood hazard risk guidelines outlined by Association of Professional Engineers and Geoscientists of BC (2012), but was modified for the Phase 1 RFMP to serve as a screening tool to help set priorities for further investigational effort in Phases 2 and 3. Because of their preliminary status, the preliminary flood risk ratings (PFRR) included herein are not to be used for specific planning or land use decisions beyond the scope of this study.

For the PFRR, a flood was defined as a condition in which a watercourse or body of water overtops its natural or artificial confines and covers land not normally under water. Following this definition, a methodology was developed for the assignment of the PFRR based on an identified likelihood of flood mechanism and associated consequences to elements-at-risk using a risk matrix that considers priorities for Phase 2 of the RFMP. The PFRR was assigned based on an equal weighting of all consequence category ratings (i.e., Land Use, Critical Infrastructure, Soil and Cultural, Total Population / Personal Hardship, and Environment) and the resultant PFRR values were defined as low, moderate, high, or very high.

The PFRR values were assigned for mapped and estimated floodplains, alluvial fans, and flood-prone watercourses/reaches within the RDCO. The results were qualitatively reviewed and confirmed using local and historic knowledge of watercourses known to flood. A summary of the PFRR results are as follows:

- Actual and estimated floodplains and alluvial fans within the RDCO had PFRR values between Low to High, while the Okanagan Lake floodplain had a value of Very High.
- For key floodplains and alluvial fan areas identified along mainstem watercourses within municipal limits, the PFRR values were High.
- The remaining flood-prone watercourses/reaches without mapped or estimated floodplain/alluvial fan areas, the PFRR values ranged between Moderate and High.

## 5 MECHANISMS FOR LAND USE MANAGEMENT ON FLOODPLAINS

The RDCO has by way of bylaw addressed some of the components of floodplain management, including climate change considerations. The existing planning mechanisms serve as the starting point for future

RDCO floodplain management through the inclusion of flood construction levels and floodplain setbacks. In general, the planning mechanisms implemented by the RDCO are consistent with the approaches used by other local and regional governments that have worked to address floodplain management.

Within the RDCO, the member municipalities, and First Nation lands, only Mission Creek, Mill Creek, and Okanagan Lake have specific flood protection requirements. However, other watercourses with Moderate and High PFRRs that lack stream-specific flood elevations or set-backs are Bellevue, Peachland, Trepanier, Powers, McDougall, Lambly, Shorts, and Vernon Creeks.

To address flooding within the RDCO, the RDCO has developed an Emergency Plan – Flood Plan (Flood Plan) that applies to all flood-prone areas. The Flood Plan lays the foundation for describing a flood event, the structure to be utilized, and the general expectations for roles and responsibilities of other levels of government, agencies, and stakeholders. The RDCO, as with other local governments, are responsible for both activation of the emergency procedures and for site level response. The Flood Plan however, does not currently outline special measures or responses for individual streams or sections of waterfront within the RDCO.

The new B.C. Dam Safety Regulation that sets requirements and best practices for all aspects of dam design, construction, operation, maintenance, removal and decommissioning of dams, came into effect on February 2016. Section 9 of the Dam Safety Regulation establishes that emergency plans are required for all dams with classifications of significant, high, very high and extreme. Dam owners within the RDCO are expected to file emergency plans with the RDCO. These plans should be included within the Flood Plan.

# 6 RECOMMENDATIONS

## 6.1 Emergency Response

Flood emergency response should continue to focus on the principles of the 2013 Emergency Flood Plan. The Flood Plan is well conceived, and encompasses all aspects of emergency planning and preparation. Improvements to response associated with the plan involve more information packaging in the planning stages, and developing processes that improve emergency operations. Any information that reduces doubt or delay during an emergency saves lives. Recommended updates to the Flood Plan are as follows:

- Compile and update key details and lists for each individual watershed or sub-catchment as required.
- All staff should be trained on the whereabouts of first responder information sheet, and should understand completely the responsibilities as a first responder.
- Dam breaches, if they occur, are not typical floods, and should be considered as a major emergency event.
- Floodplain mapping/dam breach mapping should be considered, at least, for each creek containing a very high or extreme hazard consequence dam.

- Dikes are continuously being updated and maintained. Therefore, a copy of the maintenance records should be kept on file by the RDCO and the Flood Plan should reference the location for responders to review as required.
- Appendix C of the Flood Plan should be updated to include all floodplain mapping, flood infrastructure, and areas of flood concern.

The final recommendation for the Flood Plan is to develop a flood event (historical), mechanism, damage, and mitigation database. This database will help identify or confirm watercourses that are flood-prone and/or areas at risk, and will help ensure that emergency planning staff are aware of the flood risk.

### 6.2 Phase 2 - Hazard and Risk Assessment

The scope of Phase 2 should be focused on the delineation and confirmation of the flood-prone streams and floodplains identified in Phase 1. This will help to ensure that all watercourses are considered in a local government bylaw, as well as within the Flood Plan. Section 4.5 of this report identifies the priority streams, waterfront areas, and flood infrastructure within the RDCO recommended for further assessment. The studies identified in Section 4.5 considered to have the highest priority for Phase 2 are as follows:

- Okanagan Lake flood construction level mapping for the entire RDCO.
- Wood and Kalamalka Lakes flood construction level mapping.
- Delineation and confirmation of key floodplains and alluvial fans for the Very High and High PFRR watercourses within RDCO.
- Confirmation of flood-prone watercourses/reaches within the RDCO through reconnaissance-level field assessments, focussing on the higher-risk reaches.
- Dam failure inundation mapping.

To complete a flood hazard risk assessment to modern standards, floodplains need to be delineated. Floodplain locations were identified and mapped at a screening level during Phase 1, but to accurately assign a flood hazard and risk to a watercourse or land use area, the spatial extent of flood waters under varying design criteria is required. Following this, once a floodplain(s) has been delineated and/or confirmed, the corresponding consequence ratings should be updated. Most of the consequence category information collected in Phase 1 can be used; however, some improvements to data sources (e.g. environmental elements-at-risk, building footprints) would be required for Phase 2.

### 6.3 Planning for Phase 3 – Development of Mitigation Strategies

The primary goal of Phase 3 is to further develop and expand upon the risk mitigation strategies that are already in place for the region. Phase 2 will enable this by providing more quantitative assessments of hazard, consequence, and risk in high priority areas. Mitigation strategies that can be further advanced when the Phase 2 results are available include the following:

1. Avoidance through the development of stream-specific bylaws, watershed-specific Development Permit Areas (DPAs), policies for allowing exceptions to flood bylaws or DPAs, and re-zoning.

2. Physical and biophysical improvement through flood protection structures, diversions or flood by-passes, riparian planting, and floodplain land acquisition.
3. Warning systems, education, and public awareness.
4. Monitoring, inspection and periodic review of plans and policies.

# Acknowledgements

The Phase 1 Regional Floodplain Management Plan project was directed by Janelle Taylor of the Regional District of Central Okanagan Planning Section. The project was managed by Hugh Hamilton, Ph.D., P.Ag. of Associated Environmental Consultants Inc. The consulting team included Drew Lejbak, M.Sc., Lawrence Bird, M.Sc., Rod MacLean, P.Eng., Kellie Garcia, P.Ag., Christine Callihoo, MCIP, RPP, and Dan Austin, MGIS. Senior review of the project report was by Dr. Brian Guy, Ph.D., P.Geo.

Associated thanks the individuals and organizations that provided information for this report; and those who took the time to attend the project stakeholders' workshop in December 2015.

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# List of Abbreviations

| | |
|---|---|
| APEGBC | Association of Professional Engineers and Geoscientists of BC |
| B.C. | British Columbia |
| BCERMS | British Columbia Emergency Response Management System |
| CBCCSP | Columbia Basin Climate Change Scenarios Project |
| DSR | Dam Safety Review |
| EOC | Emergency Operations Centre |
| EPP | Emergency Preparedness Plan |
| FCL | Flood Construction Level |
| GIS | Geographic Information System |
| IDF | Intensity-Duration-Frequency |
| MCRI | Mission Creek Restoration Initiative |
| MFLNRO | B.C. Ministry of Forest, Lands and Natural Resources Operations |
| MOE | B.C. Ministry of Environment |
| OBWB | Okanagan Basin Water Board |
| OBWRID | Okanagan Basin Water Resource Information Database |
| OWSDP | Okanagan Water Supply and Demand Project |
| PCIC | Pacific Climate Impacts Consortium |
| PFRR | Preliminary Flood Risk Rating |
| RDCO | Regional District of Central Okanagan |
| RFMP | Regional Floodplain Management Plan |
| RFP | Request For Proposals |
| SWE | Snow Water Equivalent |
| WMO | World Meteorological Organization |

# Glossary

| | |
|---|---|
| **Consequence** | The likelihood of damage or losses to an element-at-risk in the event of a specific hazard. |
| **Flood** | A condition in which a watercourse or body of water overtops its natural or artificial confines and covers land not normally under water. |
| **Flood Construction Level** | A designated flood level plus freeboard, or where a designated flood level cannot be determined, a specified height above a natural boundary, natural ground elevation, or any obstruction that could cause flooding. |
| **Floodplain Setback** | The required minimum distance from the natural boundary of a watercourse, lake, or other body of water to any landfill or structural support required to elevate a floor system or pad above the flood construction level, so as to maintain a floodway and allow for potential land erosion. |
| **Hazardous Flood** | A **flood** that is a source of potential harm. |
| **Hazard** | A potentially damaging event. |
| **Polygon** | A mapped spatial unit (i.e., shape) that has been identified to have similar characteristics. |
| **Risk** | A measure of the probability of a specific flood event occurring and the consequence, or adverse effects, of that event on specific elements-at-risk; including human health, critical infrastructure, property, or the environment. |
| **Waterbody** | Collective definition for ponds, lakes, and reservoirs. |
| **Watercourse** | Collective definition for creeks, streams, and rivers. |

# 1 Introduction

## 1.1 BACKGROUND TO FLOODPLAIN MANAGEMENT IN THE REGION

The Regional District of Central Okanagan (RDCO) has been one of the fastest growing areas in Canada over the past 20 years and growth is expected to continue. RDCO is a "waterfront community", characterized not only by many kilometres of lake shore but also by numerous streams and rivers that mostly originate in the upland forested watersheds around the region. That proximity to water means that flooding of developed areas can occur due to a mixture of natural conditions (e.g. rapid snowmelt or intense rainfall) and land use activity (e.g. increased impervious surfaces). As such, RDCO is committed to proactive management of flood hazards as directed by the Strategic Plan (Vision 2020), the Strategic Priorities Plan (2015-2018), and the Regional Growth Strategy Bylaw No. 1336, as well as working with the local governments that make up the RDCO, impacted agencies and stakeholders, and with the provincial government. Flood hazard management will be guided through a three-phase Regional Floodplain Management Framework, as described in the terms of reference that were prepared for RDCO by Clarke Geoscience Ltd. (2014). The three phases are:

- Phase 1 – Development of a Regional Floodplain Management Plan that identifies flood hazards and establishes the scope and priorities of Phases 2 and 3.
- Phase 2 – Flood Hazard and Risk Assessment.
- Phase 3 – Flood Risk Mitigation Strategies.

As an important step towards region-wide flood hazard management, RDCO retained Associated Environmental Consultants Inc. (AE) in September 2015 to complete Phase 1 of a **Regional Floodplain Management Plan** (RFMP). This document is the Phase 1 RFMP final report, which has been provided to RDCO. The terms of reference for Phase 1, as outlined by Clarke Geoscience Ltd. (2014), are provided in **Appendix A**.

## 1.2 RFMP RATIONALE AND REGIONAL CONTEXT

In British Columbia, flood[1] management planning refers to mitigation measures considered or implemented to reduce the effects of a hazardous flood, either by changing the likelihood of a flood occurring, or by effecting change to the consequences. Measures can be broadly divided into non-structural (e.g. land use planning, emergency response) and structural (e.g. dikes, diversions, and other structures) measures. Historically, the Provincial Ministry of Environment (MOE) actively participated in floodplain development decisions. Under Section 82 of the *Land Titles Act* (repealed), the MOE had to be consulted if any subdivision of lands was proposed in designated floodplain areas. Furthermore, the MOE had the authority to specify development controls within floodplain areas. In 2003, the MOE was divested of this

[1] The definition of flood in the RFMP is taken from APEGBC (2012*): A flood is a condition in which a watercourse or body of water overtops its natural or artificial confines and covers land not normally under water. When a flood becomes a source of potential harm it becomes a hazardous flood. (Watercourses include creeks, streams and rivers; bodies of water include ponds, lakes, and reservoirs).*

responsibility by the provincial government. The approval of developments within designated floodplain areas now rests with local government, as defined under Section 524 of the *Local Government Act*. The RDCO RFMP is intended, in part, to respond to this significant change in local government responsibility.

Previous flood hazard analyses within RDCO boundaries have been completed in a somewhat piecemeal fashion focussing on lower Mission Creek and Mill Creek in Kelowna, and lakefront areas on the west side of Okanagan Lake, with some flood mitigation works completed on Bellevue Creek and other streams (see Section 3.2). **Figure 1-1** shows the major watercourses and lakes within RDCO and the areas with floodplain mapping and flood mitigation infrastructure. With the exception of the relatively recent Mill Creek hazard analysis, much of the work that supports the current flood management framework may be considered outdated (e.g. 1980s), considering the significant growth in population and in knowledge about the effects of climate change that have occurred since that time. As such, RDCO determined that there is a need for a Region-wide, integrated analysis of flood hazard and risk that will guide future decision making. RDCO is working towards the eventual implementation of a broad-based flood mitigation strategy in a phased approach, beginning with Phase 1 (this report) – development of the RFMP including the identification of priority areas for more detailed flood hazard and risk assessment.

## 1.3 GOALS OF THE REGIONAL FLOODPLAIN MANAGEMENT FRAMEWORK

The overall objective of the overall Regional Floodplain Management framework (i.e. all three phases) is to develop a better understanding of flood risk within RDCO boundaries such that the likelihood of damage from floods is reduced. The intended outcomes of the RFMP are to:

1. Reduce flood risk. For the RFMP, risk is defined as a measure of the probability of a specific flood event occurring and the consequence, or adverse effects, of that event on specific elements-at-risk; including human health, critical infrastructure, property, or the environment.
2. Improve emergency response by identifying and prioritizing flood-prone areas and by establishing proactive measures to mitigate risk.
3. Increase resilience to climate change by increasing the ability to anticipate, absorb, accommodate and recover from flood events.

In addition, the strategies are to be consistent with other relevant legislation and policies including Official Community Plans, Development Permit Area Guidelines, Zoning Bylaws, Subdivision and Development Servicing Bylaws*, Fish Protection Act*, *Fisheries Act*, *Water Stewardship Act*, and *Dike Maintenance Act*.

REGIONAL DISTRICT of CENTRAL OKANAGAN

N
W E
S

Whiteman Creek
Shorts Creek
Vernon Creek
Lambly Creek
Powers Creek
McDougall Creek
Trepanier Creek
Peachland Creek
Mill Creek
Mission Creek
Bellevue Creek

W-5
W-6
W-7
W-8
W-9
W-10
W-11

E-2 (DLC)
E-2 (KEL)
E-3
E-4
E-5 (KEL)
E-5 (RDCO-E)

Douglas Lake
Vernon
Coldstream
Lavington
Lumby
Blue Springs
Ellison Provincial Park
Killiney Beach
Fintry Provincial Park
Nahun
Caesars
Okanagan Centre
Woodsdale
Winfield
Wilson Landing
Westside
Kelowna
Rutland
Ellison
Glenrosa
Okanagan Mission
McCulloch
Braeloch
Trepanier Provincial Park
Trader's Cove Beach Provincial Park
Graystokes Provincial Park
Denison-Bonneau Provincial Park
Echo Lake Provincial Park
Pennask Creek Park
Darke Lake Provincial Park
Okanagan Mountain Provincial Park
Myra-Bellevue Provincial Park
OKANAGAN HIGHLAND
BEAVERDELL RANGE
OKANAGAN HIGHLANDS
Big White

Legend
- Flood mitigation infrastructure
- Flood mitigation infrastructure
- Mapped Flood Plain
- Bellevue Creek
- Residual Areas
- Lambly Creek
- McDougall Creek
- Mill Creek
- Mission Creek
- Peachland Creek
- Powers Creek
- Shorts Creek
- Trepanier Creek
- Vernon Creek
- Whiteman Creek
- RDCO Boundary

0 1 2 4 6 8 10 km

Background Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia,

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DATE: June 2016
DRAWN BY: DA

**FIGURE 1-1: MAJOR WATERSHEDS IN THE RDCO, AND EXISTING FLOODPLAIN MAPPING AND FLOOD MITIGATION INFRASTRUCTURE**

Regional District of Central Okanagan

Phase 1 of the Regional Floodplain Management Plan

flood works 11x17.mxd / 6/16/2016 / 1:56:50 PM

## 1.4 GOALS OF THE PHASE 1 REGIONAL FLOODPLAIN MANAGEMENT PLAN

The goals of Phase 1 of the RFMP are to:

1. Work with RDCO to clarify the purpose and content of the RFMP.
2. Assemble, review and summarize information on the biophysical characteristics of the regional that influence flood processes and flood hazards, and identify the flood mechanisms that are active.
3. Identify and summarize existing floodplain mapping.
4. Identify and map existing flood protection infrastructure and summarize available information on effectiveness.
5. Summarize and review historical flood information, including documented effects on property, infrastructure, human health/loss of life, and the environment. Identify existing hydrometric, climate, and snowpack monitoring networks and comment on the adequacy of the system for flood risk management.
6. Identify and map existing dams and reservoirs with RDCO boundaries, and tabulate ownership and dam safety information.
7. Summarize available climate change and resulting hydrological projections, and potential implications for flood magnitude and frequency.
8. Identify, at an overview level, flood-prone stream reaches within RDCO boundaries based on elevation, landforms, and historical flood information. Compare the findings to flood hazard areas currently identified by the Regional Emergency Program.
9. For the flood-prone reaches, develop a method to set priorities for more detailed assessment based on a preliminary assessment of flood hazard and risk. Confirm the planned method with RDCO staff.
10. Carry out the preliminary risk evaluation, map the results, and recommend which flood-prone stream reaches are priorities for further work in Phase 2.
11. Review and summarize planning approaches used elsewhere in B.C. and Canada, and provide recommendations on suitable options for RDCO based on the outcome of the preliminary risk evaluation.
12. Develop recommendations for modification to the existing RDCO flood emergency plan, if warranted based on the preliminary risk evaluation; and
13. Recommend options for Phases 2 and 3.

Each of these goals is addressed in this Phase 1 report.

# 2 RFMP Phase 1 Methods

## 2.1 INFORMATION REVIEW AND MAPPING

The Phase 1 study began by completing on-line and library searches for background, technical, and planning information relevant to flood management in the RDCO. The key databases from which information was obtained are the provincial Ecological Reports Catalogue (EcoCat), the Okanagan Basin Water Board's (OBWB) Okanagan Basin Water Resource Information Database (OBWRID), and the BC Water Resources Atlas. Climate and hydrometric data were obtained from Environment Canada.

Data sources for development of the Phase 1 Geographic Information System included the following:

- Zoning (land use) – obtained from municipalities and RDCO for the areas they maintain;
- Roads – obtained from the RDCO;
- Infrastructure (e.g. storm, water, sewer) – obtained from municipalities and RDCO for the areas they maintain;
- Hospitals, care homes, ambulance stations – obtained from Interior Health;
- Power infrastructure – obtained from BC Hydro;
- Population – obtained from Statistics Canada;
- Environmental (fish and aquatic habitat) information – obtained from MOE, Fisheries Inventory and RDCO sensitive habitat inventory mapping (SHIM).
- Elevation – obtained from municipalities and RDCO for the areas they maintain;
- Floodplain mapping and flood structures – obtained from DataBC;
- Alluvial fans and fluvial soils within the RDCO – obtained from MOE, Soils Seamless Data;
- Macro reaches with reach substrate codes – obtained from DataBC;
- Alluvial aquifers – obtained from the OBWB;
- Dams – obtained from the B.C. Ministry of Forests, Lands, and Natural Resource Operations.

In addition to the on-line and library searches, information was obtained through discussions with provincial and local water management specialists (Section 2.2).

## 2.2 EXTERNAL GOVERNMENT STAKEHOLDER DISCUSSIONS

Government and stakeholder involvement in development of Phase 1 was primarily through a three hour stakeholder workshop that took place at RDCO offices in Kelowna on December 3, 2015. The organizations that attended were:

- Westbank First Nation
- Okanagan Indian Band
- B.C. Ministry of Forest, Lands, and Natural Resource Operations (MFLNRO)
- City of Kelowna
- District of Peachland
- City of West Kelowna
- District of Lake Country

- Southeast Kelowna Irrigation District
- Black Mountain Irrigation District
- Kelowna Fire Department
- Okanagan Basin Water Board
- Regional District of Central Okanagan

The goals of the workshop, which were communicated to attendees in advance, were to:

1. Help RDCO and the consultant team to confirm the desired scope and format of the Phase 1 RFMP;
2. Review existing information including but not limited to previous plans and policies; mapping of floodplains, dykes and dams; hydrometric and climate data; ecosystem mapping; and bylaws;
3. Identify any relevant information or on-going initiatives that may not be in the public domain;
4. Introduce the approach that will be used to complete a preliminary assessment of hazards and risk within Phase 1;
5. Identify issues that should be addressed in the Phase 1 RFMP; and
6. Discuss how priority areas that may warrant further review and floodplain mapping in a potential subsequent phase should be identified.

The record of meeting from the workshop is provided as **Appendix B** of this report. Other stakeholder organizations that were contacted during the Phase 1 work include the Dam Safety program of MFLNRO (Regional Water Management) and engineering/utility departments of District of Lake Country, City of Kelowna, City of West Kelowna, District of Peachland, and Glenmore-Ellison Improvement District.

## 2.3 PRELIMINARY HAZARD AND RISK EVALUATION

Flood hazard assessments have not been completed for the majority of watercourses and waterbodies within the RDCO boundaries, and only limited floodplain mapping has been completed on Mission Creek, Kelowna (Mill) Creek, and a portion of Okanagan Lake. Therefore, to aid in identifying areas at risk of flooding, and their corresponding consequences, a preliminary flood risk screening approach was developed to assign an initial flood risk rating to all watercourses within the RDCO. This screening approach was intended to identify stream reaches of probable concern and to prioritize further investigational effort in Phases 2 and 3, as well as to ensure that all watercourses/waterbodies deemed to have a high preliminary flood risk were also considered for emergency flood response planning.

A description of the preliminary flood risk screening approach and the resultant ratings for the watercourses/waterbodies within the RDCO is provided in Section 4.

# 3 Biophysical, Land-Use and Social-Community Context

This section summarizes the biophysical characteristics, including climate, land use, and hydrology of the RDCO, with particular focus on the relevance of each on flood hazards. In addition, a summary of existing floodplain mapping, flood infrastructure, and historic flood events within the RDCO is provided. Existing hydrometric and climate data sources are identified and the future impact of projected changes in climate and hydrology on flood risk are discussed. This section is intended to address all tasks identified within point three of the RFMP terms of reference (Clarke Geoscience Ltd. 2014).

Covering an area of 3,142 $km^2$, the RDCO is situated within the Okanagan Valley (Figure 1-1) and comprises four municipalities and two rural areas:

- Central Okanagan West Electoral Area
- City of West Kelowna
- District of Peachland
- Central Okanagan East Electoral Area
- City of Kelowna
- District of Lake Country

In addition, the Westbank First Nation (WFN) has five reserves (I.R. #8, I.R. #9, I.R. #10, I.R. #11, and I.R. #12) and the Okanagan Indian Band (OKIB) has one (I.R. #7).

With a population of 179,830 and a projected population of 267,717 by the year 2026, the RDCO is one of the fastest growing areas in interior B.C. (RDCO 2011; 2016).

## 3.1 BIOPHYSICAL CHARACTERISTICS THAT CONTRIBUTE TO FLOOD HAZARD

### 3.1.1 Climate of the RDCO

The RDCO is located in the southern interior of B.C., and is characterized by hot, dry summers, and cool, dry winters. Lying in the rain shadow of the Coast and Cascade mountains, the region is relatively arid due to low rates of precipitation and high rates of evaporation. Figure 3-1 presents average climatic conditions for the most recent climate normal period (i.e., 1981-2010) based on climate records collected at the Kelowna Airport Climate Station (Meteorological Service of Canada Station No. 1123970). Mean daily temperatures at this station range from 19.5 °C in July to -2.6 °C in December, with a mean annual temperature of 8.1 °C. The normal total annual precipitation is 386.9 mm.

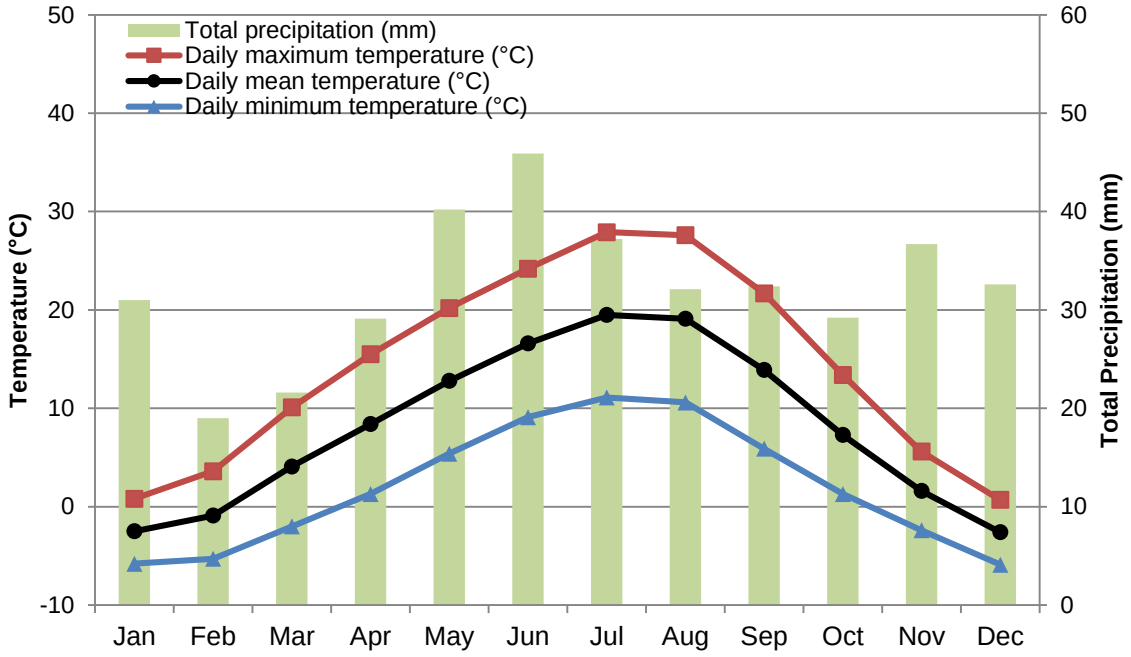
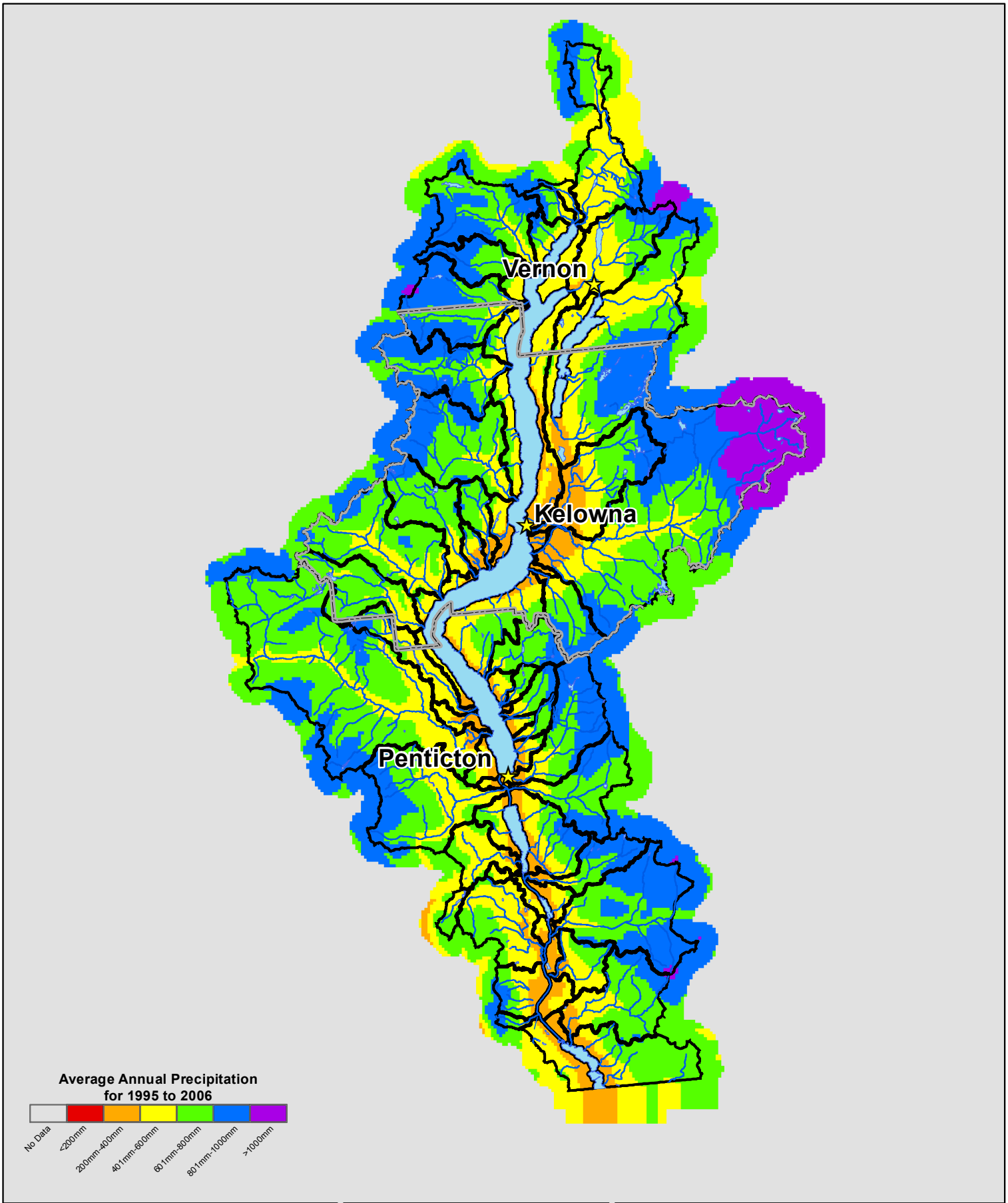



**Figure 3-1**
**1981-2010 Climate Normals for Kelowna Airport Climate Station (Climate ID: 1123970)**

The climate information presented above is derived from a weather station located in the Okanagan Valley bottom. One of the key aspects of climate in the RDCO that influences flood hazard is the much greater total precipitation and snowfall that occurs at higher elevations. Figure 3-2 displays the spatial variability associated with annual precipitation across the Okanagan Valley, and shows that considerably more precipitation (both rain and snow) occurs at high elevations (Summit 2009). Section 3.3 outlines the role of snowmelt in flood generation.




Associated Environmental

PROJECT NO.: 2015-8202.000.000
DATE: May 2016
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**FIGURE 3-2: AVERAGE ANNUAL PRECIPITATION ACROSS THE OKANAGAN BASIN**

Central Okanagan Regional District

Phase 1 of the Regional Floodplain Management Plan

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Winter snowpack accumulation and subsequent snowmelt significantly influences spring streamflows within the RDCO. Figure 3-3 displays average monthly maximum snow water equivalent (SWE), and mean monthly maximum and minimum air temperature measured at the Mission Creek snow pillow (Snow Pillow ID: 2F05P), for the period 1969-2011. The Mission Creek snow pillow is located within the RDCO at an elevation of 1,794 m and measures SWE cumulatively throughout the year.

