Mission Creek Channel and Streamway Width Assessment

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Executive summary

This project provides recommendations on the location of dykes, setback from their current location. The report assesses the characteristics of the 1938 Mission Creek channel, determines the optimal width for the new channel streamway (the distance between the setback dykes containing the Mission Creek channel and the new floodplain), and finally provides a stability analysis of the new floodplain to erosion by large floods using HEC-RAS.

Use of empirical relationships indicates that the streamway should be 300 m wide. Two options for the dyke setback locations are provided. The first option provides a wide floodplain that is still more narrow than the 300 m optimal. The second option provides setback distances are narrower still but still provide benefit to the channel and the inchannel habitat. HEC-RAS modelling of the two options for the mean annual, 100 year and 200 year floods show that there is potential for erosion of the reconstructed floodplain directly following construction when bare soil is present. However, the erosion potential decreases dramatically to acceptable levels following the growth of vegetation on the floodplain.

The report recommends that the dyke on the left bank within the Mission Creek Regional Park between the spawning channel and the park boundary be removed. It appears that there is no infrastructure in this area. The current dyke is protecting the valley wall which limits the extent of flood inundation in natural river valleys.

The next section for restoration is the Benvoulin woods area. The channel in this section shows evidence of degradation. Setting back the dykes and constructing a meander should mitigate the channel degradation in this section and decrease the grain size on the bed. If this occurs, Kokanee salmon habitat will be enhanced.

The section between the Casorso Bridge and the Gordon Bridge can be greatly improved by setting the dykes back up to 285 m. Setting back the dykes to surround the oxbow lakes would increase wetland habitat, hydrologically connect the riparian vegetation on the floodplain to the channel, and create space to build meanders.

Sedimentation currently occurs just downstream of the KLO Bridge. This section should be restored following work done to the upstream sections because the new geometry of the channel within the upstream sections should decrease the sediment being delivered downstream. Channel sections upstream of the ECO center should also be restored first to decrease the amount of sediment delivered downstream.

The section just upstream of the Casorso Bridge should not be restored at this time as it has an active floodplain on the left bank because no dyke was constructed there, the channel is currently shaded by riparian vegetation, and the channel provides spawning habitat for Kokanee.

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Acknowledgments

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Funding for this project was provided through the Okanagan Water Board. The Mission Creek Habitat Restoration Project involves a partnership (Restoration Working Group) that presently includes BC Ministry of Environment (MOE), the City of Kelowna, Central Okanagan Regional District (CORD), Okanagan National Alliance (ONA), Westbank First Nation, Department of Fisheries and Oceans Canada, the Friends of Mission Creek and the Central Okanagan Land Trust. The primary objective of the Working Group is to implement restoration projects on Mission Creek.

1. Introduction

Mission Creek is a highly disturbed river system flowing through Kelowna B.C. There are a number of serious management problems associated with the creek. Two of the most important problems on Mission Creek are habitat degradation and channel bed stability (specifically sedimentation). To address the habitat degradation of Mission Creek a working group was formed. The Mission Creek Habitat Restoration Project involves a partnership (Restoration Working Group) that presently includes BC Ministry of Environment (MOE), the City of Kelowna, Central Okanagan Regional District (CORD), Okanagan National Alliance (ONA), Westbank First Nation, Department of Fisheries and Oceans Canada, the Friends of Mission Creek and the Central Okanagan Land Trust.

Mission Creek has been heavily modified through narrowing of the channel by the building of dikes for flood control from East Kelowna Bridge to the river mouth at Okanagan Lake. The channel narrowing has modified the channel pattern, hydraulic patterns, bed sediment patterns, and energy levels within the channel at bankfull flows and above. These changes have decreased the fish habitat value for important species such as Kokanee and Rainbow trout (Gaboury and Slaney 2003). However, the changes to the river channel have also disrupted the natural sediment transport patterns within the river. Of particular concern is sediment deposition occurring at and downstream of the KLO Bridge.

