CLIMATE CHANGE
ADAPTATION PROGRAM

Freshet Flooding and Fraser Valley Agriculture: Evaluating Impacts and Options for Resilience Study

Final Report

Funding for this project has been provided by the Governments of Canada and British Columbia through Growing Forward 2, a federal-provincial-territorial initiative. The program is delivered by the Investment Agriculture Foundation of BC.

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Growing Forward 2

British Columbia

Canada

FRESHET FLOODING AND FRASER VALLEY AGRICULTURE: EVALUATING IMPACTS AND OPTIONS FOR RESILIENCE STUDY

FINAL REPORT

Prepared for:

Fraser Valley Regional District

Fraser Valley Regional District
1 – 45950 Cheam Avenue
Chilliwack, BC

9 November 2016

NHC Ref. No. 3001164

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northwest hydraulic consultants
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Prepared for:

Fraser Valley Regional District
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Prepared by:

Northwest Hydraulic Consultants Ltd.
North Vancouver, BC

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ACKNOWLEDGEMENTS

This report was prepared for:

The Fraser Valley Regional District in partnership with the BC Agriculture & Food Climate Action Initiative

Project funding provided by:

Funding for this project has been provided in part by the Fraser Valley Regional District and in part by Agriculture and Agri-Food Canada and the BC Ministry of Agriculture through the Investment Agriculture Foundation of BC under *Growing Forward 2*, a federal-provincial-territorial initiative. The Regional Adaptation Enhancement Program is delivered by the BC Agriculture & Food Climate Action Initiative.

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In addition, NHC would like to thank the agricultural producers, local government officials and others in the Fraser Valley Region who provided information during the study.

EXECUTIVE SUMMARY

The Fraser Valley Regional District (FVRD), comprised of member municipalities Abbotsford, Chilliwack, Mission, Hope, Kent and Harrison Hot Springs, and eight electoral areas, is an agricultural 'powerhouse' within the province of BC. Agriculture in the region drives $3 billion in annual economic activity and supports 18,000 Full Time Employment (FTE) jobs.

The Valley is at risk of flooding from the Fraser River. Peak flows typically occur in May-June and flood flows are dependent on the watershed snowpack and spring weather. Previous large floods occurred in 1894 and 1948 and caused failure of diking and inundation of agricultural lands. Climate change is anticipated to increase the magnitude and frequency of annual peak flows, and shift their occurrence to earlier in the spring. Flood losses from two potential floods under present climate conditions and one future scenario (year 2100) were estimated based on mapped flood extents. A major flood event, similar to the flood in 1894, would cause over $800 million in damage to farmers' crops, buildings and equipment, and the agricultural losses and associated spin-off impacts would have an economic impact of $1.1 billion on FVRD communities.

There is a range of measures in place at the regional, sector and farm levels to mitigate flooding and increase resilience. They consist of a range of structural measures such as dikes, drainage infrastructure, sediment removal, and non-structural measures, such as floodplain bylaws and emergency preparedness plans. However, they do not provide adequate protection at the design flood level. Opportunities for improvements were identified and evaluated using a multi-criteria approach, which included consideration of the effectiveness in reducing risk. The highest performing measures were dike upgrades and improved flood storage, and to a lesser degree, early warning systems and preparedness plans. There is no single solution to increasing flood resiliency in the Valley; rather, a number of measures will need to be introduced over time.

Actions to improve preparedness and capacity for flood recovery were explored, both in the immediate aftermath of a flood as well as to ensure business continuity. Many of the currently available options center around broad financial assistance in the way of business risk management programs. However, technical assistance and funding for more specific recovery programs should be considered.

A number of opportunities for improvement are provided to project partners for reducing economic losses to the agricultural sector caused by catastrophic Fraser River flooding within the Fraser Valley Regional District.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

1 INTRODUCTION

1.1 Project Background

In 2014-2015, the Fraser Valley Regional District (FVRD) and BC Agriculture and Food Climate Action Initiative partnered to support the development of a plan for agricultural adaptation to climate change for the Fraser Valley. This planning process brought together local governments and agricultural producers to identify strategies and actions for addressing climate change impacts. Implementation of the Fraser Valley Adaptation Strategies plan (including this project) is now underway and is being overseen by a local working group.

Evaluating the potential impacts and costs to agriculture associated with freshet flooding was identified as a priority in the *Fraser Valley Adaptation Strategies* plan (CAI 2015). Given the importance of agriculture and related industries to the Fraser Valley's broader economy, protecting agriculture from flood-related disruption is of high priority to the FVRD.

The project area constitutes the agricultural lands of the FVRD, mainly concentrated in the municipalities of Abbotsford, Chilliwack, Kent and the electoral areas, each with various types and intensities of agriculture.

1.2 Project Objectives

The project objectives specified by the project partners were to:

1. Assess the overall economic value of agricultural production in the Fraser Valley with a focus on the areas at risk of flooding.

2. Evaluate the potential costs and losses for agriculture and associated businesses under one or more flood scenarios.

3. Explore options for mitigating agricultural losses, increasing resilience and speeding recovery in case of a large flood.

The project was overseen by a project management team made up of representatives from FVRD, CAI, BC Ministry of Agriculture (MoA), BC Blueberry Council (BCBC) and Fraser Basin Council (FBC).

1.3 Scope of Work

The terms of reference outlined the following specific scope of services:

1. Review existing studies (referenced in RFP) for development of suitable analysis framework.

2. Refine project parameters, provide a detailed work plan and develop framework; describe planned project methodology, identify variables for inclusion in the economic analysis including but not limited to:
    a. Agricultural assets (crops, infrastructure, livestock/ poultry)
    b. Agricultural soils/ productive capacity (immediate and long term)
    c. Secondary impacts and food security impacts (food storage, processing, supply interruptions)
3. Discuss framework and parameters with project management committee and integrate input received.
4. Carry out background research and collect data. (Meet with project partners, stakeholders and technical experts for preliminary discussions, to establish points of coordination and collaboration with related projects and activities and to gather/ consolidate existing data sources. Partners as suggested in terms of reference).
5. Carry out an economic analysis, including:
    a. Assessment of broader value of Fraser Valley agricultural sector.
    b. Assessment of economic value of overall agricultural area/assets vulnerable to flooding.
    c. Flooding losses scenarios (to evaluate potential impacts of a specific flood event).
6. Complete a scan of relevant materials related to mitigating flood impacts, strengthening resilience and recovery planning.
7. Evaluate opportunities related to mitigation of flood impacts for agriculture as well as enhancing resilience and speeding recovery in the case of flooding.
8. Complete draft report.
9. Gather and integrate feedback from key partners.
10. Complete final report.
11. Share and discuss findings as determined necessary.

As per discussions with the Project Management Team at the project initiation meeting, the geographic scope of the project encompasses the agricultural areas in the FVRD that lie in the Fraser River floodplain downstream of Hope. Upland areas of Abbotsford, with potential secondary economic effects, were also considered.

1.4 Project Reporting

The present report is issued to meet above scope Item 8 and provides a summary of work completed to date. Deliverables previously provided include:

- Detailed work plan, dated 15 October 2015.
- Economic assessment final draft report "Impacts of Freshet Flooding on Agriculture", prepared by Mr. M. Robbins and Ms. K. Zimmerman, dated 5 February 2016.
- Draft progress memo "Freshet Flooding and Fraser Valley Agriculture: Flood Mitigation, Recovery and Resilience", dated 5 February 2016.

1.5 Background Studies

A number of relevant existing studies were reviewed to inform the analysis, including:

1. **Fraser River Hydraulic Model Update – Hope to Mission. Final Report (NHC 2008a)**. In 2006, Fraser Basin Council retained NHC to develop a hydraulic model of the Lower Fraser River. This work was subsequently updated for Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) by NHC in 2008.
2. **Fraser River Design Flood Level Update – Hope to Mission. Final Report (MFLNRO 2014b).** The report summarizes recent work done to update the Fraser River Hydraulic Model in the gravel reach, including updating the design profile.
3. **Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios (MFLNRO 2014a)**. MFLNRO retained NHC to assess climate change impacts on Fraser River peak flows and develop model boundary conditions for future conditions. Model runs were performed by MFLNRO. NHC's stand-alone report was included as an Appendix.
4. **The Economic Impact of Agriculture in Abbotsford (MoA 2008)**. The report summarizes the economic impact of agriculture in Abbotsford.
5. **FVRD DRAFT Agricultural Land Use Inventory data (2011-2013 survey).** To extend the analysis in report (4) to encompass all of FVRD, the Agricultural Land Use Inventory data was used by Mr. M. Robbins.)
6. **BC Agriculture & Climate Change, Regional Adaptation Strategies Series – Fraser Valley. (CAI 2015)**. The report presents five impact areas associated with climate change, one of which is "Changing Freshet Flood Risk" that led to the present work.
7. **Agricultural Economy in the Fraser Valley Regional District. Regional Snapshot Series: Agriculture (FVRD 2011)**. The report provides a general overview of economics of agriculture in the area and discusses the land reserve, diversity, challenges, opportunities and regional food security.
8. **Discussion Document: Potential Economic & Agricultural Production Impacts of Climate Change Related Flooding in the Fraser Delta (CAI 2014)**. The document explores the range of climate-related flood risks and possible impacts on agriculture in the Fraser delta region, downstream of the FVRD area, encompassing the municipalities of Delta, Surrey and Richmond.

Other reference materials were also reviewed to explore potential options to mitigate flooding and improve resilience and recovery. Agricultural regions that have experienced flooding in the recent past were researched, such as southern Alberta, Netherlands, Scotland, England and Australia, and learnings from these jurisdictions have been incorporated throughout the report.

FBC is currently leading a broader regional initiative to develop a Lower Mainland Flood Management Strategy. As part of this multi-phase project, NHC completed a flood vulnerability assessment (Final Report, 25 April 2016 for release by FBC on 30 May 2016). Whereas agriculture is included in the FBC evaluation, the present work is more detailed and focussed on the FVRD.

2 VALUE OF AGRICULTURAL ECONOMY IN FVRD

2.1 Overview Information

The FVRD is comprised of six member municipalities (Abbotsford, Chilliwack, Mission, Hope, Kent, and Harrison Hot Springs) and eight electoral areas (A to H). The area is an agricultural 'powerhouse' within the province of BC. The District is home to 2.4% of the total land farmed in BC and 14% of the province's farms, but generates 38% of the provincial gross annual farm receipts. It is the most intensively farmed area in Canada.

The FVRD contains 71,675 ha of land in the Agriculture Land Reserve (ALR), which represents 5% of the FVRD's land base. Most of the ALR lands are located in the southern portion of the Regional District, in the fertile valley bottom of the Fraser River. Almost 30,000 ha or 42% of the ALR is vulnerable to freshet flooding. The number of hectares of land in the Agricultural Land Reserve (ALR) within each municipality and electoral area is as follows (FVRD 2011):

Location	ALR (ha)
Abbotsford	27,459
Chilliwack	16,950
Mission	1,530
Hope	357
Kent	6,579
Harrison Hot Springs	134
Electoral Areas	18,771
Electoral Area A	693
Electoral Area B	5,747
Electoral Area C	1,171
Electoral Area D	823
Electoral Area E	2,929
Electoral Area F	2,236
Electoral Area G	5,172

The FVRD's comparative advantage in agricultural production comes from high quality soils, moderate climate, and abundant water. These biophysical advantages are complemented by a location that is close to large markets.

Agriculture in the FVRD is conducted in a sophisticated manner, requiring substantial capital investment (FVRD 2011). As a primary industry, the production of food and other agricultural products provides inputs to other sectors of the economy and is also a consumer of goods and services. The agriculture and agri-food sectors contribute significantly to the Gross Domestic Product (GDP) and employment at both national and provincial levels.

Agriculture in the FVRD has shown steady real growth in the last 15 years. Between 1996 and 2011, total farm capital tripled from $2.5 billion to $7.5 billion; total gross farm receipts doubled from $535 million to $1.1 billion; and total wages and salaries paid doubled from $86 million to $173 million.

The assessment of the value of the local agricultural economy was conducted by Mr. M. Robbins and Ms. K. Zimmerman, and full details are provided in Section 2 of **Annex A**.

2.2 Economic Impact of Agriculture

To estimate the potential costs and losses for agriculture and associated businesses under one or more flood scenarios, the initial step was to assess the overall economic value of agricultural production in the Fraser Valley with a focus on the areas at risk of flooding. The approach adopted for the economic impact assessment was to first evaluate the losses in expenditures on goods and services and the loss in jobs if agricultural production ceased in the FVRD.

Most economic impact studies rely on a survey of the industry for information. With primary agriculture production, Statistics Canada conducts a census every five years that provides reliable information on revenues, employment and operating expenditures in the farming community. This information was utilized for the present work.

Economic impact studies also look at the secondary or spin-off benefits within a community. When a farm worker uses his/her wages to purchase goods in the community, it creates economic activity that spreads throughout the community. When businesses use their revenues to purchase goods and services from within the community, it creates further economic activity in the community. These 'trickle down' benefits are termed 'secondary benefits'.

Given the large size and central location of the agricultural industry in FVRD, and particularly the role of Abbotsford as a hub for agri-business and value-added business in the Lower Mainland, a simple estimate of secondary benefits would fail to capture a large part of the industry's value. In 2008, the Abbotsford Chamber of Commerce Agriculture Committee partnered with the BC Ministry of Agriculture to conduct a survey of the agri-business sector in Abbotsford (MoA 2008). The basic approach involved identifying the different agri-business activities in Abbotsford, surveying the members to obtain basic economic information (revenues, payroll and jobs) and then aggregating the results to estimate the total economic impact of the agri-business sector. The present report expands the analysis from Abbotsford to include the agri-business sector in the FVRD. The list of agri-industrial businesses in Abbotsford was updated, and combined with agri-industrial operations identified in other areas of the FVRD. The average revenue and employment for each type of operation estimated from the Chamber mail-out survey results were used to estimate the economic impact of the agri-industrial sector in the FVRD.

The estimate of the economic impact of agriculture in the FVRD is divided into an estimate of the farm-based production sector and the agri-industrial sector. To prevent double counting, expenditures by farms on products in the agri-industrial sector were counted in the agri-industrial sector only. The farm gate value of products used in value-added businesses was subtracted from the value-added sector and kept with farm production.

Figure 1 summarises the economic impact of agriculture in the FVRD (in millions of dollars).

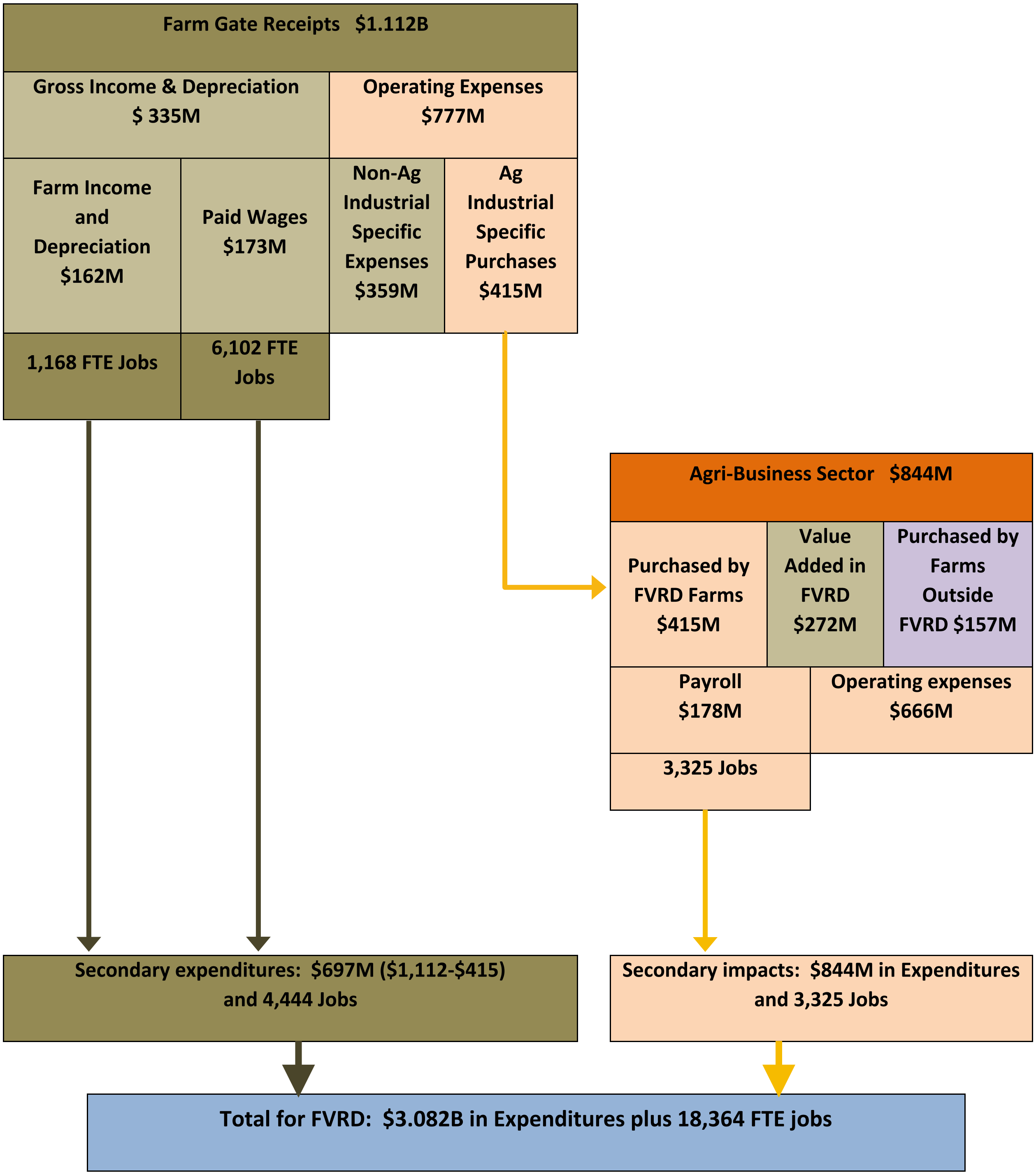

Figure 1. Summary of the economic impact of agriculture in the FVRD

As shown in the figure, Fraser Valley agriculture drives $3 billion in annual economic activity and supports 18,000 Full Time Employment (FTE) jobs. Farm-based production in the FVRD supported 11,700 FTE jobs and $1.4 billion in expenditures on goods and services. The agri-industrial and value-added sector provided an additional 3,300 FTE jobs and $1.69 billion in expenditures on goods and services. Farms outside FVRD support 18% of the agri-industrial and value-added sector.

3 FRASER RIVER FLOODING

3.1 Background

The Fraser River annual peak flow, i.e. the freshet, typically occurs between mid-May and early July. The magnitude of the peak flow is a function of the snowpack in the basin and the springtime weather, with a large snowpack in combination with sudden warm temperatures and heavy precipitation resulting in high flows.

The two largest floods on record occurred in 1894 and 1948:

- The 1894 flood had an estimated peak flow of 17,000 m^3/s at Hope, corresponding roughly to a 500 year flood. Only limited diking was in place at the time and the few berms that had been built failed. The entire floodplain was inundated and there was extensive damage to farms but overall economic impacts were relatively minor considering the sparse development in the valley at the time.
- The 1948 flood had a peak flow of 15,200 m^3/s at Hope, corresponding roughly to a 200 year flood. A more extensive system of dikes was in place by this time, but most of the ones within FVRD (Chilliwack, Kent, Abbotsford and Nicomen Island) failed. The flood had a devastating impact on agriculture with a large number of livestock lost.

Other large floods occurred in 1950 (12,600 m^3/s), 1972 (13,000 m^3/s) and 2012 (11,900 m^3/s). The 2012 flood is the fifth largest on record and had a return period of roughly 20 years. During these three floods, the dikes held and damage was largely limited to areas outside the diking. Some seepage flooding occurred on the landside of dikes and in areas where the pumping capacity was inadequate.

3.2 Existing Dikes

Over time, a network of dikes have been built to various standards to protect FVRD lands from Fraser River flooding. However, widespread flooding could still occur as a result of dike failures. Potential breach mechanisms include bank erosion, seepage and overtopping.

A recent assessment of Lower Mainland dikes for the Ministry of Forests, Lands, and Natural Resource Operations (NHC 2015a) found that a large portion of dikes along the Fraser River do not meet current standards. The Nicomen Island Dike is one of the most vulnerable dikes in the FVRD.

Although extreme flooding would occur from a dike failure, inundation may also be associated with seepage through a dike. For instance, the City of Abbotsford has mapped seepage flooding areas on the Matsqui Prairie during large freshet events.

3.3 Channel Changes

Downstream of Hope and through most of the FVRD reach, the Fraser River has a wandering gravel-bed channel. At the downstream end, near Mission, the river changes to a meandering sand-bed river with mid-channel islands. Within the gravel-bed reach, the channel has historically shifted both laterally − causing bank erosion or build-up of point bars − and vertically, causing aggradation or degradation.

Past lateral shifting has led to installation of riprap revetments that now largely restrict the natural migration of the river channel. However, in many areas the riprap is in poor condition and others have no riprap and lateral changes continue to occur. Avulsions[1] are not uncommon in the mid-channel island and gravel bar areas, and this process may alter the channel alignment such that a different section of river bank comes under attack. Hydraulic modelling has shown that avulsions can be associated with fairly large, localized changes to the design water surface profile.

To address channel aggradation, but also to extract construction material, gravel removals have been carried out in the past. Fraser River gravel removal is a polarizing subject, with strong proponents and opponents; it is not within the scope of the present work to evaluate past sediment management studies. A comprehensive summary was provided by Church (2010), in which two removal strategies were identified: 1) routine removals of material at convenient locations in volumes approximating the sediment influx (estimated to be in the order of 230,000 m^3/year); and, 2) targeted removals for profile control. The report concluded that only the first strategy would be feasible in a sustainable program.