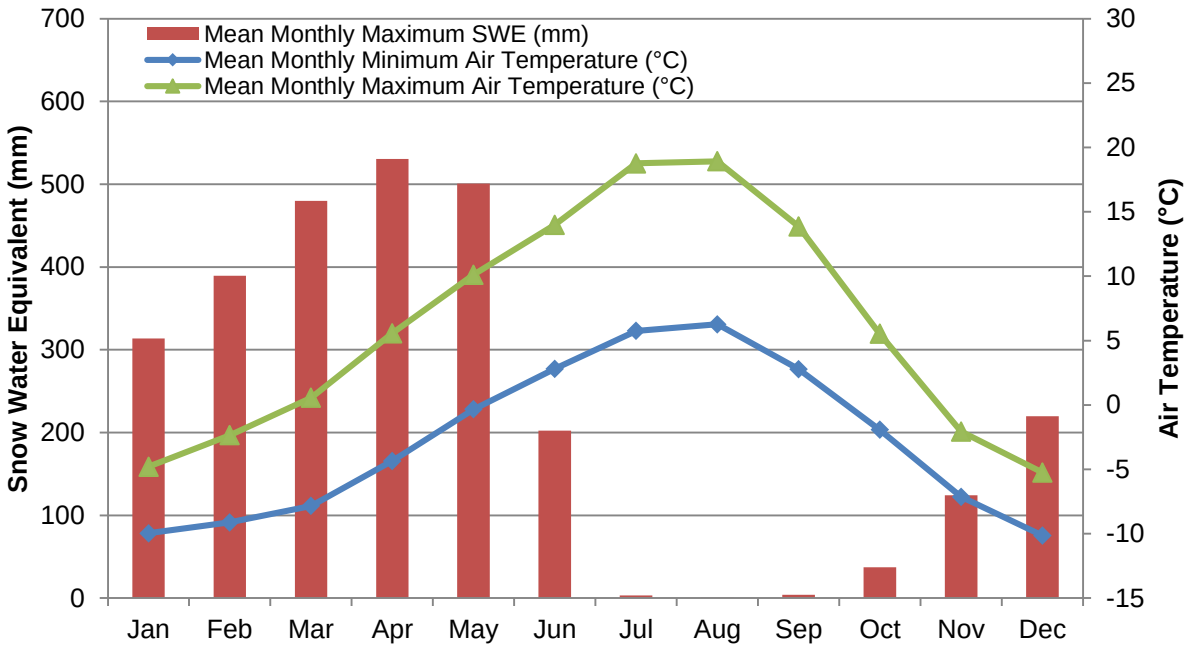


**Figure 3-3**
**1969-2011 Snow Pillow Data for Mission Creek (Pillow ID: 2F05P)**

Due to the arid climate of the Okanagan, coupled with extensive mid and upper elevation forest cover, the RDCO is prone to wildfire in its undeveloped areas. Wildfires pose multifaceted risk to communities – aside from fire damage, flood risk can be increased as a result of the creation of hydrophobic soils during wildfires. Soils can be exposed to sufficiently intense heating during a fire that they can develop a thin but impermeable internal layer due to chemical reactions. This impermeable layer then repels water, reduces infiltration, and increases surface runoff during subsequent storms. Figure 3-4 provides a summary of historic wildfires within the RDCO.

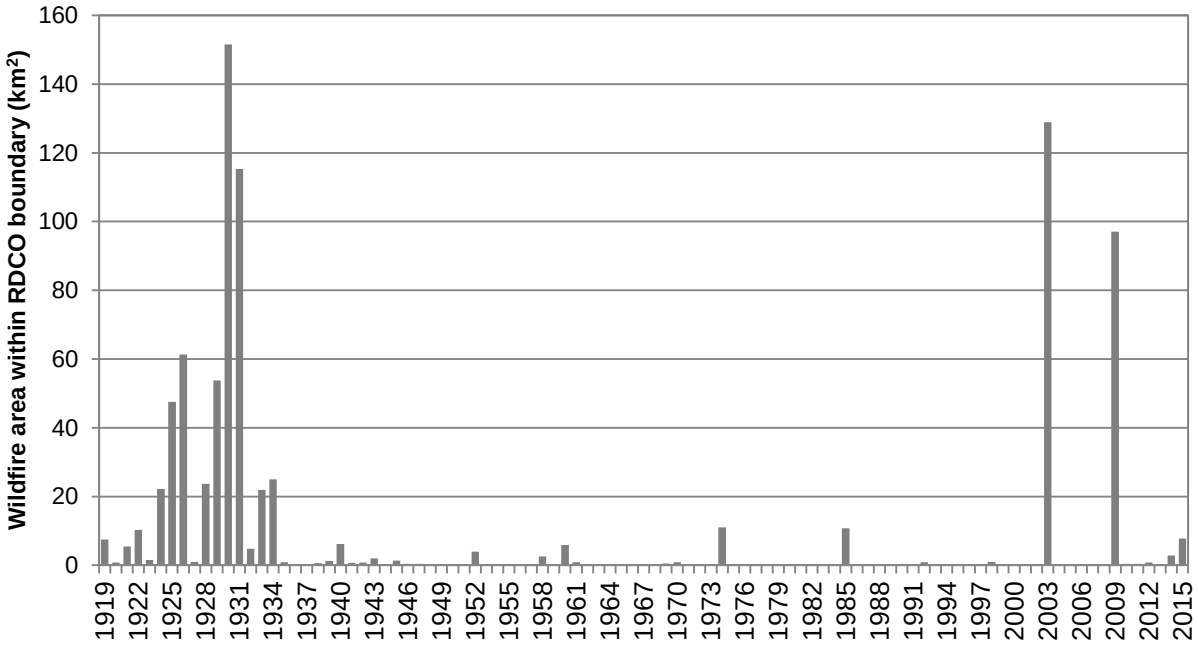


**Figure 3-4**
**Historic Wildfires within the RDCO, 1919-2015**

### 3.1.2 Landscape and Land Use within the RDCO

The RDCO lies within the Thompson Plateau, characterized by moderately steep valley sides and broad valley bottoms. Figure 3-5 provides an elevation profile for Mission Creek. The elevation profile presented in Figure 3-5 is characteristic of watercourses within the RDCO. Watercourses within the RDCO typically consist of three topographically distinct reaches:

- Headwaters originate on high plateau relief
- Steep hillslopes comprise the middle sections of many creeks
- Alluvial fans are commonly found on the valley bottom adjacent to the mainstem lakes

Population is largely concentrated in the valley bottom with the most desirable property and real estate adjacent to waterbodies and watercourses. As a result, much of the infrastructure is built on alluvial fans and floodplains, and is therefore more susceptible to flooding.

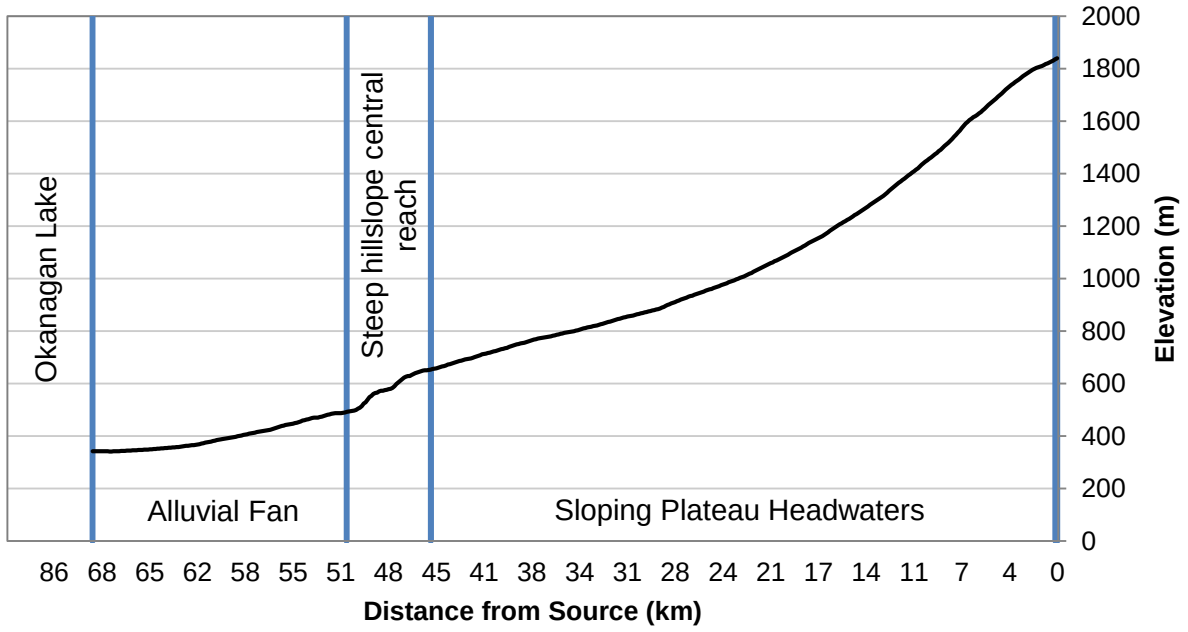


**Figure 3-5**
**Characteristic elevation profile of major watercourses within the RDCO – Mission Creek.**

Land use within the RDCO is predominantly residential, commercial, and agricultural. In addition, rural areas and forest resources are common in the high elevation plateau areas. There are 31 Regional Parks, 14 Community Parks, and 7 Provincial Parks within the Regional District boundary. Land use zoning is available for the RDCO under the Zoning Bylaw No. 871 (RDCO 2014) which applies to the Regional District except for incorporated towns and cities and First Nation Reserves. Separate land use zoning information is available (and included within official community plans) for the following incorporated towns, cities, and First Nation Reserves:

- City of Kelowna
- District of Peachland
- Westbank First Nation
- City of West Kelowna
- District of Lake Country
- Area covered by Joe Rich Rural Land Use Bylaw No. 1195

Available land use zoning was used to develop preliminary risk ratings for floodplain areas and flood prone streams identified within the RDCO (Section 4).

### 3.1.3 Hydrology of the RDCO

There are 12 watersheds within, or partly within, the RDCO boundary including the residual drainage area adjacent to Okanagan Lake (Table 3-1; Figure 1-1). The residual drainage area comprises areas which are not included in, or contributed to by main watersheds within the RDCO. The residual drainage area is

divided into eleven watershed areas consistent with the 'nodes' developed for the Okanagan Water Supply and Demand Project (Summit 2010). Residual areas are further divided into municipality boundaries herein[2] (Figure 1-1).

**Table 3-1**
**Summary of watersheds within the RDCO**

| Watershed Name | Total area of watershed ($km^2$) | Area of watershed in RDCO boundary ($km^2$) | Percentage of total watershed within RDCO (%) |
|---|---|---|---|
| Mission Creek | 841.7 | 841.7 | 100% |
| Vernon Creek | 752.8 | 288.8 | 38% |
| Residual | 617.8 | 557.2 | 90% |
| Trepanier Creek | 254.7 | 254.7 | 100% |
| Lambly Creek | 244.1 | 244.1 | 100% |
| Mill Creek | 223.7 | 223.7 | 100% |
| Whiteman Creek | 203.1 | 99.2 | 49% |
| Shorts Creek | 185.3 | 185.3 | 100% |
| Peachland Creek | 147.7 | 138.9 | 94% |
| Powers Creek | 145.5 | 145.5 | 100% |
| Bellevue Creek | 86.4 | 86.4 | 100% |
| McDougall Creek | 53.5 | 53.5 | 100% |

The Okanagan Water Supply and Demand Project (OWSPD) (Summit 2010) examined patterns of water use, availability, and licensing across the Okanagan Valley, as well as evaluated potential impacts resultant from climate change. During phase 2 of the study, Summit (2010) developed a model to estimate net and naturalized streamflows for many of the watersheds within the Okanagan Valley, including many within the RDCO. Streamflow records and streamflow estimates are critical for floodplain mapping, and flood management and response planning.

Mission Creek is the largest watershed within the RDCO with a drainage area of 841.7 $km^2$. McDougall Creek is the smallest watershed with a drainage area of 53.5 $km^2$.

[2] Residual areas are divided and defined as follows: E-2 (KEL) – portion of residual area E-2 which falls within the municipal boundary of the City of Kelowna; E-2 (DLC) – portion of residual area E-2 which falls within the municipal boundary of the District of Lake Country; E-5 (KEL) – portion of residual area E-5 which falls within the municipal boundary of the City of Kelowna; E-5 (RDCO-E) – portion of residual area E-5 which falls within the municipal boundary of the RDCO East Electoral Area. The remaining residual areas fall entirely within individual municipal boundaries.

The Okanagan Basin frequently experiences water supply and demand pressures due to high seasonal and annual variability in precipitation, evaporation and streamflow. Figure 3-6 provides an overview of annual variation in annual net inflow to Okanagan Lake for 1921-2014. In addition to water supply and demand pressures, the variable nature of climate in the region results in flood planning and mitigation challenges.

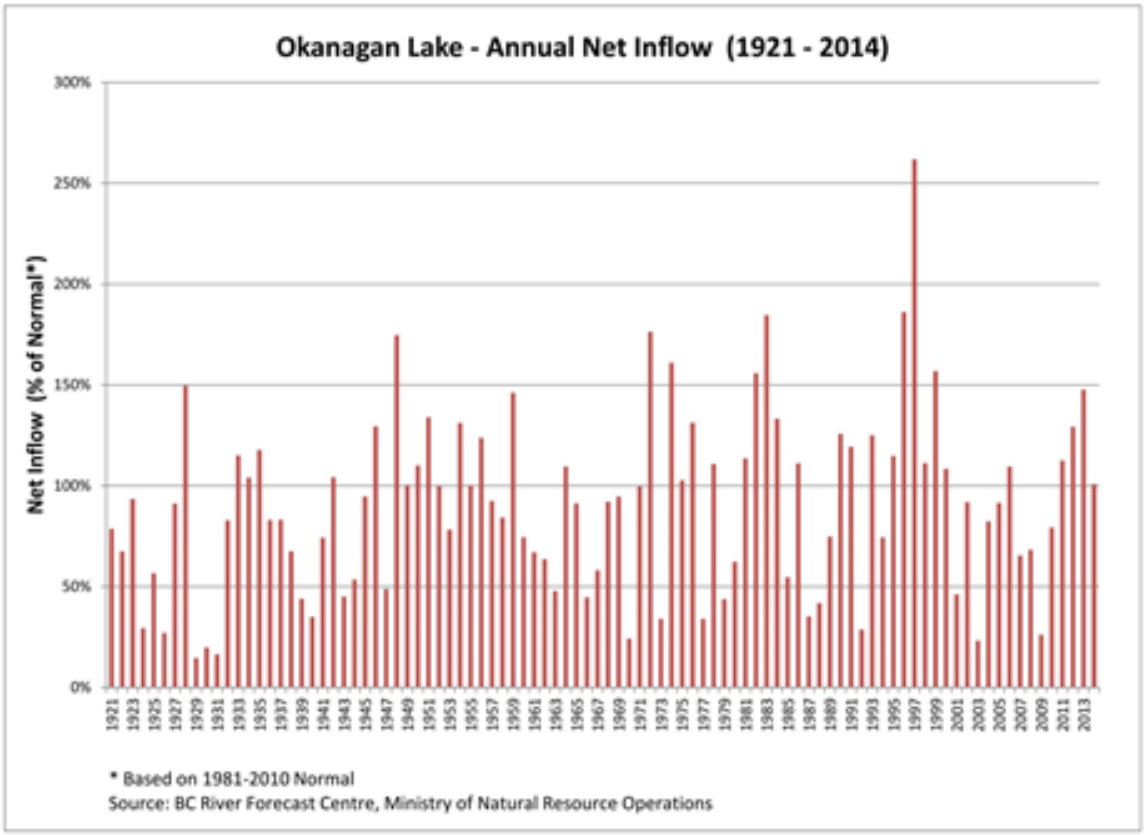


**Figure 3-6**
**Annual net inflow to Okanagan Lake, 1921-2014**

Streamflows within the RDCO are characterized by low flows during summer and winter months, with freshet typically occurring around April – June. Peak flows tend to occur in May and June. To provide an example of streamflow variability within the RDCO, Figures 3-7 and 3-8 display mean daily discharge for Mission Creek and Trepanier Creek which are situated in the east and west of the RDCO, respectively. Mission Creek near East Kelowna (Figure 3-7) has a drainage area of 795 $km^2$ and a mean annual discharge of 6.19 $m^3/s$ while Trepanier Creek near Peachland (Figure 3-8) has a comparatively small drainage area of 182 $km^2$ and a mean annual discharge of 0.866 $m^3/s$. Figures 3-7 and 3-8 highlight the annual and inter-annual variability associated with streamflows in the region.

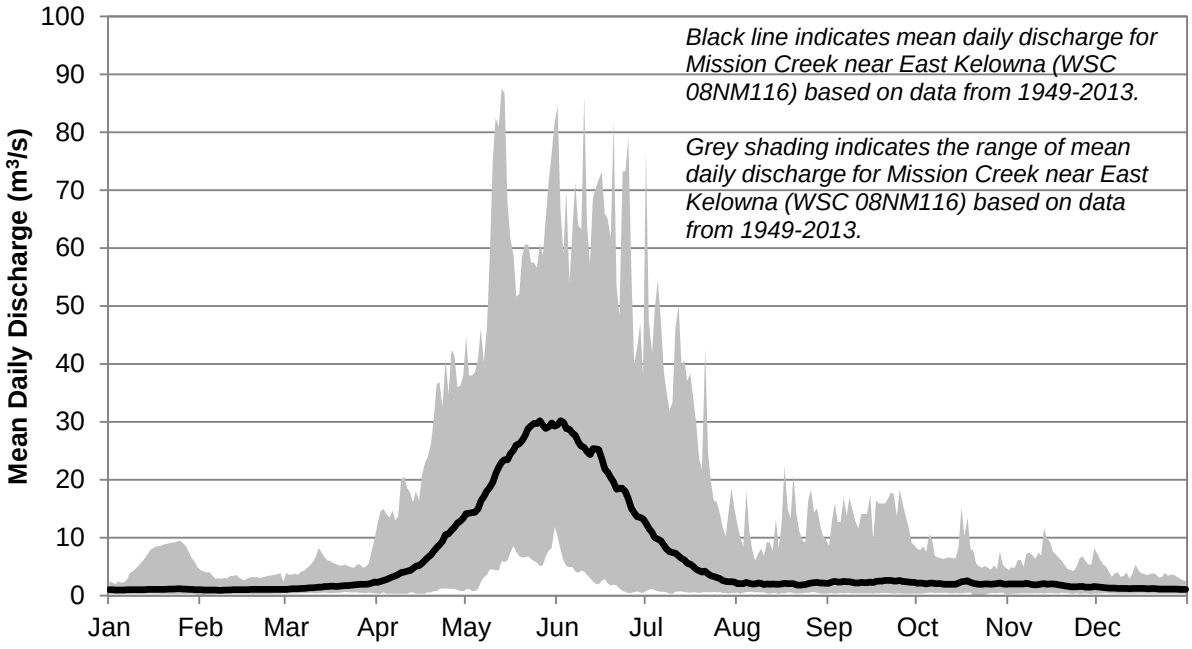


**Figure 3-7**
**Mean daily discharge for Mission Creek near East Kelowna (WSC Station No. 08NM116; Drainage area = 795 km$^2$), 1949 to 2013.**

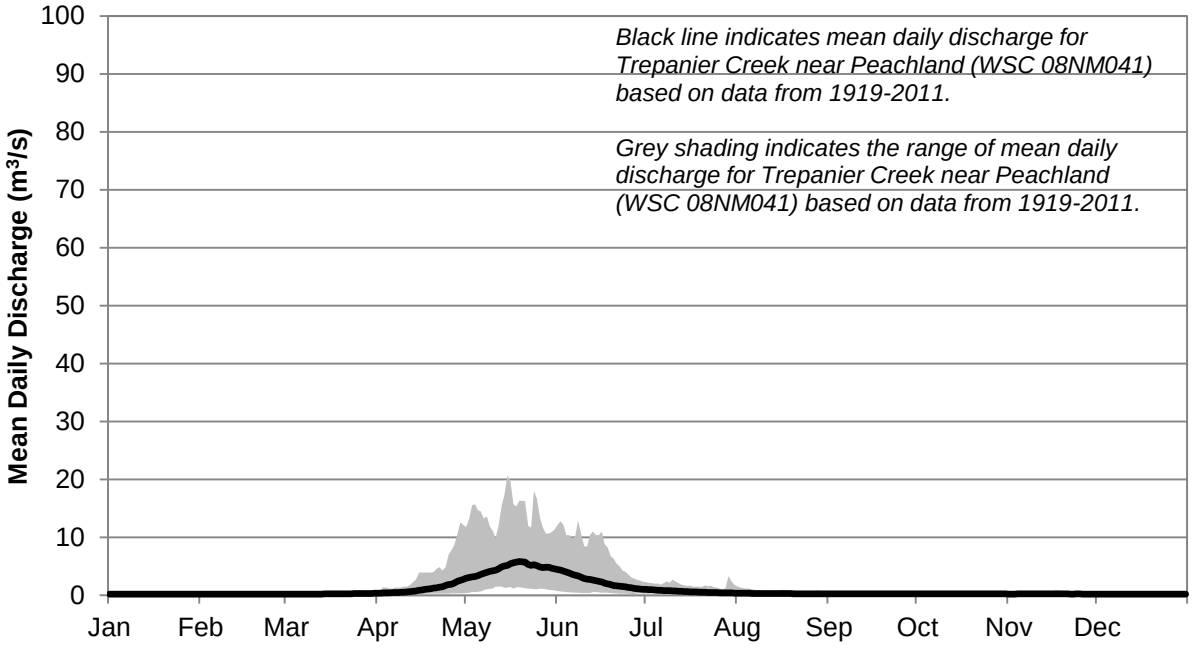


**Figure 3-8**
**Mean daily discharge for Trepanier Creek near Peachland (WSC Station No. 08NM041; Drainage area = 182 km$^2$), 1919 to 2011.**

## 3.2 EXISTING FLOODPLAIN MAPPING AND FLOOD INFRASTRUCTURE

### 3.2.1 Existing Floodplain Mapping

Historically, the B.C. Ministry of Environment (MOE) have completed floodplain mapping on select watercourses and waterbodies throughout B.C. Within the RDCO, MOE have mapped the floodplain along portions of Mission Creek and Okanagan Lake (Figure 1-1).

In 1982, MOE (1982) mapped the 1:200-year return period floodplain for the west shore of Okanagan Lake from Peachland to West Kelowna. The flood construction level designated for Okanagan Lake is 343.66 m (including freeboard). Additionally, MOE (1984) mapped the 1:200-year return period floodplain for the reach of Mission Creek from Gallagher's Canyon to the mouth.

More recently, AE (2010) completed the Floodplain Bylaw Analysis for Mill Creek, including the mapping of the Mill Creek floodplain based on the greater of three quantities; Okanagan Lake 200-year water level with 600 mm freeboard; Mill Creek 200-year maximum daily water level plus 600 mm; or Mill Creek 200-year instantaneous peak water level plus 300 mm freeboard (Figure 1-1).

In addition to floodplain mapping, Zoning Bylaw No. 871 (RDCO 2014) and Joe Rich Rural Land Use Bylaw No. 1195 (RDCO 2013a) specify numerous floodplain regulations which are widely adopted throughout the RDCO. In addition, although not specified within RDCO bylaw documents, District of Lake Country (2016) specifies a flood construction level of 393.2 m (including freeboard) for Wood and Kalamalka Lakes (which are included [or portions are] within the RDCO). Section 5.1 of this report provides information on specific floodplain regulations outlined within Zoning Bylaw No. 871 and Joe Rich Rural Land Use Bylaw No. 1195.

### 3.2.2 Existing Flood Infrastructure

To date, flood mitigation infrastructure is not widespread within the RDCO (Figure 1-1). It is our understanding that only seven watercourses have permanent flood infrastructure currently in place (Table 3-2). Note that smaller, emergency flood protection works are not included here due to the lack of regular and systematic documenting; however, emergency response efforts and associated management actions are described further in Section 3.3.2.

Information presented in Table 3-2 was obtained by way of a literature review and in part by comments received during the project workshop in December 2015 with RDCO (Associated 2015).

**Table 3-2**
**Summary of existing flood infrastructure within the RDCO.**

| Watershed | Documented Infrastructure |
|---|---|
| Bellevue Creek | • **Bellevue Creek near the mouth:** The channel is confined by constructed levees or concrete walls (Summit 1996).<br>• **Bellevue Creek near Gordon Drive:** The creek has been extensively modified throughout this reach and the banks are modified with large rip-rap (Summit 1996). |
| Mission Creek | • **Lowest reaches of Mission Creek:** The channel is partially contained by a dike system (Tetra Tech 2014):<br>  ○ The right bank dike extends from approximately Lakeshore Road Bridge to Ziprick Road (approximately 7.5 km)<br>  ○ The left bank dike extends from approximately 200 m upstream of Lakeshore Road Bridge to Casorso Road Bridge. A second portion of the left bank dike extends from 1.1 km upstream of Casorso Road Bridge to approximately 1 km upstream of KLO Bridge. |
| Trepanier Creek | • **Lower reaches of Trepanier Creek upstream of Highway 97:** The channel is confined by diking completed by the Municipality of Peachland (Summit 2004). |
| Mill Creek | • **Mill Creek Dike:** The channel is constrained by a small dike approximately 400 m long, located just north of Sexsmith road. Note that this dike was reported to no longer be in place (A. Reeder, pers. comm., 2016). |
| | • **Mill Creek High Flow Diversion:** Water is diverted from Mill Creek to Mission Creek during periods of high flow (typically between April – June freshet) (AE 2010). The diversion is controlled by a weir at the inlet on Mill Creek. |
| McDougall Creek | • **Approximately 400 m downstream from Old Boucherie Road:** Vegetation clearing and channel widening on a 400 m section of McDougall Creek was completed in spring 2014 to increase channel capacity and improve flood mitigation (Associated 2015).<br>• **Historic flood protection:** Historically, McDougall Creek channel was rip-rapped from the mouth upstream to agricultural properties below Boucherie Road (B. Magnan, pers. comm., 2016). |
| Shorts Creek | • **Bypass channel at Fintry Delta Road:** Funding was approved in 2012 for the construction of a bypass channel to divert Shorts Creek flows to a northern channel to protect Fintry Delta Road and private property. |
| Smith Creek | • **Overflow Flood Channel:** An engineered overflow channel and base flow channel were constructed on Smith Creek in 2015, located between Carrington and Witt Roads (B. Magnan, pers. com., 2016). |

In addition to the existing flood infrastructure presented above, the Mission Creek Restoration Initiative (MCRI) is an ongoing multi-phase, multi-stakeholder partnership established in 2008 to restore natural functions to the lower reaches of Mission Creek (MCRI 2016). Following the significant reduction in aquatic and riparian habitat due to channelization of Mission Creek, the primary focus of the MCRI is to restore fish and wildlife stocks and habitat within the lower reaches of the creek.

To achieve naturalization of the floodplain, the MCRI plans to set back sections of the existing dike (MCRI 2016). Further advantages of the dike set back include the reintroduction of a floodplain, which will increase the capacity for Mission Creek to pass freshet flows. As such, the risk of flooding may be reduced, although sediment deposition and possible effects on channel and floodplain capacity will need to be monitored.

In addition to the infrastructure presented above, there are 129 dams and spillways within the RDCO (Section 3.5.1).

## 3.3 FLOOD MECHANISMS AND PREVIOUS FLOODING WITHIN THE RDCO

### 3.3.1 Flood Mechanisms within the RDCO

Within the RDCO, the likelihood and consequences of flooding vary greatly depending on the nature of the watercourse/body of water, surrounding area, topographical features, and the location of the watershed. Accordingly, different watercourses/bodies of water are subject to different risks and mechanisms which may result in flooding. Flood mechanisms relevant to watercourses and waterbodies within the RDCO are presented in Table 3-3.

**Table 3-3**
**Summary of flood mechanisms within the RDCO**

| Flood Mechanism | Streams Originating at High Elevations | Valley-Bottom Streams | Bodies of Water |
|---|---|---|---|
| Rain | ✓ | ✓ | |
| Rain-on-snow | ✓ | ✓ | |
| Snowmelt | ✓ | ✓ | |
| Debris blockages and rapid release of flows | ✓ | ✓ | |
| Ice jams | | ✓ | |
| Dam break | ✓ | ✓ | |
| Dyke breach | ✓ | ✓ | |
| Sediment accumulation | ✓ | | |
| High lake levels | | | ✓ |
| Surge, wave setup, height, and run up | | | ✓ |
| Operating constraints | | | ✓ |
| Climate change | ✓ | ✓ | ✓ |

### 3.3.2 Previous Flooding within the RDCO

There is a long history of flooding within the RDCO with flood events documented as far back as 1894 (Septer 2006). Table 3-4 summarises documented historic flooding events within the RDCO. Widespread flooding is defined in Table 3-4 as flooding documented within more than one watershed, and localized flooding is defined as flooding documented within just one watershed.

**Table 3-4**
**Summary of historic flood events within the RDCO (from Septer 2006)**

| Flood Event | Watershed(s) | Flood Mechanism |
|---|---|---|
| ***Widespread Flooding*** | | |
| May 23 – June 16, 1942 | Mill Creek<br>Mission Creek<br>Okanagan Lake | Snowmelt |
| May 20 – June 2, 1983 | Kalamalka Lake<br>Mission Creek<br>Okanagan Lake | Snowmelt |
| June 11 – 13, 1990 | Joe Rich Creek<br>Mission Creek<br>Okanagan Lake<br>Okanagan River | Rain |
| Late May – Early June, 1997 | Kalamalka Lake<br>Mission Creek<br>Okanagan Lake | Rain |
| July 11 – 13, 1997 | Kalamalka Lake<br>Mill Creek<br>Okanagan Lake | Rain and Snowmelt |
| May 15 – 23, 2006 | Mission Creek<br>'Flood Watch' Issued for Most Creeks | Rain and Snowmelt |
| 2012 | Mission Creek<br>Shorts Creek<br>Mill Creek<br>Vernon Creek<br>McDougall Creek | Rain |
| 2013 | Mission Creek<br>McDougall Creek<br>Okanagan Lake | Rain |
| ***Localized Flooding*** | | |
| 1894 | Mission Creek | Snowmelt |
| 1949 | | |
| 1954 | Mill Creek | Snowmelt |
| 1997 | Joe Rich Creek | Snowmelt |
| 1928 | Okanagan Lake | Rain |
| 1948 | | Snowmelt |
| 1949 | | Rain-on-snow |
| 1951 | | Debris Flow |
| 1996 | | Snowmelt |
| 1997 | | Debris Flow |

Notable historic flood events are further discussed below; based primarily on information presented by Septer (2006) and updates published by the Central Okanagan Emergency Operations Centre (COEOC) (2016):

- **Rain-on-snow, 1990:** In early June 1990, flooding was widespread in the interior B.C. following higher than average rainfall since May 22, 1990. There are reports of flooding in the Okanagan, Kamloops, and Prince George. Within the RDCO, there was widespread flooding in the Mission Creek watershed, with the community of Joe Rich particularly affected. A storm event estimated to be between a 1-in-100 and a 1-in-400 year storm event resulted in six debris failures on the hillslope above Philpott Road. The largest debris avalanche killed three people and resulted in $10 million worth of damage.

  In addition to flooding within the community of Joe Rich, prolonged rainfall and rain-on-snow in higher elevations resulted in higher than normal streamflows within Mission Creek, and elevated water levels in Okanagan Lake. As a result, properties near the mouth of Mission Creek reportedly experienced flooding. As well, Okanagan Lake was documented to rise to approximately 15 inches higher than normal June high water levels resulting in widespread damage of shoreline properties.

- **Heavy snowpack and heavy rainfall, 1997:** A high snowpack in 1997 followed by a prolonged warm spell in mid-May resulted in widespread flooding across B.C. Subsequent saturated soils in many places enhanced the flooding impacts of the heaviest spring and summer rainfall for a large part of the province, and was the cause of slow flood recession.

  During the 1997 freshet, Mission Creek experienced the highest that had ever been recorded in the Creek. Depositing 30,000 $m^3$ of gravel in the diked channel, the total damage was estimated at $310,000. Later in the summer, Mill Creek over topped its banks in Kelowna flooding a road due to heavy rainfall. In addition, Okanagan Lake exceeded previous flood levels due to the highest spring and summer rainfall on record.

  High flows in 1997 initiated bank erosion in Shorts Creek. Dobson Engineering Ltd. (2009) estimated that the maximum daily peak flow in Short Creek in 1997 exceeded the 1:50-year event. Bank erosion initiated in 1997 has continued in subsequent years resulting in an assessment completed by Dobson Engineering Ltd. (2009) recommending remedial works to restore flow in Shorts Creek.

- **Spring Runoff and Heavy Rainfall, 2006:** Unseasonably warm spring weather in southern B.C. caused the rapid melting of above-average snowpacks. Coupled with rapid snowmelt, moderate rainfalls resulted in significant high river flows across much of southern B.C. A short-duration rain storm localized in the Mission Creek area is documented to have caused streamflows consistent with a 1:10-year return period within Mission Creek.