In 2003, the feasibility of restoring the habitat on Mission Creek through river restoration was completed (Gaboury and Slaney 2003). This report provides a well reasoned argument as to why the habitat within Mission Creek should be restored. They note that the Mission Creek channel has lost natural fluvial geomorphic processes and patterns (riffles and pools, meanders and sediment sorting), connection to the floodplain and wetlands, fish spawning and incubation habitats, diverse fish rearing habitats, diverse overwintering habitats, and fish refuge from high velocity water (Gaboury and Slaney 2003). The report also assessed the feasibility of returning the creek to a more natural state through setting back the dykes to widen sections of the river, constructing riffle-pool sequences, and realigning portions of the channel to a more meandering route. In 2004, a follow up report provided a detailed feasibility study of habitat restoration on Mission Creek (Gaboury et al. 2004). As demonstrated on the Okanagan River in 2009, rivers can be restored through setting back the dykes and restoring the river channel to a more natural state (Bull et al. 2000).

There have been a number of other reports on the condition of the Mission Creek channel, the dykes and the Mission Creek watershed including McMullen (1988), Bergman (1995), Anonymous (1997), Anonymous (1998), Anonymous (2000), Dill (2002), Epp, 2009, Epp 2009, and Burge (2009).

1.1. Background

The Group is a partnership among the Ministry of Environment, City of Kelowna, Okanagan Nation Alliance, Westbank First Nation, Regional District of the Central Okanagan, Friends of Mission Creek Society, Department of Fisheries and Oceans and the Central Okanagan Land Trust. The primary objective of the Group is to implement restoration projects on Mission Creek to re-establish functional riparian habitat, reduce erosion, sedimentation, and the flooding hazard, as well as improve fish and wildlife habitat in Mission Creek.

In 2004, a Mission Creek Habitat Restoration Feasibility study was completed by Mr. Marc Gaboury et al. This study concluded that the dykes should be setback between 50 m and 206 m, depending on location, between the Gordon Drive bridge crossing and the Mission Creek Regional Park. Five stream sections were prioritized for dyke setback construction downstream of the KLO Road crossing with the setback location based on a conceptual design. As the major constraint to completing the Mission Creek Restoration Initiative (MCRI) is the purchase of the privately owned land, a channel width and optimal streamway width assessment is required to determine the optimum setback distance for each property.

1.2. Purpose

The purpose of the channel width assessment is to determine what the historical (pre-channelization) channel widths (or range of widths) were for lower Mission Creek in areas that are proposed for dyke setback, as outlined in the 2004 feasibility study. This will assist the Group in determining how much of the individual properties that are affected by the proposed dyke setback are required for the MCRI to meet or exceed its objective. The outcome of the assessment should be a detailed property by property analysis of what the minimum and optimum channel widths required should be to reduce flooding potential and improve fish and wildlife habitat, such that property acquisition negotiations can proceed immediately should any of the properties, in whole or in part, become available for purchase. The suggested tasks for the channel width assessment are outlined below:

1. Review the 2004 feasibility study completed by Gaboury et al.
2. Conduct a historical aerial photograph interpretation to determine how Mission Creek changed over time, pre and post channelization.
3. Conduct an aerial and ground reconnaissance of lower Mission Creek and each affected property to document existing conditions.
4. Based on the historical and field reconnaissance data, model the optimum channel width for each property required to restore Mission Creek to meet the restoration objectives.

2. Study site

Mission Creek is situated within the confines of the City of Kelowna. The project site is located between the ECO Centre downstream to the Gordon Road Bridge. Mission Creek is a fourth-order stream with 38.9 km of fish-bearing streams. Numerous fish species have been identified in Mission creek including Kokanee, Rainbow trout, Brown trout, Prickly sculpin, Longnose dace and Finescale sucker (Anonymous 1997). Mission Creek has a drainage basin area of 858.8 km^2 and relief of 1829 m, with elevations ranging from 2,171 m at the summit of Little White Mountain to 342 m at the confluence with Okanagan Lake. The average annual total precipitation at Kelowna is 329.7 mm, with approximately 25% falling as snow. At an elevation of 1,250 m at McCulloch near

Hydraulic Lake, the annual precipitation increases to 702.6 mm with 52% falling as snow. Approximately the middle of the watershed, at Joe Rich, the annual precipitation is 579.4 mm with 52% as snow (Anonymous 1997).