Two-dimensional hydraulic modelling has shown that gravel removals in the form of bar-scalping have no significant impact on the design water surface profile (NHC 2004), resulting in only temporary and localized lowering of flood levels. The river design profile appears to be controlled by intermittent narrow constriction reaches that are partly confined by bedrock outcrops, revetments or other erosion resistant materials (NHC 2007).

Church (2012) indicated there is uncertainty about whether gravel accumulation over a time span of decades is the fundamental reason for a rise in water levels and suggested that channel alignment is the dominant factor. The report called for additional monitoring efforts, particularly of water levels, to better understand the long-term impacts of gravel influx.

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[1] An avulsion is when a river channel switches location, often abruptly, along part of its course.

3.4 Climate Change Impacts on Flood Flows

Climate change has the potential to impact the Fraser River flow regime. Peak river flows are anticipated to occur earlier in the spring and the magnitude and frequency of peak flood flows are expected to increase (Shreshtha et al. 2012). The Ministry of Forests, Lands, and Natural Resource Operations (2014a) reviewed potential climate change impacts on Fraser River flood levels. Based on future flow time-series developed by the Pacific Climate Impacts Consortium, NHC (2014) estimated that the present design flow, equivalent to the 1894 flood, could increase in the order of 17% under certain moderate greenhouse gas emission scenarios.

In response to more significant increases in greenhouse gas emissions, a flood equivalent to the 1894 flood of record with a present return period of roughly 500 years could have a return period in the order of 50 years at the end of the century. It should be recognized that a great deal of uncertainty surrounds these results.

Although there is a range of sea level rise estimates for BC, MFLNRO recommends adopting a 1 m sea level rise for the period 2000 to 2100 for planning purposes (Ausenco Sandwell 2011a). Modelling by MFLNRO showed that this increase in the ocean level boundary condition influences flood levels as far upstream as the Sumas River confluence, 15 km upstream of Mission (MFLNRO 2014a), potentially affecting flood levels in Matsqui Prairie and parts of Nicomen Island.

3.5 Flood Scenarios

For evaluating economic losses corresponding to severe flooding, three scenarios were considered in the present project, and are listed below. The naming and definition of Scenarios C and D are as previously defined for Fraser Basin Council's Lower Mainland Vulnerability Assessment (NHC 2016). Scenario E was selected with input from the Project Management Team.

- Scenario C – A recurrence of the Fraser River 1894 flood of record (17,000 m^3/s at Hope and approximate return period of 500 years). FVRD dikes were assumed to breach.
- Scenario D – A present-day 500 year flood incorporating a 17% flow increase for year 2100 (19,900 m^3/s at Hope) and a 1 m sea level rise, in consideration of climate change. FVRD dikes were assumed to breach.
- Scenario E – A present-day 100 year flood (14,300 m^3/s at Hope), assuming FVRD dikes in 'fair' condition or better hold and those in less than 'fair' condition fail (NHC 2015a).

Flood levels for the three scenarios are as modelled by MFLNRO (2014a) and assume that flows are confined by diking. Flood levels in the river channel were projected across the floodplain to develop inundation mapping and determine flood extents. Conservatively, flood levels were extended horizontally on the landside of dikes that were assumed to have breached. For Chilliwack, Kent and Harrison Hot Springs that have available floodplain maps (WMC 2007a and 2007b), available isolines were used to guide extension of the MFLNRO flood levels. Fraser River flood levels were not available upstream of the Highway 1 bridge at Hope and inundation mapping for District of Hope and the upstream portion of FVRD was not completed.

Mapping was readily available from the Fraser Basin Council project for Scenarios C and D but needed to be generated for Scenario E. The work was carried out in GIS and maps are included in the Maps section of this report. No consideration was given to obstructions on the floodplain (e.g. rail lines, roads) that may block or divert flood flows. Scenarios C and D are shown on a single map as there is little difference in the flood extents due to the valley topography. The purpose of the mapping is to facilitate estimating economic impacts of flooding on agriculture. The maps should not be used for setting Flood Construction Levels.

4 ESTIMATED AGRICULTURAL FLOOD LOSSES

From an agricultural perspective, the characteristics that influence the severity of flood impacts are extents, depth, duration (and velocity). The following sections represent a summary of the economic analysis of flooding on FVRD agriculture completed by Mr. M. Robbins and Ms. K. Zimmerman; the full report is provided in **Annex A**.

4.1 Approach

There is much uncertainty around the nature of a future flood event and how it will impact different farms and different production systems. Variables related to the flood event include: the flood duration, the season in which the flood occurs, the flood depths and the area inundated. Variables on the farm production side include: the type of commodity produced, the production system used, the buildings and equipment involved and the topography of the farm site. To estimate direct agricultural losses for any specific region, Thieken et al (2008) recommends considering three key variables:

- Seasonality
- Flood duration
- Commodity type

Simplifying assumptions related to these three variables were made to derive an estimate of flood losses. Based on the typical freshet hydrograph, the analysis assumes a flood that begins on June 1. A flood duration of 14 days has been shown to be the threshold for significant impact on agriculture production, and this project estimates the impact of both short duration (<14 days) and long duration ($\geq$14 days) floods under each scenario. Commodities more commonly produced in the FVRD were grouped into “commodity groups” for the purpose of this analysis.

The assessment uses information from published research papers, production guides and interviews with farmers and local production experts to estimate the percent loss from a short duration and long duration flood on each of the commodity groups. Loss estimates assume that, once they have warning of potential freshet flooding, farmers will attempt to minimize loss of revenues by: moving livestock that can easily be moved at an early stage, delaying placing broiler chicks, turkey poults and new layers, moving floriculture and nursery plants to market, and moving equipment and machinery to high ground. However, it is difficult to estimate how many livestock operations will be relocated. It was assumed that many lactating cows would unlikely be moved, leading to a disruption in milk production, and that hog operations would be challenging to move. Losses also assume that power is not interrupted, replacement plants and animals are available, there are no food safety impacts from polluted water, and farmers will plant the same commodity mix as before the flood. The summary of estimated flood losses by commodity group for floods of short and long duration is included in **Table 1,** and further discussion is provided in **Annex A**.

Table 1. Summary of estimated losses for different commodity groups

Commodity Group	Short Duration Flood Loss	Long Duration Flood Loss
Forage Corn	25%	100%
Forage Grass	50%	70%
Annuals – Vegetables	40%	75%
Perennials – Blueberries	65%	350%
Perennials – Field Nursery	0%	475%
Container Nursery	50%	50%
Field Floriculture	40%	50%
Poly Greenhouse	50%	50%
Glass Greenhouse – Vegetables	73%	73%
Glass Greenhouse – Floriculture	33%	33%
Dairy	12.5%	25%
Poultry	0%	5%
Hogs	50%	50%

With respect to building and equipment losses, post-event analysis of floods in farming areas has not identified significant losses to farm buildings. The loss to farm buildings is estimated to be 5% of the value. With dairy farms using sophisticated equipment that is not portable, and processing and on-farm sales having buildings that would experience much higher damage from flooding, estimated building losses are taken to be 7% of the value.

Clean-up and replant costs were obtained from previous research. They are incremental to labour costs and were estimated for each commodity group. Estimated clean-up costs for Forage and Annuals is $300/ha and for Perennials and Greenhouses $600/ha. Replant costs, ranging from $300/ha to $7,500/ha for different commodity groups, are summarized in **Annex A**.

The key information for the analysis of flood impacts comes from the Agricultural Land Use Inventory (ALUI), conducted in the FVRD from 2011 to 2013, and the 2011 Census of Agriculture Data. Price and yield estimates relate to 2011 as closely as possible. The flood extents for the various scenarios were overlaid on the inventory of agricultural assets to calculate areas of the different commodity groups affected and associated losses.

4.2 Results

4.2.1 Agricultural Flood Losses by Flood Scenario

Table 2 summarizes the total cost to farmers and the cost per hectare flooded for the flood scenarios with different flood durations.

Table 2. Farmer losses for the flood scenarios under different durations

Flood Scenario	Area Flooded (Ha)	Short-Duration Flood		Long-Duration Flood	
		Total Farmer Cost ($M)	Farmer Cost/Ha ($ thousands)	Total Farmer Cost ($M)	Farmer Cost/Ha ($ thousands)
Scenario C	29,029	$365	$13	$821	$28
Scenario D	29,481	$372	$13	$833	$28
Scenario E	11,977	$112	$9	$269	$23
Scenario E (Matsqui Breach alone)	3,486	-	-	$120	$34

Note: At the request of local producers, a fourth scenario equivalent to Scenario E, but with only the Matsqui dike breached, was added to the assessment.

4.2.2 Agricultural Flood Losses by Local Government Area

Table 3 summarizes the farmer costs by local government area.

Table 3. Farmer losses for the flood scenarios under different durations by local government area

	Farmer Costs ($ millions)						
	Scenario C		Scenario D		Scenario E		Scenario E (Matsqui Breach alone)
Community	Short	Long	Short	Long	Short	Long	Long
Abbotsford	149.15	282.86	149.78	284.02	1.46	6.17	119.76
Chilliwack	147.08	348.33	151.55	363.30	57.68	126.17	
Hope	0.39	0.42	0.46	0.49	0.32	0.35	
Kent	22.13	81.96	23.06	83.52	7.64	51.26	
Mission	1.19	1.42	1.21	1.47	.87	.92	
Elec. Area	45.21	106.38	45.48	106.93	43.93	84.50	
Total FVRD	**365.17**	**821.37**	**371.55**	**832.74**	**111.90**	**269.37**	**119.76**

In all cases, a long-duration flood more than doubles the cost to farmers compared to a short duration flood. This is primarily driven by the impact on perennials and the extended disruption to lactating cows.

A Matsqui Dike breach is assumed to result in a long duration flood. A flood in Matsqui Prairie was found to have a higher cost per hectare than other scenarios. This is a result of the higher proportion of perennials, particularly blueberries, and other intensive crops in the area compared to other locations.

Different parts of the agri-industrial sector would be impacted in different ways. Those in the packaging and value added sector would lose the portion of their business that relied on crops from the flooded area. Agri-industrial businesses that provide inputs to production would experience an increase in business because farms would be replanting and rebuilding damaged infrastructure.

4.2.3 Agricultural Production in the Flooded Area

Table 4 summarizes the proportion of various crops that occur in the flood extents associated with the different flood scenarios.

Table 4. Crop production type in the flooded area under different flood scenarios

Crop Production Type	Percentage of Flooded Area			
	Scenario C	Scenario D	Scenario E	Scenario E (Matsqui Breach alone)
Forage Grass/Pasture	42.8%	43.4%	48.8%	36.0%
Forage Corn	27.9%	27.3%	30.0%	23.0%
Annuals – Veg/Turf/Strawberries	7.7%	7.8%	5.2%	1.1%
Blueberries	9.8%	9.8%	6.4%	31.3%
Field Nursery/Tree	6.3%	6.2%	5.5%	3.0%
Field Floriculture	0.4%	0.4%	0.0%	0.0%
Container Nursery	0.4%	0.4%	0.2%	0.6%
Poly Greenhouse – Veg/Nursery	0.3%	0.3%	0.4%	0.1%
Poly Greenhouse – Floriculture	0.0%	0.0%	0.0%	0.0%
Glass Greenhouse – Vegetable	0.2%	0.2%	0.0%	0.9%
Glass Greenhouse – Floriculture	0.0%	0.0%	0.1%	0.0%
Farm Buildings	4.2%	4.2%	3.4%	4.0%

The shaded cells (grey colour) highlight the areas where the proportion of some crop production types is notably different between flood scenarios. The proportion of land in blueberry production that is vulnerable in a Matsqui Dike breach is much higher compared to other areas. It is also interesting to note that the 100 year flood area (Scenario E) has a higher proportion of forage land use than the flood area represented by the 1894 flood (Scenarios C and D).

4.2.4 Economic Impact of Agricultural Flood Losses on the Community

When farmers lose farm receipts, the community loses the economic benefit that those revenues create. The estimated economic impact in the community from the different flood scenarios is summarized in **Table 5**.

Table 5. Economic impact to the community from agricultural flooding

	Short-Duration Flood			Long-Duration Flood		
Flood Scenario	Farm Sales Lost ($M)	Secondary Benefits Lost[2] ($M)	Total Economic Impact ($M)	Farm Sales Lost ($M)	Secondary Benefits Lost ($M)	Total Economic Impact ($M)
Scenario C	$132	$132	**$264**	$574	$574	**$1,148**
Scenario D	$133	$133	**$266**	$580	$580	**$1,160**
Scenario E	$30	$30	**$60**	$183	$183	**$368**
Scenario E (Matsqui Breach alone)	-	-	**-**	$93	$93	**$186**

In the worst-case scenario of the 1 in 500 year flood with climate change considered, a long-duration flood would result in a $1.1 billion economic impact to the FVRD.

4.2.5 Summary

A major flood event, similar to the flood in 1894, would cause over $800 million in damage to farmers' crops, buildings and equipment, and the agricultural losses and associated spin-off impacts would have an economic impact of $1.1 billion on FVRD communities.

The estimate of farmer losses in this assessment is higher than the losses reported in other work. This result is to be expected as agriculture production per hectare in the FVRD is two to three times that of

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[2] Secondary benefits are estimated as a multiple of primary benefits. A multiple of 1.0 was used to estimate secondary economic benefits from primary economic benefits for both expenditures and jobs.

agriculture production in other areas. Estimates of the impacts of a potential flood tend to be higher than actual post-flood analysis because:

- Estimates of flood damage assume that floodwaters flow unimpeded to the full extent of the flooded area. During a flood event, internal infrastructure and uneven topography will result in patchy inundation. As a result, different farms will be affected differently in terms of flood duration and flood depth.

- Farmers will make every effort to mitigate losses. The estimates also do not consider insurance payments or government support payments to cover farm damages.

The estimated loss and economic impact reported is believed to represent a worst-case scenario.

The impact of climate change on flood extents is small in the FVRD due to its topography consisting of a relatively flat valley floor and steep valley walls. For the 500 year flood scenario, climate change only increased the flood extent by 2% and the farmer costs by 1% (assuming no inflation). Climate change has a greater effect on flood depths, however, flood depth does not have a significant impact on production losses. It may have a small effect on building losses. For the year 2100 scenario, the population, land use and development density were assumed to be the same as present.

Whereas the economic impact from a single flood event is assessed here, climate change is expected to increase the frequency of flooding, bringing additional losses over time. Also, peak river flows associated with the freshet are anticipated to occur earlier in the spring. While an earlier freshet flood would change the impact on some commodity groups, the net impact on the estimate of losses is expected to be small.

5 FLOOD MITIGATION AND RESILENCE

Information in this section on the existing flood mitigation measures within the FVRD came from discussions with local government drainage engineers and planners, Ministry of Agriculture staff, Ministry of Forests, Lands and Natural Resource Operations’ Flood Safety engineers, as well as Agriculture and Agri-Food Canada. Shortcomings in flood protection related to the agricultural sector were also identified by these groups, and formed the basis for identifying future improvement opportunities. In addition, the proposed improvement measures were informed by experiences from other jurisdictions. Input on sector-specific and farm-level measures was provided by Mr. D. Zbeetnoff.

5.1 Existing Measures

A range of flood mitigation measures are in place in the FVRD. For the present review, the measures were divided into: 1) multi-partner measures, which are implementable by the Province or other agencies and benefit the broader community; 2) sector-specific measures aimed towards protection of agricultural operations; and, 3) farm-level measures supported by individual producers.

5.1.1 Multi-partner Measures

Dikes

In the FVRD, over 100 km of dikes protect lands along the Fraser River. Some dikes follow the river banks, others are set back by several hundred metres. General information on the condition of dikes was provided in Section 3.2. Following the 1948 flood, dikes were extensively upgraded (Fraser River Board, 1963), with improvements continuing into the 1970s and 1980s under the Fraser River Flood Control Program (FRFCP). As part of emergency works, some dikes were upgraded prior to the 2007 freshet, including the Matsqui Dike in Abbotsford. The City of Chilliwack has carried out dike construction and maintenance projects, for example the realignment of a short section of the Island 22 Wing Dike (Golder 2015).

There are two main reasons for existing dikes not meeting present standards. Most of the dikes were built or upgraded to an old design profile developed by the Inland Waters Branch in 1969. More recent work based on hydraulic modelling (NHC 2008a) showed that the design profile, assuming flows are confined by dikes, is up to 1 m higher in some reaches. Secondly, provincial dike standards have become more stringent. Ultimately, dikes could fail during a recurrence of the 1894 design flood, posing a significant flood hazard. By the year 2100, climate change impacts may raise the flood profile significantly, increasing the likelihood of dikes overtopping, and exacerbating present hazards.

The gravel-bed channel between Hope and Mission is dynamic, and it was recommended that the hydraulic model be regularly updated (UMA 2001). The 2014 update (MFLNRO 2014b), based on 2008 and some 2012 bathymetry, showed localized lowering of the design profile, primarily due to two mid-island avulsions. However, MFLNRO did not adopt the revised profile for dike design, considering the channel may revert back over time to its previous configuration and higher profile.

The Province previously classified dikes as “standard dikes”, which met provincial guidelines at the time and could withstand a 200-year flood, and “non-standard dikes”, which typically protected agricultural lands and offered protection to the 50-year flood level. They were typically constructed using river dredge materials and lacked erosion protection. Along the Fraser River within the FVRD, non-standard dikes include the Sumas Lake Reclamation Dike, Nicomen Island Dike, North Nicomen Dike, Skumalasph Dike and the Silverdale Dike[3]. The dikes generally have steeper landside slopes, narrower widths and limited seepage prevention compared to FRFCP standard dikes (MWLAP 2003). During the dike upgrades between the 1960s and 1980s, cost-benefit analyses suggested that upgrading agricultural dikes was generally not economically viable, resulting in little funding made available for their improvement.

MFLNRO has developed dike patrol guidelines for diking authorities to monitor the performance of the flood control works and identify corrective actions during high water conditions. At a Mission gauge level

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[3] http://www.env.gov.bc.ca/wsd/public_safety/flood/fhm-2012/maps.html#lmd_dikemaps (Accessed 11 May 2016)

of 6.0 m GSC patrols are mobilized, at 6.5 m full daily inspections are performed and at 7.0 m crews should patrol dikes on a 24-hour basis.

In considering river processes, diking should be set back[4] sufficiently far such that no erosion protection would be required and the river would be free to meander. With the added flow conveyance area, flood levels would be lower. However, considering that many existing dikes along the Fraser River run adjacent to the channel, bank protection is an integral part of the diking and must be maintained in order to protect the existing dikes. As an example, NHC (2015b) designed bank stabilization works at a critical site at Matsqui, where the present dike would likely fail if the bank were left unattended.

Drainage Infrastructure

NHC (2015a) prepared an inventory of the hundreds of auxiliary structures (floodboxes and pump-stations) associated with the Fraser River dikes. Floodboxes rely on gravity flow and are effective only at low Fraser River water levels. Pump-station capacities are set to handle internal drainage flows and are not designed for the expected conditions during a large Fraser River flood. In the event of a dike breach, some pump-stations would likely be inundated and non-functional.

Internal flooding from seepage through or under a dike due to hydraulic pressure can increase the risk of dike failure. To address this concern, the City of Chilliwack installed 75 groundwater relief wells along the West Dike at a cost of $650,000 in 2008, from which excess groundwater is effectively piped downstream to the pumping station[5]. Where seepage boils are observed by provincial dike patrols, sand bags are placed around the boil to the level of the hydrostatic pressure to prevent further through-flow.

Sediment (Gravel) Removal

The gravel bed reach spans 55 km between Hope and Sumas Mountain. Gravel removal programs have been implemented in the past but target removals have generally not been met over the last decade or more. The main purpose of the removals has been to maintain channel capacity in the long term and to control erosion in specific areas.

Extremely large volumes of gravel (in the order of 20 million m^3 or about 100 times the annual influx) would need to be removed to have a noticeable reduction in the flood profile (NHC 2008a). Removals of this magnitude would destroy fish habitat and significantly alter the present river morphology. Church (2010) noted that sediment removal by bar scalping, the main method of removal, had little effect on local water levels. It may be possible for gravel removals to be carried out to maintain the flood profile rather than reduce it, though additional and ongoing monitoring and assessment is needed to verify this. Water level gauges installed in 2012 (NHC 2012) will help monitor long-term trends in Fraser River flood levels.

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[4] Setback dikes provide more 'room-for-the-river' and have recently been used to replace river dikes in the US and some parts of Europe.

[5] http://www.chilliwack.com/main/page.cfm?id=1551 (Accessed 6 May 2016)

Flood Storage

The Nechako River and Bridge Rivers are major tributaries to the Fraser River in its upper and middle watershed. The Fraser River Joint Advisory Board (1976) estimated that the use of the Nechako River and Bridge River storage reservoirs for flood control during the 1972 freshet reduced the peak flow of the Fraser River at Hope by approximately 1,100 m^3/s. Without the relief provided by this upstream storage, the peak flow at Hope would have reached 14,000 m^3/s, compared to the recorded peak of 12,900 m^3/s. The flow reduction likely helped to avoid the breaching of some dikes.

The Fraser River Joint Advisory Board (1976) explored different flood protection measures and recommended the construction of a diversion dam at the Lower McGregor River, diverting flows that would normally drain into the Fraser to the Peace River. By 1994, the Fraser Basin Management Program concluded that such a project would have a significant negative environmental impact and recommended against it.

Early Warning Systems

The BC River Forecast Centre provides information on the snowmelt freshet season and the outlook on flood conditions. Daily river discharges for the Fraser River are posted online during the freshet, including 10-day flow forecasts during high flows. However, the snow gauging network has undergone cut-backs and it could be argued that the remaining gauging stations are inadequate.