  In addition, MOE issued a ‘Flood Watch’ for many of the Okanagan watercourses and waterbodies due to rising water levels.

- **Heavy Rainfall, 2012:** A number of flood events were documented in 2012. A summary of events is provided as follows:
    - Spring freshet flows in Mission Creek caused serious bank erosion within the Muttitt property, located immediately upstream of Highway 33 in Joe Rich. Mission Creek breached its banks flooding the residence, a number of outhouses, and washed a trailer into the creek (Urban Systems 2012a).
    - In June 2012, high flows were the cause of substantial erosion in Shorts Creek, shifting the channel from within Fintry Provincial Park onto private property (Urban Systems 2012b). As a result of erosion, Urban Systems (2012b) recommended remedial works to construct a bypass channel to restore flows to the natural channel and protect private property.
    - In the summer of 2012, an evacuation alert was issued for 14 properties in Joe Rich due to high flows in Mission Creek resulting from high rainfall. The evacuation alert was rescinded after three days when flows in Mission Creek decreased and future weather conditions appeared stable.
    - In June 2012, part of a retaining wall along Mission Creek was washed away resulting in the issuance of an evacuation alert for the residents of 30 rental units at Walnut Grove. Large rip-rap was placed along the section of Mission Creek and the evacuation alert was subsequently rescinded.
    - A flood watch was issued in early June 2012 for Mission Creek following heavy rainfall. Localized flooding was reported along section of Mill Creek and the City of Kelowna enforced extensive sandbagging to protect at-risk areas.
    - Kelowna International Airport experiences localized flooding as a result of rising water level in Mill Creek.
    - In late April 2012, six properties along Hitchner Road were evacuated due to flooding of McDougall Creek. High streamflows in McDougall Creek flooded four homes and endangered four more.

In addition to those flooding events noted above, a number of emergency flood response efforts have been executed within the RDCO over recent years. A summary of such events was provided to us during review of the draft report (P. Johnstone, pers. comm., 2016). Table 3-5 provides a summary of the emergency flood responses within the RDCO since 2012 as reported by the Kelowna Fire Department (P. Johnstone, pers. comm., 2016).

More recently, the B.C. River Forecast Centre issued a high streamflow advisory in April 2016 for the Southern Interior, including small tributary river systems within the RDCO, including Mission Creek. In addition, the City of West Kelowna was forced to close Rotary Trails Park when Powers Creek overtopped its banks on April 20, 2016.

**Table 3-5 Summary of emergency flood responses within the RDCO reported by the Kelowna Fire Department**

| Date | Watershed | Location | Event | Action |
|---|---|---|---|---|
| April 30, 2014 | Powers Creek | Gellatly Road, just up from Boucherie Road | Smith Creek caused erosion to the bank on Gellatly Road, putting Gellatly Road at risk from slope failure. | • Environment Incident Number: 140012 |
| April 9, 2013 onwards | Mission Creek | Muttitt Property near Highway 33 | High freshet flows in Mission Creek caused concern for outbuildings on the Muttitt Property. | • State of Local Emergency Order signed on June 22, 2013. |
| May 5, 2013 | McDougall Creek | Hitchner Road | High freshet flows neared the top of existing emergency works on McDougall Creek. | • The provision of sandbags was authorized, and the EOC was elevated to Level 1 for planning. Support that was required.<br>• Environment Incident Number: 138004 |
| August 13, 2013 | Residual Area W-7 | Westside Road | A local resident diverted a slough, which flooded an adjacent property and Westside Road. | • B.C. Ministry of Transportation and Infrastructure was called to investigate. |
| April 25 – 26, 2012 | McDougall Creek | Hitchner Road | High rainfall caused McDougall Creek to breach its banks, flooding Hitchner Road and threatening other infrastructure. | • A State of Local Emergency was declared.<br>• Six homes were evacuated due to public safety concerns.<br>• Emergency assistance was provided by the Central Okanagan Regional Emergency Program and the City of West Kelowna. The Central Okanagan Regional Emergency Program is administered by the City of Kelowna Fire Department to support local government in emergencies.<br>• Emergency repair works included placement of sandbag dikes and rock reinforcement along the channel banks. |
| June 13, 2012 | Mission Creek | McCullough Bridge below Gallagher's Canyon | Due to elevated stream flows, one of the bridge abutments experienced significant deterioration due to erosion of the stream bank. | • Repairs were expedited by the City of Kelowna to restore the bridge to previous conditions.<br>• PEP Task Number: 131118 |
| June 18, 2012 | Mission Creek | Lakeshore Road | High rainfall caused water levels in Mission Creek to rise rapidly. Several homes along Truswell and Radant Roads experienced flooding. In addition, safety concerns around the Lakeshore Road bridge resulted in a closure until the water levels receded. | • Sandbagging was completed by neighborhood volunteers, supported by sandbags brought in from Penticton, courtesy of the RDOS Regional Emergency Program. The RDOS Regional Emergency Program is an integrated emergency program consisting of member municipalities within the RDOS.<br>• Crews from Civic Operations remained on the scene overnight to monitor conditions and removed debris buildup as required.<br>• Environment Incident Number: 130057 |
| June 20, 2012 | Mill Creek | Kelowna Airport | A debris blockage in Mill Creek caused flows to overtop the channels banks, resulting in flooding of a perimeter roadway and part of the airfield. | • Environment Incident Number: 120071 |
| June 22 – 23, 2012 | Middle Vernon Creek | Old Vernon Road / Jensen Road, District of Lake Country | Seven cottonwood trees caused a blockage in Old Vernon Creek resulting in rising water levels. | • Equipment was brought in to clear the blockage before flooding occurred.<br>• Environment Incident Number: 120121 |
| June 23, 2012 | Mission Creek | Priest Creek | A tree was causing a blockage of Priest Creek. | • The tree was removed before flooding occurred. |
| June 23 – 24, 2012 | Mission Creek | 11250 Highway 33 East, Joe Rich | Bank erosion in Mission Creek caused concerns over the stability of a trailer located close to Mission Creek. | • No actions were reported. |

## 3.4 HYDROMETRIC AND CLIMATE INFORMATION TO SUPPORT FLOODPLAIN MANAGEMENT

Environment Canada operates climate and hydrometric monitoring stations throughout the RDCO (Figure 3-9). Table 3-6 provides an overview of the number of active and discontinued federal and provincially operated hydrometric, snow course, snow pillow, and climate stations within the RDCO boundary. The number of active climate stations within the RDCO does not meet the World Meteorological Organization (WMO) guidelines for mountainous landscapes (MSRD 2003; Miles and Associates Ltd. 2003). In addition, Dobson and Letvak (2008) identified the current state of the hydrometric network in the Okanagan Basin, and provided recommendations for expanding the network to meet current and future requirements for the data.

**Table 3-6**
**Summary of climate and hydrometric monitoring stations within the RDCO**

| Monitoring Station | Status | Number of Stations |
|---|---|---|
| Hydrometric | **Active** | **7** |
| | Discontinued | 82 |
| Snow Course | **Active** | **10** |
| | Discontinued | 3 |
| Snow Pillow | **Active** | **2** |
| Climate Stations | **Active** | **6** |

Summit (2009) provides a summary of hydrometric stations that have been historically operated by independent agencies within the Okanagan Basin and the OBWB has lead recent initiatives for the installation of hydrometric stations at the outlet of Swalwell (Beaver) Lake and on Shorts Creek. The City of Kelowna also noted during the project workshop in December 2015 with RDCO (Associated 2015) that they operated a number of rain gauges within the city limits. Some of this hydrometric and climate information is available through the Integrated Hydrometric Data System developed by Summit (2014) (for the OBWB) to improve the dissemination of hydrometric information within the Okanagan Basin from both the Water Survey of Canada and independent agencies.

REGIONAL DISTRICT of CENTRAL OKANAGAN

Whiteman Creek
Shorts Creek
Lambly Creek
Powers Creek
McDougall Creek
Trepanier Creek
Peachland Creek
Vernon Creek
Mill Creek
Mission Creek
Bellevue Creek
W-5
W-6
W-7
W-8
W-9
W-10
W-11
E-2 (DLC)
E-2 (KEL)
E-3
E-4
E-5 (KEL)
E-5 (RDCO-E)
OKANAGAN HIGHLANDS
BEAVERDELL RANGE
OKANAGAN HIGHLANDS

N
W
E
S

**Legend**

- Climate Station
- Active Hydrometric Station
- Discontinued Hydrometric Station

**Location of Dams and Consequence Ratings (Color Coded**

- Not Classified
- Low
- Significant
- High
- Very High
- Extreme
- RDCO Boundary
- Bellevue Creek
- Residual Areas
- Lambly Creek
- McDougall Creek
- Mill Creek
- Mission Creek
- Peachland Creek
- Powers Creek
- Shorts Creek
- Trepanier Creek
- Vernon Creek
- Whiteman Creek

0 1 2 4 6 8 10 Kilometers

Background Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia,

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Associated Environmental

PROJECT NO.: 2015-8202.000.000
DATE: June 2016
DRAWN BY: DA

**FIGURE 3-9: DAMS, HYDROMETRIC STATIONS, AND CLIMATE STATIONS WITHIN THE RDCO**

Regional District of Central Okanagan

Phase 1 of the Regional Floodplain Management Plan

In addition to data collected from land-based monitoring programs, there are a number of web-based and numerical modelling tools which are available to aid flood mitigation and planning purposes. A summary of available tools is provided below:

- **Intensity-Duration-Frequency (IDF) Curves (EC 2014)[3]:** Environment Canada generate IDF curves for select climate stations across Canada based on historic precipitation data collected at each station. IDF curves provide the probability that a given rainfall intensity will occur for a defined time period. As such, IDF curves provide a useful tool for flood planning.

- **IDF_CC Software – Computerized Tool for the Development of IDF Curves under Climate Change (Simonovic et al. 2016)[4]:** This web-based tool allows users to access IDF curves for any climate station across Canada, as well as for derived stations at any location. IDF curves can be obtained for historic data, or for future climate conditions under select climate models. Data is available in graphical or tabulated formats. More information on the development of the tool and the integrated future climate scenarios can be found in Simonovic et al. (2016).

- **ClimateBC Software – High-Resolution Historic and Down-Scaled Future Projected Spatial Climate Data (Wang et al. 2012)[5]:** This web-based tool allows users to access downscaled monthly climate data from a 4 km x 4 km spatial grid to scale-free point locations. Climate variables are available for climate normal periods, as well as individual years and periods between 1901 and 2100 for select future climate models. More information on the development of the tool and the integrated future climate scenarios can be found in Wang et al. (2012).

- **Columbia Basin Climate Change Scenarios Project (Hamlet et al. 2010)[6]:** This project aims to provide site-specific future projections for multiple hydrologic and climatologic parameters. Outputs are generated for sites across the Columbia River Basin using a 10 GCM model ensemble for different emission scenarios. More information is provided Section 3.7.

- **Pacific Climate Impacts Consortium (PCIC) Plan2Adapt[7]:** The Plan2Adapt tool generates interactive maps of historical and projected future climate variables across B.C. Interpolated spatial layers are generated from historic climate data and select climate models for three climate normal periods until 2099. The Plan2Adapt tool allows users to assess projected future climates for particular Regional Districts, Health Authority Boundaries, Ecoprovinces and Forestry Regions across BC. More information is provided in Section 3.7.

[3] Environment Canada IDF Curves are available at http://climate.weather.gc.ca/prods_servs/engineering_e.html

[4] The IDF_CC Software is available online at http://www.idf-cc-uwo.ca/

[5] ClimateBC can be accessed online at http://www.climatewna.com/ClimateBC_Map.aspx

[6] Data for the Columbia Basin Climate Change Scenarios Project can be accessed online through the University of Washington's Climate Impacts Group at: http://www.hydro.washington.edu/2860/products/sites/

[7] The Pacific Climate Impacts Consortium (PCIC) Plan2Adapt tool is available online at https://www.pacificclimate.org/analysis-tools/plan2adapt

## 3.5 EXISTING DAMS AND RESERVOIRS IN THE RDCO

### 3.5.1 Dams within the RDCO

There are currently 129 dams within or upstream of the RDCO (using the most up-to-date dam information obtained from MFLNRO), with the majority located in the headwaters. In February 2016, the Government of British Columbia repealed and replaced the existing *British Columbia Dam Safety Regulation* (B.C. Reg. 44/2000) with the new Dam Safety Regulation (B.C. Reg. 40/2016) under the *Water Sustainability Act*. The Dam Safety Regulation applies to all dams that store or divert water from a stream or aquifer or both.[8]

All dams are assigned a consequence classification following Schedule 1 of the Dam Safety Regulation. This consequence classification is based on the population at risk and the potential for loss of life, loss of environmental and cultural values, and loss of infrastructure and economics. Appendix C provides a list of the dams within and upstream of the RDCO, their corresponding consequence classification, and the registered owner of the dam. The dam locations and color coded consequence ratings are shown in Figure 3-9.

Of the 129 dams, 117 have an assigned consequence rating. Of those, 47 are rated as low consequence from a dam breach, 27 are significant, 38 are high, 4 are very high, and one is extreme. The lakes and reservoirs with dams rated as very high and extreme include (Appendix C):

- Rose Valley Reservoir – located within the City of West Kelowna.
- Crooked Lake – located within the Upper Vernon Creek watershed.
- Ideal (Belgo) Lake – located within Belgo Creek watershed that drains into Mission Creek at Joe Rich.

Owners of dams which have a consequence classification of high or greater are required to complete a Dam Safety Review (DSR). DSRs are regulated by MFLNRO and involve the assessment of dam breaches (and consequences to downstream or adjacent lands) (MFLNRO 2016a; 2016b).

Note that although dam breaches present one of the most important flood hazards in the Okanagan Valley, the RFMP Phase 1 preliminary risk assessment (Section 4) does not include a new evaluation of dam breach potential because risk screening is already required by MFLNRO, and most dams have been given a consequence rating as outlined above. The Dam Breach Safety Program is discussed further in Section 4.1.2.

### 3.5.2 Lakes and Reservoirs within the RDCO

There are four large and medium-sized valley-bottom lakes within, or partly within, the RDCO boundary:

- Okanagan Lake (total surface area: 349.9 $km^2$)
- Kalamalka Lake (total surface area: 25.6 $km^2$)

[8] At the discretion of the Comptroller of Water Rights, minor dams are exempt from the regulation if they are less than 7.5 m in height and are able to impound no more than 10,000 $m^3$ of water.

- Wood Lake (total surface area: 9.1 km$^2$)
- Ellison Lake (total surface area: 2.0 km$^2$)

In addition to the large valley bottom waterbodies, there are >600 lakes and reservoirs throughout the RDCO. Appendix C provides a summary of selected upland reservoirs (that include dams) within the RDCO and the mapped dams included in Figure 3-9 correspond to the geographic locations of the selected reservoirs.

Water levels in upland reservoirs are managed throughout the year to manage both water supply and flood risk (e.g. the reservoirs are typically drawn down after freshet and through the irrigation season, creating considerable storage capacity for runoff the following spring). When the reservoirs are full in spring and early summer, significant precipitation and/or wave/surge events could cause localized flooding around lake margins or increase the potential for water to be released downstream. However, managing these hazards is part of the normal operating regime by the owners of the dams located on the reservoirs.

## 3.6 INFRASTRUCTURE POTENTIALLY PRONE TO FLOODING

As part of the B.C. Provincial Emergency Program, the Government of B.C. has produced a Critical Infrastructure[9] Rating Workbook (Provincial Emergency Program 2007). The Critical Infrastructure Rating Workbook is intended to help municipalities, industries, and communities identify critical infrastructure that may be at risk from a hazardous event, such as flooding.

Using the Critical Infrastructure Rating Workbook as a guide, critical infrastructure was identified within the RDCO flood prone areas using information identified in Section 2.1 and based in part on comments received during the project workshop in December 2015 with RDCO (Associated 2015) and follow-up discussions. Information on the critical infrastructure identified as potentially prone to flooding within the RDCO is provided in Section 4.2.4.

## 3.7 FUTURE CLIMATE CHANGE IMPLICATIONS FOR FLOOD HAZARD

### 3.7.1 Previous Studies and Climate Change Projections

Recent work at the University of Victoria's Pacific Climate Impacts Consortium (PCIC) and the University of Washington's Climate Impacts Group is directly applicable to the RDCO. PCIC has developed the 'Plan2Adapt' tool, which provides estimates of future primary climate variables such as temperature and precipitation, as well as more complex parameters derived from these primary variables, for specified geographic areas. The University of Washington has also completed a major study of climate change in the Columbia River Basin.

[9] **Critical Infrastructure Assets** are defined as "those physical resources, services, and information technology facilities, networks and assets which, if disrupted or destroyed, would have a serious impact on the operation of an organization, sector, region, or government" (Provincial Emergency Program 2007).

The PCIC Plan2Adapt tool and the University of Washington's study use an ensemble of recent (i.e. AR4) climate models[10]. Inconsistencies in model outputs between the tool and the study may exist due to a number of factors. The models used are not the same, and the modelled areas selected for the simulations are not identical. In addition, the baseline periods are different (PCIC uses 1961-1990 while University of Washington uses 1970-1999). Also, although they both use the B1 emission scenario (i.e. the one with the lowest amount of global surface warming), PCIC uses the A2 emission scenario while University of Washington uses the A1B emission scenario (the A2 scenario is slightly warmer on average and has a larger range of temperatures than the A1B scenario). Also, the middle period of future predictions centres on the 2050s for the PCIC data, while University of Washington centres on the 2040s. Nevertheless, the general trends for both temperature and precipitation are consistent, and most of the hydrological implications of the predicted changes in climate are similar.

In addition to PCIC and the University of Washington, the OWSDP completed climate and hydrologic modeling to improve the current and future state of knowledge for water resources of the Okanagan Basin. During Phase 2 of the OWSDP, future scenario modeling was completed using climate data from the CGCM2 (A2) climate model, while under Phase 3 the "dry" HadCM3 (A2) and "wet" CGCM3 (B1) climate model output was used. Modeling was completed for 2011-2040 and was compared to the OWSDP calibration period (1996-2006) (Summit 2010; Polar 2012).

The available climate change information from PCIC, the University of Washington, and the OWSDP relevant to the RDCO is summarized in the following sections.

### 3.7.2 Pacific Climate Impacts Consortium – Plan2Adapt Tool

The PCIC Plan2Adapt tool provides outputs for the RDCO and Table 3-7 summarizes the median and ranges of values expected for the 2020s, 2050s and 2080s compared to the baseline period of 1961-90 for the RDCO. These values are derived from a 15 GCM ensemble, under the A2 and B1 $CO_2$ emission scenarios.

[10] Note that AR4 is not the most recent climate model. AR5 is now available.

**Table 3-7**
**Projected climate change for the RDCO**

| Climate Variable[1] | Time of Year | Projected Change (from 1961-90 baseline) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2020s | | 2050s | | 2080s | |
| | | Median | Range | Median | Range | Median | Range |
| Mean Air Temp (ºC) | Annual | +1.0 ºC | +0.6ºC to +1.5ºC | +1.9 ºC | +1.1ºC to +2.7ºC | +2.9 ºC | +1.7ºC to +4.6ºC |
| Precip. (%) | Annual<br>Summer<br>Winter | +5%<br>-5%<br>+3% | -2% to +7%<br>-11% to +10%<br>-2% to +10% | +7%<br>-11%<br>+7% | -2% to +11%<br>-24% to -1%<br>-4% to +16% | +8%<br>-12%<br>+11% | +2% to +15%<br>-34% to +4%<br>+3% to +27% |
| Snow Depth (%) | Winter<br>Spring | -7%<br>-33% | -18% to 0%<br>-58% to +1% | -14%<br>-57% | -25% to -2%<br>-76% to -13% | -14%<br>-57% | -44% to -9%<br>-89% to -17% |
| GDD[2] | Annual | +178 | +85 to +283 | +359 | +206 to +541 | +560 | +314 to +975 |
| HDD[3] | Annual | -364 | -517 to -201 | -664 | -954 to -400 | -993 | -1541 to -588 |
| FFD[4] | Annual | +14 | +7 to +21 | +24 | +13 to +36 | +37 | +20 to +60 |

Notes:
1. Climate variables derived from temperature and precipitation datasets.
2. GDD – Growing Degree Days (given in degree days).
3. HDD – Heating Degree Days (given in degree days).
4. FFD – Frost-Free Days.

The potential hydrological impacts to the watersheds within the RDCO according to PCIC include:

- Warmer annual temperature:
  - Changes in seasonality of streamflow
  - Increased evaporation
- Winter warming:
  - Mid-winter thaw events may cause ice jams and flooding
- Wetter conditions projected in winter:
  - Higher winter streamflows and extreme precipitation events may cause flooding, or increase the risks of more severe or more frequent floods and landslides
  - Increase in storm events
- Warmer, drier summers:
  - Possibility of more prolonged and intense droughts with lower water supply during periods of peak demand
  - Reduced soil moisture and increased evaporation, increasing irrigation needs at the same time of year that streamflows are expected to decline
  - Possible declines in recharge rates for groundwater sources

### 3.7.3 Columbia Basin Climate Change Scenarios Project

The Columbia Basin Climate Change Scenarios Project (CBCCSP) is documented in Hamlet et al. (2010) and data is accessible online through the University of Washington's Climate Impacts Group[11].

The CBCCSP includes future projections for a selection of hydro-climatic parameters. Projections are provided for many locations in the Columbia River Basin including one site within the RDCO that corresponds to the following WSC hydrometric station location:

- Mission Creek near East Kelowna (Station No. 08NM116)

An example of the model projections for Mission Creek near East Kelowna is shown in Figure 3-10 and projected changes to daily flood statistics for Mission Creek are provided in Table 3-8. Note that the blue line in Figure 3-10 represents the average runoff over the baseline period, the red line represents the average runoff for each future period, and the red shading represents the runoff range for each future period.

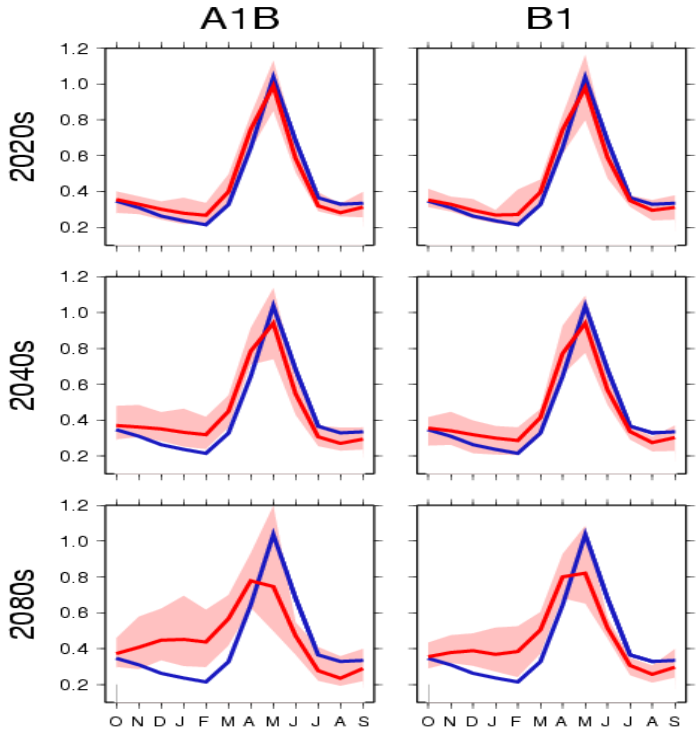


**Figure 3-10**
**Projected runoff for Mission Creek (in inches) for three future time periods (2020, 2040, and 2080) in comparison to the 1970-1999 baseline period (Source: Climate Impacts Group 2010).**

[11] Online at: http://www.hydro.washington.edu/2860/products/sites/

These outputs are derived from a 10 GCM model ensemble, under the A1B and B1 emission scenarios[12] for the periods centering on the 2020s, 2040s, and 2080s. They are compared to the baseline period of 1970-1999.

**Table 3-8**
**Projected changes to flood statistics for Mission Creek near East Kelowna (from Climate Impacts Group [2010])**

| Emission Scenario | A1B | | | | | | | | | B1 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Recurrence Interval (years) | 2020s | | | 2040s | | | 2080s | | | 2020s | | | 2040s | | | 2080s | | |
| | Ratio | | | Ratio | | | Ratio | | | Ratio | | | Ratio | | | Ratio | | |
| | Ave | Min | Max | Ave | Min | Max | Ave | Min | Max | Ave | Min | Max | Ave | Min | Max | Ave | Min | Max |
| 20 | 1.03 | 0.94 | 1.16 | 1.02 | 0.83 | 1.17 | 1.07 | 0.88 | 1.27 | 1.03 | 0.90 | 1.14 | 1.02 | 0.94 | 1.15 | 1.03 | 0.92 | 1.11 |
| 50 | 1.06 | 0.93 | 1.23 | 1.04 | 0.82 | 1.20 | 1.12 | 0.89 | 1.40 | 1.06 | 0.88 | 1.24 | 1.05 | 0.95 | 1.20 | 1.09 | 0.94 | 1.20 |
| 100 | 1.09 | 0.93 | 1.28 | 1.07 | 0.81 | 1.23 | 1.17 | 0.89 | 1.50 | 1.08 | 0.87 | 1.33 | 1.08 | 0.96 | 1.24 | 1.13 | 0.95 | 1.28 |

The following points summarize the general climate and hydrologic trends predicted for watersheds within the RDCO based on the modeled results for Mission Creek:

- Streamflow:
  - Late fall, winter and early spring flows are forecast to be greater; while late spring, summer and early fall flows will be smaller
  - Shift in hydrograph to earlier in the year
- Peak Flows:
  - Mean annual peak flows decrease under both scenarios
  - Range of peak flow projections is considerable (i.e. ranges from less to greater than simulated baseline flows (1970-1999)
  - The magnitude of extreme peak flows is projected to increase.
- Low Flows:
  - Late summer/early fall low flows decrease, winter low flows increase.
- Snow Water Equivalent (SWE):
  - Average SWE is predicted to decrease (on average) for all periods under both scenarios.

[12] The A1B and B1 emission scenarios represent two different future climate scenarios. The A1B scenario represents a medium emission scenario with increasing greenhouse gas production into the future and medium to high increases predicted in temperature and precipitation. The B1 scenario represents a scenario with significant reductions in greenhouse gas emissions in the future resulting in smaller predicted changes to temperature and precipitation (Hamlet et al. 2010).

### 3.7.4 Okanagan Water Supply and Demand Project

The OWSDP is documented by Summit (2010) and Polar (2012) and data is accessible through the Okanagan Basin Water Board. The OWSDP includes future projections of net and naturalized streamflows, water demands, and climate for watersheds within the Okanagan Basin for the following modeling scenarios:

- Changes in climate
- Changes in forest cover as a result of mountain pine beetle, wildfire, and forest harvesting
- Changes in water use efficiency
- Changes in the amount of agricultural land under irrigation
- Changes in population

The major watersheds within the RDCO (e.g. Kelowna Creek, Mission Creek, Powers Creek) were modeled within the OWDSP. The following points summarize the general climate and hydrologic trends predicted for watersheds within the Okanagan Basin and the RDCO:

- Future Climate
    - Air temperatures are projected to generally increase, but year to year variability will be high
    - Precipitation is projected to be highly variable with a general increase during the winter
    - Snowpacks are projected to be reduced at lower elevations

- Streamflows
    - Snowmelt is projected to occur earlier with meltwater runoff expected to decrease due to more rain generated runoff throughout the winter
    - Annual runoff is expected to increase, with the majority of the increase occurring between October and March. Decreased runoff is expected to occur between May and July

### 3.7.5 Climate Change Summary

Based on the available climate change information, the following is an overall summary of the general climate and hydrologic trends predicted for the RDCO:

- The climate in the RDCO is predicted to warm, and annual precipitation is predicted to increase. Summer precipitation is likely to decrease and winter precipitation is likely to increase.
- Snowpacks are projected to be increased at higher elevations but reduced at lower elevations, creating uncertainty.
- Snowmelt is projected to occur earlier with meltwater runoff expected to decrease due to more rain generated runoff throughout the winter.
- Late fall, winter and early spring streamflows are projected to be greater; while late spring, summer and early fall streamflows are projected to be smaller.
- The magnitude of extreme peak flows is projected to increase and this could cause an increase in flood and natural hazards within the RDCO.

## 3.8 FUTURE LAND USE CHANGE IMPLICATIONS FOR FLOOD HAZARD

A number of the flood mechanisms identified in Section 3.3.1 can be active in the RDCO are influenced by land use, and changes in land use could alter those mechanisms to some degree.

For streams originating at higher elevations (Table 3.3), forest harvest and the creation of forest roads to service forestry operation have the potential to change the hydrological regime; including earlier spring runoff, higher peak flows, and quicker flow routing. Under the Forest and Range Practices Regulation, forest companies must consider hydrological risks associated with harvesting (usually by completing a Watershed Assessment), including the potential for increased peak flows, and include mitigation measures to minimize peak flow hazards in the Forest Stewardship Plan. The upland forests in the RDCO have experienced considerable amounts of forest harvest over the past century, so the current hydrological regime reflects a managed forest situation. Forest harvest levels are unlikely to change significantly at the scale of RDCO, but individual watersheds could see more or less harvesting, and forest companies' planning for future forest development will continue to need to consider hydrological hazards including flooding. This RFMP can be used to help guide future Watershed Assessments (a type of risk assessment) by clarifying the consequences of increased peak flows in regional watersheds.

For valley bottom streams, and the lower reaches of stream originating in upland areas, the major influence of land use change on flood hazard is the effects of more impermeable or compacted surfaces. In the RDCO, future growth areas are constrained by Agricultural Land Reserve, topography, and Crown land (which is largely to be maintained for the traditional uses of forestry, range, and recreation). As such, densification of urban areas is expected to accommodate growth. This could have implications for stormwater runoff, but good design and operations/maintenance practices can limit flood hazard if climate change is adequately factored in. For example, new IDF curves have been developed for Canada that adjust historical data based on recent climate change projections (Simonovic et al. 2016; see Section 3.4).

With respect to agricultural land use, there currently is no reason to think that the areas in the ALR would decrease significantly because the Okanagan Valley is within Zone 1, where the provincial government recently reiterated its commitment that farming will be the primary use. Although food security is perhaps the primary reason for maintaining the ALR within RDCO, agricultural land both reduces the potential for runoff generation (compared to developed areas) and has a lower consequence profile than developed areas with a higher density of critical infrastructure.

## 3.9 INFORMATION GAP ASSESSMENT

Within the RDCO there is generally sufficient climate, hydrologic, and infrastructure data sources available to support the development of Phases 2 and 3 of the RFMP. However, information on flood magnitudes, timing, and flood mechanisms for watercourses/waterbodies is limited. Similarly, floodplain mapping has only been completed on Kelowna (Mill) Creek, Mission Creek, and a portion of Okanagan Lake within the RDCO, but some of the mapping is considered dated at this time.

Accordingly, an assessment was completed to identify and prioritize information gaps that should be addressed as part of subsequent phases of the RFMP. Sections 4.5 and 6.2 provide a summary of the results of the assessment and the identified information gaps and recommendations for future work.

# 4 Preliminary Hazard Area Identification and Priorities

This section describes the background and methodology for developing a **preliminary flood risk rating (PFRR)** of flood-prone streams in RDCO as part of the RFMP (Phase 1), and presents the results. The PFRRs are used to establish priorities for future actions during Phases 2 and 3, consistent with the RFMP terms of reference (Clarke Geoscience Ltd. 2014).

## 4.1 BACKGROUND – RISKS OF NATURAL HAZARDS

The B.C. provincial government handbooks authored by Wise et al. (2004) and Wilford et al. (2009) define risk as a measure of the probability of a specific hazardous event occurring and the consequence, or adverse effects, of that event on specific elements-at-risk, such as human health, property, or the environment. Generally speaking, the risk of natural hazards like floods and landslides is the product of hazard and consequence; and risk analysis involves identifying and quantifying the applicable hazards and consequences. Hazards are the potentially damaging events; and hazard analysis involves the review of information on the **magnitude and likelihood** of occurrence of specific hazards. Consequence refers to the likelihood of damage or losses to an element-at-risk, assuming that a specific hazardous event occurs. Analysis of consequence includes evaluation of the spatial and temporal exposure (e.g. is the element at a location and at a time when it could be affected by the hazard?), as well as the vulnerability (or resiliency) of the element-at-risk.

For flood risk, the Association of Professional Engineers and Geoscientists of B.C. (APEGBC 2012) quantifies risk as the product between the probability of a hazardous flood occurring and the potential consequences to elements-at-risk.