For the analysis, the study area was broken in to five sections based on bridge location or major changes in land use (Figure 2-1). These sections will be used for the analysis of the 1938 channel and the recommendations of dyke locations. The sections ranged in length from 932 m to 1675 m.

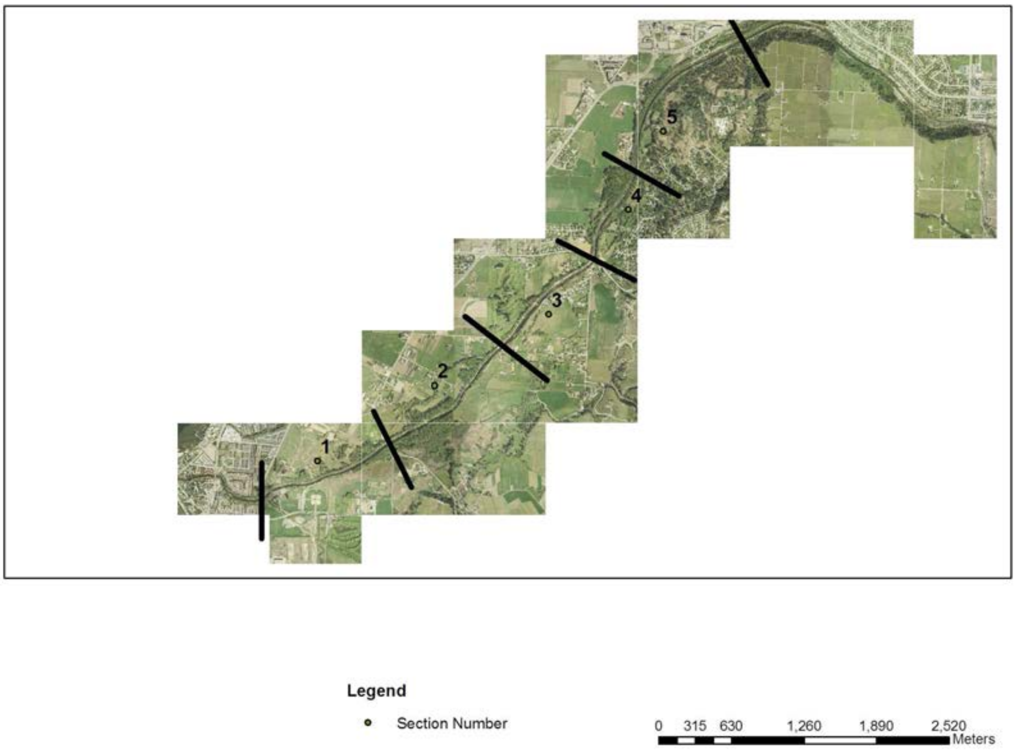


Figure 2-1. Five sections used in the analysis.

3. Gaboury et al. (2004) recommendations

Gaboury et al. (2004) made recommendations about setting back dykes on Mission Creek and prioritized the location of the works. They recommended that the work proceed from downstream to upstream. Specifically the prioritized order of constructions was:

1. Construction of a 730 m section of setback dyke on the northwest bank of Mission Creek and upstream of Casorso Road (on or affecting properties identified as: Westbank First Nation, PID 008-504-130 and PID 024-008-164),
2. Construction of a 680 m section of setback dyke on the northwest bank, downstream of Casorso Road (on or affecting properties identified as: Westbank First Nation and dedicated road allowances),
3. Construction of a 1020 m section of setback dyke on the southeast bank, downstream of Casorso Road (on or affecting properties identified as: Westbank First Nation, PID 011-099-895 and PID 014-767-538),
4. Construction of 190 m and 530 m sections of setback dyke on the northwest and southeast banks, respectively, upstream of Casorso Road (on or affecting properties identified as: PID 024-008-184, PID 009-417-770 and dedicated road allowances), and
5. Construction of a 420 m section of setback dyke on the northwest bank, downstream of KLO Road (on or affecting properties identified as: dedicated road allowances).