Starting in 2007 and during most subsequent years, MFLNRO with assistance from NHC, has carried out freshet real-time flood level forecasting. When Mission stage exceeds 5.5 m GSC, MFLNRO issues 5-day forecasted water levels on a daily basis. The information is used by the public, municipalities and agencies to plan for flood emergency response as needed. Maintaining and improving the forecasts is essential for flood response. To do so, the District should continue to read staff gauges during freshet periods and install additional gauges – preferably continuous recording gauges – as needed. NHC (2008a) developed 'Look-Up' tables that relate local flood levels along the river to the stage at Mission, which can be used to guide emergency response within the FVRD including in agricultural areas.

Some municipalities have internal flood warning systems. For instance, Abbotsford has SCADA[6] systems that trigger alarms at various levels of the river, and staff procedures have been developed to monitor the dikes during high water conditions. Chilliwack also has a SCADA system for monitoring internal water levels. The District of Kent has several well point seepage monitoring stations located inside of the dike, where water levels are monitored relative to the Fraser River water level to provide an indication of the seepage under the dike and into the District's internal drainage system.

Building and Floodplain Bylaws

Floodplain bylaws allow local governments to designate an area as a floodplain, specify the minimum elevation to which development must be constructed, and establish setback requirements. However,

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[6] SCADA stands for Supervisory, Control, And Data-Acquisition, which is a system used to monitor and control water levels.

agricultural buildings are typically exempt from Flood Construction Levels (FCLs)[7]. In most jurisdictions, including Chilliwack, Abbotsford, Mission, Kent and FVRD, farm dwellings and closed-sided livestock housing are subject to some elevation requirements.

Local governments used to be able to require buildings in the floodplain to have flood resilient features, but recent changes to the BC Building Code have restricted their ability to mandate this.

5.1.2 Sector-Level Measures

Sector-level measures have mainly focused on emergency preparedness and response as a means of reducing flood impacts. Emergency Management Guides for the pork[8], beef[9] and dairy[10] industries developed by BC Ministry of Agriculture and producer associations provide overview-level education on threats to farms, including flooding, and a list of actions that producers can take in the event of an imminent flood threat. Similar emergency management guides are currently being prepared for poultry and mixed livestock. Actions from these guides that are applicable to other commodity groups include: reviewing the potential for flooding through the BC River Forecast Centre; moving equipment, pesticides and fertilizers to higher ground; securing manure storage; ensuring generators are operational and extra fuel is on-hand.

The Ministry of Agriculture prepared a factsheet called Planning for Livestock Relocation During an Emergency[11] (June 2015) to help livestock producers to develop a livestock relocation plan. The Ministry also has an updated resource list of livestock haulers and equipment suppliers, though no formal agreements have been put into place. Marketing Boards in the regulated sectors are also involved in keeping their members informed. Plans have been developed to deal with mass livestock mortalities, emergency livestock feed and water supply, mobile dairy milking, and pre-market poultry slaughtering. These guides and plans, however, are mainly limited to livestock industries, and by addressing a range of emergency events, the information contained is at a high level and lacks specific detail applicable to flooding.

More specific guidance is available from the Province on planning for livestock relocation in the high-vulnerability Nicomen Island agricultural area. The Ministry of Agriculture-initiated study explored mitigation options to reduce flood risks, including the development of trigger water levels for protection of livestock and mobile assets (Golder 2015). Assuming that one week would be required to evacuate, and that dike overtopping governed the system response, a trigger flood stage of 6.46 m at Mission,

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[7] Flood Construction Level is the Designated Flood Level plus the allowance for freeboard and is used to establish the elevation of the underside of a wooden floor system or top of concrete slab for habitable buildings.

[8] BC Ministry of Agriculture, 2015

[9] BC Ministry of Agriculture and BC Cattlemen's Association, 2014

[10] BC Ministry of Agriculture, 2014

[11] http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/farm-management/emergency-management/factsheets/900400-1_planning_for_livestock_relocation_during_an_emergency_2015.pdf (Accessed 17 March 2016)

roughly corresponding to 11,300 m^3/s at Hope, was deemed to be the trigger point for relocation of livestock and mobile assets. Look-Up tables produced by NHC (2008) would assist other jurisdictions in relating local flood levels along the river to the stage at Mission.

5.1.3 Farm-Level Measures

On-Farm-measures can consist of both mitigation actions to modify the source of the hazard and adaptation actions to reduce the impact of flooding (by reducing the exposure to the hazard or vulnerability of the people and property affected). Some potential mitigation measures include berming fields or other high-value areas as practical and maintaining ditches to improve post-flood drainage. Adaptation measures can involve planting flood-tolerant crops, flood-proofing buildings or creating an emergency plan. No detailed survey of FVRD agricultural producers has been carried out regarding the extent to which on-farm flood mitigation measures have been implemented. As such, the information provided below represents an incomplete picture of farm-level flood readiness in the FVRD.

With the exception of farm dwellings and certain livestock structures, farm buildings are generally exempt from municipal flood-proofing requirements[12], and would therefore be built below the FCL. With respect to emergency planning, most intensive livestock and horticultural operations would be expected to have back-up generators. Some individual operators will have plans for the relocation of livestock during a flood to 'buddy farms', i.e. farms with the appropriate facilities that could accept livestock in an emergency. However, operators have indicated their reluctance to move their milking cows because disruption of the cows' routine drops milk production, and some cows may be injured in the relocation and subsequent return. Dairy farmers also believe that their insurance is not valid if the cows are moved off the property. Also, if the 'buddy farms' are located in other low-lying areas of the Fraser River floodplain, it is likely that an extreme flood threat to the FVRD will affect the viability of these options (Golder 2015).

With the threat of a large snowpack in April and warm or wet weather in early May, in addition to moving livestock, farmers are likely to carry out the following actions to reduce potential losses:

- delay placing broiler chicks, turkey poults and new layers;
- move as many floriculture and nursery plants to market as possible; and
- move equipment and machinery to high ground.

5.2 Opportunities for Improvement

Recognizing that there is a high flood hazard to low-lying lands within FVRD, this section explores how existing multi-partner level, sector level and farm level measures can be improved and new ones

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[12] http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/strengthening-farming/800-series/823400-2_flood_const_levels_and_setbacks.pdf (Accessed 9 May 2016)

introduced to increase the flood resilience of the agricultural sector in FVRD. Input on sector-specific and farm-level measures was provided by Mr. D. Zbeetnoff.

5.2.1 Multi-partner Measures

Dikes

Present dikes do not meet provincial standards and significant upgrades are recommended. By combining the results of FBC's vulnerability assessment (NHC 2016) and MFLNRO's dike evaluation (NHC 2015a), areas most urgently requiring upgrades can be identified. As the vulnerability assessment results indicate that economic losses from agriculture are generally an order of magnitude lower than from residential, commercial and institutional development, agricultural priorities will unlikely govern the upgrade selection process. However, it would be strategic for agricultural groups to partner with others where there are shared interests in upgrading dikes (i.e. in areas with both agricultural land use and larger population centres or transportation corridors).

To facilitate future dike upgrades where there is broader support, there are some considerations and actions:

- The ground in some parts of FVRD is highly porous and boils will readily form where there is a high head differential. Extensive seepage blankets would be required to control boils and seepage. In planning for future upgrades, land adjacent to dikes should be purchased, as available, to allow for larger dike footprints and establishing rights-of-way.

- Setback dikes have a number of environmental benefits and allow dike heights to be lowered given that flow conveyance is improved. However, replacing existing dikes with setback dikes would result in more land − particularly agricultural land − being located in the unprotected floodplain outside the dikes. Setback diking is unlikely to be considered, except: 1) in locations where severe erosion is occurring, and protecting existing diking is not feasible; and 2) following repeated catastrophic flooding (as could occur with climate change), requiring extensive rebuilding of severely damaged dikes.

Even if significant improvements are made to dikes, there remains the risk of dikes breaching during floods larger than the design event. With climate change impacts likely to increase flood levels, the likelihood of breaching will increase. In the long run, dikes need to be combined with other measures to prevent flooding and the associated economic losses. As there is no Provincial dike patrol program and local governments are responsible for coordinating and executing this flood preparedness activity, there should be support to ensure that trained staff is available for dike inspections in the future or standing agreements are in place with specialized consultants to assist as necessary.

Drainage Infrastructure

Extensive groundwater seepage during the Fraser River freshet has been documented along the land side of dikes in many locations including Matsqui Prairie. Although not suitable for addressing extreme flooding such as from a dike breach, seepage flooding during high-frequency events can be, to some extent, mitigated through the installation of groundwater relief wells.

Flood Storage

The storage capacity of the Kenney Dam on Nechako River and the La Joie and Terzaghi Dams on Bridge River is limited but in the event of a large flood, every effort should be made between the owners/operators (Rio Tinto Alcan, BC Hydro) and the Province to optimize flood control (NHC 2008b). In Alberta following the 2013 floods, the Province reached an agreement with TransAlta to modify operations at Ghost Reservoir for flood mitigation purposes during future high runoff periods[13].

Construction of the Lower McGregor Diversion Dam, which appeared to be a good option in the 1970's, is unlikely environmentally acceptable (Seagel and Pugh 2013). The installation of dry-storage reservoirs in the upper and mid basin areas, that would only be used during high floods, is likely to be extremely costly. However, such reservoirs have been constructed in other parts of the world. For example, in Calgary, Alberta, permitting for the Springbank Off-Stream Reservoir[14] is moving ahead so that it can be operated in tandem with the existing Glenmore Reservoir to store water volumes equivalent to the 2013 event in a future flood.

Mitigating flood risks by allowing certain agricultural lands to be inundated in order to protect more densely developed areas and downstream populations has been considered in some areas. As part of England's Making Space for Water[15] and Scotland's approach to rural flood risk management[16] program payments are provided to farmers who accept additional flooding on their land. The strategy is unlikely to be favoured in the FVRD given the relatively high value of the agricultural sector and its economic impact to the broader economy, as discussed in Section 4. It should be recognized that there is a practical limitation to raising dikes, and unless occasional catastrophic inundation and associated losses are deemed acceptable, some form of flow storage will likely need to be considered in the future.

Increased Flow Conveyance

Considering the length of the river reach through the FVRD, building a floodway is unlikely to be practical. However, opening up sloughs and side channels that were blocked off in the past has been suggested (Church 2012) in order to reduce flood levels to some extent and also improve fish habitat. Potential sloughs for consideration on the Fraser River, based in part on the volume of flood flows they could accommodate, include Nicomen and Maria sloughs. Generally, this would involve removing sediment, clearing vegetation, and adding culvert infrastructure to re-connect the slough inlet to the main channel. Some land adjacent to the sloughs may need to be acquired or internal flood protection

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[13] http://albertawater.com/work/research-projects/resilience-and-mitigation-branch (Accessed 9 May 2016)

[14] http://aep.alberta.ca/water/programs-and-services/flood-mitigation/flood-mitigation-projects/springbank-road.aspx (Accessed 6 May 2016)

[15] http://www.look-up.org.uk/2013/wp-content/uploads/2014/02/Making-space-for-water.pdf (Accessed 4 May 2016)

[16] http://www.gov.scot/resource/0039/00393714.pdf (Accessed 9 May 2016)

upgraded to facilitate this option. The hydraulic benefits and limitations of re-activating Fraser River side channels should be quantified through numerical modelling. The Fisher Slough Restoration Project in Puget Sound, WA is an example of one such project that has benefitted both farmers and fish[17].

Building and Floodplain Bylaws

Agricultural buildings have increasingly become high-value structures, such as milking barns and greenhouses. Whereas constructing to FCLs may not be feasible for many buildings in the FVRD due to the low-lying topography and predicted flood depths, encouraging flood resilient design and construction[18] is more achievable. Improved design and construction concepts include minimizing low-level windows, installing heating and electrical equipment on upper floors, using impervious cladding such as hard brick, metal and concrete, and using flood resistant insulation such as mineral wool or polystyrene. This will ensure that the value to the individual producer and the broader economy is not significantly undermined in the event of a flood. Financial incentives can be provided by senior governments to facilitate flood resilience, in view of the economic impact from agriculture in this area and secondary benefits to the larger community discussed in Section 2.

5.2.2 Sector-Level Measures

Communication of the flood hazard and risks to farmers is an important role for sector organizations. The FVRD population has not experienced flooding as a result of dikes breaching in nearly 70 years and conveying the hazard may be challenging. Workshops, during which the current and future flood risks are presented, may be helpful to obtain buy-in for flood mitigation and preparedness.

Similar to what was developed for Nicomen Island, trigger levels for relocation in other jurisdictions should be identified using the look-up tables, and the information made readily accessible. In an extreme flood scenario, relocation plans, particularly for livestock, may be difficult to execute on an individual farm basis. Conducting annual rehearsals or exercises with farmers in rotating areas to ensure the plans are effective and flood-ready would be useful. Transport of animals to safe locations is a key strategy that could be simulated with dry dairy cows (to lessen on-farm impacts), beef cattle, horses etc., thereby allowing the logistics of supplying feed and water, veterinary services, and setting up confinement areas to be worked out in practice. Golder (2015) identified a number of potential cattle relocation sites close to Nicomen Island where cattle could be moved to if it was not possible to use ‘buddy farms’.

The relocation effort will be challenged by the availability of livestock hauling trucks and cattle liners, as well as loading chutes and ramps. Some equipment will have to be brought in from elsewhere in the province or from Alberta. The relocation will be challenged by the availability of suitable shelter and feeding locations on high ground. These areas need to have the infrastructure for milking and feeding

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[17] http://www.restoration.noaa.gov/fisher_slough_project/# (Accessed 6 May 2016)

[18] Municipalities can encourage property owners to make buildings more flood resilient but they cannot require anything that exceeds the BC Building Code. An owner can voluntarily do more and a local government can require a covenant on land.

cows and proper poultry barns to accommodate birds. Mixing of different animal species and/or animals that are not used to confinement in shelter areas is likely to create management challenges. Other jurisdictions have found that arranging for the use of livestock owners' expertise has contributed greatly to improved management.

A sector-level pre-planning effort is suited to addressing these challenges, through agricultural associations and the Ministry of Agriculture. One approach is to have a letter of agreement or memorandum of understanding with potential suppliers and facilities in place before the next high freshet. Commodity associations and the Provincial ministry can also help by surveying the region to identify safe shelters for farm animals or storage facilities for agricultural products. An example of this is North Carolina Department of Agriculture's Equine Disaster Response Alliance that created an online Equine Directory for producers to find shelter for horses, including transportation and emergency evacuation information[19]. These agreements and resources would have to be revisited on a semi-regular basis to ensure that they are up-to-date and their usefulness is maintained.

Aside from emergency response, there are measures that can be undertaken on a sector-wide basis to improve flood resiliency. An example of a more holistic approach to flood planning than the guides mentioned in Section 5.1.2 is the Flood Ready Dairying Strategic Plan for the North Coast Region of NSW[20] in Australia, which identifies a range of proactive strategies for action at different stakeholder levels. Similar plans could be prepared for the larger commodity groups (e.g. greenhouses, blueberries) that do not presently have specific emergency plans.

A number of flood mitigation strategies were explored as part of the Nicomen Island Engineering Study, including improvements to conveyance and pumping infrastructure, and dike improvements. To mitigate the impacts of flooding on milking cows on Nicomen Island, it was determined that an emergency milking site would be required (Golder 2015). A conceptual plan for a temporary milking facility was developed in 2007. These types of measures require significant planning and investment.

5.2.3 Farm-Level Measures

Although there is no information on the extent to which farmers employ on-farm flood mitigation measures, it is believed that implementation of available measures is very low. Recently, a guidebook was developed for Delta's agricultural producers to support their flood preparedness and mitigation planning (NHC, 2015c and d). Whereas the nature of flooding is different in the FVRD, there may be utility in making this information available to FVRD producers and encouraging them to implement some of the measures relevant to dike breach flooding. Alternatively, the materials could be refined and made

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[19] http://www.ncagr.gov/markets/livestock/horse/EquineDisasterResponseAlliancePartners.htm (Accessed 9 May 2016)

[20] http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/530827/flood-ready-dairying-strategic-plan-north-coast-nsw.pdf (Accessed 9 May 2016)

to be more locally relevant. Workshops or information sessions could be held in order to facilitate broader use of the guidebook.

To some extent, the following measures may be helpful:

- Elevating buildings, including barns, above flood levels and using flood-resistant construction materials.
- Constructing elevated storage in agricultural buildings for valuable equipment and assets.
- Planting water-tolerant crops/varieties or cover crops to reduce erosion, such as grasses, if frequency of flooding increases.
- Installing, intensifying or maintaining tile drainage to reduce the duration of saturated soils following a flood (or during intense local rainfalls).
- Having a contingency plan for off-site relocation of stored products (e.g. from greenhouses). This includes plans for the relocation of livestock during a flood to buddy farms.
- Creating an upper floor in a poultry barn to accommodate poultry during a flood. (Hydrostatic loading would need to be considered.)
- Having temporary floodwalls (mobile or demountable) on hand to set up in case of imminent flooding.
- Installing back-up generators (above FCLs) or having alternative power sources for water evacuation, refrigeration and other processing needs.

Individual farmers will know which measures are most appropriate given their particular operations and exposure to flooding.

On any given farm, there are a range of hazardous materials that could potentially be released into the environment during a flood event. These include manure and fuel tanks, as well as pesticides, herbicides, and solvents. Options to reduce agricultural pollution in a flood event include:

- Ensuring that all livestock producers, including poultry, have plans for manure storage in the event of a flood.
- Preparing manure storage for flooding, including capping with water, manure covers or moving stockpiles to areas unlikely to flood.
- Using double-walled petroleum tanks that are less susceptible to puncture and leaks.
- Anchoring underground tanks to prevent them from floating away. Keeping tanks full of product adds weight, making it less likely that the tank will become dislodged and float away.

- Choosing a safe location for pesticides, if possible where flooding is not likely, and away from homes, ponds or streams.
- Keep pesticide storage to a minimum, for instance, by contracting to have pesticides applied, or purchasing only enough for a single season.
- Use containers that are not water-permeable to store pesticides or move water-permeable containers to higher locations if flood is imminent.
- Cap wells with heavy plastic and duct tape to keep surface water out of the well.

6 EVALUATION OF OPTIONS

6.1 Methodology

Section 5 presented existing flood mitigation measures and potential opportunities for improving these and introducing new ones. There are no obvious optimum solutions, rather a combination of measures will need to be implemented over time. To some extent, these will be selected in response to future large floods as sufficient funding may not be available for pro-active loss prevention.

The highest priority should be the prevention of loss-of-life. During the 1948 flood, 10 lives were lost. Emergency response plans, education and safe access/ egress are all key for public safety but were not specifically dealt with in the present project, which focused on the economics of agriculture within the FVRD.

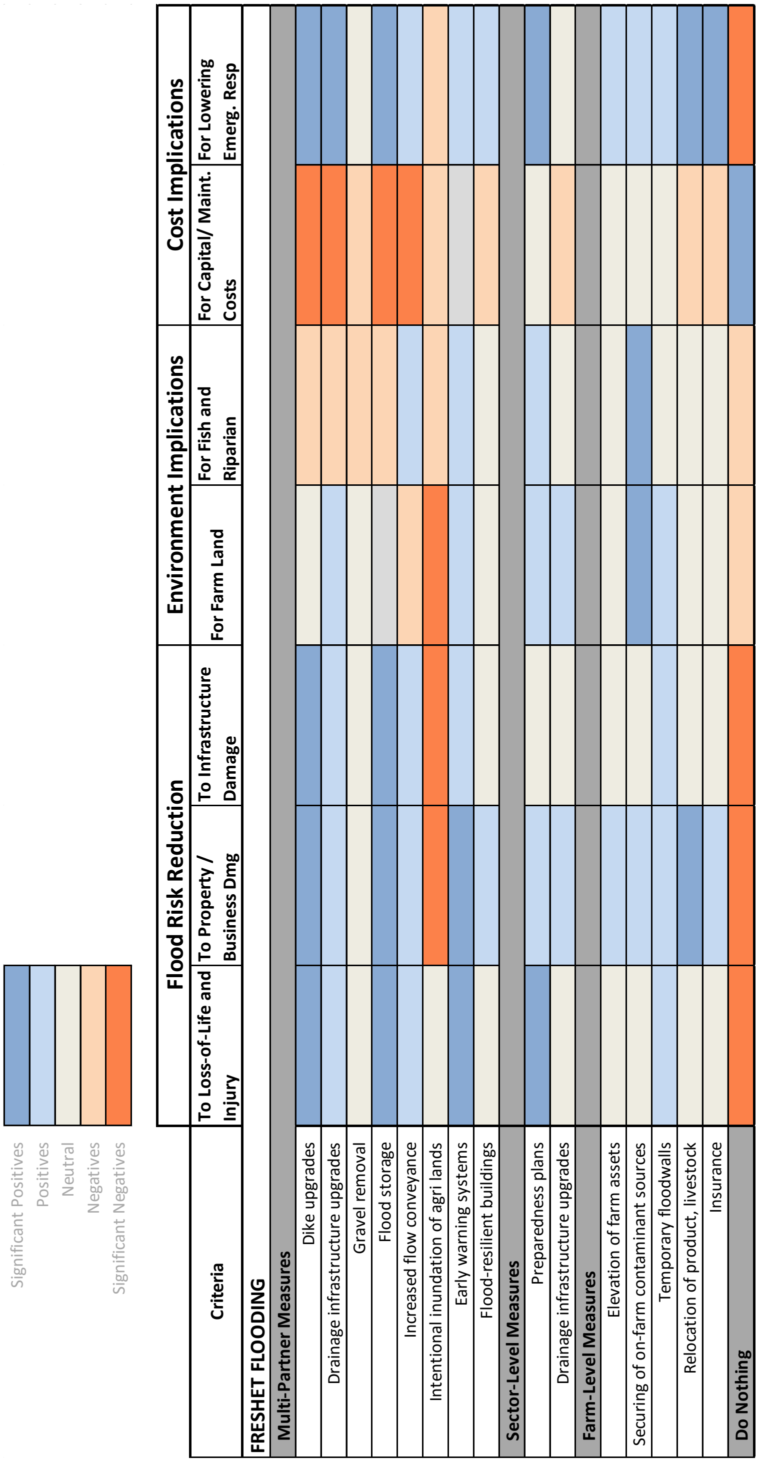
The present work forms an overview-level assessment of flood mitigation options. Costs were not developed for the various improvement opportunities and cost-benefit ratios could not be estimated based on the available information.