Understanding how risk ratings are derived is important when land planning and management decisions rely on the results of a risk analysis, or when ratings are compared between different assessments. In some cases, land managers may choose to complete a specific risk or specific value of risk analysis by incorporating additional information on vulnerability, consequence, or worth with input from appropriate specialists (Wise et al. 2004). Of note, it is generally the responsibility of land managers to understand and accept the rating definitions used in a risk analysis as they are qualitative and there may not be regional or provincial standards in place. In addition, local definitions of what constitutes acceptable, tolerable, or unacceptable levels of risk should be developed by the responsible authority (which includes local governments within their areas of jurisdiction).

### 4.1.1 Association of Professional Engineers and Geoscientists of B.C. Guidelines

APEGBC (2012) has developed professional guidelines for completing flood hazard assessments associated with common flood mechanisms (e.g. rain, rain-on-snow, snowmelt, ice jams, high lake levels and surge, climate change). Two approaches were identified when considering flood hazards:

- Standard–based Approach
    - The selection of a design threshold (e.g. 1:200-year return period plus freeboard) for the design and/or implementation of flood protection measures (including planning tools like zoning). This approach does not necessarily require a flood hazard assessment to be completed, since a land manager considers that sufficient protection is provided to any identified elements-at-risk up to the design threshold. Above the threshold, the land manager considers the risk to elements-at-risk tolerable.
- Risk-based Approach
    - A formal risk-based approach that quantifies flood consequences and combines hazard scenarios to estimate flood risk. The resulting risk is then evaluated through comparison with available risk tolerance criteria. Note that B.C. has not developed specific risk-tolerance criteria; therefore, professional practice standards are currently used to imply risk tolerance.

For the risk-based approach, the APEGBC guidelines provide various risk rating tables to help guide the scope of a risk analysis based on elements-at-risk presented (e.g. value of developments and/or vulnerable populations exposed to a flood hazard). It should be noted that neither the provincial nor federal governments have developed guidance methods for preliminary or detailed flood risk analyses, so the APEGBC (2012) guidelines are the most-recent resource available to planners and other land managers. Currently in B.C. it is at the discretion of the professional and/or land manager to guide the scope and approach of the risk analysis.

### 4.1.2 Dam Safety Program – Dam Breach

As outlined in Section 3.5.1, in February 2016, the Government of British Columbia repealed and replaced the existing *British Columbia Dam Safety Regulation* (B.C. Reg. 44/2000) with the new Dam Safety Regulation (B.C. Reg. 40/2016) under the *Water Sustainability Act*. The Dam Safety Regulation applies to all dams that store or divert water from a stream or aquifer or both.

The likelihood of a dam breach is generally considered very low (unless otherwise noted during a site-specific dam or dike safety review). However, the consequences to downstream or adjacent lands can be significant. MFLNRO (2016b) identifies that in order to determine the failure consequence classification for dams in B.C.; all elements-at-risk must be considered. Failure consequence is defined by MFLNRO (2016b) as the damage to downstream or upstream areas above and beyond the damage that would have occurred in the same event had the dam not failed.

Following this, MFLNRO (2016b) provides a failure consequence classification table to guide Dam Safety Officers and considers populations at risk, loss of life, environment and cultural values, and infrastructure and economics. The consequence classifications are based on the identified elements-at-risk and the estimated extent of flood inundation.

A dam breach is one of the most important flood hazards in the Okanagan Valley because of the number of high-elevation dams that were constructed as part of local water supply systems. However, APEGBC (2012) does not include this type of flood mechanism within professional guidelines, because dam breach assessments (and consequences to downstream or adjacent lands) have been completed (in many places in B.C., including the RDCO) through Dam Safety Reviews (DSR) regulated by MFLNRO (2016a; 2016b). As a result, for this preliminary risk screening completed for Phase 1 of the RFMP, the MFLNRO assessments that are already in place for streams within RDCO are used for the PFRR (Section 3.5). In addition, the likelihood of a dam breach is generally considered very low (unless otherwise determined by MFLNRO during a site-specific dam safety review).

## 4.2 PRELIMINARY FLOOD RISK RATING METHOD

Flood hazard assessments have not been completed for the majority of watercourses and waterbodies within the RDCO boundaries, and only limited floodplain mapping has been completed on Mission Creek, Kelowna (Mill) Creek, and a portion of Okanagan Lake (Section 3.2). To aid in identifying areas at risk of flooding, and their corresponding consequences, a preliminary screening approach was used to assign a PFRR to all watercourses within the RDCO. This high level screening approach was intended to identify stream reaches of probable concern and to prioritize further investigational effort. This approach generally follows the flood hazard risk guidelines outlined by APEGBC (2012); however, due to limited floodplain mapping within the RDCO, the APEGBC (2012) approach was modified for Phase 1 of the RFMP to serve as a screening tool only to help set priorities for more detailed risk characterization in Phase 2. Because of their preliminary status, the PFRRs must not be used for specific planning or land use decisions.

Note that for the PFRR, flood is defined as a condition in which a watercourse or body of water overtops its natural or artificial confines and covers land not normally under water. Based on this definition, the following tasks summarize the approach used to assign preliminary flood risk ratings within the RDCO:

- Task 1 – Identification of flood prone watercourses and/or reaches or waterbodies.
- Task 2 – Identification of alluvial fans and floodplains.
- Task 3 – Identification of the annual exceedance probability (or likelihood) of a flood occurring.
- Task 4 – Identification of the known elements-at-risk across a watercourse, waterbody, or are located within a floodplain or on an alluvial fan.
- Task 5 – Identification of the consequence(s) to the elements-at-risk from flooding in RDCO, reflecting the biophysical/ecological characteristics and socio-economic values in the region.
- Task 6 – Assignment of a PFRR based on the identified likelihood of flood mechanism and associated consequences to elements-at-risk.

A detailed description of the methods used to assign PFRRs within the RDCO is provided in Appendix D. The rest of this section provides a summary of the tasks (identified above) completed to assign PFRRs.

- Identification of flood-prone watercourses and/or reaches or waterbodies using available soils and stream channel morphology spatial datasets as indicators, recognizing the associated physical properties and correlation to river processes. Map 1 (Appendix E) provides the results of the flood-prone streams mapping for the RDCO.

- Identification of alluvial fans and floodplains using either existing floodplain mapping (where it exists) or by estimating floodplain limits from mapped alluvial aquifer and/or fluvial soil type polygon extents where available. Flood construction levels for Okanagan, Wood, and Kalamalka Lakes were also delineated and considered the floodplain extents for each lake. Map 1 (Appendix E) provides the results of the existing and estimated alluvial fan and floodplain mapping for the RDCO.
- The threshold values where flooding commences on most watercourses within the RDCO is currently unknown and determining those thresholds will require more detailed assessment (i.e. field surveys and or modelling). In this phase; therefore, for areas with existing floodplain mapping or estimated flood-prone areas, a 1:200 year return period flood event (i.e. a 0.5% annual probability of occurrence) was used to define the PFRR. For Okanagan Lake, the flood construction level of 343.66 m was used, while 393.2 m was used for Wood and Kalamalka Lakes.
- Identification of the known elements-at-risk across a watercourse, waterbody, or located within a floodplain was completed using available spatial datasets. The spatial datasets included identification of high and low density development areas, rural lands, future development areas, total population, critical infrastructure at risk (e.g. hospitals, water and wastewater treatment plants, bridges, highways, railways), as well as environmentally sensitive areas.
- Identification of the consequence(s) to the elements-at-risk from flooding in the RDCO was assigned using a customized consequence classification system developed to consider community-specific values, as follows: land use type, critical infrastructure, total population/personal hardship, social and cultural, and environmental consequences. The customized consequence classification scheme is provided in Table 4-1.
- Assignment of a PFRR based on the identified likelihood of flood mechanism and associated consequences to elements-at-risk using a risk matrix that considers priorities for Phase 2 of the RFMP. The risk matrix is provided in Table 4-1. The PFRR was assigned based on an equal weighting of all consequence category ratings and the resultant PFRR value represents the following in association to Phase 2:
    - Low – No further risk assessment is recommended.
    - Moderate – Risk may be tolerable and moderate priority for further risk assessment in Phase 2.
    - High – Risk is unacceptable and high priority for further risk assessment in Phase 2.
    - Very High – Risk is unacceptable and risk reduction is required. Very high priority for further risk assessment in Phase 2 and Phase 3.

**Table 4-1 Risk matrix to assign a preliminary flood risk rating to watercourses and bodies within the Regional District of Central Okanagan**

| LIKELIHOOD DESCRIPTION | | | PRELIMINARY RISK EVALUATION AND RECOMMENDATION | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | VH | Very High | Risk is unacceptable short-term (before next flood season) risk reduction required. **Very high priority for further risk assessment in Phase 2.** | | | |
| | | | H | High | Risk is unacceptable. **High priority for further risk assessment in Phase 2.** | | | |
| | | | M | Moderate | Risk may be tolerable. **Moderate priority for further risk assessment in Phase 2.** | | | |
| **Likelihood Description** | | **Annual Probability Range** | L | Low | Risk is tolerable. No further risk assessment recommended. | | | |
| Scenario expected on average every 200 yrs. | Very Unlikely | 0.007 – 0.004 | **L** | **M** | **M** | **H** | **H** | **VH** |
| **CONSEQUENCE CLASSIFICATION** | **Indices** | | **1** | **2** | **3** | **4** | **5** | **6** |
| | Land Use Type | | Forest Resource | Agriculture | Conservation Lands; Rural; Parks | Industrial | Commercial; Institutional; Future Commercial / Institutional | Residential; Future Residential |
| | Critical Infrastructure | | None | Trails/paths | Residential roads | Major Highways; Railways | Bridges; Schools; Water and Sewer Lines; Pumphouses; Power Substations | Hospitals; Health Centres; Assisted Living Centres; Emergency Services; Major Water Intakes; Water & Wastewater Treatment Facilities |
| | Social and Cultural | | Negligible impact | Slight impact; recoverable within days to weeks | | Moderate to high impact; recoverable within weeks to months | | Presence of places of worship, historical and archaeological sites, community centres, art galleries |
| | Total Population / Personal hardship | | <1 person; Negligible impact | <10 people; Slight impact; recoverable within days | <100 people; Moderate impact; recoverable within weeks | 100-500 people; Personal hardship usually recoverable within months | 501-2,500 people; Leaves significant personal hardship for years | >2,500 people; Irreparable personal hardship |
| | Environmental | | No channel present | Artificially channelized or culverted stream | Open channel present, but fish presence not confirmed | Fish-bearing stream | Fish-bearing stream with Kokanee Salmon presence | Contains a designated conservation area |

## 4.3 PRELIMINARY HAZARD AND RISK RATINGS

The results of the PFRR analysis for the RDCO are summarized in Map 2 (Appendix E) and in Tables E-1 and E-2 (Appendix E). As a reminder, these results were developed through a high-level GIS-based approach, which was intended to identify watercourses of probable concern and to prioritize further investigational effort during Phases 2 and 3 of the RFMP. The floodplains/alluvial fans and flood-prone watercourses/reaches without mapped floodplains included were considered to be a result of rain, rain-on-snow, snowmelt, debris blockages and releases of flows, ice jams, or sediment accumulation flood type events only, with dam and dike breaches not included. In addition, the floodplains were assumed to represent a 1:200-year return period flood event.

Note that the PFRRs and estimated floodplain/alluvial fan areas should not be considered definitive for inclusion within municipal bylaws and should only be considered for preliminary planning purposes at this time. These results will be updated and refined during Phases 2 and 3 of RFMP (see Section 6.2).

The following sections summarize the consequence ratings and PFRRs for watercourses within the RDCO.

### 4.3.1 Consequence Rating Summary

The consequence rating for each consequence type (Table 4-1) and the calculated and overall assigned (i.e. rounded) ratings are provided for each floodplain/alluvial fan and flood-prone watercourses/reaches without mapped floodplains in Tables E-1 and E-2 (Appendix E). A summary of the consequence ratings for floodplains/alluvial fans, flood-prone watercourses/reaches without mapped floodplains, and Okanagan Lake is provided in this section.

#### 4.3.1.1 Floodplains and Alluvial Fans

The floodplain/alluvial fans throughout the RDCO have overall consequence ratings that range between 1 and 6 (Table E-1; Appendix E). Many of the floodplain areas identified from the GIS analyses include critical infrastructure (e.g. water intakes, wastewater treatment plants, and bridges), residential land use, large numbers of people present, and kokanee salmon. The presence of these elements-at-risk influences the consequence ratings.

A summary of the results for the key floodplain/alluvial fan[13] areas within each of the major watersheds of the RDCO and Okanagan, Wood, and Kalamalka Lakes is summarized in Table 4-2. Note that in addition to the key floodplains, there are other floodplain areas within each watershed not summarized in Table 4-2; but the consequence ratings are provided for all floodplains and alluvial fans within Table E-1 (Appendix E). It is recommended that the consequence ratings for all floodplains (key and other) be considered for inclusion within Phases 2 and 3 of the RFMP.

[13] A "key" floodplain/alluvial fan area is defined as the floodplain for the mainstem watercourse that is located within the lower reaches of a watershed and within municipal limits. This floodplain is identified with an asterisk (*) in Table E-1 (Appendix E).

**Table 4-2**
**Summary of consequence ratings for key floodplain/alluvial fans within the major watersheds of the Regional District of Central Okanagan**

| Watershed | Floodplain Data Source | Estimated 1:200-year Floodplain Area ($km^2$) | Consequence Categories and Summary of Elements-at-Risk | | | | | Consequence Rating | | Preliminary Flood Risk Rating (from Table 4-1) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Flood-Prone Area Predominant Land Use Type | Critical Infrastructure | Social and Cultural | Estimated Total Population | Environmental | Calculated | Assigned Overall | |
| Mill Creek | AE (2010) | 15.0 | Industrial | At least one or more of hospitals, health centres, assisted living centres, emergency services, major water intakes, or water & wastewater treatment facilities | Moderate to high impact; recoverable within weeks to months | >2,500 | Fish-bearing stream with Kokanee Salmon presence | 5.2 | 5 | High |
| Mission Creek | MOE (1984) | 0.4 | Industrial | At least one or more of bridges, schools, water and sewer lines, pump houses, or power substations | Moderate to high impact; recoverable within weeks to months | 100-500 | Fish-bearing stream with Kokanee Salmon presence | 4.4 | 4 | High |
| Bellevue Creek | Estimated from fluvial soils mapping | 3.8 | Residential | At least one or more of bridges, schools, water and sewer lines, pump houses, or power substations | Moderate to high impact; recoverable within weeks to months | 501-2,500 | Fish-bearing stream | 5.2 | 5 | High |
| Peachland Creek | Estimated from fluvial soils mapping | 0.07 | Commercial; Institutional | At least one or more of bridges, schools, water and sewer lines, pump houses, or power substations | Moderate to high impact; recoverable within weeks to months | <100 | Fish-bearing stream | 4.0 | 4 | High |
| Trepanier Creek | Estimated from fluvial soils mapping | 0.3 | Commercial; Institutional | At least one or more of bridges, schools, water and sewer lines, pump houses, or power substations | Moderate to high impact; recoverable within weeks to months | 100-500 | Fish-bearing stream with Kokanee Salmon presence | 4.8 | 5 | High |
| Powers Creek | Estimated from fluvial soils mapping | 0.7 | Conservation Lands; Rural; Parks | At least one or more of bridges, schools, water and sewer lines, pump houses, or power substations | Moderate to high impact; recoverable within weeks to months | 100-500 | Open channel present, but fish presence not confirmed | 3.8 | 4 | High |
| McDougall Creek | Estimated from fluvial soils mapping | 2.4 | Industrial | At least one or more of hospitals, health centres, assisted living centres, emergency services, major water intakes, or water & wastewater treatment facilities | Moderate to high impact; recoverable within weeks to months | 501-2,500 | Fish-bearing stream | 4.8 | 5 | High |
| Lambly Creek | Estimated from alluvial fan mapping | 0.6 | Conservation Lands; Rural; Parks | At least one or more of bridges, schools, water and sewer lines, pump houses, or power substations | Slight impact; recoverable within days to weeks | <10 | Fish-bearing stream with Kokanee Salmon presence | 3.6 | 4 | High |
| Shorts Creek | Estimated from fluvial soils mapping | 1.2 | Conservation Lands; Rural; Parks | Residential Roads | Slight impact; recoverable within days to weeks | <10 | Fish-bearing stream | 3.0 | 3 | Moderate |
| Vernon Creek | Estimated from fluvial soils mapping | 6.8 | Conservation Lands; Rural; Parks | At least one or more of hospitals, health centres, assisted living centres, emergency services, major water intakes, or water & wastewater treatment facilities | Moderate to high impact; recoverable within weeks to months | 501-2,500 | Fish-bearing stream with Kokanee Salmon presence | 4.6 | 5 | High |
| Okanagan Lake | Estimated using Flood Construction Level | 6.1 | Commercial; Institutional | At least one or more of hospitals, health centres, assisted living centres, emergency services, major water intakes, or water & wastewater treatment facilities | Moderate to high impact; recoverable within weeks to months | >2,500 | Fish-bearing stream with Kokanee Salmon presence | 5.6 | 6 | Very High |
| Wood and Kalamalka Lakes | Estimated using Flood Construction Level | 0.8 | Residential | At least one or more of hospitals, health centres, assisted living centres, emergency services, major water intakes, or water & wastewater treatment facilities | Moderate to high impact; recoverable within weeks to months | <100 | Fish-bearing stream with Kokanee Salmon presence | 4.9 | 5 | High |

#### 4.3.1.2 Flood-Prone Watercourses/Reaches without Mapped Floodplains

The flood-prone watercourses/reaches without mapped floodplains throughout the RDCO had overall consequence ratings that ranged between 1 and 5. The flood-prone watercourses/reaches within the headwater areas were generally assigned an overall rating between 1 and 3 due to limited land use zoning in the headwater areas, limited infrastructure crossing the creek (other than forestry bridges), and the presence and absence of fish within watercourses due to fish barrier considerations within the lower reaches. For the watercourses/reaches within the lower portions of the watersheds, overall consequences ratings are between 3 and 5 due to the presence of land uses (residential, commercial) adjacent to watercourses, critical infrastructure (e.g. bridges, watermain crossings), and the presence of either fish bearing watercourses or man-made channels.

A summary of the consequence rating results for flood-prone watercourses/reaches per watershed (and residual area) (as identified in Figure 1-1 and Map 1) is provided in Table E-2 (Appendix E). The results indicate that Mill, Mission, Trepanier, and Vernon Creek watersheds have the highest number of flood-prone watercourses/reaches, while Mill, Mission, and Vernon Creek watersheds and residual area E-2 (KEL) have the highest number of flood-prone watercourses/reaches with overall consequence ratings between 3 and 5.

### 4.3.2 Preliminary Flood Risk Rating Summary

The preliminary flood risk ratings for each floodplain/alluvial fan and flood-prone watercourse/reach are provided in Tables E-1 and E-2 (Appendix E), respectively; in Table 4-2 for the key floodplain/alluvial fan areas within each of the major watersheds; and presented within Map 2 (Appendix E). The results were qualitatively reviewed and confirmed using local knowledge of watercourses known to flood, as well as using the summary of historic flood events within the RDCO included in Section 3.3.2.

A summary of the PFRRs for the floodplains/alluvial fans, flood-prone watercourses/reaches, and Okanagan, Wood, and Kalamalka Lakes is provided in the sections 4.3.2.1 to 4.3.2.3.

#### 4.3.2.1 Floodplains and Alluvial Fans

The floodplains/alluvial fans throughout the RDCO have PFRRs between Low to High, while the Okanagan Lake floodplain has a rating of Very High (Map 2; Appendix E). The PFFRs for the key floodplains/alluvial fans within each of the major watersheds of the RDCO and Okanagan, Wood, and Kalamalka Lakes are summarized in Table 4-2. Note that other floodplain areas within each watershed are not summarized here, but their PFRRs are provided within Table E-1 (Appendix E).

The PFRR for the key floodplains/alluvial fans within the RDCO was High, except for the Okanagan Lake floodplain, which was rated as Very High. Note that the PFRRs presented herein are based on an equal weighting of all consequence category ratings; however, by implementing a different weighting to the consequence values, a different PFRR may result. As a result, the PFRRs are used here are only to guide

the development of the RFMP and the ratings may be updated during Phase 2 after more detailed assessments are completed.

At a minimum the PFFR results presented here should be considered for flood planning, but all estimated floodplain/alluvial fan areas should be confirmed during subsequent phases of the RFMP. Understanding that the confirmation and mapping of every floodplain/alluvial fan within the RDCO may be unachievable, Section 4.5 highlights the priority streams and waterfront areas that are recommended to be investigated further during Phases 2 and 3 of RFMP.

#### 4.3.2.2 Flood-Prone Watercourses/Reaches without Mapped Floodplains

The flood-prone watercourses/reaches throughout the RDCO have PFRRs ranging between Moderate and High (Map 2; Appendix E). A summary of the PFRRs per watershed (and residual area) (as identified in Figure 1-1) is provided in Table 4-3. The results show that Mill, Mission, Powers, and Vernon Creek watersheds and residual areas E-2 (KEL) and E-3 have the highest number of flood-prone watercourses/reaches with a High PFRR.

Similar to the floodplain/alluvial fan results, the PFRR results for the flood-prone watercourses/reaches should be considered for flood planning, but should be confirmed during subsequent phases of the RFMP. Section 4.5 highlights the priority streams and waterfront areas that are recommended to be investigated further during Phases 2 and 3 of RFMP.

**Table 4-3**
**Summary of preliminary flood risk ratings for flood-prone watercourses/reaches without mapped or estimated floodplains within the Regional District of Central Okanagan**

| Watershed | Total Number of Flood-Prone Reaches within Watershed[1] | Number of Flood-Prone Reaches per Preliminary Flood Risk Rating | | | |
|---|---|---|---|---|---|
| | | Low | Moderate | High | Very High |
| Mill Creek | 102 | - | 86 | 16 | - |
| Mission Creek | 226 | - | 217 | 9 | - |
| Bellevue Creek | 1 | - | 1 | - | - |
| Peachland Creek | 29 | - | 27 | 2 | - |
| Trepanier Creek | 43 | - | 40 | 3 | - |
| Powers Creek | 29 | - | 22 | 7 | - |
| McDougall Creek | 8 | - | 7 | 1 | - |
| Lambly Creek | 30 | - | 29 | 1 | - |
| Shorts Creek | 19 | - | 18 | 1 | - |
| Vernon Creek | 45 | - | 37 | 8 | - |
| Whiteman Creek | 14 | - | 14 | - | - |
| E-2 (DLC) | 0 | - | - | - | - |
| E-2 (KEL) | 26 | - | 14 | 12 | - |
| E-3 | 8 | - | 1 | 7 | - |
| E-5 (KEL) | 3 | - | 1 | 2 | - |
| E-5 (RDCO-E) | 3 | - | 3 | - | - |
| W-10 | 2 | - | 2 | - | - |
| W-11 | 5 | - | 5 | - | - |
| W-5 | 1 | - | - | 1 | - |

| Watershed | Total Number of Flood-Prone Reaches within Watershed[1] | Number of Flood-Prone Reaches per Preliminary Flood Risk Rating | | | |
|---|---|---|---|---|---|
| | | Low | Moderate | High | Very High |
| W-6 | 3 | - | 3 | - | - |
| W-7 | 7 | - | 3 | 4 | - |
| W-8 | 9 | - | 1 | 8 | - |
| W-9 | 1 | - | 1 | - | - |

Note:
1. The total number of flood-prone reaches within a watershed considers all watercourses (e.g. tributaries) and is not specific to the mainstem portion of the creek alone. Flood-prone watercourses/reaches were defined as described in Appendix D.

## 4.4 CURRENT REGIONAL EMERGENCY PROGRAM PRIORITY AREAS

Regional emergency planning and response is the responsibility of the Regional Emergency Program and Emergency Support Services organization. If an emergency occurs, the Regional Emergency Program activates the Emergency Operations Centre (EOC) to serve as headquarters for the response. Historical emergencies within the RDCO have consisted primarily of wildfires and flooding, although landslides and major rain and wind storm events have been documented. The 2003 Kelowna Mountain Park wildfire reinforced the commitment of all jurisdictions to act together in different capacities, whether through shelters, supplies, volunteers, equipment (private and public), communications, government interaction and leadership. The community recognizes that any fire, flood or natural event impacting one community can easily impact a neighbouring community.

The latest version of the RDCO Emergency Plan – Flood Plan (Flood Plan) is a reflection of the level of preparedness, communication and response required (RDCO 2013b). The Flood Plan was developed to:

- Assist emergency personnel in responding quickly and effectively to potential disasters such as wildfires, landslides, major storms, chemical spills, floods, plane crashes, or earthquakes;
- Provide a concentrated assessment and decision-making body that is best able to utilize all available resources within RDCO, and if necessary, from the Provincial and/or Federal Governments; and
- Provide guidelines for recovery after an emergency.

The program's core is a process based on the British Columbia Emergency Response Management System (BCERMS). The BCERMS is a thorough and comprehensive emergency response protocol intended for any form and any extent of emergency[14]. The System is activated at the request of a

[14] The details involving the BCERMS can be found at: http://www2.gov.bc.ca/gov/content/safety/emergency-preparedness-response-recovery/emergency-response-and-recovery

community once a first response has been identified and level of emergency identified. The BCERMS has a series of protocols which activates trained responders, administrators, financial plans and leaders into a coordinated team.

With respect to flooding within the RDCO, the Emergency procedures itemized above apply, although the history of flooding demonstrates that the impacts are not as spatially wide-spread as fire. The Flood Plan lays the foundation for describing a flood event, the structure to be utilized, and the general expectations for roles and responsibilities of other levels of government, agencies and stakeholders.

The RDCO, as with other local governments, is responsible for both activation of the Emergency procedures and for Site Level Response. This site level response is typically actioned by the fire department. The RDCO's responsibilities include:

- Establishing an incident command post;
- Directing available resources at the incident;
- Notifying the EOC of situational awareness on a regular interval and in coordination with the EOC;
- Establishing response parameters in consultation with the EOC;
- Implementing emergency plans;
- Implementing flood protection measures;
- Providing information officers for media liaison; and
- Providing post-flood information about health issues, cleanup, and other issues.

The Flood Plan identifies three different levels of flood emergency:

- Stage 1 – Flood Alert
- Stage 2 – Flood Order
- Stage 3 – All Clear

There is a significant reliance on external communications and measurement from others that form part of the Alert and Order stages noted above. Feedback and information is also provided from more web-based sources of information like provincial snow pillows, weather services and flow information from the River Forecast Centre. These groups are also capable of issuing their own advisories in anticipation of combined or worsening conditions. The RDCO currently has hourly information available from a number of different areas, including Mission Creek (Kelowna), Brenda Mines (Peachland), Whiteman Creek (Fintry), Okanagan Lake, and Kalamalka Lake (as an indicator of conditions in the north part of the region). These services may include an emergency communication as follows:

- **High Streamflow Advisories** – River levels are rising or expected to rise rapidly, but that no *major* flooding is expected. Minor flooding in low-lying areas is possible.
- **Flood Watches** – River levels are rising and will approach or exceed bank full. Flooding of areas adjacent to affected rivers may occur.
- **Flood Warning** – River levels have exceeded bank full or will exceed bank full imminently, and that flooding of adjacent areas will result.

The current Flood Plan applies to all flood-prone areas within the RDCO, and does not outline special measures or responses for individual streams or sections of waterfront. Within Appendix C of the Flood

Plan, a table of dike and dam locations and floodplain mapping within the RDCO is provided. A consequence rating is provided for the dams listed, but the ratings have not been updated to reflect the new Dam Safety Regulation consequence ratings. In addition, for selected dams, the Flood Plan states that a separate action plan has been devised, but no further information is provided.

## 4.5 DISCUSSION: PRIORITY STREAMS AND WATERFRONT AREAS FOR FURTHER ASSESSMENT AND PLANNING

Based on the results of the background review, PFRR assessment (Map 1 and tables in Appendix C; Table 4-3), and review of the Flood Plan, this section identifies the priority streams, waterfront areas, and flood infrastructure that are recommended for further assessment during Phase 2 of the RFMP. The recommendations are discussed according to the areas in which the flood-prone streams and waterfront areas are located.

***Mission Creek floodplain mapping update and dike breach analysis***

- Tetra Tech EBA (2014) identified critical dike areas that were at risk of not meeting the 1:200-year peak flow return period design. Since the majority of the lower reaches of Mission Creek are diked and adjacent to urban developed areas, for emergency planning purposes a dike breach analysis should be completed to assess the potential impact of dike failure at critical points during a design flood to identify areas potentially at risk.
- The floodplain mapping completed by MOE (1984) for Mission Creek is currently out of date. Using the information collected by Tetra Tech EBA (2014), floodplain mapping of Mission Creek should be updated[15]. The update should include the previously mapped areas, as well as developing floodplain mapping for the Joe Rich area, the reach upstream and downstream of the Black Mountain Irrigation District water intake, areas along the lower reaches of the watershed that do not include diking, as well as for the area at the mouth of the creek (below the Lakeshore Road bridge).

***Okanagan Lake Flood Level Mapping***

- The flood construction level designated for Okanagan Lake is 343.66 m (including freeboard), which represents the 1:200-year return period peak lake level. MOE (1982) mapped a portion of Okanagan Lake between Peachland and West Kelowna using this lake level. Based on the understanding that MFLNRO is responsible for setting the flood level and for lake level management, the preliminary assessment of lands, structures, and critical infrastructure below the flood level completed in Section 4.3.1 and outlined in Map 2 (Appendix E) should be confirmed since the flood construction level for Phase 1 was estimated using publically-available digital elevation model information. As the population of the Okanagan Basin continues to increase, and more development is likely to be proposed along the waterfront of Okanagan Lake, high resolution elevation information (e.g. LiDAR) should be obtained for the area adjacent to Okanagan Lake within the RDCO. Publically available digital elevation information is only considered sufficient at the overview screening level; therefore, high resolution information is necessary to confirm whether

[15] Information on floodplain mapping standards is provided in Section 6.

any areas present or in the future could be cut-off from emergency support during a design flood event.

***Wood and Kalamalka Lakes Flood Level Mapping***

- The flood construction level designated for Wood and Kalamalka Lakes as defined by the District of Lake Country (2016) is 393.2 m (including freeboard). The return period of this peak lake level is not known. Similar to Okanagan Lake, understanding that MFLNRO is responsible for setting the flood level and for lake level management for Wood and Kalamalka Lakes, the preliminary assessment of lands, structures, and critical infrastructure below the flood level completed in Section 4.3.1 and outlined in Map 2 (Appendix E) should be confirmed since the flood construction level for Phase 1 was estimated using publically-available digital elevation model information. As the population of the District of Lake Country continues to increase, and more development is likely to be proposed, high resolution elevation information (e.g. LiDAR) should be obtained for the area adjacent to the lakes within the RDCO and Regional District of North Okanagan. Publically available digital elevation information is only considered sufficient at the overview screening level; therefore, high resolution information is necessary to confirm whether any areas present or in the future could be cut-off from emergency support during a design flood event.

***Major Floodplains and Alluvial Fans within RDCO***

- No floodplain mapping or floodplain/alluvial fan delineation has been completed for watercourses within the RDCO with the exception of the lower reaches of Mission and Kelowna (Mill) Creeks. The approximate location and extent of floodplains/alluvial fans have been estimated for the major watersheds at a screening level in this report using GIS tools, but the spatial extent cannot be confirmed or estimated for the design flood event return period(s) without further investigations including field work.
- As such, it is recommended that the High PFRR floodplains/alluvial fans within urban or residential developments (e.g. Lake Country [Vernon Creek], West Kelowna [Powers and McDougall Creeks], Peachland [Peachland and Trepanier Creeks], Kettle Valley [Bellevue Creek]) be confirmed. These floodplains/alluvial fans are the ones listed with a High PFRR in Table 4-2. The floodplain/alluvial fan confirmation will need to consider a design flood event (e.g. 1:200-year return period), but will help to confirm whether or not existing bylaws and emergency planning is sufficient to address the flood risk.

***Flood-prone watercourses/reaches within the RDCO***

- Numerous flood-prone watercourses/reaches were identified within the RDCO (Section 4.2.1; Maps 1 and 2 [Appendix E]) based primarily on GIS analyses. Field confirmation of the reaches given a High or Moderate PFRR is recommended to guide Phases 2 and 3. Where urban or residential developments are present adjacent to the flood-prone watercourse/reach, the field assessment should also determine whether or not existing bylaws and emergency planning is sufficient to address the flood risk at these locations.