It is recognized that the FVRD and other local governments will not be able to implement the multi-partner measures discussed without partnership and support from other sources. However, all levels of measures were evaluated in a high-level Multi-Criteria Analysis (MCA) to assess relative advantages and disadvantages. Options were rated as significantly positive, positive, neutral, negative and significantly negative in terms of risk reduction, environmental and cost implications. The classification was partly based on input received from the Project Management Team and other project partners.

6.2 Outcome

Table 6 shows the preliminary rating of multi-partner, sector and farm level measures. Measures that mitigate flood losses and provide positive risk reduction was given a blue shading. Environmental damages are negatives (orange shading) whereas improvements are positives (blue shading). High capital and maintenance costs associated with each option are negatives (orange shading), while the reduction in emergency expenditures is positive (blue shading). The shading is relative and was based on professional judgement and discussions with local governments.

Table 6. Evaluation matrix of flood mitigation measures based on risk reduction, environmental and economic criteria.



🟦	Significant Positives
🔷	Positives
⬜	Neutral
🔶	Negatives
🟧	Significant Negatives

	Flood Risk Reduction			Environment Implications		Cost Implications	
Criteria	To Loss-of-Life and Injury	To Property / Business Dmg	To Infrastructure Damage	For Farm Land	For Fish and Riparian	For Capital/ Maint. Costs	For Lowering Emerg. Resp
FRESHET FLOODING							
Multi-Partner Measures							
Dike upgrades	🟦	🟦	🟦	⬜	🔶	🟧	🟦
Drainage infrastructure upgrades	🔷	🔷	🔷	🔷	🔶	🟧	🟦
Gravel removal	⬜	⬜	⬜	⬜	🔶	🔶	⬜
Flood storage	🟦	🟦	🟦	▒	🔶	🟧	🟦
Increased flow conveyance	🔷	🔷	🔷	🔶	🔷	🟧	🔷
Intentional inundation of agri lands	⬜	🟧	🟧	🟧	🔶	🔶	🔶
Early warning systems	🟦	🟦	🔷	🔷	🔷	▒	🔷
Flood-resilient buildings	⬜	🔷	⬜	⬜	⬜	🔶	🔷
Sector-Level Measures							
Preparedness plans	🟦	🔷	⬜	🔷	🔷	⬜	🟦
Drainage infrastructure upgrades	⬜	🔷	⬜	🔷	⬜	🔶	⬜
Farm-Level Measures							
Elevation of farm assets	⬜	🔷	⬜	⬜	⬜	⬜	🔷
Securing of on-farm contaminant sources	⬜	🔷	⬜	🟦	🟦	⬜	🔷
Temporary floodwalls	🔷	🔷	🔷	🔷	⬜	⬜	🔷
Relocation of product, livestock	⬜	🟦	⬜	⬜	⬜	🔶	🟦
Insurance	⬜	🔷	⬜	⬜	⬜	🔶	🟦
Do Nothing	🟧	🟧	🟧	🔶	🔶	🟦	🟧

Based on the evaluation, the following general comments on the options are provided (in rough priority order):

- Dike upgrades, including bank protection, are costly and generally have adverse environmental impacts, but are effective at reducing losses over large areas until they are breached. The same is true for the flood storage (dam) option.
- Early warning systems and preparedness plans can reduce risk to life and serious injury, and provide some means to protect farm assets at low costs.
- The farm-level measures have some benefit for reducing damage, with relocation of livestock and safely stored products having significant benefits.
- Opening sloughs and side channels may have some positive impact by increasing flow conveyance and improving fish habitat. However, benefits and limitations need to be quantified through hydraulic modelling.
- Gravel removals are not effective in lowering the flood profile but may have merit in terms of maintaining the flood profile (Church 2010). Long-term monitoring of Fraser River water levels are recommended (Church 2012).
- Drainage infrastructure upgrades will have nominal benefit in reducing damage during extreme floods, but can potentially assist with a faster recovery as the flood recedes.
- Flood-resilient buildings may minimize damage to the buildings but are ineffective for reducing damage to farmland and infrastructure.

7 FLOOD RECOVERY

Flood recovery refers to the actions taken to restore and rebuild impacted areas. Recovery is generally divided into short-term and long-term actions. In the context of the agricultural sector, recovery can be divided into immediate actions taken to recover from a disaster and long-term actions to restart business operations. A summary of the measures that are in place and opportunities for improvement are provided in the following sections. These were informed respectively by interviews with Ministry of Agriculture and Agriculture and Agri-Food Canada and from applicable experiences from other jurisdictions. Input to this section was provided by Mr. D. Zbeetnoff.

7.1 Disaster Recovery

Emergency Management BC approval will likely be required before producers can return to their lands. MFLNRO may need to intentionally breach dikes to speed drainage where water is ponded on the landside of dikes. Provincial government officials will likely determine which buildings are unsafe and will have to be demolished. Gas lines and electric services will be turned on when deemed safe to do so. Farmers will need to take stock of their damage, plan for clean-up and make preparations for having evacuated animals returned. Domestic water will need to be certified safe before use. There may be a need to pump ponded waters from buildings and low-lying areas.

7.1.1 Existing Measures

Some general information is available from EMBC on emergency response and recovery:

- Cleaning up after the Flood – General Information (http://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/embc/flooding/flood_clean_up.pdf)
- Response and Recovery (http://www2.gov.bc.ca/gov/content/safety/emergency-preparedness-response-recovery/emergency-response-and-recovery)

Available agriculture-specific measures to consider include:

- **Livestock Return:** Livestock that was moved at an early stage, i.e. horses, sheep, beef cows, dry dairy cows and heifers need to be returned to the farm. There is Provincial Support for Livestock Relocation during an Emergency (March, 2011)[21] – this policy allows for the relocation of livestock for eligible farm businesses during an evacuation 'alert' stage. It also allows for the reimbursement by EMBC of response costs incurred by local authorities in order to relocate livestock. Reimbursement rates, including costs for the return of relocated livestock will only be considered for a maximum of 96 hours (4 days) following an "evacuation rescind".
- **Carcass Disposal Plans:** There is a potential for animal carcasses to end up as flood debris particularly if animal relocations do not occur. Any dead animals will need to be reported and disposed of according to municipal and provincial regulations, perhaps by burial, compost or incineration. Some livestock producers complete and implement Environmental Farm Plans, which advise on mass mortality disposal planning[22].
- **Back-up Power:** It is anticipated that livestock production operations and other operations reliant on power will have well-maintained backup generators. This is particularly important because low-density neighbourhoods, such as those in the FVRD agricultural areas, and non-critical services are lowest-priority for BC Hydro in terms of restoring power.
- **Pumping Capacity:** Assuming that critical equipment was stored or moved to higher ground, farmers will generally have access to some pumps to facilitate the removal of ponded waters from their properties and, in turn, a quicker return to production.

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[21] http://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/embc/policies/livestock_relocation_policy.pdf (Accessed 9 May 2016)

[22] http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/environmental-farm-planning/efp-reference-guide/full_efp_reference_guide.pdf (Accessed 9 May 2016)

- **Feed and Water:** Clean, uncontaminated feed and water needs to be available for the animals post-flood. It is expected that emergency plans will have taken into account access to clean water and uncontaminated feed (if applicable).

Farmers have several insurance options to recover from flooding, including federal and provincial business risk insurance and risk management programs and private insurance:

- **Federal AgriStability Program**[23]**:** Delivered by the province, AS protects producers against declines in their net farming income due to market conditions, production loss or increased costs of production. A payment is made when the production margin in the program year falls more than 30% below a 5-year reference margin. AS will cover a portion of the additional income decline where hazards increase allowable expenses such as feed costs, or decreased revenue from sales such as livestock, hay or other crops[24].
- **Federal AgriInvest Program**[25]**:** AI helps producers manage small income declines of less than 15% and provides support for investments to mitigate risks or improve market income. An AI account builds as producers make annual deposits based on a percentage of their Allowable Net Sales and receive matching contributions from federal, provincial, and territorial governments. Disasters can trigger the use of these funds.
- **Federal Disaster Financial Assistance Arrangements**[26]**:** In the event of a large-scale natural disaster, the federal government provides financial assistance to provincial and territorial governments through the Disaster Financial Assistance Arrangements (DFAA), administered by Public Safety Canada. Payments are made to the province, not directly to affected individuals, small businesses or communities. Eligible expenses include, but are not limited to, evacuation operations, restoring public works and infrastructure to their pre-disaster condition, as well as replacing or repairing basic, essential personal property of individuals, small businesses and farmsteads.
- **Provincial Production Insurance**[27]**:** Production Insurance is available for most crop and plant losses caused by specified naturally occurring perils, including floods. PI coverage varies depending on the crop or plant and choice of coverage purchased. It does not provide coverage for stored crops or livestock mortality.

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[23] http://www.agr.gc.ca/eng/?id=1291990433266 (Accessed December 2015)

[24] http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/farm-management/emergency-management/factsheets/900500-1_business_insurance_and_risk_management_tools_for_agriculture_2015.pdf (Accessed 17 March 2016)

[25] http://www.agr.gc.ca/eng/?id=1291828779399 (Accessed December 2015)

[26] http://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/rcvr-dsstrs/dsstr-fnncl-ssstnc-rrngmnts/index-eng.aspx#a01 (Accessed December 2016)

[27] http://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/programs/insurance-and-income-protection/production-insurance (Accessed 17 March 2016)

- **Provincial EMBC Disaster Financial Assistance**[28]**:** In the event of a provincially declared disaster, the EMBC Disaster Financial Assistance program would compensate individuals for essential uninsurable losses and/or reimburse local governments for damaged infrastructure. For reference, the Disaster Recovery Program (DRP) was established following the 2013 Alberta floods to provide assistance to agricultural operators in order to help cover the cost of clean-up and repair of eligible agricultural operations[29]. It covered existing facilities, essential fences, certain irrigation panels, and well cleaning.
- **Private Insurance:** Private Insurance is available for livestock injuries or mortalities, temporary livestock relocations, infrastructure losses (barns, buildings, milking equipment, etc.) and other farm losses[30,31]. However, there is no requirement for farms to hold insurance against flood losses, and it is not known how many producers in FVRD are insured. Recently, overland flood insurance for residential properties has started to become available in BC; the extent to which coverage is available for FVRD farm residences is currently not known.

7.1.2 Opportunities for Improvement

The following opportunities for improvement were identified:

- **Drainage Improvements:** For short duration flood events, and depending on the existing condition of farm fields, laser levelling or installing drainage tiles in advance of a flood may help to minimize ponding water and/or facilitate surface runoff. Note that these actions would be ineffective in long-duration events, such as that of two or more weeks of freshet flooding.
- **Ditch Maintenance:** Maintaining both on-farm and municipal ditches is another proactive action that would promote faster flood recovery. Recent changes to the Fisheries Act that lift restrictions on farmers’ ability to maintain drainage ditches should be clarified and communicated to producers.
- **Improved Damage Reporting:** A quick means for farmers to report on flood damage sustained to their properties and operations would help authorities in determining the extent of damage caused by flooding and assessing potential support measures. The Flood Damage Report – Online Submission tool[32] available from the New South Wales government in Australia is a useful tool that allows farmers to quickly report flood damage to infrastructure, livestock and crops for this purpose. A similar tool could be developed for local conditions.

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[28] http://www2.gov.bc.ca/gov/content/safety/emergency-preparedness-response-recovery/emergency-response-and-recovery/disaster-financial-assistance (Accessed 9 May 2016)

[29] http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/com14476/$FILE/Disaster%20Recovery%20Program%20for%20Agricultural%20Operators.pdf (Accessed 24 February 2016)

[30] http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/farm-management/emergency-management/factsheets/900500-1_business_insurance_and_risk_management_tools_for_agriculture_2015.pdf (Accessed 17 March 2016)

[31] http://www.cooperators.ca/en/Insurance/farm/livestock-and-poultry-insurance.aspx (Accessed 13 May 2016)

[32] http://www.dpi.nsw.gov.au/content/responses/flooding-2012/flood-damage-report (Accessed 9 May 2016)

- **Local Restoration and Repair Program:** There are a number of programs in the US that assist producers with drainage channel restoration and levee repair in the aftermath of a flood. One of these is the Emergency Watershed Protection Program, which helps with restoring agricultural drainage by removing channel blockages, cleaning drainage ditches, and repairing smaller breaches in levees. Similarly, land clearing and soil restoration programs exist, such as the Emergency Conservation Program[33], which helps with sand and debris removal on fields, repairing fences, etc. Technical assistance is a large part of these programs. Programs akin to this can be established to offer an organized response to agricultural flood recovery within the FVRD.
- **Flooding Easements:** Establishing easements for controlled flood spill areas should be considered in areas particularly hard-hit by flooding. Long-term or Land Retirement Programs, such as the Emergency Watershed Protection Flood Easement program[34], are present in the US, whereby if the producer determines that selling property is the best option, and if the property is conducive to floodplain and habitat restoration, the program would allow for acquisition of the land. Alternatively, easements are acquired from the landowner to restore acreage's floodplain functions and provide habitat. Voluntary buyout options were offered in 2011 to agricultural producers affected by chronic and long-term flooding in the Shoal Lakes area in Manitoba[35]. Following severe and frequent flooding, a similar program could be considered.
- **Reduction of Environmental Restrictions:** The agricultural sector in the FVRD could pursue permissions to temporarily lift some environmental requirements in the aftermath of a flood so that farmers and land managers can carry out recovery actions without delay. In the UK, farmers or landowners did not need Natural England's prior permission to carry out emergency works on land which was affected by the 2015 floods.
- **Mass Mortality Disposal Plan:** If farmers respond to a flood by abandoning their livestock, the cleanup responsibility may end up with the local authority. A commodity-level plan should be developed in advance to address the costs associated with mass mortalities.
- **Pumping Program:** While farmers may have their own pumps, additional high-capacity pumps could be brought in to assist with drainage. Diesel-powered pumps may be necessary if electrical power is unavailable.

7.2 Business Continuity

After a flood, agricultural businesses need to resume their operations as quickly as possible. The timing of replanting and return to dairy production will depend on the duration of the flood. Some factors that may slow recovery and affect the restoration of business include: interruption of power; disruption of transportation routes that allow for delivery of feed, clean water, replacement plants, and getting goods to market; availability of replacement plants and animals; and food safety or organic certification impacts from polluted water. Access to labour and equipment for the agricultural sector will be

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[33] http://www.usda.gov/documents/fact-sheet-usda-programs-assist-individuals-small-businesses.pdf (Accessed 10 May 2016)

[34] Ibid.

[35] http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=20165&md=1 (Accessed 10 May 2016)

challenged by impacts to other sectors in an extreme flood, in that it would be competing with broader recovery efforts.

7.2.1 Existing Measures

Most of the frameworks that presently exist to assist with business continuity are centered around financial support. These include:

- **AgriRecovery Framework:** Canada's AgriRecovery Framework[36] provides a process for the federal government to compensate the agricultural sector for extraordinary, uninsurable costs that would arise in the event of an extreme flood, thereby assisting farm operations in resuming as quickly as possible following a disaster. Extraordinary costs are those that producers would not incur under normal circumstances, but that are necessary to mitigate the impacts of a disaster and/or resume farming operations as quickly as possible following a disaster. Funding implemented under AR is cost-shared on a 60/40 basis with the province.
- **Advance Payments Program:** The federal Advance Payments Program[37] (APP) can be used to minimize post-flood financial obligations by providing loans and interest subsidies for recovery costs until production can be re-established. Participating producer organizations deliver cash advances under the APP when applied for by producers, and in BC, the commodities covered include cattle, tree fruit and vegetables, among others.

7.2.2 Opportunities for Improvement

General

More frequent and intensive flooding is anticipated with climate change. Over time, with flooding events occurring more often, the opportunity for quick recovery may be reduced. To ensure that agricultural operations have resources to reinvest, a number of improvements could be considered:

- **Return of Livestock and Goods:** Letters of agreement with truck and/or equipment suppliers that are developed for flood relocations should cover the return of animals and products to the original farm.
- **Restoration of Access Routes:** While road repairs are being carried out, trucks may need to be guided through work areas to facilitate the transport of agricultural products and to allow re-supply to local markets, such as occurred in Queensland, Australia in the 2010 floods[38]. Arrangements may need to be made in advance with BC Ministry of Transportation and Infrastructure to enable this.

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[36] http://www.agr.gc.ca/eng/?id=1387480598562 (Accessed 11 May 2016)

[37] http://www.agr.gc.ca/eng/?id=1290176119212 (Accessed 6 May 2016)

[38] http://www.regionalaustralia.org.au/wp-content/uploads/2013/06/RAI-Natural-Disasters-Report-Case-Studies.pdf (Accessed 11 May 2016)

- **Pollution Control:** A major flood event would overflow manure lagoons and floodwaters would pick up other potential contaminants. Escape of manure off farms is mainly a concern where manure is generated by intensive livestock operations. Farmers returning to their lands after floods will need to make sure that their equipment and water supplies are clean. There are a number of potential actions that – if planned ahead – would support agricultural operations in getting back to business:
    - An organized effort will be required to respond to any contamination related to release of agricultural chemicals into the broader environment. It is important to have plans in place for possible cleanup requirements, with appropriate dissemination of information through a medical health officer.
    - Free well-water testing could be provided, similar to what was established in Manitoba in 2011[39], where the cost for testing to confirm that water was safe for use was subsidized for a period post-flood.
    - Farms will need to be inspected to ensure that any contaminants brought onto the farm by floodwaters have not negatively impacted food safety and/or organic certification. Planning is required to ensure availability of inspectors to resume getting goods to market. For instance, the Minnesota Department of Agriculture helps agricultural businesses with flood recovery steps that include verifying the safety of stored food products[40].
- **Crop Selection:** Farmers will not necessarily want to replant or restock the same commodities they farmed pre-flood, especially if they were observed to be sensitive to inundation or erosion. It may be helpful to have additional business planning and production, agronomy and/or soils expertise available to producers in the near-term after a flood event to assist them to move to other commodities, particularly if they meet market (and profitability) needs.

Rebuilding

Damage to some farm buildings may be beyond repair and those structures will need to be rebuilt. This circumstance presents an opportunity to make the new building more flood resilient. However, flood recovery funding should not be limited to actions that restore agricultural land to the state it was in before flooding took place. Future resiliency can be encouraged through incentives. For instance, the Farming Recovery Fund set up for farmers in the December 2015 UK floods, covers work to re-site or re-locate on the basis of improved positioning away from river edges, raising parapets or relocating to a less vulnerable access point in the field[41].

With interest and available resources, producers may initially consider relocating a building, particularly if it contains high-value assets, to a less vulnerable part of the property or another property altogether. Based on general flood-resilient design and construction principles, the building could be elevated (on a

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[39] http://www.cfib-fcei.ca/english/article/3165-2011-flood-compensation-programs-for-business-and-agricultural-producers.html (Accessed 9 May 2016)

[40] http://www.mda.state.mn.us/about/aer/flooding/fldrecagfdbiz.aspx (Accessed 6 May 2016)

[41] https://www.gov.uk/government/news/recovery-fund-for-flood-affected-farmers-opens (Accessed 10 May 2016)

pad or stilts) such that its critical elevation is above the design flood level. Exterior finishes (brick, metal, concrete) that are more flood resilient could be used in construction. Building utilities and electricals should ideally be raised relative to ground levels to reduce their susceptibility in a future flood. Neither building elevation nor materials are mandated at present (except for elevating farm dwellings and some livestock structures) but would improve the lifespan of the new structure. Developing a flood-proofing guidance document that is specific to agricultural buildings (farm storage structures, grain cribs, livestock barns, greenhouses, etc.) may be useful.

Financial Support

Recognizing that small business play a big role in the Alberta economy, the Province established the Alberta Flood Recovery Loan Guarantee Program for businesses following the 2013 floods. The program was eligible to agricultural producers, to provide them with long-term assistance to help stabilize operations and rebuild flood-damaged property.[42] Alberta also created the Flood Recovery Interest Rebate Program[43], which was eligible to agricultural producers who took loans under the loan guarantee program, and provided rebates of four percent interest. Both these programs helped operations get back to business as quickly as possible, and could be considered for BC following a flood.

8 CONCLUSIONS

Based on the work completed, the following main conclusions are drawn:

1. The total economic impact of agriculture in the FVRD exceeds 3 billion in expenditures and over 18,000 FTE jobs.
2. Forty percent (40%) of lands within the ALR are vulnerable to flooding.
3. Fraser River dikes do not presently meet provincial standards, and climate change impacts are likely to increase flood hazards.
4. Agricultural flood losses are primarily a function of seasonality, flood duration and commodity type.
5. A number of broad regional, agricultural sector and farm level flood mitigation measures are in place but currently do not provide adequate protection.
6. There is no single solution to increasing flood resiliency in the valley; rather, a number of measures will need to be introduced over time.

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[42] http://www.alberta.ca/flood-recovery-loan-guarantee-program.cfm (Accessed 9 May 2016)

[43] http://www.alberta.ca/alberta-flood-recovery-interest-rebate-program.cfm (Accessed 9 May 2016)

9 KEY OPPORTUNITIES FOR IMPROVEMENT

9.1 Flood Mitigation and Resilience

9.1.1 Multi-partner

- Implement upgrades to critical dikes, including their erosion protection, to present standards[44] .
- Support the dike patrol measures implemented by local governments as developed by the Province. Ensure that trained staff is available for dike inspections in the future, or standing agreements are in place with specialized consultants to assist as necessary.
- Maintain and update the (MFLNRO) Fraser River hydraulic model as a key tool for simulating the design profile and forecasting flood levels.
- Maintain and expand the (MFLNRO) flood level forecasting system by continuing to read staff gauges during freshet periods and facilitating the installation of additional gauges (preferably continuous reporting gauges). Monitor water levels over time.
- Undertake modeling of the FVRD river reach in 2D (to allow refinement of the design flood profile for the north and south river banks) as there are significant flood level variations between the two banks.
- Develop a program to monitor changes to river morphology and/or the riverine ecosystem that may result from sediment removals.
- Develop detailed, up to date floodplain maps for FVRD to more accurately define flood hazards (taking advantage of current National Disaster Mitigation Program funding).
- Address less extreme flooding – such as seepage – through installation of groundwater relief wells (where suitable).
- Evaluate benefits and limitations of opening up sloughs and side channels that were blocked off in the past (for improvement of flow conveyance/co-benefit of improved fish habitat).
    - Sloughs for initial consideration (based in part on the volume of flood flows they could accommodate) include Nicomen and Maria sloughs.
- Continue to participate in the Fraser Basin Council's initiative to develop a flood management strategy for the Lower Mainland.
- Encourage and support flood resilient design and construction for agricultural buildings including:
    - Minimizing low-level windows, installing heat and electrical equipment on upper floors, using impervious cladding, using flood resistant insulation etc.
    - Availability of incentives would likely increase adoption of flood resilient construction.

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[44] Upgrades will not protect against floods larger than the design event, which is expected to occur more frequently in the future as a result of climate change impacts on the Fraser River flow regime. There is a practical limit to raising dikes and other flood mitigation measures must also be considered.

9.1.2 Agriculture sector level

- Coordinate workshops to present the current and future flood risks (to improve knowledge of impacts and obtain buy-in for flood mitigation and preparation actions).
- Identify trigger levels for relocation in various sub-areas of the Fraser Valley (using the look-up tables and the information made readily available).
- Prepare plans [proactive strategies] for larger commodity groups that do not currently have specific emergency plans (e.g. blueberries, greenhouses).
- Develop collective livestock relocation plans and conduct periodic rehearsals or exercises with producers in rotating areas to ensure the plans are effective and flood ready:
    - Develop letters of agreement/memorandums of understanding with potential suppliers and facilities (for moving and housing livestock).
    - Survey the region to identify safe shelters for farm animals or storage facilities for agricultural products.
    - Revisit agreements/resources on a semi-regular basis to ensure they are up to date (and usefulness is maintained).
    - Identify any key measures out of Nicomen Island plan (particularly when other plans are completed) to identify high priority sector level needs (e.g. temporary milking facility).

9.1.3 Farm-level

- Develop a concise pamphlet for FVRD agricultural producers regarding flood hazards preparation for an imminent flood, evacuation, recovery from a flood and financial options.
- Refine materials from Delta farm-level guidebook (for improved FV relevance).
- Undertake workshops/information sessions to facilitate broader use of the guidebook (and/or other materials related to individual farm preparedness and mitigation actions).
- Develop a specific handout/fact sheet (and possibly cost-share incentives) for actions that will reduce potential for agricultural pollution in the case of a flood event.

9.2 Flood Recovery

9.2.1 Disaster recovery

- Implement drainage improvements and maintenance:
    - Undertaking laser leveling or installing tile drains on farm fields in advance of a flood can help to minimize ponding and facilitate surface runoff in short-duration, minor flood events.
    - Maintain both on-farm and municipal ditches (to promote faster flood recovery).
    - Clarify and communicate recent changes to the Fisheries Act that alter (some) restrictions on farmers' ability to maintain drainage ditches.
- Develop an efficient means (ahead of flooding) for farmers to report on flood damage sustained to their properties (e.g. Flood Damage Report On-line Submission tool).
- Create a local restoration and repair program that is positioned to respond following a flooding event (an organized response to: restoring agricultural drainage, cleaning drainage ditches,

removing sand and debris from fields, repairing fences and – primarily – supplying technical assistance post-flood).

- Consider establishment of program for flooding easements.
- Develop a pumping program to ensure pipes and high capacity pumps are available to assist with drainage (identify equipment availability and offer technical assistance for proper operation).

9.2.2 Business continuity

- Ensure agreements with truck/equipment suppliers for livestock relocation also covers the return of animals and products to the home farm.
- Create advance arrangements (with Ministry of Transportation) to ensure that agricultural products can be moved through road repair areas to get to market.
- Initiate a program to support producers to proactively plan to prevent potential pollution in the event of a flood.
- Develop clear plans for (post-flood) supports for agricultural operations with ensuring equipment and water supplies are clean:
    - Organized process for response, cleanup and information dissemination in the case of contamination related to release of agricultural chemicals.
    - Provision of free well-water testing for a period following a flood.
    - Ensure that inspectors are available to producers (in a timely fashion) to ensure that contaminants haven't negatively impacted food safety/organic certification.
- Establish a "Farming Recovery Fund" to provide both technical services and incentives for producers to rebuild more resilient operations (possibly re-siting to less vulnerable locations, increasing building elevations, flood resilient exterior finishes etc.).
- Model post-flood financial support programs on those offered by Alberta in 2013 (Flood Recovery Loan Guarantee Program and Flood Recovery Interest Rebate Program).

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Annex A: Impacts of Freshet Flooding on Agriculture

Fraser Valley Regional District

Impacts of Freshet Flooding on Agriculture

Final Draft Report
February 5, 2016

Prepared by: Mark Robbins
Kathleen Zimmerman

Executive Summary

The Fraser Valley Regional District (FVRD) is an agricultural powerhouse within the province. The district is home to 2.4% of the total land farmed in BC and 14% of the province's farms, but generates 38% of the provincial gross annual farm receipts. It is the most intensively farmed area in Canada.

The FVRD's comparative advantage in agriculture production comes from high quality soils, moderate climate, and abundant water. These biophysical advantages are complemented by a location that is close to large markets. The region has a comparative advantage in raspberries for the mild climate and well drained soils; blueberries for season extension; nursery for growth rate; and dairy for forage production.

Agriculture in the FVRD has shown steady real growth in the last 15 years. Between 1996 and 2011 total farm capital tripled from \$2.5 billion to \$7.5 billion; total gross farm receipts doubled from \$535 million to \$1.1 billion; and total wages and salaries paid doubled from \$86 million to \$173 million.

Agriculture in the FVRD drives \$3 billion in annual economic activity and supports 18,000 FTE jobs. Farm based production supports 11,700 FTE jobs and \$1.4 billion in expenditures on goods and services. The agri-industrial and value added sector provides an additional 3,300 FTE jobs and \$1.69B in expenditures on goods and services. Farms outside FVRD support 18% of the agri-industrial and value-added sector.

A major flood event, similar to the flood in 1894, would cause over \$800 million in damage to farmers' crops, buildings and equipment and have an economic impact of \$1.1 billion on FVRD communities.

This study estimates the impact on agricultural production of four flooding scenarios.

1. A repeat of the 1894 Freshet flood with today's conditions. This is a 1 in 500-year freshet flood. All dikes are assumed to breach. [Flood Scenario C]
2. A repeat of the 1894 flood including the impacts of climate change. All dikes are assumed to breach. [Flood Scenario D]
3. A 1 in 100-year freshet flood. It assumes dikes in 'fair' condition or better hold, and those in less than 'fair' condition fail. [Flood Scenario E]
4. A 1 in 100 year freshet flood assuming the Matsqui dike failed. [Flood Scenario E - variant]

The freshet flood is assumed to occur on June 1. The most critical characteristic of a flood, in determining losses, is the duration of the flood. The first three scenarios are analyzed for a short duration flood (<14 days) and a long duration flood (>14 days). A Matsqui breach is assumed to be a long duration flood.

The following table is a summary of the total farmer costs and farmer costs per hectare.

		Short Duration		Long Duration	
Flood Scenario	Hectares Flooded	Total Farmer Cost ($M)	Farmer Cost/Ha ($ thousands)	Total Farmer Cost ($M)	Farmer Cost/Ha ($ thousands)
Scenario C	29,029	$ 365	$ 13	$ 821	$ 28
Scenario D	29,481	$ 372	$ 13	$ 833	$ 28
Scenario E	11,977	$ 112	$ 9	$ 269	$ 23
Scenario E - variant	3,486			$ 120	$ 34

Total farmer costs by local government area are:

	Farmer Costs ($ millions)						
	Scenario C		Scenario D		Scenario E		Scenario E - variant
Community	Short	Long	Short	Long	Short	Long	Long
Abbotsford	149.15	282.86	149.78	284.02	1.46	6.17	119.76
Chilliwack	147.08	348.33	151.55	363.30	57.68	126.17	
Hope	.39	.42	.46	.49	.32	.35	
Kent	22.13	81.96	23.06	83.52	7.64	51.26	
Mission	1.19	1.42	1.21	1.47	.87	.92	
Elec. Area	45.21	106.38	45.48	106.93	43.93	84.50	
Total FVRD	365.17	821.37	371.55	832.74	111.90	269.37	

Farmer costs by hectare by local government area are estimated to be:

	Farmer Costs/Ha ($ thousands)						
	Scenario C		Scenario D		Scenario E		Scenario E - variant
Community	Short	Long	Short	Long	Short	Long	Long
Abbotsford	13.7	25.9	13.7	26.0	4.3	18.3	34.4
Chilliwack	15.1	35.8	15.1	35.6	10.5	22.9	
Hope	4.3	4.6	4.2	4.4	2.6	2.9	
Kent	5.8	21.6	5.9	21.4	4.9	32.8	
Mission	4.8	5.7	4.9	5.9	3.2	3.4	
Elec. Area	10.6	25.0	10.6	25.0	10.5	20.3	
Avg. FVRD[1]	12.6	28.3	12.6	28.2	9.3	22.5	

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[1] Weighted Average

The local government areas with the most intensive agriculture, particularly perennials (nursery and blueberries), have the highest farmer costs/ha. Long duration floods more than double the farmer costs/ha in the intensively farmed areas.

Different parts of the agri-industrial sector would be impacted differently. Those in the packaging and value added sector would lose the portion of their business that relied on crops from the flooded area. Agri-industrial businesses that provide inputs to production would experience an increase in business because farms would be replanting and rebuilding damaged infrastructure.

When farmers lose farm receipts, the community loses the economic benefit that those revenues create. It is estimated that the different flood scenarios would have the following economic impact in the community:

Economic Impact to the Community of Flooding Events ($M)						
Flood Scenario	Short Duration			Long Duration		
	Farm Sales Lost	Secondary Benefits Lost	Economic Impact	Farm Sales Lost	Secondary Benefits Lost	Economic Impact
Scenario C	$132	$132	$264	$574	$574	$1,148
Scenario D	$133	$133	$266	$580	$580	$1,160
Scenario E	$30	$30	$60	$183	$183	$368
Scenario E - variant				$93	$93	$186

In the worst-case scenario, a major long-duration flood would result in a $1.1 billion economic impact to the FVRD.

This estimate of farmer losses is higher than other studies have reported. This result is expected as agriculture production per hectare in the FVRD is two to three times that of agriculture production in the other areas studied.

Estimates of the impacts of a potential flood tend to be higher than actual post flood analysis because:

- Estimates of flood damage assume that flood waters flow unimpeded to the full extent of the flooded area. During a flood event, internal infrastructure and uneven topography will result in water flowing unevenly across the flood area. As a result different farms are affected differently in terms of flood duration and flood depth.
- Farmers will make every effort to mitigate losses.

The estimated loss and economic impact in this report should be considered a worst case scenario.

Outline

1. Overview of Agriculture in the FVRD

The Fraser Valley Regional District (FVRD) is an agricultural powerhouse within the province. The district is home to 2.4% of the total land farmed in BC and 14% of the province's farms, but generates 38% of the provincial gross annual farm receipts (39)(40). It is the most intensively farmed area in Canada[2].

The FVRD's comparative advantage includes the three cornerstones of agricultural production: high quality soils, moderate climate, and abundant water. These biophysical advantages are complimented by a location that is close to large markets. The agricultural sector in the FVRD is also well supported by research, education and extension services[3] located in the region.[4]

The climate, soil and water provide the region with a comparative advantage in several agricultural commodities: raspberries for the mild climate and well drained soils; blueberries for season extension; nursery for growth rate; and dairy[5] for forage production. Proximity to market supports local sales of vegetables, floriculture and nursery crops. Easy access to transport enables blueberry, floriculture and nursery products to reach export markets.

The FVRD farmers are able to take advantage of the established air, rail and port facilities in the Metro Vancouver region, as well as nearby border crossings into the US. International trade agreements continue to lower trade barriers for Fraser Valley agricultural products, including two recent trade agreements for blueberries with China and South Korea (47).

1.1 The Land Base for Agricultural Production

The FVRD contains 71,675 ha (22) of land in the Agriculture Land Reserve (ALR), which represents 5% of the FVRD's land base. The breakdown of ALR land area by jurisdiction is provided in **Table 1**. Most of the ALR lands are located in the southern portion of the Regional District, in the fertile valley bottom of the Fraser River (20). Almost 30,000 ha or 42% of the ALR is vulnerable to freshet flooding.

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[2] FVRD produced approximately $17,500/ha in gross farm gate receipts in 2011. By comparison, the BC average was $1,124/ha, and the Niagara region of Ontario produced $8,046/ha in gross farm gate receipts (Statistics Canada, 2011).

[3] Extension in agriculture refers to the transfer of research and knowledge to the farm level. This is usually done by the provincial Ministry of Agriculture or the education/research institutions.

[4] E.g. the Pacific Agri-Food Research Centre in Agassiz, the UBC Dairy Education and Research Centre in Agassiz, the University of the Fraser Valley's agriculture programs in Chilliwack and the largest regional office of the BC Ministry of Agriculture.

[5] The climate and the soils provide the exceptional growing conditions for the cool season grasses and forage corn that feed dairy cows. The quality of the feed is one of the reasons why the FVRD ranks as one of the best regions in the world for milk production (BC Ministry of Agriculture, 2013).

Table 1. ALR Land Area by Jurisdiction

Jurisdiction	Land Area (ha)	Land Area (%)
Abbotsford	27,459	38
Chilliwack	16,950	24
Hope	357	0
Kent	6,579	9
Mission	1,530	2
Harrison Hot Springs	134	0
Electoral Areas	18771	26
Electoral Area A	693	
Electoral Area B	5,747	
Electoral Area C	1,171	
Electoral Area D	823	
Electoral Area E	2,929	
Electoral Area F	2,236	
Electoral Area G	5,172	

Chilliwack has some of the highest number of frost-free days in the province[6]. The region experiences approximately 1,700 mm of precipitation a year, with most of it falling between October and April. The significant rainfall levels replenish local aquifers, which are then used for irrigation purposes during the summer months (50). The lowlands along the Fraser River are protected from high water levels by ditches, dikes and pumps in the spring and winter. In contrast, in the summer, Fraser River water is pumped into the ditches for irrigation purposes. The moderate climate plus access to abundant water supplies makes agriculture production in the FVRD resilient to many impacts of climate change.

The area of farmland that is irrigated increased by 41% from 8,003 ha in 1996 to 11,277 ha in 2011 (22). The increase corresponds to the growth in high value crops that are dependent on summer irrigation for optimum growth.

1.2 Agricultural Commodities Produced in FVRD

FVRD farms produce a diversity of crops and livestock, and the region is the first or second leading producer in the province in terms of many key commodities (**Table 2**).

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[6] https://www.veseys.com/ca/en/learn/reference/frost/canada

Table 2. FVRD Production by Commodity Type and Ranking in BC (40)

Commodity/Category	% BC Total	Rank in BC
Blueberries (ha)	39%	2nd
Broccoli (ha)	79%	1st
Brussels sprouts (ha)	95%	1st
Cauliflower (ha)	51%	1st
Dairy Cows	60%	1st
Goats	23%	1st
Greenhouse Floriculture Area (sq. m.)	33%	2nd
Greenhouse Vegetable Area (sq. m.)	27%	2nd
Hens and Chickens	63%	1st
Mushroom Growing Area (sq. m.)	42%	2nd
Nursery Area (ha)	37%	1st
Farms with Organic Products	13%	2nd
Raspberries (ha)[7]	81%	1st
Sod (ha)	45%	1st
Total Area in Vegetables (ha)[8]	33%	2nd
Turkeys	56%	1st

1.3 Agriculture – A Dynamic Business Sector

The agriculture sector is large, it is growing and it is changing.

The total area farmed in the FVRD has increased by 17%, from 54,454 ha in 1996 to 63,838 ha in 2011 (22). If this trend continues, by 2021, another 7,000 additional hectares will come into production, accounting for almost all the unused farmland currently in the ALR within the FVRD.

Agriculture in the FVRD has shown steady real growth in the last 15 years. Total farm capital tripled from $2.5 billion in 1996 to $7.5 billion in 2011; total gross farm receipts doubled from $535 million in 1996 to $1.1 billion in 2011; and total wages and salaries paid also doubled from $86 million in 1996 to $173 million in 2011. Farm gate receipts in 2011, inflation adjusted to 1996[9], were $793 m. This represents real growth in output of 48% and an annual compounded rate of real growth in output of 2.66%. (Note: See Section 6.1.)

In the residential zone, this type of growth on a fixed land base is called densification. In the farming zone, it is called intensification. For agriculture to continue to grow at 2.66% annually on a fixed land base, it must produce more

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[7] Raspberry acreage in the FVRD also represents 47% of all raspberry acreage in Canada.

[8] Not including potatoes.

[9] http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ46a-eng.htm

from the same amount of land. **Table 3** shows the average farm gate receipts per hectare for different crops.

Table 3. Annual Farm Gate Receipts for different Commodity Types

Commodity Type	Estimated Annual Farm Gate Receipts per Hectare in Production[10]
Forage Grass/Pasture/Cereal	$3,040
Forage Corn	$3,120
Annuals - Veg/Turf/Strawberry	$7,500
Blueberries	$26,260
Field Nursery/Tree	$30,000
Field Floriculture	$30,000
Container Nursery	$500,000
Poly Greenhouse – Vegetable	$150,000
Poly Greenhouse – Floriculture	$150,000
Glass Greenhouse – Vegetable	$600,000
Glass Greenhouse – Floriculture	$700,000

Growth in output has come from using more land, but more importantly from shifting from lower value forage and pasture production to higher value berry, nursery and greenhouse production.

Matsqui Prairie may be the best example of how agriculture production has changed over time. A farmer who was present during the 1948 flood mentioned that almost every farm in 1948 had some milking cows. Today, there are 21 dairy farms in Matsqui Prairie. Many of the forage fields have been converted to blueberries, nursery and greenhouses. The revenue per hectare in Matsqui Prairie is $22,000 compared to $17,000 for the FVRD as a whole.

In FVRD, the area of higher revenue per hectare crops and production systems has increased since 1996 (39)(40) (**Table 4**).

Table 4. Revenue of crops and production systems over time

Commodity/ Production System	Area in 1996	Area in 2011	Total % increase	Annual Compounded Growth Rate[11]
Nursery	913 ha	1703 ha	87%	4.2%
Blueberry	721 ha	3258 ha	450%	10.6%
Greenhouse[12]	225,000 m^2	1.1 million m^2	442%	11.2%

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[10] From supplementary Excel worksheet

[11] See Section 6.1 for more details

[12] Both vegetables and floriculture.

Livestock numbers have fluctuated, depending on the livestock type (39)(40) (**Table 5**). Growth in the supply managed commodities (poultry and dairy) is closely tied to population growth[13]. Annual compounded population growth rate between 1996 and 2011 was 1.28 %[14]. The strength in poultry production comes in part from an increase in the per capita consumption of poultry products[15].

Table 5. Livestock production over time

Commodity/ Production System	Number in 1996	Number in 2011	% Change	Annual Compounded Growth Rate[10]
Poultry − Birds	7.7 m	12.4 m	60%	3.2%
Dairy Cows	41,617	44,029	6%	.4%
Dairy Farms	567	324	**-43%**	**-3.7%**
Cows/Farm	73	136	86%	

More intensive crops and production systems can support higher land values compared to forage production. As dairies sell or reorganize, some have opted to move out of the FVRD; mostly to the interior of the province. The dairies that remain have increased the size of their herds. Dairies that have left have been replaced by more intensive horticulture production.

The comparative advantage of agriculture in the FVRD is derived from its good soil, moderate climate and abundant water. These have contributed to the FVRD becoming the most intensely farmed area in North America[16]. This comparative advantage will not change over time and provides the potential for continued strong growth in the agricultural sector.

1.3.1 Agriculture as an Industrial Sector

Agriculture, as an industrial sector, is characterized by businesses that buy their inputs locally, sell and value-add to their products locally and hire a workforce that lives locally. These characteristics result in agriculture having a high economic impact on the community where it is located.

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[13] The supply management system manages supply to match consumer demand and restricts imports to achieve this. As a result growth in production in the sector is tied to growth in population.

[14] http://www.bcstats.gov.bc.ca/StatisticsBySubject/Demography/PopulationEstimates.aspx

[15] From 24.9 kg/person in 1996 to 30.9 Kg/person in 2014. http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/poultry-and-eggs/poultry-and-egg-market-information/industry-indicators/per-capita-consumption/?id=1384971854413

[16] Checks of output in the San Fernando Valley and regions in Florida indicate farm gate receipts are lower than the FVRD.

Agriculture’s comparative advantage is biophysical as compared to inexpensive industrial land or labour. This comparative advantage is permanent and will enable agriculture as a sector to continue to grow.

BC farmers produce half of the food consumed by British Columbians. Demand for food is recession proof. For these reasons the agriculture sector typically shows slow but steady growth over time.

Stable real growth and high local economic impact means agriculture has a large economic impact within the FVRD.

2. The Economic Impact of Agriculture in the FVRD

The goal of an economic impact study is to answer the general question: what would be the impact on a community if a specific industry ceased to exist? This estimate looks at the loss in expenditures on goods and services and the loss in jobs if agriculture production suddenly ceased in the FVRD.