***Trepanier and Bellevue Creek Dike Maintenance Assessments***

- Diking is present for a small area along the lower reaches of Trepanier Creek, while levees are located along Bellevue Creek. The parties responsible for the maintenance of the Trepanier and Bellevue Creek dikes/levees should be confirmed and hydraulic capacity assessments should also be completed to confirm the dike/levees are able to contain the design flood. However, at a minimum, confirmation should be obtained that dike/levee maintenance assessments are being completed within the necessary timeframes that meet requirements outlined by the *Dike Maintenance Act*.

***Dam Failure Inundation Mapping***

- 129 dams were identified within and upstream of the RDCO boundary (Section 3.5). The majority of dams have been classified as low, significant, or high consequence; however, three dams have been rated as very high and extreme. Due to the potential impact to downstream areas, dam inundation studies should be completed beginning with the dams rated very high and extreme. These dams include:
    i. Crooked Lake – located within the Upper Vernon Creek watershed.
    ii. Ideal (Belgo) Lake – located within the Belgo Creek watershed that drains into Mission Creek at Joe Rich.
    iii. Rose Valley Reservoir – located within the City of West Kelowna. A constructed emergency spillway is present for a short distance downstream of the dam on Faulkner Creek, but after Mar Jok Elementary School (approximately 2 km downstream), no other spillways have been constructed.

# 5 Mechanisms for Land Use Management on Floodplains

## 5.1 EXISTING POLICIES, GUIDELINES, AND BYLAWS

The RDCO has by way of bylaw addressed some of the components of floodplain management, including climate change considerations. The existing planning mechanisms serve as the starting point for future RDCO floodplain management. Zoning Bylaw No. 871 (RDCO 2014) specifies the following flood construction levels[16] for properties used for dwelling purposes, business, or storage of goods, which are susceptible to damage by floodwater:

- 343.66 m Geodetic Survey of Canada datum for land adjacent to Okanagan Lake
- 3.0 m above the natural boundary of Mission Creek
- 1.5 m above the natural boundary of *any other watercourse* (emphasis added).

In addition, floodplain setbacks[17] are specified as follows (RDCO 2014):

- 15.0 m from the natural boundary of Okanagan Lake
- 7.5 m from the natural boundary of a lake, swamp or pond
- 30.0 m from the natural boundary of Mission Creek
- 15.0 m from the natural boundary of *any other nearby watercourse* (emphasis added)
- 7.5 m from the natural boundary of any standard dyke right-of-way, or structure for flood protection or seepage control.

With the exception of Mission Creek and Okanagan Lake, Zoning Bylaw No. 871 uses catch-all definitions for other watercourses. Joe Rich Rural Land Use Bylaw No. 1195 also specifies the above flood construction levels and floodplain setbacks, with the exception of those specific to Okanagan Lake.

When complete, the RFMP can include specific requirements for other higher risk watercourses and waterbodies. Table 5-1 summarizes the key existing bylaws, plans and policies of RDCO member communities. In general, the planning mechanisms that have been implemented are consistent with the approaches used by other local and regional governments that have also worked to address floodplain management (see Section 5-2 below).

[16] **Flood construction level** is defined as 'a designated flood level plus freeboard, or where a designated flood level cannot be determined, a specified height above a natural boundary, natural ground elevation, or any obstruction that could cause flooding' (RDCO 2014).

[17] **Floodplain setback** is defined as 'the required minimum distance from the natural boundary of a watercourse, lake, or other body of water to any landfill or structural support required to elevate a floor system or pad above the flood construction level, so as to maintain a floodway and allow for potential land erosion' (RDCO 2014).

**Table 5-1**
**Key planning policies of RDCO member communities**

| Member Communities within the RDCO | Floodplain-Focused Planning Policies |
|---|---|
| City of Kelowna | Selective floodplain management areas such as for Mill Creek (i.e. Bylaw No. 10248) (City of Kelowna 2011) |
| City of West Kelowna | Floodplain management approach included within City of West Kelowna Bylaw 154 identifies the adoption of RDCO's Zoning Bylaw No. 871 (City of West Kelowna 2011) |
| District of Peachland | Floodplain construction requirements – Floodplain regulations (i.e. No. Bylaw 2100) (District of Peachland 2014) |
| District of Lake Country | Floodplain construction requirements included within Zoning Bylaw No. 561 (District of Lake Country 2016) |
| Westbank First Nation | Land Use Bylaw No. 2007-01 – Development on floodplains (Westbank First Nation 2007) |

Westbank First Nation Land Use Bylaw No. 2007-01 recommends that in order to minimize the hazard of floodplains on development, low impact development (such as green space and recreation uses and development) shall be located in these areas in order to regulate any development within the floodplains (Westbank First Nation 2007).

## 5.2 FLOOD HAZARD AREAS NOT CURRENTLY ADDRESSED BY BYLAWS

Within RDCO and the member municipalities, only Mission Creek, Mill Creek, and Okanagan Lake have specific flood protection requirements. From Table 4-3, other watercourses with moderate or high PFRRs that lack stream-specific flood elevations or set-backs are Bellevue Creek, Peachland Creek, Trepanier Creek, Powers Creek, McDougall Creek, Lambly Creek, Shorts Creek, and Vernon Creek. The results of Phase 2 would determine whether stream-specific regulation is beneficial to help reduce risk. Possible tools in addition to regulation by bylaw are outlined in Section 6-3.

## 5.3 SUMMARY OF PLANNING APPROACHES FOR FLOODPLAIN MANAGEMENT

Floodplain management approaches in British Columbia can be generally placed into two categories: structural approaches such as dikes and diversions, and non-structural approaches; with the non-structural measures being realized primarily at the local government level (Arlington Group and EBA 2010). Public Safety Canada (2016) defines non-structural measures as "non-physical measures that incorporate the measurement and assessment of the risk environment and contribute to comprehensive, proactive risk reduction investments, e.g.

- floodplain mapping;

- risk assessments;
- insurance incentives;
- public awareness programs;
- regulating land use (building codes, bylaws, and enforcement);
- acquiring property on the floodplain and relocating structures; and
- reusable equipment used to undertake flood mitigation".

The "regulating land use" approach to flood mitigation can be expanded to include planning initiatives that enable the restoration of the ecological function of floodplains and riparian areas. Well-designed restoration programs can improve water storage and make the floodplain more resilient (e.g. mature riparian trees reduce the velocity of flood waters and contribute to bank strength).

According to Public Safety Canada, floods are the country's most costly natural disasters in terms of property damage (Government of Canada 2015). Local and regional governments play an essential role in safe-guarding Canadians (including homes and property) from the impacts of flooding especially floodplains located within our urban areas.

To that end, the approval of developments within designated flood plain areas rests with local governments, as defined in British Columbia under Section 910 of the *Local Government Act*. Through the legislative framework of the Local Government Act, local and regional governments have access to a number of regulatory tools to proactively address the safe-guarding of Canadians from floodplain impacts including:

- Planning policies;
- Zoning bylaws;
- Development bylaws and permits;
- Subdivision requirements;
- Engineering standards;
- Flood proofing; and
- Permits and inspections.

For example, a floodplain development bylaw is able to address a variety of factors as follows:

- Establish flood construction levels (FCLs) for new development and redevelopment areas.
- Establish land-filling controls for rights-of-way and private parcels.
- Consider flood protection enforcement (i.e., unauthorized fills).
- Consider whether minimum building elevations would be applied consistently for all development types including residential, commercial, industrial, and institutional.
- Assess risk (public safety, financial, liability, public acceptance).
- Confirm impact on disaster flood assistance coverage.
- Allow process for variances.

Floodplain management typically involves the adoption of land use regulations for identified floodplains. Land use regulations are based on the premise that the specified hazard area will continue to be flooded on occasion. The intention of land regulation is to restrict or direct the use of the land to activities and structures amenable to such occurrences. This non-structural approach is accomplished by reserving or

zoning the lands for such purposes and is the least costly method of flood damage reduction if implemented prior to major development of the floodplain. Land acquisition in the floodplain is another method of controlling land use. It has an advantage over legislative restrictions in that the agency involved has direct control over development within the area. Table 5-2 provides a summary of local government floodplain management approaches that are employed in Canada, including examples of Canadian municipalities that use each of the main approaches.

**Table 5-2**
**Local government floodplain management approaches used in Canada**

| Selected Floodplain Focused Policy Directions and Actions | | | |
|---|---|---|---|
| **Policy Goals** | **Policy Directions** | **Policy Actions** | **Source** |
| Avoid floodplain impacts | To minimize the impacts of damage as a result of floodplain inundation | Establish Natural Hazard Area | City of Nanaimo (2008)<br>City of West Kelowna (2011) |
| | | Comprehensive Development Area Plans | City of West Kelowna (2011) |
| Limit development in floodplains | To minimize the impacts of damage as a result of flooding | Floodplain regulation:<br>i) Toronto - not permitting new development within the floodplain except within Special Policy Areas (SPAs)<br>ii) Calgary - not permitting new development within floodways (some exceptions) | City of Toronto (2014)<br>City of Calgary (2007) |
| Limit development in floodplains and minimize floodplain inundation impacts | To minimize the impacts of damage as a result of flooding | Floodplain regulation such as Designated Flood Plain Standards and Requirements (i.e. increased setbacks and requirements for elevating the ground floor of buildings (FCL) | City of Vancouver (2014a; 2014b)<br>City of North Vancouver (2015)<br>District of West Vancouver (Undated)<br>District of Squamish (2014)<br>RDCO (2014 – see Section 5.1) |

| Selected Floodplain Focused Policy Directions and Actions | | | |
|---|---|---|---|
| **Policy Goals** | **Policy Directions** | **Policy Actions** | **Source** |
| Minimize floodplain inundation impacts | To minimize the impacts of damage as a result of floodplain inundation | Floodplain Management Bylaw - no areas are exempt from flood-proofing requirements in the floodplain; increased flood-proofing requirements for residential development | City of Chilliwack (2007) |
| Limit potential local government liability in floodplains | | Flood Plain Section 219 Covenant and Priority Agreement registered under the *Land Title Act* | City of Prince George (2014); City of Port Coquitlam (Undated); City of Grand Forks (2004) and numerous others |
| Limit potential negative impacts to the floodplain | | Floodplain Guideline (3.4.1) | City of Langford (2008) |

## 5.4 OPTIONS FOR EMERGENCY RESPONSE PROGRAM UPDATE

The Emergency Response measures in the RDCO Emergency Plan – Flood Plan (Flood Plan) require the leadership of the Emergency Operations Centre (EOC). The EOC processes are well documented, and tested. Once the EOC process is enacted, municipal staff and stakeholders become resources on the ground.

The planning framework proposed in the subsequent phases of the RFMP will provide additional information, data and processes that help reduce risks and increase public safety during a flood emergency. Much of this information can be processed and maintained as preparation materials for use during the response phase.

Options for enhancing the emergency response program can be linked to providing timely and accurate information for use during an emergency event. We look at other response processes and examples of events that relate to these issues.

### 5.4.1 Dam Breach Emergency/Response Plans

A Dam Safety Emergency Response Plan is a similar related activity to flood management plans, but specifically address information and activities related to a dam breach event. Dam Safety Emergency Response Plans are typically enabled when there is a risk of breach, imminent breach or an actual breach event. The impacts of dam breaches can be loss of life, destruction of property, impacts to critical infrastructure and long term environmental impacts.

The new B.C. Dam Safety Regulation sets requirements and best practices for all aspects of dam design, construction, operation, maintenance, removal and decommissioning of dams. The regulation came into effect in February 2016. Section 9 of the Dam Safety Regulation states that emergency plans are required for all dams with Hazard Classifications of Significant, High, Very High and Extreme. These plans must include:

- A record describing the actions to be taken by the owner if there is an emergency at the dam.
- A record containing information for the use of the local emergency authorities for the dam for the purpose of preparing local emergency plans under the *Emergency Program Act*.

From a flood management plan perspective, a dam breach is a singular and very low probability event. Dams and their associated works are designed to withstand extreme precipitation and flooding events (1;10,000-year return periods or greater). Dam breaches can also be categorized in terms of sunny day failures, such as a structural failure due to seepage, poor maintenance (e.g. tree roots, animal burrowing), acts of terrorism, or failure of pipeline or outlet. Dam Safety Emergency Response Plans are legislated items, and dam owners are required to update the plans regularly. Dam owners are expected to file dam emergency plans with the RDCO, which become part of the RDCO EOC.

Dam Safety Emergency Response Plans are useful sources of information that can supplement information within the flood management planning framework. These plans also provide the contact information of those downstream, as well as clear actions of the first responder. Most plans include information packages with clear instructions on communications protocols, levels of responsibility and evacuation routes.

### 5.4.2 Example #1 - The City of Calgary and the 2013 Flood

In aftermath and analysis of the 2013 flood of the Bow River in Calgary, the Conference Board of Canada (Vroegop 2015) identified a number of lessons learned and recommendations for future flood emergency management which are relevant to the RDCO Flood Plan. The key recommendations are that:

- Proper record of activities and costs should be tracked, along with recovery metrics and performance indicators
- Community leaders and external stakeholders should be included and connected directly to the EOC chair
- Skills inventories are in place for staff, and that they have enhanced training in place for situational awareness of vulnerable populations.

The Conference Board's Calgary Flood study concluded that starting recovery right away and matching its intensity to response efforts proved invaluable. Recommended actions included:

- Consider training for municipal employees whose recovery-related roles take them beyond their regular duties and place them in highly stressful environments.
- Strengthen knowledge management practices to help build depth in essential recovery skills and positions.
- Assigning a human resources advisor to recovery with specific roles and responsibilities to support staff when joining or transitioning out of recovery work.
- Monitor internal and external business continuity planning to ensure staff are able to provide services to the public.
- Increase pre-event situational awareness for those citizens who lack the ability to request assistance through regular channels.

### 5.4.3 Example #2 - Windstorm of August 29, 2015 in Vancouver, BC

Following a large windstorm in the Lower Mainland of B.C. on August 29, 2015, the City of Richmond responded by developing recommended preparations for future responses to emergencies (City of Richmond 2015). Included in a long list of recommended actions are the following items that are applicable for flood emergency response within the RDCO.

1. Business cases should be developed for additional portable generators in capital budget submissions.
2. Power redundancy should be required for critical infrastructure. This may include transfer switches, permanent standby generators, photovoltaic cells, wind generated power, etc.
3. Consideration should be given for storage of generator fuel. Issues include difficulties of monitoring fuel levels, fuelling during extended hours and managing shortages.
4. BC Hydro had issues with call-taking capacity, their website, and response to downed wires.
5. Maintain staff training and support to foster team development and the building of capacity for critical timely decision-making.

# 6 Recommendations

## 6.1 EMERGENCY RESPONSE

As described earlier, the most recent Flood Plan of the RDCO Regional Emergency Plan was developed in 2013. Although an update may be of value to incorporate the findings in this RFMP Phase 1 report, flood emergency response should continue to focus on the principles of the 2013 Emergency Flood Plan. The Flood Plan is well conceived, and encompasses all aspects of emergency planning and preparation.

The RDCO can improve the Flood Plan response process by developing detailed information packages for different areas during the planning stage, and adjusting local processes that improve emergency operations. The following suggestions are consistent with the recommendations from the recent case studies from the Cities of Calgary and Richmond noted in Section 5.5:

1. Compile and update key details and lists for each individual watershed as required; with a reminder that not all EOC trained personnel or those responsible may be available at critical moments. Single pre-constructed data sheets with tested procedures and contact requirements in sequence should be maintained.
2. The RDCO GIS and expert systems should all be coordinated with the most accurate topographical data and river forecasting information to provide the following information for immediate access:
    - Estimated flood limits for 1:10-year, 1:200-year return periods and more extreme events.
    - Up-to-date inventories of all infrastructure, buildings, houses.
    - An updated roll of all properties, including addresses, phone numbers.
    - A map pointing out areas of concern, particularly culvert crossings and bridges at risk of washout.
3. Floodplain hazard and risk maps can be used to identify and support residents and infrastructure already situated within flood-prone areas. Mapping historically impacted areas will formalized what is currently known and allow for more efficient and effective emergency response during flood events.
4. All staff should be trained on the whereabouts of first responder information sheets, and should understand the responsibilities as the first responder.
5. RDCO Operations procedures should be regularly tested to improve emergency flood response.
6. Conceive plan for situations where road washouts, lack of communication, fuel shortages or where power shortages may impact users.
7. Plan for emergency management of wildlife and farm animals.
8. Confirm locations of suitable construction materials, machinery suppliers and emergency supplies.
9. Maintain an Emergency Response File with compiled information for a first responder.
10. Train key staff on the importance and responsibilities of the first contact and first responder during an emergency.

In addition to the recommendations listed above, the current Flood Plan applies to all flood-prone areas within the RDCO, but does not have special measures or responses for individual streams or sections of

lakefront. With respect to the Flood Plan as part of the RDCO Regional Emergency Plan, there are areas where further detail is required to help mitigate emergencies when they happen by having the appropriate and best information available. Priority updating to the Flood Plan is suggested based on the following:

- Dam breach issues – dam breaches are not typical floods, and should be considered as a major emergency event. They usually occur without warning, but emergency planning for each is generally similar. It is recommended that the following be included within the Flood Plan:
    - Under the new B.C. Dam Safety Regulation dam consequence classifications have been updated. As a result, the table included within Appendix C of the Flood Plan will need to be modified to accommodate the dams with significant, high, very high and extreme classifications (Appendix C). We note that each dam owner with ratings of significant or higher should have a dam emergency response plan of their own and these plans should be obtained and kept on file at the EOC, as well as referenced within the Flood Plan as to whether or not an emergency response plan is available.
    - Dams rated with a Low hazard consequence do not require a plan. The RDCO has a list of the locations of these facilities (Appendix C).
    - During major precipitation events, flood response should always consider dams upstream, and ensure that the owners have spillways clear of debris.
- Floodplain mapping/dam breach mapping should be considered, at least, for each creek with a very high or extreme hazard consequence dam. In most instances, these should already be available in some form.
- Dikes are continuously being updated and maintained. Therefore, a copy of the maintenance records should be kept on file by the RDCO and the Flood Plan should reference the location for individuals to review the records.
- Appendix C of the Flood Plan should be updated to include all floodplain mapping, flood infrastructure, and areas of flood concern. The appendix should also include where the supporting information can be viewed or obtained.

The final recommendation for the Flood Plan is to develop a flood event, mechanism, damage, and mitigation database. Through Phase 1 of the RFMP, literature was reviewed to identify flood events within the RDCO. However, through this review, previous reporting of specific flood mechanisms, associated damage, and any mitigative works, has been inconsistent. Therefore, to capture flood hazards within the RDCO, a database should be developed to capture all reported historical and future flood events and associated spatial extents of flooding, damage, mitigative works, and emergency response challenges (if any). This database will help identify or confirm watercourses consistently under flood and/or areas at risk and will help ensure that emergency planning is aware of the flood risk. The responsibility for the development and maintenance of this database should be placed with the RDCO to determine, but it is suggested that the maintenance of the database should be completed by the group that currently collects and summarizes the flood emergency response information (i.e. Kelowna Fire Department).

The ultimate goal of the Flood Plan is to assure that the EOC has the detailed information it requires to efficiently and quickly manage the responses for local needs. Any delays due to inaccuracy, missing information or poor contact information can increase the risk to public safety.

## 6.2 PHASE 2 – HAZARD AND RISK ASSESSMENT

Due to the preliminary nature of the PFRR assessment, the scope of Phase 2 should be focused on the delineation and confirmation of the floodplains and flood-prone streams identified in Phase 1. This will help to ensure that all watercourses are considered from a local government bylaw standpoint, as well as within the Flood Plan.

Understanding that bylaws are currently in place to protect people and infrastructure from flood impacts (Section 5.1), the spatial extent of flooding under natural or dam breach conditions is still unknown for a lot of watercourses within the RDCO. As the population increases in the RDCO and development continues to encroach on waterfront areas and adjacent to watercourses, the need for floodplain mapping is becoming more important.

Section 4.5 identifies the priority streams, waterfront areas, and flood infrastructure within the RDCO recommended for further assessment. The studies considered to have the highest priority for Phase 2 are as follows (see Section 4.5 for a summary of the recommended scope of work):

- Okanagan Lake flood level mapping for the entire RDCO;
- Wood and Kalamalka Lakes flood level mapping;
- Delineation and confirmation of floodplains and alluvial fans for the Very High and High PFRR watercourses (Table 4-2) within RDCO;
- Confirmation of flood-prone watercourses/reaches within the RDCO through reconnaissance-level field assessments, focussing on the higher-risk reaches; and
- Dam failure inundation mapping.

In order to complete a flood risk assessment to modern standards, floodplains need to be delineated. Floodplain locations were identified and mapped at a screening level during Phase 1, but to accurately assign a flood hazard and risk to a watercourse or land use area, the spatial extent of flood waters under varying design criteria is required. The general steps in completing a flood risk assessment are outlined within Section 4.2, but to properly delineate a floodplain, a combination of hydraulic modeling and surveying is required. This is recommended for Okanagan Lake and the major watercourses and floodplains/alluvial fans included within Table 4-2 with critical infrastructure or urban developments within the lower reaches.

It is important to note that Canadian national floodplain mapping guidelines are currently in development by Natural Resources Canada and Public Safety Canada. Since water management is a provincial government responsibility, the guidelines allow flexibility amongst the provinces. Additional information is expected from the federal government soon.

Once a floodplain(s) has been delineated and/or confirmed, the corresponding consequence ratings should be updated. Most of the consequence category information collected in Phase 1 can be used; however, the following information sources are required to improve the Phase 2 risk assessment:

- Mapping of environmental elements-at-risk.
    - To identify relative value of stream habitat that is vulnerable to flood damage, it is recommended that a systematic approach to mapping of sensitive fish and riparian habitat across RDCO be completed. The current mapping of aquatic habitats with environmental concerns is not consistent throughout the RDCO. Sensitive habitat inventory mapping (SHIM) has been completed on some watercourses and knowledge of the presence/absence of fish is available for most watercourses, but detailed fish habitat and riparian area mapping for all watercourses has not been completed. If the RDCO would like to consider sensitive fish habitat as elements-at-risk, overview-level riparian and aquatic habitat mapping should be completed for all watercourses to allow assignment of relative habitat ratings (e.g. low, moderate, high) in reaches that are most vulnerable to flooding, and to summarize the results within a Geographic Information System (GIS) spatial dataset.

      This would start as desktop study combining compilation and review of existing studies and maps with aerial photography interpretation (e.g. to characterize the presence or absence of fish barriers and riparian buffers in flood-prone reaches), and would require a field component completed for those priority streams not yet assessed. Specifically it is recommended that the RDCO:
        - Identify areas of known salmonid spawning (lakeshore or stream).
        - For streams of concern, identify the first limiting salmonid fish barrier upstream of the mouth.
        - Qualify and quantify salmonid habitat from the mouth to the first barrier.
        - Quantify riparian function along identified salmonid reaches.

      In addition to helping to characterize important salmonid habitat at risks from flooding, it would provide better information on riparian function, which will also inform the assessment of stream resilience to flooding.

- Mapping of building footprints per land use type.
    - The estimation of economic losses due to flooding is a large part of a flood hazard assessment. To support the estimated loss, an understanding of the cost of land and corresponding structures within different land use zoning is required. Specifically, a spatial dataset of building footprints is needed to quantify the costs at the parcel or zone scale. This building footprint dataset could then be combined with cadastral information in the future to support a flood hazard assessment within any watercourse. Note that buildings footprints built to RDCO floodplain regulation standards could also be considered within the spatial dataset. B.C. Assessment may have some of this information already available, which the RDCO may be able to obtain through a data-sharing agreement.

## 6.3 PLANNING FOR PHASE 3 – DEVELOPMENT OF MITIGATION STRATEGIES

The primary goal of Phase 3, which would be initiated after completion of Phase 2, is to further develop and expand upon the risk mitigation strategies that are already in place for the region. Phase 2 will enable this by providing more quantitative assessments of hazard (which includes both the magnitude of hazardous flood events and the probability of their occurrence), consequence, and risk in high priority areas. Mitigation strategies that can be further advanced when the Phase 2 results are available include the following, adapted from the categories identified in the project terms of reference (Clarke Geoscience 2014).

1. Avoidance
    a. Development of stream-specific bylaws comparable to Kelowna's Mill Creek Bylaw No. 10248
    b. Watershed-specific Development Permit Areas. These may be suitable for flood fringe areas or other areas where a flood bylaw is too restrictive for the land uses that could occur
    c. Policy and procedures for allowing exceptions to flood bylaws or DPAs
    d. Re-zoning
    e. Incorporation of flood risk management mechanisms into the higher-level plans developed by RDCO and the member municipalities (e.g. planned update to the City of Kelowna's Agricultural Plan)
2. Physical and Biophysical Improvements
    a. Flood protection structures (new, upgrades, or movement to "make room for the river" where appropriate)
    b. Diversions or flood by-passes
    c. Riparian planting (to strengthen stream banks and reduce flood velocities. Note: This would be mostly suitable for smaller streams and/or to augment other structural and non-structural measures)
    d. Floodplain land acquisition
3. Warning systems, education, and public awareness
    a. Updates to regional and watershed-specific emergency plans
    b. Updates to public awareness and education programs, including programs targeted to specific sectors such as land development and agriculture
4. Monitoring, Inspection and Periodic Review of Plans and Policies
    a. Periodic review and update of the RFMP, including consideration or new climate change projections or evidence from flood events subsequent to preparation of the Phase 1 RFMP
    b. Periodic review and update of the Regional Emergency Plan
    c. Scheduled inspections of flood protection structures
    d. Expansion of the weather, hydrometric, and snow monitoring networks.
    e. Procedures for photographic and other documentation of flood events to help calibrate models.

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# Appendix A – Terms of Reference

# Terms of Reference for a Regional Floodplain Management Framework for the Regional District of Central Okanagan

December 16, 2014

clarke geoscience ltd.

RDCO
REGIONAL DISTRICT of CENTRAL OKANAGAN

## Table of Contents

## 1.0 Introduction

Clarke Geoscience Ltd. was retained by the Regional District of the Central Okanagan (RDCO) to prepare Terms of Reference for a Regional Floodplain Management Framework.

Under the 2014-2015 Water Conservation and Quality Improvement (WCQI) Grant Program administered by the Okanagan Basin Water Board, RDCO was awarded partial funding for the project. The overall objective is to better understand the flood risk within the Central Okanagan region such that the likelihood of flood damage is reduced.

The Regional Floodplain Management Framework will consist of three phases:

Phase 1 – Regional Floodplain Management Plan
Phase 2 – Flood Hazard and Risk Assessment Studies for Priority Areas
Phase 3 – Flood Risk Mitigation Strategies for Priority Areas

The following Terms of Reference will primarily focus on Phase 1, but will include scoping and framework for subsequent phases.

## 2.0 Scope of Work

The scope of work for this project is to prepare Terms of Reference for the Regional Floodplain Management Framework. Preliminary scope was provided in the WCQI Grant Application. However, additional scoping detail has been provided by RDCO as the work has progressed.

The scope of work included the following tasks:

Task 1 – Conduct interviews with RDCO staff to clarify the project scope, desired outcomes, and requirements.

Task 2 - Review existing policies and in-house mapping of RDCO floodplain mapping and review available digital floodplain and watercourse information available from Data BC and RDCO.

Task 3 – Conduct interviews with other local governments within the RDCO to find out current approaches to floodplain hazard identification, mapping and management.

Task 4 – Research floodplain hazard management strategies from other areas of Canada and British Columbia.

Task 5 – Develop a checklist of required tasks for the various phases of the project.

Task 6 - Research and provide a list of possible funding sources for future phases of the project.

## 3.0 Project Rationale and Desired Outcomes

A meeting with RDCO staff and OBWB director Anna Warwick Sears was held on June 26, 2014 to discuss study objectives and outcomes. Results of the discussion helped guide the study direction and are incorporated within the report.

### 3.1 Rationale for the Project

Within their jurisdiction, the RDCO is challenged with addressing flood hazards to existing development, and addressing potential hazards to proposed development on previously undeveloped lands. Currently, existing structures in flood-prone lands remain at risk until redevelopment triggers a development application through the RDCO. In the absence of floodplain maps, guidelines for land use management are incorporated into bylaws. However, the approaches are inconsistent and potentially overlook the broad, regional perspective.

There remains, too, a general lack of understanding within the general public that floodplain issues are dealt with at a local government level.

The rationale for the floodplain management framework includes:

- the project will provide RDCO a framework for development-related decision making on flood-prone lands;
- the project will enable effective and efficient emergency response planning;
- the project will help identify any infrastructure planning priorities;
- the project will provide further understanding of how predicted changes in climate may affect flood risk and will help identify areas most vulnerable to flood;
- the regional framework allows for a coordinated and consistent approach that is more easily communicated to the general public;
- the need to address hazard management with a regional, coordinating role in efforts aimed at adaptation and mitigation, emergency planning, risk assessment, drought management and other related efforts (including rockfalls, floods, fires, pine beetle, etc.) is identified as a priority within the RDCO Strategic Plan (Vision 2020 – Planning for the Future);

- the project is consistent with the RDCO Regional Growth Strategy (Bylaw 1336; 2013) directive to work with local governments and provincial agencies to assess and mitigate risks in floodplains; and,

- future phases of the regional Floodplain Management Plan will identify and prioritize flood risk mitigation strategies, including identifying and securing funding sources to protect the region.

## 3.2 Desired Outcomes

RDCO is leading efforts to develop a regional approach in the Okanagan but will focus on applying the Framework to lands within its own jurisdiction. All member municipalities, however, have related interests associated with floodplain management and a desired outcome of the project is that the regional Floodplain Management Framework will provide a coordinated and consistent approach to flood protection throughout the Central Okanagan.

RDCO has identified several specific outcomes of the Regional Floodplain Management Framework. These include:

1. Reduce flood risk. Floodplain mapping will strengthen the ability of local governments to address long-term planning practices and asset management. Floodplain hazard and risk maps may be used to restrict development in potentially hazardous locations. The mapping may be used to develop proactive policies regarding new development, or changes to existing development.

   The hazard identification process will help us understand flood hazards and through identification of upstream dams and reservoirs, for example, will help to identify potential flood hazards to downstream areas.

2. Improve emergency flood response. Floodplain hazard and risk maps can be used to identify and support those already situated within flood-prone areas. Mapping historically impacted areas will formalize what is currently known and allow for more efficient and effective emergency response during flood events. Mapping also provides a means for proactive (as opposed to reactive) strategies to mitigate risks that are focused on priority areas.

3. Increase the Resilience to Climate Change. Floodplain maps increase resiliency to changing flood risk by increasing the ability to anticipate, absorb, accommodate and recover from flood events. Hydrologic analysis will include climate change scenarios and this information may be used for asset management and infrastructure planning.

## 4.0 Existing Mapping and Floodplain Management Policies at RDCO

### 4.1 Background on Local Government Floodplain Responsibilities

Local governments are responsible for flood hazard management within their own jurisdictions. Responsibility for flood hazard management shifted to local governments in 2003, when the *Flood Hazard Statutes Amendment Act* was enacted. Prior to this, flood hazard management was the responsibility of the Province of British Columbia.

Provincial guidelines for managing land use in flood-prone areas were produced in 2004 as the *Flood Hazard Area Land Use Management Guidelines* (MWLAP).

The Province mandates that local governments must incorporate floodplain map information, where these maps exist. When mapping is available, the 200-year floodplain is delineated and the Flood Construction Level is defined. This information may be incorporated into bylaws and land use planning decisions.

Where floodplain mapping does not exist, the *Flood Hazard Area Land Use Management Guidelines* provide recommended horizontal and vertical setbacks from watercourses, lakes, and other water bodies. These Guidelines form the basis for current RDCO floodplain management policies and regulations within OCPs/RLUB and Zoning Bylaw.

### 4.2 Provincial Floodplain Mapping in RDCO

Floodplain mapping was completed by the Province of British Columbia in 1984, Water Management Branch, for Lower Mission Creek and by the City of Kelowna for Mill Creek in 2010. Mapped areas, the extent of which is shown on the enclosed map (Figure 1), all lie within the City of Kelowna.

Floodplain mapping for Lower Mission Creek was completed within the limits of the City of Kelowna. The mapping does not extend floodplain limits across the fan beyond the protective dikes (excerpt shown in Figure 2).

A recent hydraulic capacity study on Lower Mission Creek determined the 200-year flood profile and evaluated the adequacy of dike crest elevations along the existing system (Tetra Tech EBA, 2014). The report identified several critical dike sections with inadequate freeboard between KLO Road and Lakeshore Road. Maintenance of the dikes is the responsibility of the Province of British Columbia; one of the few dikes that remain within the provincial realm of responsibility.