Most economic impact studies rely on a survey of the industry for their information. With primary agriculture production, Statistics Canada conducts a census every five years that provides very reliable information on revenues, employment and operating expenditures in the farming community.

Economic impact studies also look at the secondary or spin-off benefits within a community. When a farm worker uses his/her wages to purchase goods in the community, it creates economic activity that spreads throughout the community. When businesses use their revenues to purchase goods and services from within the community, it creates further economic activity in the community. These ‘trickle down’ benefits are termed ‘secondary benefits’. (Note: See Section 6.8.)

The size of the industry, and the central location in the Fraser Valley, has contributed to FVRD, and particularly Abbotsford, becoming a ‘hub’ for agri-business and value-added business in the Lower Mainland. This unique aspect of agri-business in Abbotsford means the size of the agri-business and value added sector is larger than would be expected in other farming communities. To simply estimate the ‘secondary benefits’ of a typical agriculture community would miss a large part of the agri-business and value added sector in Abbotsford.

In 2008, the Abbotsford Chamber of Commerce Agriculture Committee partnered with the BC Ministry of Agriculture to conduct a survey of the agri-business sector in Abbotsford. This report uses the survey results to extend the analysis to include the agri-business sector in FVRD (25).

The estimate of the economic impact of agriculture in the FVRD is divided into an estimate of the farm-based production sector and the agri-industrial sector. To prevent double counting, expenditures by farms on products in the agri-industrial sector were counted in the agri-industrial sector. The farm gate value of products used in value-added businesses was subtracted from the value-added sector and kept with farm production.

Figure 1 summarises the economic impact of agriculture in the FVRD. All values are in millions of dollars. Agriculture drives $3 billion in annual economic activity and supports 18,000 FTE jobs.

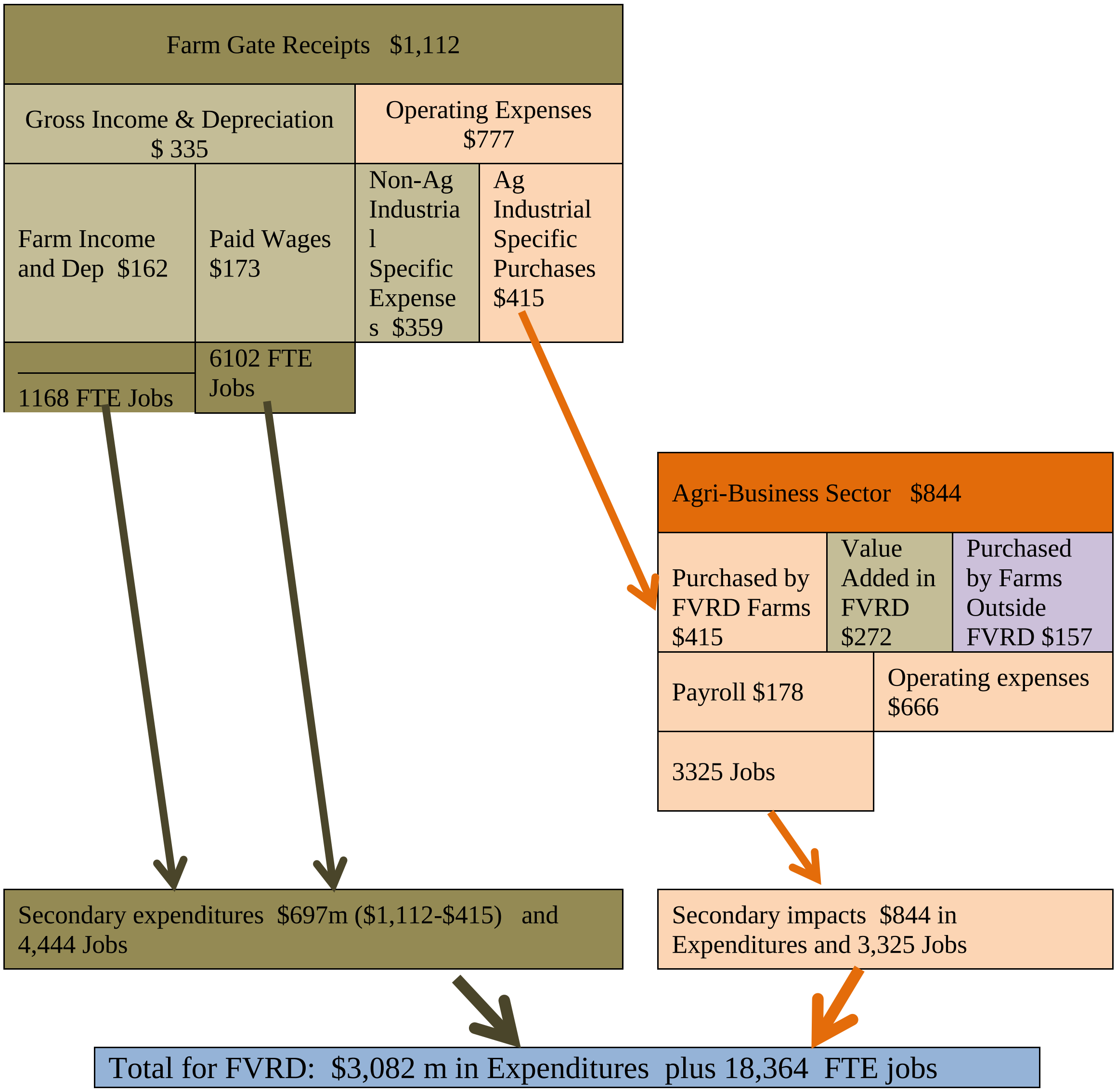

Figure 1. Economic impact of agriculture in the FVRD

Farm based production in the FVRD supported 11,700 FTE jobs (4,444 + 1,168 + 6,102) and $1.4 billion ($697 M of farm gate receipts and $697 M in secondary expenditures) in expenditures on goods and services.

The agri-industrial and value added sector provided an additional 3,300 FTE jobs and $1.69B ($844 M + $844 M) in expenditures on goods and services. Farms outside FVRD represent 18% of the agri-industrial and value-added sector. This compares to 40% in the Abbotsford study. This means that one-fifth of the agri-industrial sector in the FVRD is supported by farms in Metro Vancouver.

The main focus of this report is to explore how a major flooding event will impact agricultural production and its resulting economic impact within the FVRD.

3. Impact of a Major Flooding Event on Agriculture in the FVRD

Estimating the impact of a major flood event on agricultural production is challenging, because it is difficult to predict the time and the nature of the flood event and how it will impact different farms and different production systems. Variables related to the flood event include:

- The duration of the flood,
- The season in which the flood occurs,
- The level of the flood waters, and
- The area inundated.

Variables on the farm production side include:

- The type of commodity produced,
- The production system used,
- The buildings and equipment involved, and
- The topography of the farm site.

3.1 Methodology Framework for Estimating the Impact of a Freshet Flooding Event in FVRD

A presentation at the International Symposium of Flood Defense in 2008 discussed the current ‘Methods for the Evaluation of Direct and Indirect Flood Losses’ (13). For estimating direct agricultural losses for any specific region, it recommends considering three key variables:

- Seasonality,
- Duration of the flood, and
- Commodity type.

Seasonality

This study examines freshet flooding in the FVRD. Freshet flooding typically occurs in late May or early June. The historic 1948 flood started on May 24. This study assumes a freshet flood that occurs on June 1 (Note: See Section 6.2.).

Duration

The duration of the flood impacts many commodity types. Perennials can typically withstand a short duration flood but will be totally lost in a long duration flood. Annuals can be replanted if there are sufficient growing days to harvest after the flood recedes. Forage crops replanted in early July will produce a fall crop, but if planted in late July only grasses can be grown and the crop will be small.

Confinement production systems (i.e. poultry) are less affected by the duration of the flood. The longer the flood the longer the gap in production of the impacted farms and the less opportunity for poultry producers, and the sector as a whole, to make up for lost production.

Other studies and flood analysis have suggested that a flood duration of less than 14 days has much less impact on agriculture production than a flood duration over 14 days.[17] This study estimates the impact of both short duration (<14 days) and long duration flood (>14 days) events under each flood scenario analyzed.

Commodity Type

The variability in flood characteristics and types of agricultural production have limited the development of precise models for estimating damage and loss. Most studies have used a general approach of identifying the crops grown and estimating how much each type of production would be lost in a flood event.

In ex-post analysis[18], the duration of the flood is known, yet it is important to note that varying soil type, topography and drainage infrastructure resulted in a large variation between farms in flood duration within a single flooding event (6).

Some crops have similar production systems and revenues per hectare. This study grouped common commodities in the FVRD into ‘commodity groups’ for the purpose of analysis. They are:

- Forage grasses/pasture,
- Forage corn,
- Annuals including vegetables, turf and strawberries,
- Blueberries (including blackberries and raspberries[19]),
- Perennials including field nursery and fruit, nut and Christmas trees,
- Container nursery,
- Field Floriculture,
- Poly greenhouses for vegetable and nursery production,
- Poly greenhouses for floriculture,
- Glass greenhouses for vegetable production,
- Glass greenhouses for floriculture,

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[17] Discussed more in Appendix I.

[18] Studies that analyze the damage to agricultural production after the flood has occurred. Ex-ante studies estimate damage to agricultural production of a future flood event.

[19] There are very few raspberries grown in the floodplain because they prefer better drained soils in the uplands.

- Dairy,
- Poultry,
- Hogs.

3.2 Other studies on the Economic Impact of Flooding on Agriculture in the Fraser Valley

BC Climate Action Initiative published a Discussion Paper: Potential Economic and Agricultural Production Impacts of Climate Change Related Flooding in the Fraser Delta (44). The main focus of this report was the impact of seasonality and salt concentration on losses to agricultural production. The case studies included a short duration freshet flood in Richmond.

3.3 Methodology

The methodology framework used in the Fraser Delta study is adopted for this study. This study broadens the commodity groups analyzed and uses additional information from published research papers, production guides and interviews with farmers and local production experts.[20]

The key information for the analysis comes from the Agriculture Land Use Inventory (ALUI) (26) conducted in the FVRD from 2011 to 2013 and the 2011 Census of Agriculture Data (39)(40). Price and yield estimates relate to 2011 as best as possible.

3.4 Estimated losses for specific commodity groups

Freshet floods come with some warning. A large snowpack in March, warm weather in early May and/or a forecast of heavy rain are all warning signs.

Loss estimates assume that farmers will make every effort to minimize loss of revenues by:

- Moving livestock that can easily be moved at an early stage. i.e. horses, sheep, beef cows, dry dairy cows and heifers;
- Delaying placing broiler chicks, turkey poults and new layers;
- Moving as many floriculture and nursery plants to market as possible; and
- Moving equipment and machinery to high ground.

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[20] A list of interview comments is in Appendix II.

It is also assumed that:

- Replacement plants and animals are available[21];
- Power is not interrupted;
- There are no food safety or organic certification impacts from polluted water; (Note: See Section 6.3.) and
- Farmers will continue with the same commodity mix as before the flood. (Note: See Section 6.4.)

3.4.1 Annual Crops and Forages

By June 1, the soil is warm[22], annuals are planted and forages are in full growth mode. Farmers will have taken the first cut of grass from forage fields. A short-duration flood on June 1 will kill forage corn and annual crops that have been newly planted, and forage grass will be damaged to the point where replant is required.

A short-duration flood will permit replanting in early July on well-drained fields. Forage corn and forage grasses can be planted in anticipation of a late fall harvest[23]. Annual crops can also be planted in anticipation of a late fall harvest. Most vegetable production in the valley is direct market or grown for specific markets. Replant disrupts the established relationship with markets, so crops replanted may not provide similar returns as those lost in the flood.

A long-duration flood would delay replant to almost August 1[24]. Forage corn would no longer be an option and any late fall harvest from replanted forage grass would be small. Replant by vegetable farmers would be limited to crops for winter sales[25].

Estimated loss for annual crops, forage corn and forage grass is as follows:

Flood Type	Annuals	Forage Corn	Forage grass
Short Duration	40%	25%	50%
Long Duration	75%	100%	70%

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[21] There will be challenges in getting replacement plants and animals, particularly perennials. It is impossible to estimate to what degree this will happen and thus the economic impact. Following the 2004 Avian Influenza outbreak in poultry the North America industry rallied to support the FVRD layer farms in restocking. It is anticipated that this will occur in all commodity types after a major flood event.

[22] Average temperature: http://www.eldoradocountyweather.com/canada/climate2/Abbotsford.html

[23] http://extension.psu.edu/plants/crops/grains/corn/silage/corn-silage-production-and-management

[24] Assuming the longer flood would result in more clean-up and longer time to get fields ready to replant. In 1948, farmers were not able to replant until mid-August.

[25] This could include root crops or overwintering cole crops.

3.4.2 Perennials

Two California studies, DRMS[26] and the ARkStorm (14), looked at flooding impacts on perennials. Their loss estimates considered that perennials either survive or continue to normal harvest, or die, depending on the duration of the flood. One reason for this approach is that California has a wide range of perennials from fruit and nut trees to vines and berries. In the FVRD, the dominant perennial crops are blueberries and field nursery.

Nursery

A nursery farmer interviewed felt that his field plants would survive a short-duration flood and be marketable. Typically 75% of field and container nursery stock is sold in early spring to meet the home garden market demand. With the threat of a freshet flood, more stock would likely be moved off-site for sale.

A long-duration flood would kill or render the remaining field nursery stock unsaleable. Field stock is planted on a six-year rotation. This means annual revenues are approximately 1/6th of the mature value of the planting.

For a long-duration flood, it is estimated that the loss in revenue in the flood year would be 25%. Replanted stock is not saleable for several years, so the first three years would have no sales and the next three would have 50% of the annual pre-flood year sales. Total loss would be 25% of annual revenues in the year of the flood, 300% of annual revenues for the first three years of replant, and 150% of annual revenues for years four to six of replant. Total estimated loss is 475% of annual revenues in the pre-flood year.

Container nursery stock is on a much shorter growing cycle. Some stock lost in the flood will be for the following year's sales. Container nursery loss is estimated at 25% for the flood year and a further 25% for the following year or 50% of current year revenues:

Flood Type	Field Nursery	Container Nursery
Short Duration	0%	50%
Long Duration	475%	50%

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[26] Delta Risk Management Strategy. http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/drms_execsum_ph1_final_low.pdf

Field Floriculture

Field floriculture consists is primarily of daffodils, tulips and gladiolas. Tulips and daffodils are harvested before June 1. Gladiolas are harvested later. Flooded fields will reduce the harvest of bulbs for sale or replant for next year's crop. A long duration flood will further reduce the harvest of bulbs. Field floriculture loss is estimated at:

Flood Type	Field Floriculture
Short Duration	40%
Long Duration	50%

Blueberries

Blueberry farmers interviewed felt that even a short-duration flood on June 1 would reduce yield and kill some plants. Much of the research on flooding impacts on blueberries has been done on the rabbiteye blueberry plants that are native to lowlands in Florida. Rabbiteye blueberry plants can survive up to 28 days of inundation without significant loss of plants or reduction in yield (3)(4). A review of the flood tolerance of different highbush blueberry varieties in China (5) found that Bluecrop was flood tolerant up to 21 days of inundation. This study measured survivability as compared to impact on yield. Abbott (1) studied the impact of flooding on fruit set in highbush blueberries. Most plants survived up to 4 months flooding, however, yield was impacted by 30%.

While the research suggests that flooding would have less impact than farmers expect, it is important to note that the research studies grow plants in ideal soil (and drainage) conditions before and immediately after the flooding treatment. This is not the case in the field.

All studies noted that flooding impacts on blueberries appeared to be cumulative. Several short-duration floods will have the same impact as one long-duration flood. [27]

FVRD has some very high producing blueberry fields that on June 1 are in full growth. It is reasonable to expect that yield would be impacted by a short-term flood on June 1. There are low-lying areas in some fields and some weaker fields where plants may not survive and need to be replaced. The estimated annual loss in yield for blueberries (surviving plants), from a short-term flood, is 40%. (Note: See Section 6.5.) It is estimated that 10% of the production area will require re-planting and that production in these areas is impacted for five years – the time required for blueberry plants to reach industry-average production

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[27] This is why it is important for farmers to consider drainage improvements prior to planting.

levels. An additional 25%[28] loss in annual yield is added to account for loss and replanting[29]. Estimated yield loss for a short duration flood is 65%.
A long-duration flood would kill enough of the blueberry plants to require a full replant. Production will be lost for the flood year and the subsequent five years would have reduced yield. The estimated loss of yield from a long-duration flood would be 100% for the flood year plus half of current yields over five years.[30] Therefore, the loss estimate for a long-duration flood is 100% plus 250%, or 350% of annual revenues in the pre-flood year:

Flood Type	Blueberries
Short Duration	65%
Long Duration	350%

3.4.3 Poly Greenhouse Vegetable and Nursery

Poly greenhouses are used for propagating vegetable and nursery plants and for growing potted nursery stock. Plants are grown on the ground or on raised benches.

Approximately 75% of nursery stock is marketed by June. The normal turn-over time for potted plants is 18 months. A flood on June 1 would result in the loss of 25% of the stock planned for sale in the current year and all of the stock started in preparation for sale the following year. After the flood, replanting will start for the following year's sales. It is anticipated that the loss of stock planned for sale the following year will reduce revenue by 25%.

Estimated loss by potted nursery and poly greenhouse is 25% of revenues from flood year and 25% of revenues the following year or 50% of annual revenues, as shown in the table below. A longer-duration flood will not significantly increase revenue loss.

Flood Type	Poly Greenhouses Vegetable and Nursery
Short or Long Duration	50%

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[28] It takes 5 years to reach full production so it is estimated that yield over the first 5 years will be 50% of pre-flood levels. 5 years at 50% equals 250% of annual yield. This applies to 10% of the planting. In terms of the full planted area it represents a 25% of the annual farm receipts.

[29] 5 years production at ½ yield or 500% of current yield /2.

[30] Another approach would be to estimate the difference in current and replant yields for each of the first 5 years, multiply by the estimated prices and discount by the estimated interest rate. Taking half the yield over the 5 year impacted period was easier and likely provides a similar estimate.

3.4.4 Glass Greenhouse

Vegetables

Tomatoes, peppers and cucumbers are the main greenhouse vegetable crops in the FVRD. Tomatoes and peppers are grown on an annual cycle with new plants started in January, harvested until November when the plants are removed, the greenhouse cleaned and prepared for the next new planting.

Harvest in April and May represents approximately 20% of the annual crop. A short duration flood on June 1 would kill the plants and after clean-up, it is unlikely that it would be economic to replant until the following January. A longer duration flood would not change the impact on annual revenues. The loss in annual revenue for both short- and long-duration flooding events for greenhouse tomatoes and peppers is estimated at 80%.

Cucumbers are planted three times a year. If the June 1 flood was assumed to happen at the midway point of a growing cycle, the lost harvest would represent 1/6th (half of 1/3rd) of the annual revenues. A long-duration flood may delay replant in cucumbers, so cucumber loss for long-duration flood is estimated at 1/5th of the annual revenues[31].

The proportion of the greenhouse sector in FVRD growing the three main vegetables is 2% Tomatoes, 87% Peppers and 11% Cucumbers[32].

Pro-rating the estimated losses for the different vegetable types over their respective proportion of the industry gives a weighted estimate of loss in the greenhouse vegetable sector:

	Estimated Loss	Proportion of Sales	Weighted Proportion of Loss Short & Long Duration
Tomatoes	.80	.02	.01
Peppers	.80	.87	.70
Cucumbers	.17(.20)	.11	.02
Total Weighted Loss			.73

Floriculture

Floriculture greenhouses grow either on raised benches or at ground level. Plants on raised benches would survive a flood event while plants on the ground would not.

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[31] An extra 2 weeks' delay represents 4% of the year.

[32] From BC Hothouse

An estimate of the distribution between production on benches and on the ground is[33]:

Production Type	% of Total Production
Potted plants on benches	52%
Potted plants on ground	18%
Cut flowers in raised pots	15%
Cut flowers in soil	15%
	100%

Potted plants on the ground and cut flowers grown in soil would be lost. The major market for potted plants and cut flowers is in the spring. Replant costs may be higher if bulbs and seedlings for next year's harvest are lost. The estimated loss by floriculture greenhouses is 33% (18%+15%) of annual revenues.

The loss of annual revenues by greenhouse vegetable and floriculture production is estimated at:

Flood Type	Vegetables	Floriculture
Short or Long Duration	73%	33%

3.4.5 Dairy

In 1948, a large dairy farm milked 20 cows. The industry is now characterized by fewer, much larger herds[34] and more sophisticated milking equipment. More herds are using robotic milking systems that change cows from two to three scheduled milkings per day to milking on demand.

During the 1948 historic flood event, all dairy cows were relocated to higher ground or to temporary accommodation at the Abbotsford Airport. Today, the logistics of moving larger herds using different milking systems is a greater challenge. Most farmers have plans to move their non-lactating animals; however, they are reluctant to move their milking cows because disruption of the cows' routine drops milk production, and some cows will be injured in the relocation and subsequent return.[35]

It is not possible to estimate how many farmers will move their lactating cows under imminent threat of flooding and how many cows will be injured. The question from an economic loss perspective is how much will the annual milk production be impacted? (Note: See Section 6.6.)

One farmer, with 240 milking cows on robotic milkers, estimated a short-term relocation would reduce milk production by 50% over three months. A long-term relocation would have even greater impacts. A dairy farmer located outside the

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[33] From provincial Horticulture Specialist.

[34] The average herd in the FVRD is 170 milking cows with one very large farm milking several thousand cows.

[35] Dairy farmers have indicated that their insurance is not valid if the cows are moved off the property.

dikes has relocated his herd prior to a flood event. He moved to a similar facility with a similar feeding and milking system. The cows were on a traditional milking system – not robotic milkers. He did not experience measurable loss in production.

In a major flood event it is unlikely that many herds will be moved under ideal conditions, and most herds on robotic milkers will be facing a change in milking system.

Estimated loss in annual milk production is:

Flood Type	Production Lost	% of Annual Milk Production
Short Duration	30% over 3 months	7.5%
Long Duration	30% over 6 months	15%

The majority of dairy cows are housed year round. Land is used to produce forage and to utilize the manure as fertilizer. Loss of forage yields is considered in the forage section (3.3.1). The value of forage for milk production is subtracted from milk revenues. The milk revenues are considered value added to forage production.

3.4.6 Poultry Production

Broilers grow for approximately 40 days in an eight-week cycle. With some warning, placement can be delayed or production directed to other barns outside the flooded area. Turkey production is similar except the grow period is longer so delaying placement or relocating production is more challenging. Layers housed in cages over deep pit manure systems will be high enough to survive a flood. New free-run barns are at ground level, so some losses may occur depending on where the flock is in the production cycle.[36] It is estimated that in the poultry sector, a short-term flood will not result in any loss of farm gate revenues, and a long-term flood will cause a modest 5% loss in revenues primarily in the table egg and turkey sectors.

3.4.7 Hog Production

Hog production in the Fraser Valley is primarily farrow to finish.[37] It takes just over 6 months from farrow to finish. It is challenging to move a hog operation as

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[36] If close to the end of the cycle then the farmer may ship the birds a bit early.

[37] Farms maintain sows (farrow) and they keep the piglets and grow them (finish) to market hogs.

hog facilities are quite unique[38]. Biosecurity is also a concern when moving hogs to another facility and then returning to the original barn.

Hog facilities are built at ground level so all the animals would be vulnerable in a major flood.

Estimated loss for hog production is 50% of annual revenues.

3.4.8 Estimated Losses for Different Commodity Groups

The table below provides a summary of estimated losses for different commodity groups for both short duration and long duration floods.

Commodity Group	Short Duration	Long Duration
Forage Corn	25%	100%
Forage Grass	50%	70%
Annuals - Vegetables	40%	75%
Perennials – Blueberries	65%	350%
Perennials – Field Nursery	0%	475%
Container Nursery	50%	50%
Field Floriculture	40%	50%
Poly Greenhouse	50%	50%
Glass Greenhouse – Vegetables	73%	73%
Glass Greenhouse - Floriculture	33%	33%
Dairy	12.5%	25%
Poultry	0%	5%
Hogs	50%	50%

3.4.9 Estimated Building and Equipment Losses

Traditional farm buildings are metal clad with concrete footings or treated pole construction. Flood water does not cause much damage to these buildings. The HAZUS (11) model for estimating losses in the residential areas starts at 10% of building value for low flood depths. Post-event analysis of floods in farming areas has not identified significant losses to farm buildings. The loss to farm buildings is estimated to be 5% of value. Dairy farms are using much more sophisticated equipment that is not portable, and processing and on-farm sales have buildings that would experience much higher damage from flooding. In areas with a high concentration of dairy farms and on-farm packaging, estimated building losses are 7% of value[39].

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[38] The hog industry has reduced in size over the last several years so in the short term there might be some empty facilities that could support the relocation of a hog farm.

[39] See detailed Excel worksheet for estimate of building value.

3.4.10 Estimated Clean-Up and Replant Costs

Post-flood analysis has estimated the cost of clean-up at $70/ha (6) and Porter estimated cleanup costs in the ARkStorm scenario at $650/ha (38). Replant costs in this study are costs incremental to labour costs.[40] They are estimated for each commodity group:

Commodity Group	Estimated Clean-Up Cost/Ha
Forage/Annuals	$300
Perennials/Greenhouses	$600

Replant costs are also incremental to labour costs. They are estimated in the detailed worksheet provided and summarized in the table below:

Commodity Group	Estimated Replant Cost/Ha
Forage	$300
Vegetables	$500
Blueberries	$8,500
Field Nursery	$7,500
Poly Greenhouse − Vegetable	$7,500

4 Impact of Flooding Under Select Scenarios

The Fraser Valley has experienced two major freshet flooding events - 1894 and 1948. In 1894, flows were similar to those of a 1 in 500 year (0.2% chance of occurence) freshet flooding event). The 1948 flood was approximately a 1 in 200 year (0.5% chance of occurrence) freshet event.

In 1948, most dikes along the Fraser River breached. The Vedder River dike held, and so Sumas Prairie was not flooded.

Four flooding scenarios were considered in this study:

1. A repeat of the 1894 Freshet flood with today's conditions (referred to as 1894). This is a 1 in 500-year freshet flood. All dikes are assumed to breach. [Flood Scenario C]
2. A repeat of the 1894 flood including the impacts of climate change (referred to as 1894+CC). All dikes are assumed to breach. [Flood Scenario D]

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[40] Other studies include the labour for replant and clean-up but deduct labour from lost farm receipts. In this study we assumed farms would try to keep their staff and simply redeploy them from harvesting chores to clean-up and replant. This is a reasonable assumption and retains the appropriate revenue loss that is used to estimate economic impact.

3. A 1 in 100-year freshet flood (referred to as 1:100). It assumes dikes in ‘fair’ condition or better hold, and those in less than ‘fair’ condition fail. [Flood Scenario E]
4. A 1 in 100 year freshet flood assuming the Matsqui dike failed (referred to as Matsqui breach). [Flood Scenario E - variant]

The naming and definition of Scenarios C and D are as previously defined for FBC’s Lower Mainland Vulnerability Assessment (NHC 2016). Scenario E was selected with input from the PMT.

All flooding scenarios are analyzed considering a short duration flood and a long duration flood. It is assumed that flood waters cover the full extent of the flooded area unimpeded.

4.1 Flood Extents

Table 6 summarizes the extent of flooding under the different scenarios.

Table 6. Flood Area in FVRD under different flood scenarios

Flood Scenarios	FVRD Flood Area in Ha	% of Scenario D
Scenario C	29,029	98%
Scenario D	29,481	100%
Scenario E	11,977	41%
Scenario E - variant	3,486	12%

Climate change has a very small impact on the area flooded under 1894 flood conditions. The 1894 flood today would cover 98% of the area covered with a similar magnitude flood that incorporated climate change. The flood depths would be greater with climate change.

The impact of a 1:100-year flood event, assuming that only dikes in ‘fair’ or better condition held, affects different parts of the region differently (**Table *7***).

Table 7. Flood Area per jurisdiction under different flood scenarios

	Scenario C	Scenario D	Scenario E	Scenario E - variant
Abbotsford	10,910	10,929	336	3,486
Chilliwack	9,718	10,010	5,517	
Hope	91	112	121[41]	
Kent	3,800	3,899	1,563	
Mission	248	249	271	
Elec. Area	4,262	4,282	4,169	
Total	29,029	29,481	11,977	3,486

Most of Abbotsford would be protected in a 1:100 year flood event. Glen Valley is the only vulnerable area. 40% of Chilliwack would be protected. The dikes in Kent would protect 60% of the vulnerable area, but other communities on the north side of the river are vulnerable to a 1:100 year flood.

4.2 Estimated Cost to Farmers of Flood Scenarios

Table 8 summarizes the total cost to farmers and the cost per hectare flooded for the four scenarios with different flood durations.[42] The breakdown by local government is shown in **Table 9**.

Table 8. Farmer Costs and Costs per hectare under different flood scenarios

		Short Duration		Long Duration	
Flood Scenario	Hectares Flooded	Total Farmer Cost ($M)	Farmer Cost/Ha ($ thousands)	Total Farmer Cost ($M)	Farmer Cost/Ha ($ thousands)
Scenario C	29,029	$ 365	$ 13	$ 821	$ 28
Scenario D	29,481	$ 372	$ 13	$ 833	$ 28
Scenario E	11,977	$ 112	$ 9	$ 269	$ 23
Scenario E - variant	3,486			$ 120	$ 34

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[41] It is not reasonable to expect the area flooded to increase for Hope and Mission between an 1894 flood and a 1:100 year flood. The vulnerable area estimates were calculated by different people which likely contributed to the slight differences in hectares.

[42] Detailed calculations are in the excel worksheet

Table 9. Farmer Costs ($ million) by local government under different flood scenarios

	Scenario C		Scenario D		Scenario E		Scenario E - variant
Community	Short	Long	Short	Long	Short	Long	Long
Abbotsford	149.15	282.86	149.78	284.02	1.46	6.17	119.76
Chilliwack	147.08	348.33	151.55	363.30	57.68	126.17	
Hope	.39	.42	.46	.49	.32	.35	
Kent	22.13	81.96	23.06	83.52	7.64	51.26	
Mission	1.19	1.42	1.21	1.47	.87	.92	
Elec. Area	45.21	106.38	45.48	106.93	43.93	84.50	
Total FVRD	365.17	821.37	371.55	832.74	111.90	269.37	

Farmer costs per hectare by local government area are provided in **Table 10**.

Table 10. Farmer Costs per Hectare ($ thousand) by local government under different flood scenarios

	Scenario C		Scenario D		Scenario E		Scenario E - variant
Community	Short	Long	Short	Long	Short	Long	Long
Abbotsford	13.7	25.9	13.7	26.0	4.3	18.3	34.4
Chilliwack	15.1	35.8	15.1	35.6	10.5	22.9	
Hope	4.3	4.6	4.2	4.4	2.6	2.9	
Kent	5.8	21.6	5.9	21.4	4.9	32.8	
Mission	4.8	5.7	4.9	5.9	3.2	3.4	
Elec. Area	10.6	25.0	10.6	25.0	10.5	20.3	
Avg. FVRD[43]	12.6	28.3	12.6	28.2	9.3	22.5	

In all cases, a long duration flood more than doubles the cost to farmers compared to a short duration flood. This is primarily driven by the impact on perennials and the extended disruption to lactating cows.

A flood in Matsqui Prairie has a higher cost per hectare than other scenarios. This is because of the higher proportion of perennials, particularly blueberries, and other intensive crops compared to other areas. **Table 11** shows the proportion of different crops in the different flood scenarios.

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[43] Weighted Average

Table 11. Proportion of various commodity groups in the flooded area under different flood scenarios

Commodity Group	Percentage of Flooded Area			
	Scenario C	Scenario D	Scenario E	Scenario E - variant
Forage Grass/Pasture	42.8%	43.4%	48.8%	36.0%
Forage Corn	27.9%	27.3%	30.0%	23.0%
Annuals - Veg/Turf/Strawberries	7.7%	7.8%	5.2%	1.1%
Blueberries	9.8%	9.8%	6.4%	31.3%
Field Nursery/Tree	6.3%	6.2%	5.5%	3.0%
Field Floriculture	0.4%	0.4%	0.0%	0.0%
Container Nursery	0.4%	0.4%	0.2%	0.6%
Poly Greenhouse − Veg/Nursery	0.3%	0.3%	0.4%	0.1%
Poly Greenhouse − Floriculture	0.0%	0.0%	0.0%	0.0%
Glass Greenhouse – Vegetable	0.2%	0.2%	0.0%	0.9%
Glass Greenhouse – Floriculture	0.0%	0.0%	0.1%	0.0%
Farm Buildings	4.2%	4.2%	3.4%	4.0%

The shaded cells (tan colour) highlight the areas where the proportion of some commodity types is different. The proportion of land in blueberries in Matsqui Breach is much higher compared to other areas. It is also interesting to note that the 100-year flood area has a higher proportion of forage land use than the flood area represented by the 1894 flood.

4.3 Economic Impact of Flooding Events on the Community

When farmers lose farm receipts, the community loses the economic benefit that those revenues create. Based on the information in Section 2, it is estimated that the different flood scenarios would have the following economic impact in the community (**Table 12**).

Table 12. Economic Impact to the Community of Flooding Events ($M)[44]

Flood Scenario	Short Duration			Long Duration		
	Farm Sales Lost	Secondary Benefits Lost	Economic Impact	Farm Sales Lost	Secondary Benefits Lost	Economic Impact
Scenario C	$132	$132	$264	$574	$574	$1,148
Scenario D	$133	$133	$266	$580	$580	$1,160
Scenario E	$30	$30	$60	$183	$183	$368
Scenario E - variant				$93	$93	$186

In the worst-case scenario, a major long-duration flood would result in a $1.1 billion economic impact to the FVRD.[45]

4.3.1 Farmer Costs and Economic Impact

Losses to farm gate receipts is a loss to both the farmer and to the community. However, farm gate revenue losses have secondary impacts in the community that don't impact the farmer, and similarly there may be costs of flooding for the farmer that don't necessarily impact the community. For example, if a forage corn crop is damaged, the farmer will incur costs to replace the feed for his cows and while this will reduce the farm profits, it won't necessarily reduce the farm gate sales (production of milk).

How an individual farmer spends the farm gate receipts can impact the profitability of the farm, but not necessarily the level of expenditures in the community.

5 Discussion

The ALR in the FVRD is the most intensely farmed area in North America. It generates over $1.1 billion in farm gate receipts which flow through agricultural industrial and value added businesses in the community to generate $3 billion in economic activity.

A major flood event, similar to the flood in 1894, would cause over $800 million in damage to farmers' crops, buildings and equipment and have an economic impact of $1.1 billion on FVRD communities.

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[44] Secondary benefits are estimated as a multiple of primary benefits. A multiple of 1.0 was used to estimate secondary economic benefits from primary economic benefits for both expenditures and jobs.

[45] It is difficult to break the economic impact by municipality as the Statistics Canada census areas do not coincide with municipal boundaries, except for Abbotsford.

While a major flood event would be devastating for farms in the vulnerable areas, only 40% of the ALR in the FVRD is in the floodplain. The Abbotsford Airport and Mount Lehman uplands are intensely farmed areas outside the floodplain. After clean-up, livestock sectors will return to normal. Horticulture sectors, excluding greenhouse vegetables, will begin replant activities.

Different parts of the agri-industrial sector will be impacted differently. Those in the packaging and value added sector will lose the portion of their business that relied on crops from the flooded area. Agri-industrial businesses that provide inputs to production will experience an increase in business because farms will be replanting and rebuilding damaged infrastructure.

The estimate of farmer losses in this study is higher than the losses reported in other ex-poste studies (green colour) and ex-ante studies (light blue colour) (**Table 13**). This is to be expected as agriculture production in the FVRD is two to three times that of agriculture production in other ex-ante studies.

Table 13. Comparison of economic losses between this study and other studies

Flood Event	Farmer Cost per Hectare	
	Short Duration	Long Duration
Scenario C	$12,600	$28,000
Scenario E	$ 9,300	$23,000
Scenario E - variant		$34,000
ARkStorm		$7,358
England, 2007 - Horticulture		$13,750
England, 2007 - average		$2,406
England, 2012	$ 350	$1,840
California, 1997		$3,633
Arkansas, 2014 − forage		$403

One reason for the high cost per hectare in the FVRD is the intensity of agriculture production in the region. The flood in England was over a lowland area primarily used for grazing and some forage production. Some dairy farms were impacted. While California is intensely farmed it still has a high proportion of annual crops relative to perennials and livestock

The other reason ex-ante studies tend to overestimate actual losses is that internal infrastructure, such as roads and railways, which limit the impact of the flow of floodwaters, cannot be modelled. In this study, floodwater is assumed to spread unimpeded. This assumption will contribute to higher estimated losses. In addition, farmers will make every effort to mitigate losses.

The estimated loss and economic impact reported here should be considered a worst-case scenario.

The estimates do not consider insurance payments or government support payments to cover farm damages. Insurance/government payments reduce farmer costs (offset lost farm gate receipts) and thus reduce the economic impact to the community. (Note: See Section 6.7.)

For the FVRD, the impact of climate change on flood extents is small. For the 1894 flood scenario, climate change only increased the flood extent by 2% and the farmer costs by 1%. Climate change has a greater effect on flood depths, however, flood depth does not have a significant impact on production losses. It may have a small effect on building losses.

In the future, farmer losses will increase if more forage land is converted to perennial crops. Perennials have the highest loss per acre because it takes several years for new plantings to reach marketable size or level of fruit production. Greenhouse and confinement livestock operations experience high losses from the flood event but are able to resume production relatively soon after the flood subsides.

6. Author’s Notes

6.1 Real Growth

The growth in industry revenues from one period to the next is a combination of an increase in output and an increase in prices. The increase in prices is due to inflation. Real growth is the total increase in industry revenues minus the amount due to inflation.

When money is put into savings, the interest rate quoted is the annual rate that compounds over time. The interest earned after each period then earns interest in the next period.

When one looks at real industry growth, e.g. over a period of five years, it is informative to know what the average annual rate of growth was, from year one to year five. This is called the compound annual growth rate. In this report it is referred to as real growth.

6.2 Impact of an Early or Late Freshet

The freshet flood analyzed in this report was assumed to occur on June 1. There is a high probability that a freshet flood would occur between May 15 and June 15. If it occurred in late May, less of the nursery and floriculture stock would be sold but there would be a longer subsequent growing season for annuals and forage crops. If the freshet occurred after June 1, more nursery and floriculture stock would be sold and more greenhouse vegetables would be harvested, but annuals and forage crops would have a shorter growing season. Livestock would not be affected.

While an earlier freshet flood would change the impact on some commodity groups, the net impact on the estimate of losses would be small.

6.3 Food Safety and Organic Certification Impacts from Polluted Water

A major flood event would overflow manure lagoons and flood water would pick up other potentially harmful materials. Different crops have different ‘days to harvest’ following manure application. Replanted annuals and forage crops would be fine. Blueberries may be impacted depending on the time to harvest and the degree of contamination. Organic farmers may need to have their farms inspected to ensure that any contaminants brought onto the farm by the flood waters have not negatively impacted their organic certification.

Contaminated water will impact industry revenues but there are many factors involved, and it is beyond the scope of this study to estimate the economic impact.

6.4 Post Flood Commodity Mix

The estimate of economic impact to agriculture assumes that farmers replant or restock the commodities they farmed pre-flood. This will not necessarily be the case, as some farmers will move to other commodities. Agriculture is a dynamic industry with farmers changing to different commodities to meet market (and profitability) needs. A flood event will accelerate any planned changes in production.

After the 1948 flood, the provincial government initiated an incentive program for planting blueberries. This was the start of the blueberry industry in Matsqui Prairie where 30% of the land is now in blueberry production.

6.5 Blueberry Yield from Surviving Plants

No research projects were found that directly assess yield loss due to flooding. Abbott (1) found 30% of the fruit on plants that were flooded for an extended time had dropped off before harvest. Other research on the impact of flooding on blueberry plants has dealt mostly with plant survival. They have found that rabbiteye and highbush blueberries can survive extended flood periods. It is important to recognize that the research projects grow the blueberry plants in ideal soil conditions, expose them to flooding, then return them to ideal soil conditions. In the field, soil conditions are rarely as ideal as in the research lab.

Another important finding in several of the research projects was that flooding events have a cumulative impact (1)(3)(4). A series of short flooding events have the same impact as one long flooding event.

Blueberry farmers believe that short duration flooding will have a significant impact on their yield. It is important to recognize that for a freshet flood on June 1, fruit set will have occurred. The impact on yield only relates to the ability of the surviving plant to ripen the fruit.

The research suggests that most plants will survive a short duration flood but will not be as vigorous relative to if they had not undergone a flooding event. It is estimated that yield will be reduced by 40%.

6.6 The Farmers' Dilemma in Choosing to Move Animals Pre-Flood

Livestock farmers are in business. A decision to move animals, when threatened with a flood, must support the long term viability of the operation. Livestock farmers are also custodians of animals and therefore have a responsibility under the "BC Prevention of Cruelty to Animals Act" to protect animals from circumstances likely to cause distress.

These two responsibilities will put livestock farmers in a very difficult position as the threat of flooding approaches.

6.7 Insurance

Farmers have several insurance options related to losses from flooding including the federal agri-stability program, the provincial production insurance program and private insurance. There is no requirement for farms to hold insurance against flood losses.

Insurance payments to farmers and any other payments to offset losses from flooding will reduce the economic impact to the community.

6.8 Economic Multipliers for Agriculture

Economic impact studies try to measure the impact of an industry to a community. They try to answer the question: if the industry suddenly disappeared tomorrow, what would the impact be on the community in terms of expenditures and jobs?

Answering this question requires a look at the industry itself and also the impact expenditures in wages and materials that the industry has on other businesses in the community. These are termed secondary benefits.

There are many detailed studies that track expenditures through a community. In general, they find that the more an industry pays in wages, and the more they purchase goods in the community, the greater the secondary benefits.
Studies on agriculture suggest the secondary benefits are high because farms tend to be relatively labour intensive, farm workers tend to live in the community and farms tend to buy as much as possible in the community.

Secondary benefits are estimated as a multiple of primary benefits. For agriculture, estimates for secondary benefits have ranged from .8 of the primary economic activity to 1.5 times the primary economic activity.

Some of the FVRD farmers need to go to other communities for farm equipment and processing. Given this, a multiple of 1.0 was used to estimate secondary economic benefits from primary economic benefits for both expenditures and jobs.

Appendix I - Previous Analysis of the Impacts of a Flood Event on Agricultural Production

Studies on the impact of flooding on agriculture production can be separated into those that analyze loss after a flood event (ex-post studies) and those that estimate the damage to agriculture of a future flood (ex-ante studies).

Bremond (2) reviewed 42 of these studies to identify common approaches. The ex-post studies identified common categories of direct loss:

- Crop loss and yield reduction,
- Damage to perennial material,
- Injuries and fatalities to livestock,
- Loss of livestock production (e.g. milk, eggs),
- Damage to soil – erosion and deposits,
- Damage to buildings,
- Damage to machinery and equipment, and
- Damage to stored materials – e.g. feed, inputs.

They also recognized that floods induced additional costs including:

- Clean-up costs,
- Replant cost, and
- Reduced yield in subsequent years.

Bremond's (2) review found that many ex-ante analysis used damage functions from ex-post studies.