Mill Creek, and the Mill Creek Diversion, forms part of the flood management infrastructure for the City of Kelowna. Flood hazard analysis was completed for Mill Creek by Associated Engineering for the City of Kelowna in 2010 and the results of

the study led to the identification of Flood Construction Levels (FCLs) along the creek and development of the Mill Creek Floodplain Bylaw No. 10248; 2011.

Flood mitigation dikes also exist along Bellevue Creek. These dikes, constructed in 1981, form part of the flood management infrastructure within the City of Kelowna and the Regional District of Central Okanagan.

## 4.3 RDCO Mechanisms to Restrict Land Use in Flood-Prone Areas

Current mechanisms to restrict land use in flood prone areas are contained within the RDCO zoning bylaw and Official Community Plans (OCPs) Rural Land Use Bylaw (RLUB). In the absence of floodplain mapping, RDCO relies upon the *Flood Hazard Area Land Use Management Guidelines*.

Flood hazard studies are requested when a variance to the setback requirements of the zoning bylaw is proposed. For variance applications, the District requires a report by a qualified professional that certifies that "the land may be used safely for the intended purposes" and/or to identify possible remedial works.

### 4.3.1 Zoning Bylaw and OCP/RLUB Bylaws

The RDCO Zoning Bylaw No. 871 (2000) specifically references flood hazard and provides Floodplain Regulations (section 3.28) for managing land use.

Flood hazard area land use planning policies are also referenced in the following RDCO OCPs/RLUB:

- Brent Road – Trepanier OCP Bylaw No. 1303, 2012
- South Slopes OCP Bylaw No. 1304, 2012
- Ellison OCP Bylaw No. 1124, 2006 (rev. 2014)
- Rural Westside OCP Bylaw No. 1274, 2010 (rev. 2014)
- Joe Rich Rural Land Use Bylaw No. 1195, 2007 (rev. 2014)

In each bylaw document, although the precise wording varies, the policies are the same with respect to how flood hazard is approached. For each OCP the policy objective is to:

> "Discourage development that may be damaged by flooding from being located on land that might be flooded as identified by the setbacks and elevation provisions recommended by the Water Management officials of the Province of BC and outlined in Zoning Bylaw No. 871, s. 3.28 Floodplain Regulations."

The Floodplain Regulations of the Zoning Bylaw indicate a horizontal setback of 15 meters (30 m for Mission Creek) and flood construction levels 1.5 meters

above the natural boundary of a watercourse (3.0 m for Mission Creek; and 343.66 m GSC datum for Okanagan Lake).

Where construction is proposed on existing parcels that are adjacent to watercourses, buildings should meet those construction and location requirements. Development of property should be consistent with the provincial "Flood Hazard Land Use Management Guidelines".

### 4.3.2 Emergency Response and Disaster Financial Assistance

For existing properties that are at risk of flooding, RDCO is able to respond to a flood event within the constraints of the Provincial Emergency Program (PEP) of Emergency Management BC. While PEP provides disaster response assistance at the time of flooding, the program does not allow for protective measures.

A Regional Emergency Flood Plan for RDCO outlines emergency operations during flood events (RDCO, 2013). Flood responders use triggers (such as >25 mm of rain in 24 hours) to initiate monitoring of priority areas known to be flood-affected[1]. Flood responders working within the Regional Emergency Program would benefit from having a formalized and documented flood hazard map. The mapping may be used to focus resources in advance of an emergency and will provide rationale for mitigation works. In addition, flood hazard mapping would identify flood-prone areas that are vulnerable to hydrologic changes (i.e. due to fire) or dam/dike breach that were not historically affected by flood.

The Compensation and Disaster Financial Assistance Regulation (BC Reg. 124/95) under the Emergency Program Act indicates that financial assistance is not available for the repair, rebuild or replacement of structures located within a designated[2] floodplain if it is damaged in a flood.

Existing structures that predate floodplain designation would be eligible for assistance provided construction has followed local bylaws and there are no covenants on the property title restricting development.

The regulation also indicates that claimants are expected to take action to protect property before, during or after the flood event. Flood hazard mapping would help identify areas at risk such that protective measures may be pursued.

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[1] Jason Brolund, Deputy Fire Chief, City of Kelowna

[2] Floodplain designation is defined under the *Local Government Act* and may be derived from a floodplain map, local government bylaws, or by covenant.

## 5.0 Floodplain Management Policies in Other Jurisdictions

### 5.1 National Floodplain Management Framework

The National Floodplain Management Framework was recently developed by Public Safety Canada (2014) as an initial step to reduce and mitigate flood risk across Canada. The document identifies the type and extent of information required, the key technical standards and guidelines that are applicable, the anticipated costs, and a list of future initiatives.

The National Framework suggests that results of a risk assessment may be used to establish priorities for updating mapping. If floodplain mapping already exists then the risk priority would be based on the potential for inundation and density of development (urban vs. rural).

Where floodplain mapping does not exist, as is the case for most of RDCO, then according to the Framework, floodplain mapping should be completed for small to moderate sized watercourses in urban areas[3], with priority based on:

1. The size of the upstream catchment areas (where size increases risk);
2. The known history of flooding (where a known flood history increases risk);
3. The density of development (where higher density increases risk); and,
4. The presence of a well-defined valley systems where development is not permitted (where development restrictions decrease risk).

The National Framework also proposes performance and mapping standards for different levels of study intensity, where a higher level of intensity is justified for urban areas and a lower level of intensity for undeveloped and rural areas. The standards address requirements for the following key areas:

- Base mapping
- Regulatory event for flood hazard mapping
- Flood risk database
- Age of mapping
- Climate change adaptation

### 5.2 Floodplain Management Practices in British Columbia

Few jurisdictions have undertaken floodplain mapping updates, or Regional Flood Management Plans, since 2004. Some information on a few examples are provided here.

[3] Specific definitions are not provided in the 2014 document.

### 5.2.1 Lower Mainland Flood Management Strategy

The Fraser Basin Council has recently initiated work on the Lower Mainland Flood Management Strategy. Phase 1 of the strategy, to be completed in 2014-2015 identified three priority tasks:

1. Analyse multiple flood scenarios and determine projected water levels for each scenario to better understand risks.
2. Complete a regional assessment of flood vulnerabilities, consequences and costs.
3. Review effectiveness of flood protection, policies and plans. The focus will be on identifying opportunities for improvement, at a local and regional level.

Phase 2 of the strategy will be to develop a regional strategy and action plan, including recommendations for sustained funding.

### 5.2.2 Cowichan Valley Regional District (CVRD)

The CVRD updated floodplain mapping and developed an Integrated Flood Management Plan (IFMP) for the Lower Cowichan-Koksilah River floodplain in 2009. The IFMP incorporated different types of flood mapping and produced the following products:

- Updated floodplain maps, showing the 200-year flood construction levels, flood extent and a higher hazard floodway zone, which is differentiated from the lower hazard (shallow or low velocity) flood fringe zone.
- Flood scenario maps showing different hypothetical flood spills and inundation zones for future events.

The mapping was completed using 2005 LiDAR data, supplemented with ground surveys and bathymetric surveys. The total project cost was $350,000, which included additional ecological (fisheries sensitivity mapping) and social assessments[4].

### 5.2.3 Regional District of East Kootenay (RDEK)

RDEK is in the process of completing a Regional Flood Hazard Study (Bruce Geotechnical Consultants, draft 2012) to assess and prioritize flood hazard areas in the region for further analysis and management planning. The study inventoried vulnerable infrastructure, including buildings, critical facilities (i.e. fire halls, hospitals, schools), utility systems, First Nations reserves and sensitive habitat where located within a known flood hazard area. Flood hazard areas were previously identified on a broad regional basis by the Province of BC. The estimated vulnerability of the "Elements at Risk", based

[4] Project funding was through UBCM Innovations Fund, Cowichan Tribes, BC Provincial Emergency Program, and local government.

solely on assessed value, provides support for prioritization of future projects.

## 6.0 Required Tasks for a Regional Floodplain Management Framework

Required tasks for a Regional Floodplain Management Framework are proposed in the following section. The tasks may form the basis for the development of a Request For Proposal.

### 6.1 Project Phases

A number of different phases are identified within the Regional Floodplain Management Framework. A diagram illustrates the phasing of the project and the relationship between these phases (Figure 3), which include:

Phase 1 – Floodplain Management Plan and prioritization for subsequent phases.

Phase 2 – Flood Hazard and Risk Assessment

Phase 3 – Flood Risk Mitigation Strategies

### 6.2 Regional Floodplain Management Plan (Phase 1)

The project area for Phase 1 may involve the entire RDCO region, including areas within the municipal areas of Kelowna, West Kelowna, Westbank First Nation, Okanagan Indian Band, Peachland and Lake Country. The study area will be determined as part of the Phase 1 activities.

**Phase 1 tasks include:**

1. Conduct interviews with affected municipalities, First Nations and other stakeholders,
2. Clarify the purpose and content of the Floodplain Management Plan
3. Provide context and background for flood hazards in RDCO
    a. Confirm study area extent
    b. Describe the physical and hydrological characteristics of Central Okanagan with a focus on flood hazard
    c. Collate information available on past flood events in the Central Okanagan and summarize the financial impact of some of the more recent flood events in the RDCO
    d. Identify existing floodplain mapping

e. Identify existing flood protection infrastructure, and summarize what is known about their effectiveness
f. Identify hydrometric and climate data sources (former and existing) in the RDCO
g. Locate and identify ownership of upstream dams and reservoirs
h. Generalize climate change projections and implications for flood hazard
i. Summarize data gaps

3. Identify and Prioritize Flood Hazard Areas

a. Identify hazard-prone streams in RDCO at an overview-level – on the basis of elevation and landform (specific methodology to be proposed by consultant)
b. Compare the hazard areas with known priority areas identified by the Regional Emergency Program
c. Develop Prioritization Criteria
d. Summarize results of prioritization

4. Mechanisms for Land Use Management on Floodplains

a. Compare results (mapped flood hazard areas) with existing floodplain bylaw regulations
b. Recommend options for land use management in flood-prone areas (planning approaches)
c. Provide recommendations for emergency response (triggers, monitoring, priority areas)
d. Recommend options for subsequent phases of the floodplain management framework.

### 6.3 Flood Hazard and Risk Assessment (Phase 2)

Results of the floodplain management plan (Phase 1) will determine whether subsequent phases of the study move forward. If the flood hazard area mapping indicates that existing bylaws are sufficient in managing land use in flood-prone areas, then the rationale for completing subsequent Phases will change.

Before more detailed assessments are completed, there is a need to develop the framework and Terms of Reference for the next Phases of flood hazard and risk assessment .

The flood hazard and risk assessment methodology should follow the *Professional Practice Guidelines for Legislated Flood Assessments in a Changing Climate in BC* (APEGBC, 2014). Tasks should include more information on the following:

1. Hazard and risk assessment (analytical) methods
2. Define flood hazard and define the regulatory event

3. Flood Hazard Analysis
    a. Hydrology (incl. climate change scenarios)
    b. Hydraulics
    c. Mapping
4. Risk Assessment
    a. Identify and inventory consequences/vulnerabilities. Refer to the Critical Infrastructure Rating Workbook to identify and rate critical infrastructure within a geographic area that may be at risk (see EMBC)
    b. Determine level of tolerable risk
    c. Risk analysis
    d. Risk evaluation and prioritization
    e. Information Management and Data Sharing – mapping (method to relate flood hazard to potential damages) – improved access, interactive tools (example, figure)

### 6.4 Risk Mitigation Strategies (Phase 3)

Once priority areas are identified through the risk assessment (Phase 2), strategies to mitigate, or reduce, flood risk to property will be identified in Phase 3.

Risk mitigation strategies, or options, to be considered may include:

1. Avoidance through planning mechanisms (i.e. bylaws, Development Permit areas)
2. Physical improvements (i.e. flood protection structures)
3. Warnings, education and public awareness
4. Monitoring and inspection

This Phase would include the documentation and analysis of current flood risk mitigation measures and policies on a regional basis. It would also include a review of the effectiveness of current flood-proofing measures, bylaws and other management activities.

Phase 3 includes recommendation for best practices and priorities for future investments in mitigation works.

## 7.0 Potential Project Funding Sources

In accordance with the Regional Growth Strategy, it is recommended that RDCO proceed with and fund Phase 1 of the project. The flood hazard area mapping exercise would provide a preliminary overview-level assessment of potentially flood-prone areas and would help determine future needs for flood hazard and risk assessment.

The results of Phase 1 may be used immediately by RDCO to guide development-related decision-making on flood prone lands. Should the RDCO encounter proposals for development within a flood hazard area, then a more detailed assessment may be requested of the applicant. Alternatively, RDCO can fund projects within priority areas as additional funding becomes available.

Potential sources of funding for floodplain assessment projects include the following:

- Okanagan Basin Water Board (OBWB) Water Conservation and Quality Improvement Grants and other possible granting opportunities [URL: www.obwb.ca];

- Provincial Flood Protection Program (FPP) of Emergency Management BC and the federal Building Canada Fund of Infrastructure Canada to provide annual funding (to 2017) for infrastructure projects that provide flood protection to BC communities [URL: www.th.gov.bc.ca/BCFCC];

- Real Estate Foundation provides grants that support policy, planning and management that addresses issues related to outdated plans and tools, inadequate infrastructure and incomplete information on rivers, streams and lakes in BC [URL: www.refbc.com/grants];

- The Community Works Fund (CWF) is a program that uses gas tax funds. It is an annual allocation available to local governments in British Columbia to support local priorities.[URL: http://www.ubcm.ca/EN/main/funding/renewed-gas-tax-agreement/community-works-fund.html]

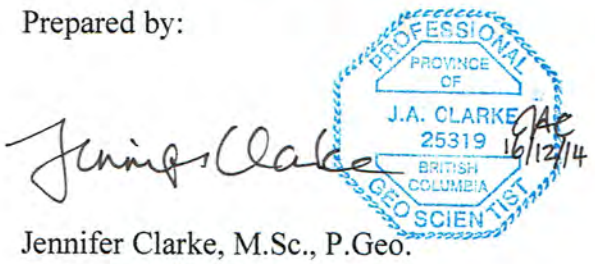
- The Infrastructure Planning Grant Program within the BC Ministry of Community, Sport and Cultural Development offers grants to support local government in projects related to the development of sustainable community infrastructure. Grants up to $10,000 are available to help improve or develop long-term comprehensive plans that include, but are not limited to: capital asset management plans, integrated storm water management plans, water master plans and liquid waste management plans. [URL: http://www.cscd.gov.bc.ca/lgd/infra/infrastructure_grants/infrastructure_planning_grant.htm]

## 8.0 Closure

This letter has been prepared for the exclusive use of the Regional District of Central Okanagan. The assessment has been carried out in accordance with generally accepted

practice. Judgement has been applied in developing the recommendations in this report. No other warranty is made, either expressed or implied.

Prepared by:

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Encl.: Figures 1 to 3

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**Definitions (from Bylaw 871)**

DESIGNATED FLOOD means a flood, which may occur in any given year, of such magnitude as to equal a flood having a 200-year recurrence interval, based on a frequency analysis of unregulated historic flood records or by regional analysis where there is inadequate stream flow data available. Where the flow of a large watercourse is controlled by a major dam, the designated flood shall be set on a site specific basis.

DESIGNATED FLOOD LEVEL means the observed or calculated elevation for the designated flood, which is used in the calculation of the flood construction level.

FLOOD LEVEL OR FLOOD CONSTRUCTION LEVEL means a designated flood level plus freeboard, or where a designated flood level cannot be determined, a specified height above a natural boundary, natural ground elevation, or any obstruction that could cause ponding.

FLOODPLAIN means an area, which is susceptible to flooding from an adjoining watercourse, lake or other body of water.

FLOODPLAIN SETBACK means the required minimum distance from the natural boundary of a watercourse, lake, or other body of water to any landfill or structural support required to elevate a floor system or pad above the flood construction level, so as to maintain a floodway and allow for potential land erosion.

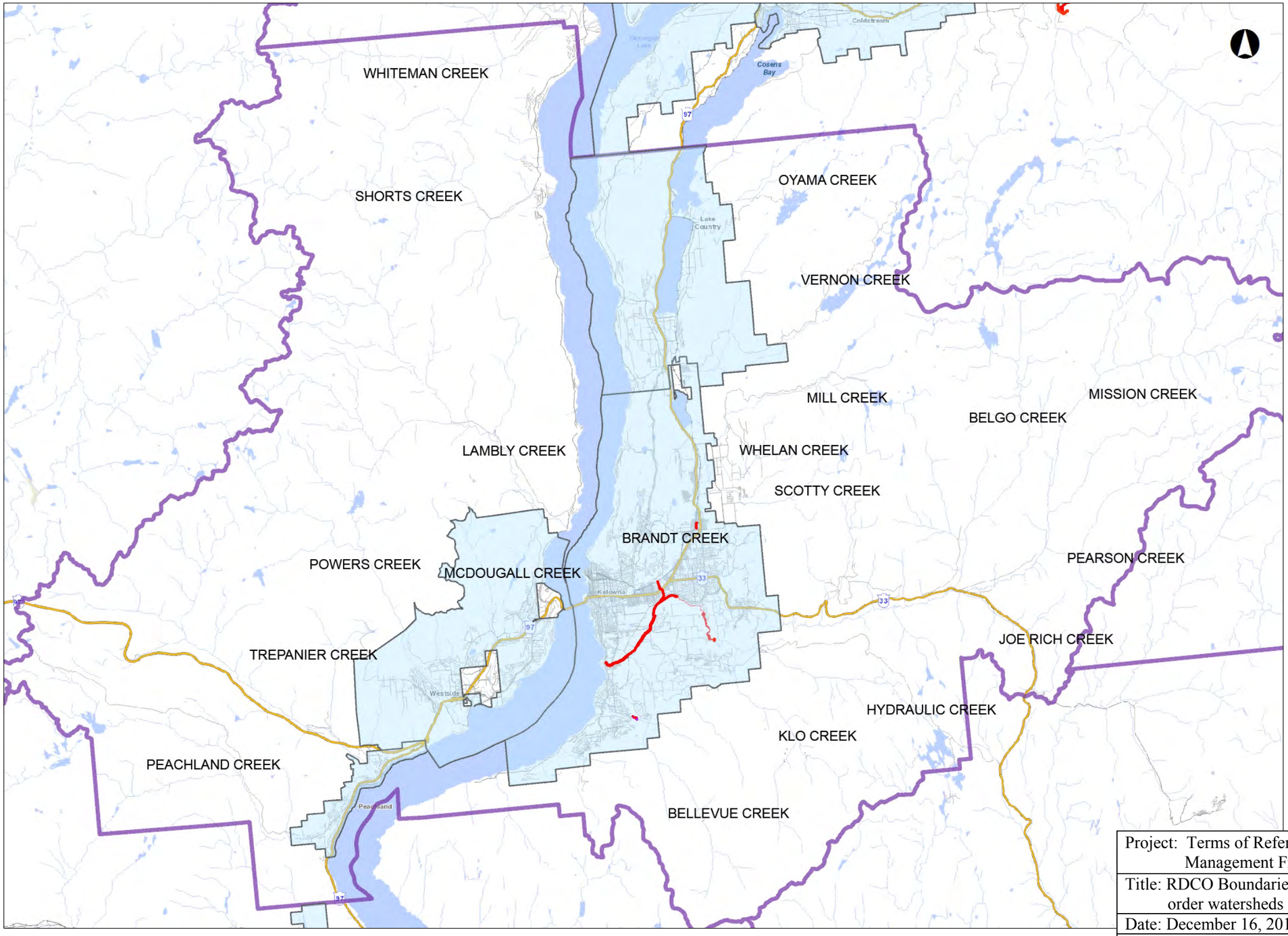
FREEBOARD means a vertical distance added to a designated flood level, used to establish a flood level.

HABITABLE AREA means any space or room, including a manufactured home, that is or can be used for dwelling purposes, business, or the storage of goods which are susceptible to damage by floodwater.

MINIMUM PONDING ELEVATION means a minimum construction level assigned to reduce possible flood damage due to ponding of local drainage during a severe local storm.

NATURAL BOUNDARY means the visible high watermark of any lake, river, stream, or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river, stream, or other body of water a character distinct from that of the banks thereof, in respect to vegetation, as well as in respect to the nature of the soil itself and also includes the edge of dormant side channels of any lake, river, stream, or other body of water.

STANDARD DIKE means a dike built to a minimum crest elevation equal to the flood construction level and meeting standards of design and construction approved by the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) and maintained by an ongoing authority such as a local government body.



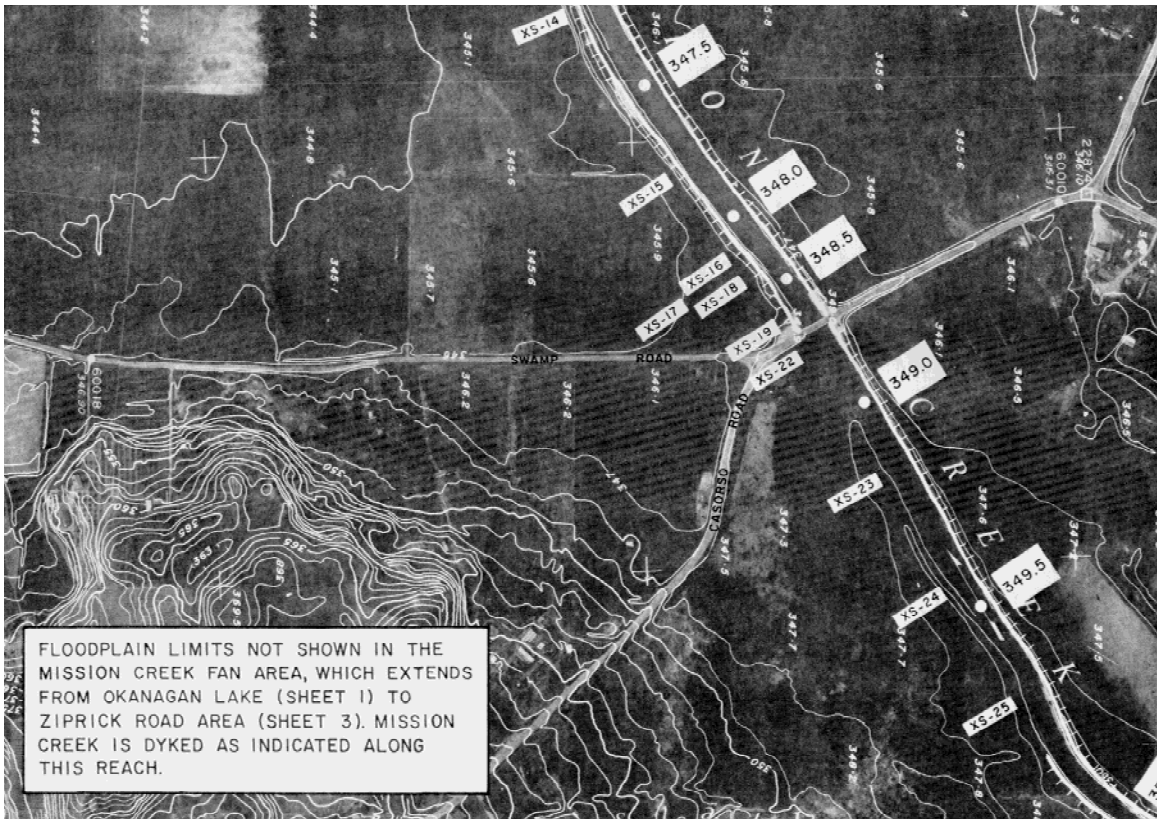

Project: Terms of Reference for a Regional Floodplain Management Framework for the RDCO

Title: RDCO Boundaries, showing municipal areas and third-order watersheds

Date: December 16, 2014 | Figure No.: 1

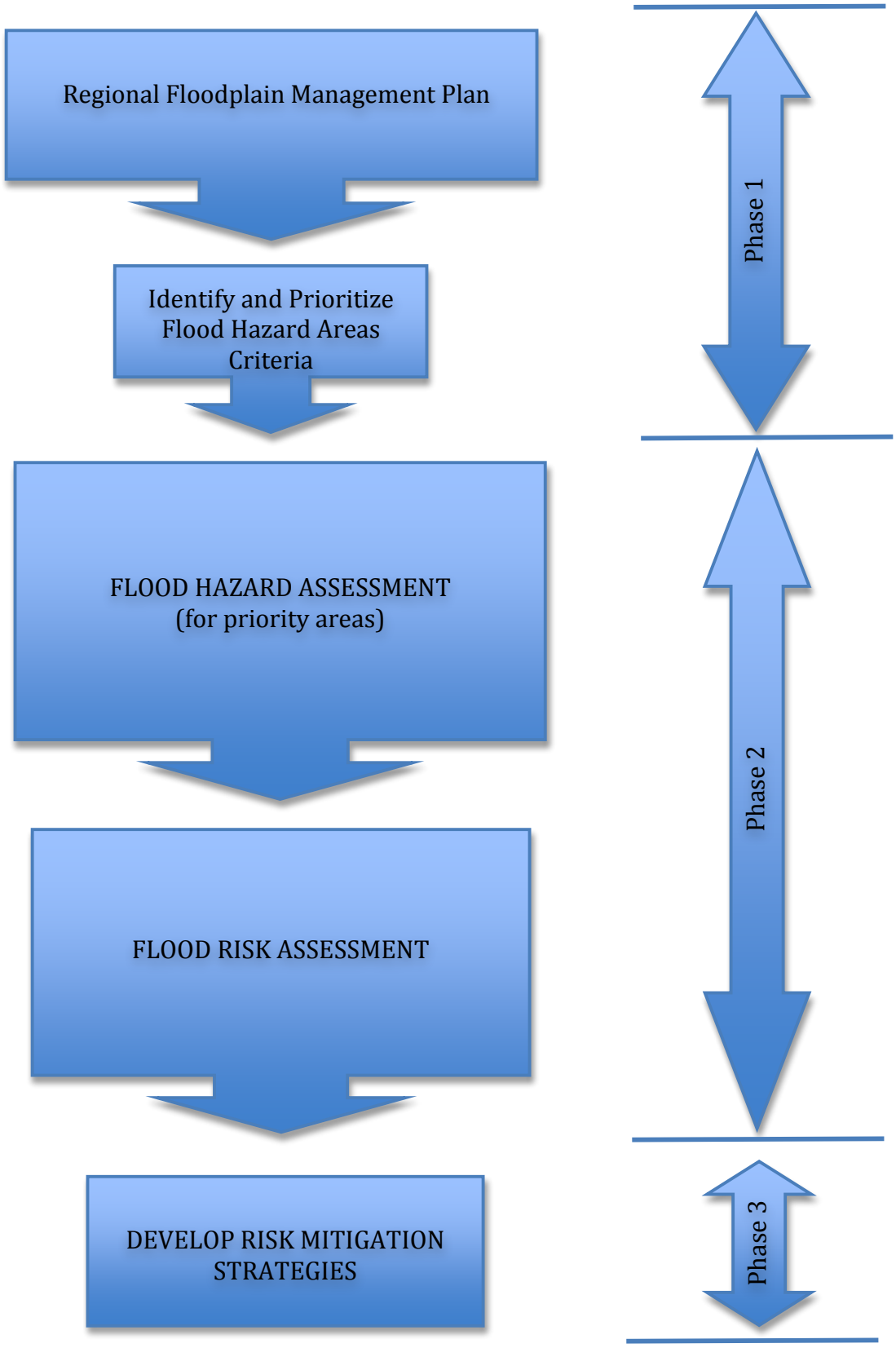
Clarke geoscience ltd.

Figure 2: Excerpt from Mission Creek Floodplain Map (1984)




Source: Mission Creek Floodplain Map, Ministry of Environment, Water Management Branch. Drawing 84-43-1, scale 1:5000. Sept 1984.

**FIGURE 3: FLOODPLAIN MANAGEMENT FRAMEWORK**



# Appendix B – Record of Meeting

| | | | |
|---|---|---|---|
| **Date:** | December 3, 2015 | **File:** | 2015-8202 |
| **Time:** | 1:00-4:00 p.m. | **Page:** | 1 of 5 |
| **Project:** | Regional Floodplain Management Plan | | |
| **Subject:** | Stakeholder Workshop | | |
| **Client:** | Regional District of Central Okanagan | | |
| **Location:** | Woodhaven Boardroom | | |
| **Present:** | Andrew Reeder, City of Kelowna<br>Brent Magnan, City of West Kelowna<br>Anna Warwick Sears, Okanagan Basin Water Board<br>Corine Gain, District of Peachland<br>Graeme Dimmick, Westbank First Nation<br>Jason Angus, City of Kelowna<br>Keith Louis, Okanagan Indian Band<br>Kevin Burtch, Black Mountain Irrigation District<br>Paul Wolanski, District of Lake Country<br>Shaun Reimer, Forest, Lands, and Natural Resource Operations<br>Toby Pike, Southeast Kelowna Irrigation District<br>Travis Whiting, Kelowna Fire Department<br>Yi Li, Forest, Lands, and Natural Resource Operations<br>Janelle Taylor, Regional District of Central Okanagan<br>Margaret Bakelaar, Regional District of Central Okanagan<br>Ron Fralick, Regional District of Central Okanagan<br>Chris Radford, Regional District of Central Okanagan<br>Wayne Darlington, Regional District of Central Okanagan<br>Dan Wildeman, Regional District of Central Okanagan<br>Hugh Hamilton, Associated Environmental Consultants<br>Kellie Garcia, Associated Environmental Consultants<br>Drew Lejbak, Associated Environmental Consultants | | |
| **Distribution:** | Those Present | | |

## RECORD OF MEETING

This Record of Meeting is considered to be complete and correct. Please advise the writer within one week of any errors or omissions, otherwise this Record of Meeting will be considered to be an accurate record of the discussions. Additional information captured on draft maps at the workshop has been recorded separately and will inform the next stages in the project.

**AGENDA:**

1. Welcome, background on the Regional Floodplain Management Plan (RFMP) Project, and introductions
2. Define purpose of the workshop and review Agenda
3. Reiterate why floodplain management planning is important
4. Introduce scope of Phases 1 (current phase), 2 (Flood Hazard/Risk), and 3 (Mitigation Strategy)
5. Summarize existing information and flood-prone streams
6. "Walk Around" – view mapped information and identify information gaps

7. Share information on existing floodplain management strategies and plans
8. Identify & brainstorm issues related to flood planning (collaborative exercise)
9. Review & identify features and content of the RFMP (collaborative exercise)
10. Introduce approaches to Preliminary Hazard, Consequence, and Risk ratings
11. Identify & brainstorm flooding consequences, including values and infrastructure (collaborative exercise)
12. Wrap-up, invitation for additional feedback, and closing comments

**KEY DISCUSSION POINTS:**

***Agenda Item 7: Share information on existing floodplain management strategies and plans and recent activity***

- **Anna, OBWB:** The BC Real Estate Association (BCREA) is a source for floodplain information and mapping in the province. They also have tools for local governments, such as strategies for securing funding. They are also advocating for new and updated floodplain mapping and planning for flood emergency response (Note: see http://www.bcrea.bc.ca/government-relations/flood-protection).
- **Keith, OKIB:** Middle Vernon Creek had a temporary diversion structure to keep water in Ellison Lake (since removed).
- **Graham, WFN:** Completed flood assessment of Keefe Creek in 2015. Several undersized culverts have been identified on streams flowing through WFN lands. WFN underground storage structures; are they maintained and what is the associated risk?
- **Corine, District of Peachland:** Peachland will be updating official community plan in 2016-17. Would like to include floodplain mapping in the OCP and subsequently include updated regulations in a floodplain bylaw.
- **Margaret and Chris, RDCO:** RDCO is addressing how to deal with floodplain exemptions. Emergency works are present, but not necessarily documented. RDCO can provide a list, but it is unclear who owns the works and should manage them. Recent projects include: MOTI Shorts Creek (received approval because it could influence highway) and a property on Mission Creek (RDCO worked with the province) –armouring was completed (as a house was lost). Once infrastructure is installed who funds the management of the works afterwards? Who is responsible?
- **Toby, SEKID:** SEKID has completed a dam safety review and it is available on their website.
- **Brent, City of West Kelowna:** McDougall Creek located between ALR lands and therefore management is limited. Smith Creek: removed infrastructure due to geotechnical concerns; new construction has begun – a new high flow channel is being built. Lots of changes observed in Smith Creek. Rosevalley Dam – reviewing setbacks downstream of the drawdown ditch. Shannon Lake is a flood controlled system and does not have issues with sedimentation, yet accretion applications are being approved. West Kelowna working on floodplain exemption bylaws and having problems with wording to capture everything.
- **Kevin, BMID:** Offered to share data on reservoirs. Release values based on hydrometric stations. Have done safety reviews of dams and can share that information.
- **Yi and Shaun, FLNRO:** See the RFMP as an important project for dam safety and Section 9 considerations. Management of Okanagan Lake is informed by the Fish Water Management Tool. Tool is dated and it is being modernized to adapt to climate change and patterns. Tools for net inflow forecasts by the River Forecast

Centre need updating. This has begun and will be completed in 2016. EMBC has agreed with the policy that if they fund works, they will fund removal or maintenance. On a liability standpoint, it is currently unknown who is ultimately responsible for works. Shaun is aware of Section 9 bank protection for district/municipalities; condition of the section 9 is that the district is responsible. Ice jam on Mission Creek (Casoro Bridge) in 1995/1996 and risk to jamming on lower reaches of Mission Creek. Climate change could increase the risk of ice jam flooding due to greater winter flows.