I.1 Ex-Post Studies

One of the most referenced ex-post studies is the analysis by Posthumus (9) of the lowland floods in England in the summer of 2007. The predominant agricultural crops were horticulture, field crops, cereal crops and dairy production. The flood event involved 42,000 ha, and on average, the land was submerged for three weeks and was waterlogged for a further three weeks. The estimated damage[46] per hectare is summarized below:

Average Flood Damage/Ha - Summer 2007				
Horticulture	Field Crops	Cereals	Dairy	Weighted Average
$13,750	$4,050	$1,700	$2,115	$2,406

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[46] Converted from pounds to Canadian dollar at the November 6 rate of 2.00. https://www.google.ca/?gfe_rd=cr&ei=7_Y8Vvn-E5Ht8wfvjrrwCw&gws_rd=ssl#q=current+exchange+rate+british+pound+to+canadian+dollar

In 2012, Somerset England experienced spring flooding at the end of April. Five thousand hectares were flooded and some areas remained flooded longer than others. In his analysis, Morris (6) divided the damage estimate into areas that experienced short term flooding (<14 days) and areas that experienced long-term flood (>14 days). Agriculture production was primarily pasture, forage and some livestock production.

The estimated weighted average damages per hectare were:

Flood Duration	Weighted Average Damages
Short Duration Flooding	$350/ha
Long Duration Flooding	$1,840/ha

Morris (6) also estimated the replant cost for pasture and forage at $435/ha.

The Mississippi River valley experienced a large flood (43) in 1993 that covered 4 million hectares of farmland. Losses/damages were estimated at $5 billion. This is a weighted average of $1,250 US per hectare.

The 1997 flood of the Sacramento and San Joaquin River systems in California covered 24,500 hectares and caused an estimated $89 million in damages. This is weighted average damage of $3,633 US per hectare (27).

In 2014, Arkansas experienced floods (16) that covered 87,500 hectares of farmland causing $35.6 m in damages. This is a weighted average of $407 US/ha.

The following table summarizes the ex-post analysis discussed above.

Flood Experience	Dominant Production	Weighted Average Damages[47]
Mississippi (1993)	Forage, Dairy	$1,250 USD
California (1997)	Horticulture	$ 3,633 USD
England (2007)	Forage, Horticulture	$ 2,406 CAD
Somerset, England 2012 (long duration)	Forage	$ 1,840 CAD
Arkansas 2014	Forage	$ 407 USD

I.2 Ex-Ante Studies

In 2006, Wein et al. (14) estimated the damages and losses from an ARkStorm[48] flooding scenario in California. Crop losses were estimated using an adaptation of the crop production loss model developed for the Delta Risk Management Strategy (DRMS) Phase 1 Report.

Wein et al. (14), in the analysis of ARkStorm, divided the approach to estimating crop losses to those that experienced short duration floods (<14 days) and those experiencing long duration floods (>14 days).

The model provides a general framework for estimating crop losses based on the duration of the flood. For a spring flood, it would be as follows:

Framework for Estimating Crop Losses	
Duration <14 days	Duration >14 days
• Grain/forage crops lost • Annual crops lost • Perennial crops survive to harvest	• Grain/forage crops lost • Annual crops lost • Perennial plants killed

Wein et al. (14), in the ARkStorm analysis, applied this framework for estimating crop loss for perennials. No partial losses were considered for flooding duration of less than 14 days. They estimated crop losses per hectare of $ 7,358.

This project examines the impact of a freshet flood on the agricultural sector in the FVRD. Freshet floods typically occur from the end of May to early June. The two largest freshet floods on the Fraser River occurred in 1894 (May) and 1948 (May 31[49]). This study assumes the flood occurs on June 1.

Published articles (6)(14), and interviews with farmers and production specialists confirm that two weeks of inundation is a critical point for plant survival. With a freshet flood on June 1, flood duration is also critical for making replant choices. Replanting in early July as compared to early August changes the potential crops and markets for annual crops, and the ability to harvest a fall forage crop.
The flood scenarios with river flows similar to the 1894 freshet assume no dikes. They in essence define the potential extent and depth of the flood[50]. While hypothetical dike breaches can be modelled, there is no way of knowing how and where a dike will actually fail, and the infrastructure the water must navigate to get to the full extent of the potential flooded area. Even within a localized area, topographical differences may result in different farms experiencing different

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[48] An **ARkStorm** (for Atmospheric River 1000 Storm) is a hypothetical but scientifically realistic "megastorm" scenario. The event would be similar to exceptionally intense California storms which occurred between December 1861 and January 1862.

[49] The peak flow was June 10 but the Matsqui dike breached on May 31.

[50] More detailed modelling, incorporating hypothetical breaches and the impact of infrastructure, are complex and beyond the scope of this project.

flood durations. Modelling these differences is complex and beyond the scope of this project.

The DRMS framework for considering crop losses under different flood duration will be adopted with some refinement for perennials under a short duration flood. The most informative approach, particularly with the intensity and diversity of agriculture in the FVRD, is to define duration of the flood as short term (<14 days) and long term (>14 days). In terms of outside boundaries to duration, it is unlikely any freshet flood scenario could be drained in less than 7 days,[51] and the 1948 freshet flood took 4 to 6 weeks to drain.

Losses under the different flood scenarios are estimated as if the whole area experienced a short duration flood, and again as if the whole area experienced a long duration flood.

The approach to estimating the impact of a freshet flood on annual revenues of agricultural production is as follows:

- The areas inundated by the flood are described for three regional flood scenarios and one localized flood scenario (Matsqui Prairie).
- Revenue losses (Farm Receipts[52]) are estimated as follows:
    - Commodities are grouped according to similar production systems and revenue per hectare – termed commodity groups.
    - GIS mapping and the Agricultural Land Use Inventory (ALUI) (26) information are used to identify the area of production for each commodity group under each flood scenario.
    - Published research and local expertise are used to estimate the proportion of crop loss for each commodity group under the different flood durations.
    - Current market prices and average yields are used to estimate revenues per hectare for each commodity group.[53].
    - Lost revenue is estimated for each commodity group by multiplying the % loss estimates by the yield per hectare and the average market price.
- Farm Building losses are estimated as follows:
    - Use ALUI information to identify the area in the flooded area covered by farm buildings.[54]

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[51] Coastal flooding in the Fraser Delta as the result of a breach in a dike is estimated to take 7 days to drain assuming the breach can be repaired within 48 hours.

[52] Farm gate receipts is a common measure of farm sales and is reported by Statistics Canada.

[53] Average yields come from Ministry of Agriculture Budgets and industry marketing associations.

[54] Statistics Canada groups farm land and buildings in an asset category so the best approach to estimating the farm building inventory in the flood zone is to use the ALUI information.

  - Estimate the market value of farm buildings using current replacement cost.
  - Use published information and local knowledge to estimate a % loss for buildings under specific flood scenarios.
  - Residences are not included.
- Farm Machinery losses are estimated as follows:
  - Use Statistics Canada value of farm equipment in a census area. Prorate the value for the census area to the area flooded.
  - Use published data and local expertise to estimate losses for farm equipment.
- Replant costs are estimated using Ministry of Agriculture budgets and market costs for inputs.
- Clean-up costs are estimated using published data.

Appendix II - Interviews with Farmers and Local Production Experts

Provincial Berry Specialist

- Felt a 14 day flood would harm most blueberry plants to the point that replant is necessary.
- Wide range of management across the FVRD.
- Wide range of production per acre but suggested 6 – 8 tons is a reasonable average.
- If there was seepage and localized flooding in May and June, he has seen plants impacted very quickly. There is a question of their long term productivity because of *Phytopthera* root rot.
- E.g. On Nicomen Island, fields with low spots are still not performing well 6 to 7 years after a localized flooding event.
- Yields have changed over time as well. E.g. Richmond used to get 3 tons/acre with (passive) subsurface irrigation and now gets 10+tons/acre with intensive management.
- Flooding of >2 weeks would lead to extensive damage in a Matsqui Prairie farmer’s fields. If the bushes were totally covered for one week in May/June the plants would die or no longer be commercially viable because they would have been actively photosynthesizing.
- He recommended looking for information on flooding in other areas of the world for damage impact assessments, e.g. Germany/Eastern Europe/Japan/Chile.

Dairy Farmer in Matsqui Prairie. 1948 flood survivor

- Matsqui Prairie covers 10,000 acres.
- 1948 flood from a breach – old clay dikes with cottonwoods – a storm had uprooted some of the cottonwoods.
    - Unsure if it would have overtopped if there was no breach.
    - Took 24 hours to reach his farm after breach (railway acted as buffer).
    - Lasted 6 weeks – replanted oats in late August to get some green feed.
- Most farms had dairy cows. Average herd then was 20 cows.
    - Most moved animals to the Abbotsford airport (still in post war state – not commercial).
    - They moved their milk cows to high ground on north side then moved to the airport because the milking support was there.

    - Milkers were the single unit portable ones so easy to move to another site.
    - Rented a barn on Sumas Prairie (didn't flood) for balance of summer.
- Mostly forage in Matsqui Prairie. A few berries. Essentially all plants died except for some apple trees.
- The Vedder Dike held so Sumas Prairie did not flood.
- Dike breaches further up the river flooded Greendale and other parts of Chilliwack.
- The book 'High Waters' covers a lot of the points.

Dairy Farmer – Matsqui Prairie

- Cows on robotics don't adapt well to traditional milking system.
- Cows are very high producing – finely tuned machines.
- Disruption will disrupt production for at least 3 months – off at least 50%.
- Clean-up is a complicated by overflow of manure pits.
- Machinery will be damaged:
    - $250,000 - $300,000 per robotic machine ($5,000/cow).
    - $1.5 m for other machinery/pumps ($5,000/cow).
- Save the cows with the best genetics first.
- Concerned with the lack of dredging in the Fraser River. He feels dredging keeps the main flow in the centre of the river protecting the dikes from impacts of erosion.

Dairy Farmer - Nicomen Island

- Will lose insurance coverage if he moves cows off the farm.
- Nicomen and Barnston Island are the only two places where they must truck cows. Other places have some options to move to higher ground.
- Timing of transport is a challenge - if they wait until the milk truck can't come then the transport truck can't come either.
- If move the cows they lose 20% to 50% production depending on where the cow is in the lactation cycle.
- Milking system can be moved to higher area – except maybe the tank.
- Clean-up will be substantial – silt in everything.
- Fields will need to be replanted.
- Unsure if stored feed will survive – haylage probably, bunker feed possibly not.
- Concerned about contamination from flood water.
- Concerned pumps will be damaged so they won't be able to drain area after the flood subsides.

Chilliwack - Nursery

- Field plants can handle up to 2 weeks but at 3 weeks are unsaleable.
    - Take up 7 – 10 years to get full inventory back up.
- Potted plants are too hard to move in part because you need a watering system at the receiving location.
    - With advance notice may be able to move some potted material out early.
- Need to recognize the difference between surviving and being saleable.

Matsqui Prairie - Blueberry Farm + Value Added Packaging
- he used to get more flooding on his property, prior to the building of the retention pond that holds the storm water from the Clayburn hills area.
- he used to get flooding up to his driveway.
- his farm is outside of the area that was covered by the drainage and irrigation improvements funded by the federal program (ALDA??); Bateman Road is the cut off for the improvement area.
- heavy rain could lead to the reservoir backing up.
-if his blueberry plants were covered with water for 2 weeks "they'd be done."
- the change from dairy to berry since 1948 means that a flood that occurred today would have different impacts for agriculture.
- the risk level for a flood is rising because the river is not being dredged; why isn't there annual dredging anymore?
- his packing facility is 20 feet tall.
- some of the equipment in the packing facility is moveable (with enough advance warning), but not the refrigeration and cooling equipment, so the latter would be damaged.
- any new refrigeration equipment or replacement parts would have to be ordered from the US; no one carries inventory any more.
- while it may be repairable, it would take time, e.g. it took 2 weeks to get a replacement part for a pump.
- it is human nature to leave the decision to move as late as possible.
- they were lucky last year to get enough water to irrigate their plants.
- he also has a receiving station in Delta, so he could divert some of his product there.
- there would also be food safety implications of re-starting the packing facility if it was impacted by silt and debris.
- both of the blueberry packing facilities in Matsqui Prairie are on city sewer and water, so they could only operate if the water and sewer were not impacted by the flooding.
- he could move fertilizer and pesticide to a higher location or a neighbouring farm.
- the BC Blueberry Council could supply numbers about the size of the blueberry industry, and its impact on the local economy, e.g. employment, farm processing, and value added, and the new trade agreements with China and South Korea.

Sumas Prairie - Cut Flower Producer

Daffodil and tulip cut flowers are sold by June.

- Gladiola bulbs would be lost.
- Replant bulbs lost.
- Replant bulbs worth about $7,500/ha.
- Revenues $30,000 -$40,000/ha.
- Some fields on 2 year cycle so only replant one-half the field.
- Greenhouse just used for winter production.
- Storage houses much higher level of construction.

Provincial Nursery and Greenhouse Specialist

- even if there was a lot of advance notice, it is unclear where nurseries could find an alternate location to ship their plants to that would have sufficient irrigation; it would also be a huge cost to move an entire nursery's inventory.

- in 2007, a nursery in Maple Ridge experienced a flood, due to local government work on a nearby river associated with a storm event.

  - all of their pots floated away, even the 1 gallon pots.
  - the gravel in their container beds was moved, and the ground cloth in other locations of the nursery was covered in gravel and silt.
  - the operator of that nursery lost everything; the whole property was covered in silt and gravel, which plugged all the pores in the growing media.
  - he stared growing again later that year, and has since switched to growing vegetable transplants.
  - his polyhouses were not damaged; he didn't lose any buildings or infrastructure.

- A nursery in Matsqui Prairie has a system of rolling benches that are raised above the ground, which would make his nursery stock less vulnerable to flooding (although it's done for efficiency reasons).

- A nursery on Nicomen Island refused to move their nursery container stock during the most recent freshet flood warnings (2012?).

- for in-ground tree nurseries, the impact would vary with the duration of the flooding, and the debris/silt accumulation; there would also be the longer term impacts of root rot diseases.

- vegetable greenhouses – most grow their crops in grow bags which are on the ground, so the crop would be killed in a flood.

- assuming that seeds and a propagator could be found (not a guarantee), a vegetable greenhouse operator would have to wait 7 weeks to order new tomato/pepper transplants; all tomato and some cucumber transplants are grafted, meaning the propagator would have to grow twice as many plants (tops for production, and bottoms for root structure).

- the grower would be waiting 2 to 3 months before a harvest could be resumed.

- he/she would have harvested some vegetables prior to June 1.

- in most greenhouses, electrical lines and irrigation tanks are underground, making them very vulnerable to flooding.
- pesticides and fertilizers could be moved to higher shelves.
- after the flood there would be the additional time and cost to clean out and disinfect the greenhouse.
- there are no commercial vegetable greenhouses in Chilliwack.
- temporary farmworker housing would probably not be affected since it's required to be raised to the flood construction level.
- the large ornamental greenhouses on Fairfield Island would be at risk from a freshet flood.
- for growers who grow chrysanthemums for cut flowers, it would be difficult to get replacement stock and re-start because all plant material has to be guaranteed to be free of white rust (a quarantine disease in Canada and the US).
- for growers who grow potted plant material, summer is a transition time; e.g. the bedding plant material grown in the spring is mostly sold by the end of June; and potted plants like poinsettias are brought in in July/August. The key issue is whether the greenhouse could be cleaned up and disinfected in time.
- it is possible that if the floodwaters caused localized erosion it could result in building/greenhouse structural damage.
- Greendale/Yarrow is a very high risk area.

Blueberry Farmers – Matsqui Prairie

- he thinks there will be a blowout at the base of the dike, rather than an over-the-top flooding.
- he believes that dredging the river could reduce the risk of a dike breach.
- DFO only gave the local government a 2 month window to do any dredging, which was impossible to meet.
- as a result, there is a sand bar in the middle of the river that is growing.
- seepage and boils are increasing every year.
- the seepage in 2012 resulted in water in their fields that was 3 to 4 inches deep.
- water covered the roots for 3 weeks, and the field was wet for longer than that.
- plants are noticeably stunted in the sections of their fields with the most seepage.
- repetitive wetness during the growing season is a "death by inches" problem.
- if there was a dike blowout, it would take weeks to remove the water, since there are no pumps and Matsqui Prairie is essentially a "bowl."
- it takes the plants 3 to 4 years to recover after a seepage event.
- to control seepage, the local government should be looking at reinforcing the base of the dike with large rocks or cement.

Kent - Dairy Farmer and Direct Market Cheese

- the barn near their house didn't flood in 1948.
- the nearby property (about two miles west), was flooded up to the hayloft in 1948 .

- The former owner moved to the property in 1947. He spent the whole summer removing debris from his fields in 1948, and it took him two years to get his forage fields back into production.
- the area's cattle were moved to a nearby cemetery, at a higher elevation; an unintended consequence was that all the cattle got cowpox.
- the train track acted as a dike.
- very little feed is produced on dairy farms today; e.g. if a cow needs 50 lbs. dry matter/day, about 30 lbs. is from grain and the rest is from silage.
- if there was a flood today, the feed supply for the cattle would be crucial.
- the cattle would need to be moved out of the area, and since there are no dairy barns in the nearby Interior (e.g. Merritt), the most likely location would be across the US border.
- the Agassiz pump is very old and very inefficient, and the fish ladder was installed too high; the pump came from when Sumas Prairie was drained; Kent municipality owns the pump and would need to get DFO permission to replace it; now there are SAR frogs in the area.
- there was a flood (around 1990) that occurred during Freshet and a heavy rainfall; the municipality had to rent diesel pumps to move the water, and he got compensation for the corn he lost.
- the municipality wanted to cut the trees on the dike at the Harrison Mills bridge and MoE wouldn't let them.
- blackberry clearing in ditches was done annually on the wet side of the tracks; it can't be done anymore because of the SAR frogs.
- if a flood occurred today there would be no way to get rid of the water; there's a good chance that the Agassiz pump would lose its power.

Sumas Prairie - Vegetable Farmer (Wholesale and Direct Marketer)

- 1974/1975 there was a previous flooding event. The Vedder Canal broke during a storm event; Stewart Creek flooded between No. 4 and No. 5 Road; the railway was washed out.
- 1990 – the Nooksack River flooded. Cole Road was under water
-the 1948 flood didn't affect Sumas Prairie, but there was flooding in Matsqui Prairie.
- a previous Abbotsford Mayor suggested that in case of a freshet flood, Abbotsford farms might be sacrificed to save Richmond.
- if there was a June 1 freshet that totally flooded his fields, he would have planted all of his parsnips and potatoes, and he would lose those crops for the year; carrots would have been planted but could be re-planted later; storage cabbage transplants would still be in his greenhouse and would potentially be lost.
- if he lost his transplants, there is a very limited source of alternate propagators who would have available plants.
- if he was able to get back on his fields in early July, his ability to plant different crops would vary with market demands.
- he didn't think there would be a market for crops that require refrigeration, e.g. salad crops.

-there would be a big impact on his fresh market vegetable sales (vs. storage crop sales), which are about one-third of his sales.
- getting seed to re-plant could be a problem (e.g. the varieties you want in a short time period).
- he would lose his early corn sales; corn might be stunted but not killed?
- the sandy soils in Sumas Prairie would be less impacted by flooding than the silt/clay soils in Delta.
- if he could replant by July 10, he estimated he would have lost about two thirds of his normal income, and a flood would devastate his roadside stand sales.
- food safety guidelines require 120 days from manure application to harvest, which might impact the types of vegetables that could be planted.
- he would have to spend time removing debris from his fields.
- in his buildings, there would be mold in his coolers, and his compressors would be damaged since they are on the ground.
- pesticides could be moved to higher levels in the buildings.
- in 1955, there was a "silver thaw" that brought down power lines and the whole of Sumas Prairie was under water.
- the Barrowtown Pump Station has six pumps that normally run at a low speed; at a high speed they could move more water; but would power to the Pump Station be lost in a flood?
- he didn't think that Sumas Prairie flooding would last for more than a week or two.
- he is more concerned about other weather events, e.g. the heavy fall rains in 2010 affected his parsnips.
- fields that had tile drainage were okay, and the cost to install tile drainage is about $500/acre so it is a very worthwhile investment, even in rented fields.

Sumas Prairie - Vegetable Farmer (Direct Market Only)
- if he had one foot of water on June 1st, everything he had planted before that point would rot in the field.
- of his 12 acres, about two thirds would be planted, so he assumes that 8 acres would be lost at 100%.
- he would have harvested some early vegetables prior to June 1.
- he doesn't know if the flood water/debris would have an impact on his organic certification.
- because of the 120 day to harvest food safety requirement for manure application, he may not be able to replant up to 60% of his crops.
- his market plan is not set up that way – he relies on being able to sell a diversity of crops.
- CSAs and farmers' markets are how he markets his product.
- his 3 polyhouses would be full of his own transplants on June 1 – those would probably be lost.
- in his buildings he would lose his packaging inventory.
- winter vegetables, e.g. brassicas, onions, carrots, provide 20% of his revenues.
- in the case of a freshet flood, he would re-plant if he had the financial resources and the seed was available.

- he was unsure of the potential impacts of soil erosion, and the time that would be needed for debris removal and clean up.
- how much time would be needed to mulch the dead vegetation and plough it under?
- his farm has sandy soils, but no tile drainage.
- he started his farm in 2010.

Poultry Industry Marketing Board Staff

For broilers production (and turkey) can be moved to other facilities for a short period of time with sufficient lead time.

- caged layers probably OK.
- new free run layer barns are built close to the ground so would be impacted by a flood.

Nicomen Island (Outside Dyke) - Dairy Farmer

- had to move milking cows when flood was imminent
- moved to a newer barn in Matsqui Prairie with similar feeding and milking system
- had no loss in production
- noted that it was an ideal situation

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