- **Paul, District of Lake Country:** Low lying developments have considered flooding; groundwater issues and dewatering that occurs and requires mechanical dewatering needs and ditches that hold water. Currently considering flooding in new zoning. At a 2004 meeting in RDCO office the province put the pressure on municipalities to manage flood hazard. Upland retention is a good mechanism for flood mitigation.
- **Wayne, RDCO:** RDCO owns a dyke section on Bellevue Creek. We inspect it annually. Investigations on whether the dyke is still protected under current Q200s. Feels that this plan will help recommend management of the dykes.
- **Jason and Andrew, City of Kelowna:** Mill Creek bylaw and attenuation studies. Parks department is restoring channel banks. Hydrometric/climate information is available. Flood protection strategies included in the integrated stormwater management plans – six basin plans to mitigate flooding in these areas. Storage retention models are used for planning within the City. Looking at floodplain mapping for Mission Creek and some orthophoto and LiDAR review. Inherited a number of dams recently.

***Agenda Item 8: Identify and brainstorm issues related to flood planning***

The following are points raised during the discussion:

- Jurisdiction and liability: liability on dykes is challenging – dyking authorities no longer exist.
- Floodplain mapping gets outdated. How relevant is the existing (1980s) floodplain mapping? Are there approaches that would make any new mapping better address uncertainty?
- Part of floodplain mapping is to identify upstream elements (infrastructure) that could influence downstream flood management. Aspects like wildfires, road development, impervious surfaces that could influence peak flows downstream. Models that could include the changes downstream. Development processes don't account for changes in surface areas sometimes.
- Will potential downstream effects from wildfires be considered in the plan?
- Generally, potential downstream effects of land use and development are assessed by the responsible provincial or local government body. What can be done to ensure that the upstream management is consistent with downstream management?
- Cumulative risks could be captured on maps.
- Land resource management plans that considered hydrologic change on quantity and quality used to be required by the province within regional districts. Useful, but no longer required.
- Forest companies still need a qualified professional to complete an assessment, but there are no longer round table discussions before approval of forest development plans.
- Cohesive mapping would be good idea to ensure that all municipalities are consistent.

- Floodplain mapping needs to be updated (e.g. Peachland natural lands have changed). FCL and setbacks don't make sense because they are based on old information. Need new information to build confidence.
- Plan should consider hazards posed by beaver dams and other natural dams.
- The RFMP should be consistent with and inform the Flood Emergency Plan.
- The hazards posed by existing upper elevation dams and reservoirs should be addressed in the plan. Dam safety plans are understood to be in place for all dams.
- Land Act has wording about the identification of HWM and wave action.
- Bylaws include building restrictions on alluvial fans to mitigate risk.
- Potential insurance implications if you complete mapping of developed areas. Not popular due to cost implications.
- If people are able to personalize the potential effects of floods, they will be more accepting of measures to mitigate risk.
- The plan should identify the different approaches to mitigate risk that are available to RDCO and the member communities.

***Agenda Item 9: Review & identify features and content of the RFMP***

- A strategy for community collaboration needs to be included in the plan.
- Phase 1 will include some of the planning tools (e.g. used in other regional districts, municipalities) that will help the RDCO. Fraser Valley Regional District recently went through a similar planning exercise.
- What is the industry standard for tolerable risk? That should be considered. APEGBC guidelines consider changes into the future.
- Ecosystems are not considered in the approach, they need to be considered for watershed health.

***Agenda Item 11: Identify & brainstorm flooding consequences, including values and infrastructure***

The following consequences of flooding were identified during the discussion:

- B.C. has published guidelines to identify critical infrastructure. These guidelines will be used to identify and map such infrastructure in Phase 1, but the RFMP will also identify other values subject to flooding.
- Environmental: structural flood management can reduce habitat quality, including wetland habitat.
- Recreational fisheries can be affected with social, economic, and environmental consequences.
- Tourism – flood could have an economic impact (short-term) but also affect reputation.
- Rain-driven events could influence lake management.
- Potential increases in storage (e.g. by raising dams) could help reduce annual peak flows, but unlikely it will eliminate flooding from larger events.
- Recreation/parks - possible social impacts (e.g. Kananaskis).
- Unique characteristics of OKIB reserve lands are that "upstream" lands are managed by other agencies. Dam replacement has recently occurred on reserve lands.
- Water treatment – human health: turbidity can diminish water treatment processes.
- Sanitation: low lying areas could be impacted due to flooded septic systems.

- Agriculture: orchards/cattle can be impacted.
- Farm Practices Protection Act doesn't require landowners to give up land for flood protection; limited options on agriculture lands.
- Emergency response/911 and communications/power grids could be impacted.
- Human health impacts.
- Senior population is particularly vulnerable to flooding impacts.
- Loss of potential developable land has economic consequences.
- Land values are unique.
- Industrial land use (e.g. if there is chemical storage/contamination in the floodplain).

**SUMMARY OF KEY DISCUSSION POINTS AND FEEDBACK:**

- The group generally agreed that there is value in a Regional Floodplain Management Plan.
- There was general agreement that the Terms of Reference and scope of the RFMP is appropriate, and an understanding that Phase 2 will provide more detailed analyses of flood risk for high priority areas.
- The consequences of flood extend beyond Critical Infrastructure to a number of other economic, social-community, and environmental values. The plan should consider those consequences in Phases 1 and 2.
- The Phase 1 RFMP will include a summary and review of planning tools and approaches for floodplain management that are appropriate for RDCO.
- RDCO may be particularly vulnerable to flood hazards because of the combination of climate change, population growth, topography, and the desire of residents and visitors to be near the water.
- The issue of responsibility for maintaining or decommissioning dams and dykes, and who is liable if they fail, are questions that came up repeatedly during the workshop. Similarly, clarification of responsibility for emergency flood mitigation was raised a number of times.
- The plan must include a strategy for collaboration between the government jurisdictions within RDCO because flooding can cross jurisdictional boundaries, and sharing of information will help build consistency in flood management approaches across the regional district.

# Appendix C – Summary of Dams within the RDCO

**Table C-1 Summary of dams, owners, and consequence ratings for all dams located within and upstream of the RDCO boundary**

| Dam Name | Dam Owner | Consequence Rating[1] |
|---|---|---|
| Rose Valley Reservoir | City of West Kelowna | Extreme |
| Crooked Lake | District of Lake Country | Very High |
| Ideal (Belgo) Lake - Control (West) | Black Mountain Irrigation District | Very High |
| Ideal (Belgo) Lake - Saddle (East) | Black Mountain Irrigation District | Very High |
| Ideal (Belgo) Lake - Spillway (Center) | Black Mountain Irrigation District | Very High |
| Big Horn Reservoir - Control | City of West Kelowna | High |
| Big Horn Reservoir - Spillway | Black Mountain Irrigation District | High |
| Bulman Dam (Moore Lake) | Glenmore-Ellison Improvement District | High |
| Damer Lake | District of Lake Country | High |
| Dobbin Lake - Control | City of West Kelowna | High |
| Fish Hawk Lake | Black Mountain Irrigation District | High |
| Fraser (Frazer) Lake | South Okanagan Mission Improvement District | High |
| Graystoke Lake | Black Mountain Irrigation District | High |
| Horseshoe (Islaht) Lake Dam (West) | City of West Kelowna | High |
| Horseshoe (Islaht) Lake Saddle Dam (Center) | City of West Kelowna | High |
| Horseshoe (Islaht) Lake Spillway Dam (East) | City of West Kelowna | High |
| Industry Brook - Control | Private (Edmond Ranches Ltd.) | High |
| Industry Brook - Saddle | Private (Edmond Ranches Ltd.) | High |
| Jackpine Lake | City of West Kelowna | High |
| James Lake - Control | Black Mountain Irrigation District | High |
| James Lake - Saddle | Black Mountain Irrigation District | High |
| Lambly - Control | City of West Kelowna | High |
| Lambly - Saddle | City of West Kelowna | High |
| Mair Pond | Private (V. Blaskovich) | High |
| McCulloch - Control (Wardlaw) | Southeast Kelowna Irrigation District | High |
| McCulloch - Saddle (East Dam) | Southeast Kelowna Irrigation District | High |
| McCulloch - Saddle (Haynes Lake) | Southeast Kelowna Irrigation District | High |
| McCulloch - Saddle (Lynx Lake) | Southeast Kelowna Irrigation District | High |
| McCulloch - Saddle (South Dam) | Southeast Kelowna Irrigation District | High |
| McKinley Reservoir (Glenmore) | Glenmore-Ellison Improvement District | High |
| Oyama Lake - Control | District of Lake Country | High |
| Oyama Lake - Saddle | District of Lake Country | High |
| Oyama Lake - Spillway | District of Lake Country | High |
| Paynter Lake - South Saddle | City of West Kelowna | High |
| Paynter Lake - Control | City of West Kelowna | High |
| Paynter Lake - Middle Saddle | City of West Kelowna | High |
| Peachland Lake | District of Peachland | High |
| Postill Lake | Glenmore-Ellison Improvement District | High |
| Silver Lake - Control | District of Peachland | High |
| South Lake | Glenmore-Ellison Improvement District | High |
| Swalwell (Beaver) Lake | District of Lake Country | High |
| Tadpole Lake - Control | City of West Kelowna | High |
| Tadpole Lake - Spillway | City of West Kelowna | High |
| Browne Lake - Control | Southeast Kelowna Irrigation District | Significant |
| Browne Lake - Spillway | Southeast Kelowna Irrigation District | Significant |
| Eldorado Balancing Reservoir | District of Lake Country | Significant |
| Fish Lake | Southeast Kelowna Irrigation District | Significant |
| Glen Lake | District of Peachland | Significant |
| Glenrosa Lake - Control | Private (F. Ficke & B. Gertrude) | Significant |
| Hadden Dam - Lower (Settling Pond) Bmid | Black Mountain Irrigation District | Significant |
| Hayman Lake | Private (R. Yeulett) | Significant |
| Hidden Lake (Mcdougall) | Private (R. Ensign) | Significant |
| Hill Spring | Private (Interval Investments Inc.) | Significant |
| James Lake - Spillway | Black Mountain Irrigation District | Significant |
| Knox Lake | Private (Holland Holdings Ltd.) | Significant |
| Loch Long - Control | Black Mountain Irrigation District | Significant |
| Loch Long - North Saddle | Southeast Kelowna Irrigation District | Significant |
| Loch Long - West Saddle | Southeast Kelowna Irrigation District | Significant |
| Long Meadow - Control | Southeast Kelowna Irrigation District | Significant |
| Long Meadow - N/W Saddle (H) | Southeast Kelowna Irrigation District | Significant |
| Long Meadow - S/E Saddle (K) | Southeast Kelowna Irrigation District | Significant |
| Scotty Creek (Little Trapper) | Black Mountain Irrigation District | Significant |
| Scotty Creek Intake - Bmid | Black Mountain Irrigation District | Significant |
| Silver Lake - Spillway | District of Peachland | Significant |
| Stevens Reservoir Dam - Upper Pond Bmid Intake | Black Mountain Irrigation District | Significant |
| Turtle Lake - Control (North) | Southeast Kelowna Irrigation District | Significant |
| Turtle Lake - Cut-Off (South) | Southeast Kelowna Irrigation District | Significant |
| Vernon Creek Intake (Wocid) | District of Lake Country | Significant |
| Weddell Lake | Private (Holland Holdings Ltd.) | Significant |
| Smith Creek Pond[2] | City of West Kelowna | Significant |
| Allan Creek Meadow | Private (R. Yeulett) | Low |
| Bowen Creek | Private (P. Keller) | Low |
| Canyon Lakes (Klo Creek) - Lower Saddle Dam | Southeast Kelowna Irrigation District | Low |
| Canyon Lakes (Klo Creek) - Upper | Southeast Kelowna Irrigation District | Low |
| Clarence Brook | Private (A. Hoyer & H. Winifred) | Low |
| Colton Spring | Private (G. Westgate) | Low |
| Crawford Slough | Private (No. 21 Great Projects Ltd.) | Low |
| Day Pond | Private (E. Day) | Low |
| Echo Lake (Nr Swalwell) | Fish & Wildlife Science & Allocation Sec | Low |
| Ellison (Duck) Lake | District of Lake Country | Low |
| Esperon Lake | City of West Kelowna | Low |
| Ford Pond | Private (R. Bonar) | Low |
| Glenmore Avocet Pond | City of Kelowna | Low |
| Glenrosa Lake - Saddle | Private (F. Ficke & B. Gertrude) | Low |

| Dam Name | Dam Owner | Consequence Rating |
|---|---|---|
| Hydraulic Creek Diversion (Sekid) | Southeast Kelowna Irrigation District | Low |
| Hydraulic Creek Intake (Sekid) | Southeast Kelowna Irrigation District | Low |
| Jack Smith Lake | Private (F. Amrein) | Low |
| Keefe Pond | To Be Determined - Pending | Low |
| Lacoma Lake | Private (H. Moeller) | Low |
| Lambert Pond | Not Available | Low |
| Lambly Creek Intake | City of West Kelowna | Low |
| Law Creek | Private (J. Klein) | Low |
| Leon Creek | Not Available | Low |
| Leon Creek #2 (K4) | Not Available | Low |
| Leon Creek #3 (M4) | Not Available | Low |
| Mccall Lake | Wildlife Branch | Low |
| Michael Brook Pond[3] | City of Kelowna | Low |
| Mill (Kelowna) Creek | Glenmore-Ellison Improvement District | Low |
| Mission Lake | Black Mountain Irrigation District | Low |
| Mission Slough | Private (G. Kirk) | Low |
| Oyama Creek - Intake Dam | District of Lake Country | Low |
| Peachland Creek Intake | District of Peachland | Low |
| Pigeon Creek | Private (W. Bepple) | Low |
| Powers Creek Intake | Not Available | Low |
| Rock Face Creek | Private (Sunset Ranch Golf Developments Ltd.) | Low |
| Scotty Creek - Sunset Ranch | Black Mountain Irrigation District | Low |
| Second Creek Pond | Private (B. Kalt) | Low |
| Sladen Pond | Not Available | Low |
| Taylor Meadow - Control (South) | Private (R. Ensign) | Low |
| Taylor Meadow - Spillway (North) | Private (R. Ensign) | Low |
| Tranfield Swamp | Private (R. Tranfield) | Low |
| Trepanier Intake (Peachland) | District of Peachland | Low |
| Walroy Lake | Private (Glenwest Properties Ltd.) | Low |
| Webber Lake - Control (Banana Lk) | City of West Kelowna | Low |
| Webber Lake - Saddle (@ North) | City of West Kelowna | Low |
| Wilson Lake | District of Peachland | Low |
| Woodsdale Swamp | Private (R. Griffin & M. Adams) | Low |
| Chatterton Lake | District of Lake Country | Not Classified |
| Conroy Lake - Lower | Glenmore-Ellison Improvement District | Not Classified |
| Conroy Lake - Upper | Glenmore-Ellison Improvement District | Not Classified |
| High Lake | District of Lake Country | Not Classified |
| Lamboo Pond (Herod Brook) | Private (F. Mcfadden Et Al.) | Not Classified |
| Lebanon Creek Reservoir | Private (A.G. Appel Enterprises Ltd.) | Not Classified |
| Loch Katrine | Black Mountain Irrigation District | Not Classified |
| Loch Oichie | Black Mountain Irrigation District | Not Classified |
| Mcdougall Creek Pond | Private (R. Longley) | Not Classified |
| Murray Lake Dam (Murray Meadows) | Black Mountain Irrigation District | Not Classified |
| Pear Lake | Not Available | Not Classified |
| Whelan Creek (Upper) Dam | District of Peachland | Not Classified |

Notes:

1. Consequence classifications as defined through Schedule 1 of the Dam Safety Regulation. Data source: MFLNRO.
2. Smith Creek Pond was reported by the City of West Kelowna to have been removed in 2015 (B. Magnan, pers. comm., 2016).
3. The City of Kelowna reported that no dam structure was present on Michael Brook Pond and the City planned to discuss (with MFLNRO) the removal of t dam from MFLNRO's dam summary list (A. Reeder, pers. comm., 2016).

# Appendix D – Technical Memorandum: Preliminary Flood Risk Rating Methods

| | | | |
|---|---|---|---|
| **Date:** | June 20, 2016 | **File:** | 2015-8202.000.004 |
| **To:** | Regional District of Central Okanagan | | |
| **From:** | Hugh Hamilton; Drew Lejbak | | |
| **Project:** | Regional Floodplain Management Plan: Phase 1 | | |
| **Subject:** | Preliminary Flood Risk Ratings Methods | | |

# APPENDIX D

## 1 INTRODUCTION

As part of the development of the Regional Floodplain Management Plan (RFMP) (Phase 1) for the Regional District of Central Okanagan (RDCO), a preliminary flood risk rating (PFRR) method was developed to assign a risk rating to flood prone areas. This appendix summarizes a process for developing a PFRR for the RFMP (Phase 1). The PFRR are used to establish priorities for future actions during Phases 2 and 3, consistent with the RFMP terms of reference (Clarke Geoscience Ltd. 2014). The approach outlined within this appendix was presented to the RDCO and was accepted in February 2016.

The PFRR results are summarized in Section 4 of the Phase 1 final report.

## 2 PRELIMINARY FLOOD RISK RATING – METHODS

For the PFRR, flood is defined as a condition in which a watercourse or body of water overtops its natural or artificial confines and covers land not normally under water. Based on this definition, the following tasks summarize the approach used to assign preliminary flood risk ratings within the RDCO:

- Task 1 – Identification of flood-prone watercourses and/or reaches or waterbodies.
- Task 2 – Identification of alluvial fans and floodplains.
- Task 3 – Identification of the annual exceedance probability (or likelihood) of a flood occurring.
- Task 4 – Identification of the known elements-at-risk across a watercourse, waterbody, or which are located within a floodplain or on an alluvial fan.
- Task 5 – Identification of the consequence(s) to the elements-at-risk from flooding in RDCO, reflecting the biophysical/ecological characteristics and socio-economic values in the region.
- Task 6 – Assignment of a preliminary flood risk rating based on the identified likelihood of flood mechanism and associated consequences to elements-at-risk.

The following sections outline how each task was completed for the RDCO RFMP.

### 2.1 Identification of Flood-Prone Watercourses and/or Reaches (Task 1)

Currently, information is available on historic flood events within the RDCO (Section 3.3.2 of the final report), but corresponding watercourse reaches under flood threat or the extents of potential flooding are generally not defined or delineated. Therefore, to identify flood-prone watercourses and/or reaches (and waterbodies) within the RDCO, available soils and stream channel morphology spatial datasets were used as indicators, recognizing the associated physical properties and correlation to river processes. These datasets included alluvial aquifer mapping completed for the Okanagan Water Supply and Demand Project (Summit 2010), provincial soils mapping (Province of B.C. 2015), and provincial stream macro reach mapping (MOE 2015).

Using the available datasets, the following screening criteria were used to define flood prone watercourses and/or reaches:

- All watercourses and/or reaches falling within a mapped alluvial aquifer were considered flood prone.
- All watercourses and/or reaches outside of a mapped alluvial aquifer, but within a fluvial soil type polygon[1] defined by Province of B.C. (2015), were considered flood prone.
- All watercourses and/or reaches outside of a mapped alluvial aquifer and fluvial soil type polygon, but defined to be an alluvial macro reach by MOE (2015), were considered flood-prone.
- The consulting team reviewed the initial mapping results and made some minor adjustments based on their knowledge of watercourses from previous project work within the region.

Map 1 (Appendix E of the final report) provides the results of the flood-prone watercourse and/or reach mapping for the RDCO.

### 2.2 Identification of Alluvial Fans and Floodplains (Task 2)

The following summarizes how alluvial fans and floodplains were identified within the RDCO:

- Mission Creek[2], Kelowna (Mill) Creek, and a portion of the western shore of Okanagan Lake (from Peachland to West Kelowna) have had floodplain mapping completed for a 1:200-year return period event (Section 3.2; Figure 1-1 of the final report). These floodplain extents were considered to represent floodplains for rain, rain-on-snow, snowmelt, debris blockages and releases of flows, ice jams, and sediment accumulation flood type events.
- For other watercourses and/or reaches that do not have floodplain mapping completed, but were identified as flood-prone within the RDCO (Task 1), the following summarizes how alluvial fans and floodplains were estimated:
    - For flood-prone watercourses and/or reaches (Task 1), floodplain extents were assumed to be represented by mapped alluvial aquifer and/or fluvial soil type polygon extents where available (Map 1 [Appendix C])[3]. These floodplain extents were considered to represent floodplains for rain, rain-on-snow, snowmelt, debris blockages and releases of flows, ice jams, and sediment accumulation flood type events.
    - For flood-prone watercourses and/or reaches (Task 1) without alluvial aquifer or fluvial soil type polygon mapping available, floodplain extents were not estimated. These watercourses were generally located either within headwater areas or were small steep and short tributaries that contribute directly to Okanagan Lake where there were limited elements-at-risk. Note that these reaches were still included within the preliminary risk analysis in order to capture the sections of watercourses that may be prone to flooding and could be relevant to Phases 2 and 3 of the RFMP.

[1] A polygon is a mapped spatial unit (i.e. shape) that has been identified to have similar characteristics (e.g. fluvial soil, lacustrine soil).

[2] The furthest upstream floodplain mapping of Mission Creek by MOE (1984) was available digitally by MOE (2015b); however, the diked portion from the floodplain mapping was not available. The diked section was considered a flood- prone reach and the floodplain extent was estimated to be within the dikes.

[3] For some watersheds, fluvial soil type polygons were present that were not adjacent to a mapped watercourse. These polygons were still considered a floodplain due to their relic fluvial nature.

  - For watercourses and/or reaches identified not to be flood-prone (Task 1; Map 1 [Appendix E of the final report]), no alluvial fans or floodplains were considered to be present.

- For Okanagan Lake, the lake floodplain area outside of the mapped extent from Peachland to West Kelowna was represented by all land adjacent to the lake that falls below the flood construction level of 343.66 m (including freeboard) defined by MOE (1982)[4]. This floodplain extent was considered to represent the floodplain for high lake level, surge, wave setup, height, and run up, and operating constraint flood type events.
- For Wood Lake and the portion of Kalamalka Lake included within the RDCO, lake floodplain areas were represented by all lands adjacent to the lakes that fall below the flood construction level of 393.2 m (including freeboard) identified within the District of Lake Country's Zoning Bylaw No. 561 (District of Lake Country 2016)[5]. Similar to Okanagan Lake, this floodplain extent was considered to represent the floodplain for high lake level, surge, wave setup, height, and run up, and operating constraint flood type events. Note that Wood and Kalamalka Lakes were assumed to be one lake for this assessment due to the connection of the two lakes through the canal in Oyama.
- New estimates of floodplain extents from dam or dike breach type events were not undertaken for Phase 1 because:
  - The only dikes located within the RDCO are along Lower Mission Creek and they are designed to withstand a 1:200-year return period peak flow event (Tetra Tech EBA 2014). Some critical dike sections were identified by Tetra Tech EBA (2014), but due to the uncertainty of when a dike breach could occur and under what flood magnitude, it was assumed that the critical sections would be improved and able to withstand a 1:200-year return period without breach.
  - Dam safety is the responsibility of the provincial government (Section 3.5.1 of the final report). No dam breach inundation mapping is available for the RDCO. Dam breach assessments are completed separately through DSRs required by MFLNRO. At present, there is no publically-accessible database of DSRs.

Map 1 (Appendix E of the final report) includes the mapped and estimated floodplains within the RDCO and the flood construction levels for Okanagan, Wood, and Kalamalka Lakes.

### 2.3 Identification of Annual Exceedance Probability (Task 3)

Currently, the threshold values where flooding commences on most watercourses within the RDCO are unknown. Similarly, the flood extents, depths, velocities, and durations for design events are only known qualitatively for areas not previously studied. Therefore, for areas with existing floodplain mapping or estimated floodplains, **a 1:200-year return period** flood event (i.e. a 0.5% annual probability of occurrence) was used to define the PFRR in Phase 1. This is consistent with the standard-based approach outlined by APEGBC (2012) and standard floodplain mapping in B.C.

[4] To estimate the extent of land that falls below the Okanagan Lake flood construction level (FCL), an elevation of 344 m was assumed adequate to represent the FCL. This elevation was selected as digital elevation information at a 2 m resolution was only available for the area around Okanagan Lake within the RDCO.

[5] To estimate the extent land that falls below the Wood and Kalamalka Lakes FCL, an elevation of 393 m was assumed adequate to represent the FCL. This elevation was selected as digital elevation information at a 1 m resolution was only available for the area around Wood and Kalamalka Lakes within the RDCO.

### 2.4 Identification of known Elements-at-Risk (Task 4)

Available spatial (GIS) information[6] was used to identify high and low density development areas, rural lands, future development areas, total population, critical infrastructure at risk (e.g. hospitals, water and wastewater treatment plants, bridges, highways, railways), and environmentally sensitive areas within the RDCO.

For each defined flood-prone area, elements-at-risk were grouped or estimated as follows:

- Land use type (e.g. urban development, rural) elements-at-risk were summarized using available spatial information and zoning bylaw definitions (e.g. RDCO [2014]).

- Critical infrastructure elements-at-risk were identified using tables published by the Provincial Emergency Program (2007) as a guide and grouped using available spatial information. The critical infrastructure elements-at-risk considered were[7]:
    - Trails/paths;
    - Residential roads;
    - Major highways and railways;
    - Bridges;
    - Schools;
    - Water and sewer lines;
    - Pump houses;
    - Power substations;
    - Hospitals, health care centres, assisted living centres, and emergency services;
    - Major water intakes (for water purveyors and municipalities); and
    - Water and wastewater treatment facilities.
- Social and cultural elements-at-risk were grouped using available spatial information. The elements-at-risk considered were:
    - Places of worship;
    - Community centres;
    - Art galleries; and
    - Archaeological sites.
- Total population density was estimated using spatial population density information available from Statistics Canada (2016) for the RDCO and municipalities located within the RDCO boundaries. The population census information was based on information collected in 2011, but was considered representative of current population densities within the RDCO. The spatial population density information is based on census tract information; therefore, population densities vary within urban and rural populated areas located in the RDCO.
- Environmentally sensitive area elements-at-risk were estimated through consideration of the presence of conservation areas (as defined through local zoning bylaw definitions) within the flood-prone area, through the

[6] Spatial information was obtained from the RDCO, City of Kelowna, City of West Kelowna, District of Peachland, District of Lake Country, Interior Health, FortisBC, and BC Hydro.

[7] High pressure gas lines were not considered since spatial datasets are not publically available for the RDCO.

known presence and/or absence of fish within the watercourses, as well as the presence and/or absence of culverted, channelized, or open channels. Note that limited spatial (GIS) information was available for terrestrial or aquatic habitat in many of the watercourses in RDCO. Fish presence/absence spatial information was obtained from MOE (2016).

### 2.5 Identification of Consequence(s) to Elements-at-Risk (Task 5)

APEGBC (2012) provides an example risk matrix to determine the relative level of flood risk for proposed developments, which includes a consequence classification scheme. For the RFMP, a customized consequence classification system was developed to include community-specific values, based in part on comments received during the project workshop in December 2015 with RDCO (Associated 2015) and follow-up discussions. The customized consequence classification scheme is provided in Table 2-1. Included within the scheme is a consequence rating of 1 to 6, where a higher value indicates a higher consequence. For each consequence category included within the scheme, a consequence rating was qualitatively assigned based on professional judgment.

A consequence category specifically related to safety or loss of life was not included in Phase 1 at this time, since loss of life or level of injury cannot be quantified at the screening level. However, the presence or absence of human populations is captured in several of the categories.

**Table 2-1 Customized consequence classification scheme for the RFMP (modified from APEGBC 2012)**

| Consequence Categories | Consequence Rating | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Land Use Type | Forest Resource | Agriculture | Conservation Lands; Rural; Parks | Industrial | Commercial; Institutional; Future Commercial / Institutional | Residential; Future residential |
| Critical Infrastructure | None | Trails/paths | Residential roads | Major Highways; Railways | Bridges; Schools; Water and Sewer Lines; Pump houses; Power Substations | Hospitals; Health Centres; Assisted Living Centres; Emergency Services; Major Water Intakes; Water & Wastewater Treatment Facilities |
| Social and Cultural | Negligible impact | Slight impact; recoverable within days to weeks | | Moderate to high impact; recoverable within weeks to months | | Presence of places of worship, historical and archaeological sites, community centres, art galleries. |
| Total Population / Personal Hardship | <1 person; Negligible impact | <10 people; Slight impact; recoverable within days | <100 people; Moderate impact; recoverable within weeks | 100-500 people; Personal hardship usually recoverable within months | 501-2,500 people; Leaves significant personal hardship for years | >2,500 people; Irreparable personal hardship |
| Environmental | No channel present | Artificially channelized or culverted stream | Open channel present, but fish presence not confirmed | Fish-bearing stream | Fish-bearing stream with Kokanee Salmon presence | Contains a designated conservation area |

***Consequence Ratings - Alluvial Fans/Floodplains***

For the flood-prone areas (mapped or estimated [Task 4]), the following summarizes how consequence ratings were assigned for each of the consequence categories:

- The Land Use Type consequence category was categorized according to RDCO (2014) and the municipal zoning bylaws for each community within the RDCO boundaries. The overall Land Use Type consequence rating is the weighted average based on land area per zone[8].
- For the Critical Infrastructure consequence rating, the rating includes the presence or absence of elements-at-risk. Note that the consequence rating is based on the presence of a single element-at-risk only; the number of elements-at-risk of a single type present within a flood-prone area is not weighted differently because of the screening level nature of the PFFR assessment for Phase 1 of the RFMP.
- For the Total Population / Personal Hardship consequence rating, population density information available from Statistics Canada (2016) for the RDCO and the municipalities located within the RDCO boundaries was used to estimate the total population within each floodplain area. Specifically, the reported population per $km^2$ value (from census tract information) for the RDCO and each municipality was applied to the zoned lands within each flood-prone area to approximate the total population.
- For the Social and Cultural consequence rating, the rating includes the presence or absence of elements-at-risk. When no elements-at-risk were present (or could not be identified), the Social and Cultural consequence rating was assigned by taking the average between the Land Use Type and Total Population / Personal Hardship consequence ratings[9]. This approach was felt to adequately consider social and cultural impacts to the population present, as well as impacts to the respective land use types present.
- For the Environmental consequence rating, the rating includes presence or absence of conservation lands in flood-prone areas (highest value), as well as a presence or absence of fish and culverted, channelized, or open streams. The presence of kokanee salmon was considered to have a higher consequence rating due to their status in the Okanagan as a species-at-risk.

Once a consequence rating was assigned for each category, an overall consequence rating for the flood-prone area was assigned based on equal weighting of each category (i.e. each criteria worth 20%).

***Consequence Ratings - Flood-Prone Watercourses/Reaches without Mapped Floodplains***

For the flood-prone watercourses/reaches without alluvial aquifer or fluvial soil type polygon mapping available (Task 4), the following summarizes how consequence ratings were simplified and assigned for each of the consequence categories:

- Without spatial extents of alluvial fans/floodplains available, the overall Land Use Type consequence rating was considered the weighted average based on the length of zone along each flood-prone watercourse/reach.
- Without spatial extents of alluvial fans/floodplains available, the rating includes the presence or absence of elements-at-risk that cross the watercourse/reach only. Elements-at-risk adjacent to the watercourse/reach were not included since the extent of flooding is unknown.
- Without spatial extents of alluvial fans/floodplains available, the Total Population / Personal Hardship and Social and Cultural consequence ratings were not considered since the extent of flooding is unknown.

[8] The weighted average consequence rating values were rounded up or down to the closest category rating for all values.

[9] Within Table 2-1, the presence of a social and cultural element(s)-at-risk is given the highest consequence category rating (i.e. 6). No spatial information was available for social and cultural elements-at-risk; therefore, the average consequence rating between the Land Use Type and Total Population / Personal Hardship ratings were used.

- For the Environmental consequence rating, the rating includes presence or absence of conservation lands adjacent to the watercourse (highest value), as well as a presence or absence of fish and culverted, channelized, or open streams.

Once a consequence rating was assigned for each category, an overall consequence rating for the flood-prone watercourse/reach was assigned based on equal weighting of each category (i.e. each criteria was worth 33% since Total Population and Social and Cultural consequence categories were not considered).

### 2.6 Identification of a Preliminary Flood Risk Rating (Task 6)

To identify a PFRR for the defined floodplain areas, the risk matrix presented by APEGBC (2012) for proposed developments was adopted and modified. The modifications included the addition of the customized consequence categories and ratings (Table 2-1), the re-definition of the PFRRs to assign a rating and its resultant priority to Phases 2 and 3 of the RFMP, and the shifting of the risk matrix to consider the removal of 'very low' risk within the matrix[10]. The modified risk matrix is provided in Table 2-2.

Using the modified risk matrix (Table 2-2), a preliminary risk evaluation and recommendation is assigned based on identified likelihoods and the overall consequence rating. As noted in Section 2.3, a 1:200-year return period flood event was used for all mapped or estimated floodplains, which is assumed to represent areas effected by rain, rain-on-snow, snowmelt, debris blockages and releases of flows, ice jams, sediment accumulation, and high lake level flood type events.

Blair and McPherson (1994) identify that conditions for optimal alluvial fan and floodplain development include:

- Topographic settings where streams become unconfined after emerging from constrained upland basins.
- High stream sediment loads (i.e., bed load and suspended sediment load).
- Climatic conditions capable of generating extreme stream discharges.

All of these settings are present within the RDCO. Therefore, even though climate change projections for the Okanagan region are indicating a potential for increased flood risk (Section 3.7 of the final report), the inclusion of alluvial fans and fluvial soil polygons is a considered a conservative estimate of the extent of high-magnitude, low-frequency flood events because these landforms have been created by such events.

Finally, for the PFRR, climate change is considered through the approach to identify flood-prone watercourses and/or reaches.

[10] APEGBC (2012) included a risk rating of 'very low' and 'low' within the risk matrix. For Phase 1, the separation of these two ratings was judged not to be important at the screening level; therefore, both ratings were combined into a 'low' rating.

**Table 2-2 Risk matrix to assign a preliminary flood risk rating to watercourses and bodies within the Regional District of Central Okanagan**

| LIKELIHOOD DESCRIPTION | | | PRELIMINARY RISK EVALUATION AND RECOMMENDATION | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | VH | Very High | Risk is unacceptable short-term (before next flood season) risk reduction required. **Very high priority for further risk assessment in Phase 2.** | | | |
| | | | H | High | Risk is unacceptable. **High priority for further risk assessment in Phase 2.** | | | |
| | | | M | Moderate | Risk may be tolerable. **Moderate priority for further risk assessment in Phase 2.** | | | |
| **Likelihood Description** | | **Annual Probability Range** | L | Low | Risk is tolerable. No further risk assessment recommended. | | | |
| Scenario expected on average every 200 yrs. | Very Unlikely | 0.007 – 0.004 | **L** | **M** | **M** | **H** | **H** | **VH** |
| **CONSEQUENCE CLASSIFICATION** | **Indices** | | **1** | **2** | **3** | **4** | **5** | **6** |
| | Land Use Type | | Forest Resource | Agriculture | Conservation Lands; Rural; Parks | Industrial | Commercial; Institutional; Future Commercial / Institutional | Residential; Future Residential |
| | Critical Infrastructure | | None | Trails/paths | Residential roads | Major Highways; Railways | Bridges; Schools; Water and Sewer Lines; Pumphouses; Power Substations | Hospitals; Health Centres; Assisted Living Centres; Emergency Services; Major Water Intakes; Water & Wastewater Treatment Facilities |
| | Social and Cultural | | Negligible impact | Slight impact; recoverable within days to weeks | | Moderate to high impact; recoverable within weeks to months | | Presence of places of worship, historical and archaeological sites, community centres, art galleries |
| | Total Population / Personal hardship | | <1 person; Negligible impact | <10 people; Slight impact; recoverable within days | <100 people; Moderate impact; recoverable within weeks | 100-500 people; Personal hardship usually recoverable within months | 501-2,500 people; Leaves significant personal hardship for years | >2,500 people; Irreparable personal hardship |
| | Environmental | | No channel present | Artificially channelized or culverted stream | Open channel present, but fish presence not confirmed | Fish-bearing stream | Fish-bearing stream with Kokanee Salmon presence | Contains a designated conservation area |

## 3 PRELIMINARY FLOOD RISK RATING – RESULTS

The results of the PFRR analysis for the RDCO are summarized in Section 4.3 of the final report As a reminder, the results were developed through a high-level GIS-based approach, which was intended to identify watercourses of probable concern and to prioritize further investigational effort during Phases 2 and 3 of the RFMP. The alluvial fans/floodplains and flood-prone watercourses/reaches included were considered to be a result of rain, rain-on-snow, snowmelt, debris blockages and releases of flows, ice jams, or sediment accumulation flood type events only, with dam and dike breaches not included. In addition, the floodplains were assumed to represent a 1:200-year return period flood event.

The preliminary flood risk ratings and estimated alluvial fan/floodplain areas should not be considered definitive for inclusion within local government bylaws and should only be considered for preliminary planning purposes at this time.

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# Appendix E – Maps and Preliminary Flood Risk Rating Results

REGIONAL DISTRICT of CENTRAL OKANAGAN

Whiteman Creek

W-5

Vernon Creek

Kalamalka Lake

Shorts Creek

E-2 (DLC)

Wood Lake

Lambly Creek

W-6

E-2 (KEL)

Mill Creek

Powers Creek

McDougall Creek

W-7

Mission Creek

Trepanier Creek

W-8

E-3

E-4

Peachland Creek

Okanagan Lake

E-5 (KEL)

W-9

W-10

E-5 (RDCO-E)

Bellevue Creek

W-11

**Legend**

- Flood-Prone Watercourse/Reach
- Unlikely Flood-Prone (based on Phase 1 Evaluation)
- Flood-Prone Areas
- RDCO Boundary
- Contributing Watershed Boundary

0 1 2 4 6 8 10 Kilometers

Background Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Associated Environmental

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DATE: June 2016
DRAWN BY: DA

**MAP 1: MAPPED OR ESTIMATED FLOOD-PRONE WATERCOURSES/REACHES AND FLOOD-PRONE AREAS WITHIN THE RDCO**

Regional District of Central Okanagan

Phase 1 of the Regional Floodplain Management Plan

REGIONAL DISTRICT of CENTRAL OKANAGAN

Whiteman Creek

Vernon Creek

W-5

Shorts Creek

E-2 (DLC)

Kalamalka Lake

Wood Lake

Lambly Creek

W-6

E-2 (KEL)

Mill Creek

Powers Creek

McDougall Creek

W-7

Mission Creek

Trepanier Creek

W-8

E-3

E-4

Peachland Creek

Okanagan Lake

E-5 (KEL)

W-9

W-10

E-5 (RDCO-E)

Bellevue Creek

W-11

## Legend

### Flood-Prone Stream Risk Rating

- Low
- Moderate
- High
- Very High
- Unlikely Flood-Prone (based on Phase 1 Evaluation)

### Flood-Prone Area Risk Rating

- Low
- Moderate
- High
- Very High
- RDCO Boundary
- Contributing Watershed Boundary

| Rating | Preliminary Flood Risk Rating Definitions |
|---|---|
| Very High | Risk is unacceptable short-term (before next flood season) risk reduction required. Very high priority for further risk assessment in Phase 2. |
| High | Risk is unacceptable. High priority for further risk assessment in Phase 2. |
| Moderate | Risk may be tolerable. Moderate priority for further risk assessment in Phase 2 |
| Low | Risk is tolerable. No further risk assessment recommended. |

0 1 2 4 6 8 10 Kilometers



Associated Environmental

PROJECT NO.: 2015-8202.000.000
DATE: June 2016
DRAWN BY: DA

**MAP 2: PRELIMINARY FLOOD RISK RATINGS FOR FLOOD-PRONE AREAS AND FLOOD-PRONE STREAMS WITHIN THE RDCO**

Regional District of Central Okanagan

Phase 1 of the Regional Floodplain Management Plan

**Table E-1 – Preliminary flood risk rating results for floodplain//alluvial fans within the major watersheds of the RDCO**

| Watershed[1] | Object ID[2] | Data Source[3] | Area ($km^2$) | Consequence Classification Rating[4] | | | | | | Preliminary Flood Risk Rating[5] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Land Use Type | Critical Infrastructure | Social and Cultural | Total Population / Personal Hardship | Environmental | Overall | |
| Bellevue Creek | 25 | Soils | 0.15 | 2 | 1 | 3 | 3 | 3 | 2 | M |
| | 26 | Soils | 3.82* | 6 | 5 | 6 | 5 | 4 | 5 | H |
| E-2 (DLC) | 27 | Soils | 0.05 | 6 | 3 | 4 | 2 | 3 | 4 | H |
| | 28 | Soils | 0.04 | 6 | 3 | 4 | 2 | 3 | 4 | H |
| | 29 | Soils | 0.01 | 6 | 5 | 4 | 2 | 3 | 4 | H |
| | 30 | Soils | 0.02 | 4 | 3 | 3 | 2 | 1 | 3 | M |
| | 31 | Soils | 0.07 | 2 | 3 | 2 | 2 | 3 | 2 | M |
| | 32 | Soils | 0.06 | 2 | 3 | 2 | 2 | 1 | 2 | M |
| | 33 | Soils | 0.04 | 6 | 5 | 4 | 2 | 3 | 4 | H |
| E-2 (KEL) | 34 | Soils | 0.19 | 3 | 5 | 4 | 4 | 3 | 4 | H |
| | 35 | Soils | 0.40 | 2 | 3 | 3 | 3 | 1 | 2 | M |
| | 36 | Soils | 0.01 | 2 | 1 | 2 | 2 | 1 | 2 | M |
| | 37 | Soils | 0.07 | 2 | 3 | 3 | 3 | 3 | 3 | M |
| | 38 | Soils | 0.01 | 5 | 1 | 3 | 1 | 1 | 2 | M |
| | 39 | Soils | 0.03 | 3 | 1 | 3 | 2 | 3 | 2 | M |
| | 40 | Soils | 0.05 | 5 | 1 | 4 | 2 | 3 | 3 | M |
| | 41 | Soils | 0.01 | 2 | 1 | 2 | 2 | 1 | 2 | M |
| E-5 (KEL) | 42 | Soils | 0.01 | 5 | 5 | 4 | 2 | 3 | 4 | H |
| | 43 | Soils | 0.05 | 2 | 1 | 3 | 3 | 1 | 2 | M |
| | 44 | Soils | 0.03 | 6 | 3 | 4 | 2 | 1 | 3 | M |
| | 45 | Soils | 0.06 | 4 | 3 | 4 | 3 | 1 | 3 | M |
| | 46 | Soils | 0.06 | 4 | 5 | 4 | 3 | 3 | 4 | H |
| E-5 (RDCO-E) | 47 | Soils | 0.02 | 3 | 1 | 2 | 1 | 3 | 2 | M |
| | 48 | Soils | 0.06 | 2 | 5 | 2 | 1 | 3 | 3 | M |
| Lambly Creek | 1 | Aquifer | 0.61* | 3 | 5 | 3 | 2 | 5 | 4 | H |
| | 49 | Soils | 0.04 | 3 | 1 | 2 | 1 | 3 | 2 | M |
| | 50 | Soils | 0.02 | 2 | 1 | 2 | 1 | 3 | 2 | M |
| McDougall Creek | 51 | Soils | 0.10 | 5 | 5 | 4 | 3 | 3 | 4 | H |
| | 52 | Soils | 0.04 | 5 | 3 | 4 | 3 | 3 | 4 | H |
| | 53 | Soils | 2.44* | 4 | 6 | 5 | 5 | 4 | 5 | H |
| Mill Creek | 2 | AE (2010) | 15.0* | 4 | 6 | 5 | 6 | 5 | 5 | H |
| Mission Creek | 3 | MOE (1984) | 0.40* | 4 | 5 | 4 | 4 | 5 | 4 | H |
| | 54 | Soils | 0.10 | 2 | 5 | 3 | 3 | 3 | 3 | M |
| | 55 | Soils | 0.15 | 2 | 5 | 3 | 3 | 3 | 3 | M |
| | 56 | Soils | 0.10 | 2 | 1 | 3 | 3 | 3 | 2 | M |
| | 57 | Soils | 0.03 | 2 | 3 | 2 | 2 | 3 | 2 | M |
| | 58 | Soils | 0.04 | 1 | 5 | 1 | 1 | 4 | 2 | M |
| | 59 | Soils | 0.02 | 5 | 1 | 4 | 2 | 3 | 3 | M |
| | 60 | Soils | 0.01 | 3 | 1 | 3 | 2 | 1 | 2 | M |
| | 61 | Soils | 0.02 | 2 | 1 | 2 | 2 | 3 | 2 | M |
| | 62 | Soils | 0.11 | 4 | 1 | 4 | 3 | 3 | 3 | M |
| | 63 | Soils | 0.02 | 4 | 1 | 3 | 2 | 3 | 3 | M |
| | 64 | Soils | 0.06 | 1 | 1 | 2 | 3 | 3 | 2 | M |
| | 65 | Soils | 0.08 | 4 | 1 | 4 | 3 | 3 | 3 | M |
| | 66 | Soils | 0.06 | 4 | 1 | 4 | 3 | 3 | 3 | M |
| | 67 | Soils | 0.03 | 5 | 1 | 4 | 2 | 3 | 3 | M |
| | 68 | Soils | 0.00 | 4 | 1 | 3 | 1 | 3 | 2 | M |
| | 69 | Soils | 0.03 | 1 | 1 | 1 | 1 | 3 | 1 | L |
| | 70 | Soils | 0.05 | 2 | 1 | 2 | 1 | 1 | 1 | L |
| | 71 | Soils | 0.03 | 2 | 6 | 2 | 1 | 1 | 2 | M |
| | 72 | Soils | 0.08 | 3 | 1 | 2 | 1 | 3 | 2 | M |
| | 73 | Soils | 0.01 | 3 | 1 | 2 | 1 | 3 | 2 | M |
| | 74 | Soils | 0.07 | 1 | 1 | 1 | 1 | 3 | 1 | L |
| | 75 | Soils | 0.01 | 2 | 1 | 2 | 1 | 3 | 2 | M |
| | 76 | Soils | 0.02 | 2 | 1 | 2 | 1 | 3 | 2 | M |
| | 77 | Soils | 0.01 | 3 | 1 | 2 | 1 | 3 | 2 | M |
| | 78 | Soils | 0.24 | 1 | 1 | 2 | 3 | 3 | 2 | M |
| | 79 | Soils | 0.04 | 1 | 1 | 2 | 2 | 3 | 2 | M |
| | 80 | Soils | 0.06 | 1 | 1 | 1 | 1 | 1 | 1 | L |
| | 81 | Soils | 0.01 | 3 | 1 | 2 | 1 | 3 | 2 | M |
| | 82 | Soils | 0.05 | 3 | 1 | 2 | 1 | 3 | 2 | M |
| | 83 | Soils | 0.07 | 4 | 6 | 3 | 1 | 3 | 3 | M |
| | 84 | Soils | 0.07 | 3 | 5 | 2 | 1 | 3 | 3 | M |
| | 85 | Soils | 0.05 | 3 | 4 | 2 | 1 | 3 | 3 | M |
| | 86 | Soils | 10.99 | 2 | 5 | 3 | 3 | 4 | 3 | M |
| Okanagan Lake | 24 | Flood Construction Level | 6.11* | 5 | 6 | 6 | 6 | 5 | 6 | VH |
| Peachland Creek | 87 | Soils | 0.07* | 5 | 5 | 4 | 3 | 3 | 4 | H |
| | 88 | Soils | 0.03 | 6 | 3 | 4 | 2 | 1 | 3 | M |

| Watershed[1] | Object ID[2] | Data Source[3] | Area (km$^2$) | Consequence Classification Rating[4] | | | | | | Preliminary Flood Risk Rating[5] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Land Use Type | Critical Infrastructure | Social and Cultural | Total Population / Personal Hardship | Environmental | Overall | |
| Powers Creek | 89 | Soils | 0.01 | 1 | 1 | 1 | 1 | 1 | 1 | L |
| | 90 | Soils | 0.68* | 3 | 5 | 4 | 4 | 3 | 4 | H |
| | 91 | Soils | 0.01 | 2 | 1 | 2 | 2 | 1 | 2 | M |
| | 92 | Soils | 0.31 | 3 | 3 | 3 | 3 | 1 | 3 | M |
| | 93 | Soils | 0.03 | 2 | 1 | 2 | 2 | 1 | 2 | M |
| | 94 | Soils | 0.16 | 3 | 1 | 3 | 3 | 3 | 3 | M |
| | 95 | Soils | 0.04 | 4 | 1 | 3 | 2 | 3 | 3 | M |
| | 96 | Soils | 0.22 | 4 | 3 | 4 | 3 | 1 | 3 | M |
| | 97 | Soils | 0.02 | 4 | 1 | 4 | 3 | 1 | 3 | M |
| | 98 | Soils | 0.11 | 5 | 3 | 5 | 4 | 1 | 4 | H |
| | 99 | Soils | 0.21 | 3 | 5 | 4 | 4 | 3 | 4 | H |
| Shorts Creek | 5 | Soils | 1.18* | 3 | 3 | 3 | 2 | 4 | 3 | M |
| Trepanier Creek | 100 | Soils | 0.35* | 5 | 5 | 5 | 4 | 5 | 5 | H |
| | 101 | Soils | 0.12 | 2 | 5 | 3 | 3 | 3 | 3 | M |
| | 102 | Soils | 0.02 | 2 | 4 | 2 | 1 | 1 | 2 | M |
| | 103 | Soils | 1.93 | 1 | 1 | 2 | 3 | 3 | 2 | M |
| Vernon Creek | 104 | Soils | 1.63 | 3 | 4 | 4 | 4 | 1 | 3 | M |
| | 105 | Soils | 0.02 | 2 | 1 | 2 | 2 | 1 | 2 | M |
| | 106 | Soils | 0.01 | 2 | 1 | 2 | 1 | 1 | 1 | L |
| | 107 | Soils | 0.02 | 2 | 1 | 2 | 2 | 1 | 2 | M |
| | 108 | Soils | 0.07 | 2 | 3 | 3 | 3 | 1 | 2 | M |
| | 109 | Soils | 6.81* | 3 | 6 | 4 | 5 | 5 | 5 | H |
| | 110 | Soils | 0.02 | 2 | 1 | 2 | 2 | 3 | 2 | M |
| | 111 | Soils | 0.25 | 2 | 1 | 3 | 3 | 3 | 2 | M |
| | 112 | Soils | 0.16 | 2 | 3 | 2 | 2 | 1 | 2 | M |
| | 113 | Soils | 0.08 | 2 | 1 | 2 | 2 | 1 | 2 | M |
| | 114 | Soils | 0.02 | 2 | 1 | 2 | 2 | 1 | 2 | M |
| | 115 | Soils | 0.01 | 3 | 3 | 2 | 1 | 1 | 2 | M |
| | 116 | Soils | 0.04 | 2 | 1 | 2 | 2 | 1 | 2 | M |
| | 117 | Soils | 0.04 | 2 | 5 | 2 | 2 | 3 | 3 | M |
| | 118 | Soils | 0.01 | 2 | 1 | 2 | 1 | 1 | 1 | L |
| | 119 | Soils | 0.82 | 2 | 3 | 3 | 3 | 3 | 3 | M |
| | 120 | Soils | 0.30 | 2 | 5 | 3 | 3 | 3 | 3 | M |
| | 121 | Soils | 1.39 | 2 | 4 | 3 | 4 | 1 | 3 | M |
| | 122 | Soils | 0.23 | 4 | 4 | 4 | 3 | 1 | 3 | M |
| W-5 | 19 | Soils | 0.03 | 3 | 5 | 2 | 1 | 3 | 3 | M |
| W-6 | 123 | Soils | 0.31 | 4 | 5 | 3 | 2 | 3 | 3 | M |
| | 124 | Soils | 0.03 | 6 | 5 | 4 | 1 | 3 | 4 | H |
| | 125 | Soils | 0.03 | 4 | 5 | 3 | 1 | 3 | 3 | M |
| | 126 | Soils | 0.06 | 5 | 5 | 3 | 1 | 3 | 3 | M |
| | 127 | Soils | 0.01 | 5 | 3 | 3 | 1 | 3 | 3 | M |
| | 128 | Soils | 0.02 | 3 | 1 | 2 | 1 | 3 | 2 | M |
| | 129 | Soils | 0.02 | 6 | 1 | 4 | 1 | 3 | 3 | M |
| | 130 | Soils | 0.18 | 5 | 1 | 4 | 2 | 1 | 3 | M |
| | 131 | Soils | 0.12 | 4 | 1 | 3 | 1 | 1 | 2 | M |
| | 132 | Soils | 0.06 | 3 | 3 | 2 | 1 | 1 | 2 | M |
| | 133 | Soils | 0.00 | 3 | 3 | 2 | 1 | 3 | 2 | M |
| W-7 | 134 | Soils | 0.02 | 5 | 5 | 4 | 2 | 3 | 4 | H |
| | 135 | Soils | 0.12 | 4 | 3 | 4 | 3 | 1 | 3 | M |
| | 136 | Soils | 0.04 | 6 | 3 | 4 | 2 | 1 | 3 | M |
| | 137 | Soils | 0.02 | 6 | 3 | 4 | 2 | 1 | 3 | M |
| | 138 | Soils | 0.22 | 4 | 3 | 4 | 3 | 1 | 3 | M |
| | 139 | Soils | 0.09 | 6 | 3 | 5 | 3 | 1 | 4 | H |
| | 140 | Soils | 0.07 | 5 | 3 | 4 | 2 | 1 | 3 | M |
| | 141 | Soils | 0.08 | 3 | 3 | 2 | 1 | 1 | 2 | M |
| | 142 | Soils | 0.11 | 5 | 5 | 3 | 2 | 3 | 4 | H |
| | 143 | Soils | 0.09 | 6 | 3 | 4 | 1 | 3 | 3 | M |
| | 144 | Soils | 0.23 | 5 | 4 | 4 | 2 | 1 | 3 | M |
| | 145 | Soils | 0.04 | 6 | 3 | 4 | 1 | 3 | 3 | M |
| | 146 | Soils | 0.16 | 6 | 3 | 4 | 2 | 3 | 4 | H |
| | 147 | Soils | 0.01 | 3 | 1 | 2 | 1 | 1 | 2 | M |
| | 148 | Soils | 0.05 | 6 | 1 | 4 | 1 | 1 | 3 | M |
| | 149 | Soils | 0.22 | 3 | 3 | 3 | 2 | 1 | 2 | M |
| W-8 | 150 | Soils | 1.29 | 4 | 5 | 5 | 5 | 3 | 4 | H |

| Watershed[1] | Object ID[2] | Data Source[3] | Area ($km^2$) | Consequence Classification Rating[4] | | | | | | Preliminary Flood Risk Rating[5] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Land Use Type | Critical Infrastructure | Social and Cultural | Total Population / Personal Hardship | Environmental | Overall | |
| Wood / Kalamalka Lakes | 151 | Flood Construction Level | 0.79 | 6 | 6 | 4 | 3 | 5 | 5 | H |

Notes:

1. Watersheds as delineated within Figure 1-1 of the final report.
2. Polygon reference number used for mapping purposes. The specific polygons can be identified by contacting Associated Environmental Consultants Inc.
3. Data sources from available soils mapping (soils), alluvial aquifer mapping (aquifer), reported flood construction levels for respective lakes, or existing floodplain mapping.
4. Consequence classification rating as defined through Table 4-1 of the final report. The overall rating is the weighted average for all consequence categories that is round up or down to the closest whole number (e.g. a value of 4.4 rounded to 4 and a value of 4.5 rounded to 5).
5. Preliminary Flood Risk Ratings as defined through Table 4-1 of the final report. L = Low; M = Moderate; H = High; VH = Very High.

**Table E-2 – Preliminary flood risk rating results for flood prone reaches/watercourses within the major watersheds of the RDCO**

| Watershed[1] | Total Number of Flood-prone Reaches[2] | Consequence Rating | Number of Flood-Prone Reaches per Corresponding Consequence Rating | | | |
|---|---|---|---|---|---|---|
| | | | Land Use Type | Critical Infrastructure | Environmental | Overall |
| Bellevue Creek | 1 | 1 | 1 | 1 | - | - |
| | | 2 | - | - | - | 1 |
| | | 3 | - | - | 1 | - |
| | | 4 | - | - | - | - |
| | | 5 | - | - | - | - |
| | | 6 | - | - | - | - |
| E-2 (DLC) | 0 | 1 | - | - | - | - |
| | | 2 | - | - | - | - |
| | | 3 | - | - | - | - |
| | | 4 | - | - | - | - |
| | | 5 | - | - | - | - |
| | | 6 | - | - | - | - |
| E-2 (KEL) | 26 | 1 | 3 | 8 | - | - |
| | | 2 | 9 | - | - | 6 |
| | | 3 | 7 | 1 | 26 | 8 |
| | | 4 | 1 | - | - | 8 |
| | | 5 | 2 | 17 | - | 4 |
| | | 6 | 4 | - | - | - |
| E-3 | 8 | 1 | - | 1 | - | - |
| | | 2 | 1 | - | - | 1 |
| | | 3 | 1 | - | 5 | - |
| | | 4 | 3 | - | 3 | 5 |
| | | 5 | 1 | 7 | - | 2 |
| | | 6 | 2 | - | - | - |
| E-5 (KEL) | 3 | 1 | - | - | - | - |
| | | 2 | 1 | - | - | - |
| | | 3 | 1 | - | 3 | 1 |
| | | 4 | 1 | - | - | 2 |
| | | 5 | - | 3 | - | - |
| | | 6 | - | - | - | - |
| E-5 (RDCO-E) | 3 | 1 | 1 | 3 | - | - |
| | | 2 | - | - | - | 3 |
| | | 3 | 2 | - | 3 | - |
| | | 4 | - | - | - | - |
| | | 5 | - | - | - | - |
| | | 6 | - | - | - | - |
| Lambly Creek | 30 | 1 | 17 | 26 | - | - |
| | | 2 | 7 | - | - | 20 |
| | | 3 | 6 | 3 | 23 | 9 |
| | | 4 | - | - | 1 | 1 |
| | | 5 | - | - | 6 | - |
| | | 6 | - | 1 | - | - |

| Watershed[1] | Total Number of Flood-prone Reaches[2] | Consequence Rating | Number of Flood-Prone Reaches per Corresponding Consequence Rating | | | |
|---|---|---|---|---|---|---|
| | | | Land Use Type | Critical Infrastructure | Environmental | Overall |
| Shorts Creek | 19 | 1 | 17 | 18 | - | - |
| | | 2 | 1 | - | - | 18 |
| | | 3 | 1 | - | 16 | - |
| | | 4 | - | - | 3 | 1 |
| | | 5 | - | 1 | - | - |
| | | 6 | - | - | - | - |
| Trepanier Creek | 43 | 1 | 34 | 39 | - | - |
| | | 2 | - | - | - | 37 |
| | | 3 | 8 | - | 38 | 3 |
| | | 4 | - | 1 | 5 | 3 |
| | | 5 | - | 2 | - | - |
| | | 6 | 1 | 1 | - | - |
| Vernon Creek | 45 | 1 | 22 | 29 | - | - |
| | | 2 | 7 | - | - | 26 |
| | | 3 | 8 | 2 | 41 | 11 |
| | | 4 | - | - | 4 | 5 |
| | | 5 | 5 | 14 | - | 3 |
| | | 6 | 3 | - | - | - |
| W-10 | 2 | 1 | 1 | 2 | - | - |
| | | 2 | - | - | - | 1 |
| | | 3 | - | - | 2 | 1 |
| | | 4 | - | - | - | - |
| | | 5 | - | - | - | - |
| | | 6 | 1 | - | - | - |
| W-11 | 5 | 1 | 5 | 5 | - | |
| | | 2 | - | - | - | 5 |
| | | 3 | - | - | 5 | - |
| | | 4 | - | - | - | - |
| | | 5 | - | - | - | - |
| | | 6 | - | - | - | - |
| W-5 | 1 | 1 | - | - | - | - |
| | | 2 | - | - | - | - |
| | | 3 | - | - | 1 | - |
| | | 4 | - | - | - | - |
| | | 5 | - | 1 | - | 1 |
| | | 6 | 1 | - | - | - |
| W-6 | 3 | 1 | - | 1 | - | - |
| | | 2 | - | - | - | 1 |
| | | 3 | 3 | 2 | 3 | 2 |
| | | 4 | - | - | - | - |
| | | 5 | - | - | - | - |
| | | 6 | - | - | - | - |

| Watershed[1] | Total Number of Flood-prone Reaches[2] | Consequence Rating | Number of Flood-Prone Reaches per Corresponding Consequence Rating | | | |
|---|---|---|---|---|---|---|
| | | | Land Use Type | Critical Infrastructure | Environmental | Overall |
| McDougall Creek | 8 | 1 | 4 | 7 | - | - |
| | | 2 | 2 | - | - | 6 |
| | | 3 | - | - | 8 | 1 |
| | | 4 | 1 | - | - | - |
| | | 5 | - | 1 | - | 1 |
| | | 6 | 1 | - | - | - |
| Mill Creek | 102 | 1 | 54 | 62 | - | - |
| | | 2 | 26 | - | - | 64 |
| | | 3 | 10 | 13 | 98 | 22 |
| | | 4 | 1 | - | 4 | 12 |
| | | 5 | 7 | 21 | - | 4 |
| | | 6 | 4 | 6 | - | - |
| Mission Creek | 226 | 1 | 155 | 206 | - | - |
| | | 2 | 19 | - | - | 198 |
| | | 3 | 44 | 14 | 202 | 19 |
| | | 4 | 1 | 1 | 14 | 8 |
| | | 5 | 4 | 2 | 10 | 1 |
| | | 6 | 3 | 3 | - | - |
| Peachland Creek | 29 | 1 | 24 | 23 | - | - |
| | | 2 | - | - | - | 25 |
| | | 3 | 5 | 4 | 26 | 2 |
| | | 4 | - | - | 1 | 2 |
| | | 5 | - | 2 | 2 | - |
| | | 6 | - | - | - | - |
| Powers Creek | 29 | 1 | 17 | 21 | - | - |
| | | 2 | - | - | - | 20 |
| | | 3 | 5 | 2 | 23 | 2 |
| | | 4 | 4 | 4 | 2 | 5 |
| | | 5 | - | 2 | 4 | 2 |
| | | 6 | 3 | - | - | - |

| Watershed[1] | Total Number of Flood-prone Reaches[2] | Consequence Rating | Number of Flood-Prone Reaches per Corresponding Consequence Rating | | | |
|---|---|---|---|---|---|---|
| | | | Land Use Type | Critical Infrastructure | Environmental | Overall |
| W-7 | 7 | 1 | 2 | 1 | - | - |
| | | 2 | - | - | - | 1 |
| | | 3 | 2 | - | 7 | 2 |
| | | 4 | 1 | - | - | 4 |
| | | 5 | 2 | 6 | - | - |
| | | 6 | - | - | - | - |
| W-8 | 9 | 1 | 1 | - | - | - |
| | | 2 | - | - | - | - |
| | | 3 | - | 1 | 9 | 1 |
| | | 4 | 3 | - | - | 7 |
| | | 5 | 4 | 8 | - | 1 |
| | | 6 | 1 | - | - | - |
| W-9 | 1 | 1 | - | 1 | - | - |
| | | 2 | - | - | - | 1 |
| | | 3 | 1 | - | 1 | - |
| | | 4 | - | - | - | - |
| | | 5 | - | - | - | - |
| | | 6 | - | - | - | - |
| Whiteman Creek | 14 | 1 | 10 | 10 | - | - |
| | | 2 | 4 | - | - | 10 |
| | | 3 | - | 4 | 10 | 4 |
| | | 4 | - | - | 4 | - |
| | | 5 | - | - | - | - |
| | | 6 | - | - | - | - |

Notes:

1. Watersheds as delineated within Figure 1-1 of the final report.
2. The total number of flood-prone reaches considers all watercourses (e.g. tributaries) within a watershed and is not specific to the mainstem portion of the creek alone. Flood-prone watercourses/reaches were defined as described in Appendix D of the final report.