The areas of each property that would need to be purchased were determined and are shown in Table 1.

3.1. Casorso Road

Gaboury et al. (2004) determined that the 730 m section of setback dyke immediately upstream of Casorso Road had priority for construction because:

1. There was significant logistical and financial benefits associated with coordinating setback dyke construction with the planning and construction of a new Casorso Road bridge by the City of Kelowna,
2. This section of channel is highly utilized by Kokanee for spawning and, in comparison to the other proposed setback dyke sections, offers a wider setback distance that would result in greater benefits to native fish species habitats, and
3. There was a strong willingness by the City of Kelowna, affected landowners and community organizations to cooperate with the setback dyke project in this section of channel.

Preliminary designs for the 730 m section of setback dyke upstream of Casorso Road were proposed by Gaboury et al. (2004). The impact of setting back dykes on the

Mission Creek Greenway viewing platform was also assessed and options were discussed with the City of Kelowna and Friends of Mission Creek to ensure that any potential access or visual impacts caused by dyke setback were mitigated. This project does not review these restoration designs.

They proposed that a new floodplain will be contoured on the right bank by removing the existing dyke. The floodplain will be constructed at an elevation 1.2 m above the channel bottom. The new floodplain elevation would allow for overtopping of the central channel banks when flows are greater than a three year flood. Low elevation flow retard bars will be constructed on the new floodplain to deflect flood flows towards the existing mainstem and reduce soil erosion while vegetation is becoming established. The re-established floodplain and riparian zone will be revegetated with a diversity of native grasses, shrubs and trees.

Table 3-1. Area of each private and Crown land parcel required for setback dyke construction in Mission Creek. Dedicated road allowances are not included (from Gaboury et al. 2004).

Bank of River	Ownership	Cross Sections	Plan Number (PID#)	Total Lot Area (ha)	Area of Lot Required for Setback Dyke Construction (ha)	% Within Setback Area
Southeast	Private	13 to 16	011-099-895	6.77	1.36	20%
Northwest	Private[1]	22 to 26	008-504-130	18.07	2.50	14%
Northwest	Private[1]	26	024-008-168	4.54	0.13	3%
Southeast	Private	30 to 31	009-417-770	7.23	0.3	75%
Northwest	Private[2]	39A to 42	001-714-7911	3.37	4.08	31%
Northwest	Private[2]	41 to 42	001-714-783	10.21	0.61	6%
Southeast & Northwest	Private[2]	41A	011-074-132	2.42	0.63	26%
Northwest	Private	42	011-074-281	1.95	0.26	13%
Southeast & Northwest	Private	43	007-938-675	2.43	0.81	33%
Southeast & Northwest	Private	43 to 46	011-074-311	12.19	3.12	26%
Southeast & Northwest	Private	47 to 50	003-979-440	7.04	1.75	25%
Southeast	Crown / Other	9 to 13	014-767-538	12.50	0.99	8%
Northwest	Crown / Other[1]	22	Westbank FN	2.03	0.13	6%
Southeast & Northwest	Crown / Other	16 to 20	Westbank FN	2.03	0.62	31%
Northwest	Crown / Other	41	024-208-124	0.89	0.89	100%
Southeast & Northwest	Crown / Other	46 to 47	017-816-874	22.61	2.06	9%
Northwest	Crown / Other	27 to 28	024-008-184	1.33	0.55	41%

Private Lands[1] - Highest Priority Setback Dyke Site, Immediately Upstream of Casorso Road
Private Lands[2] - Benvoulin Woods Area

The setback dyke would adhere to the Provincial standard dyke design and have top widths of 4 m, a 2:1 side slope for the dyke on the side closest to the creek, and similar top elevations as the existing dykes. The dykes would be constructed using spoil from construction of the floodplain and removal of the existing dykes.

In the preliminary design, the viewing platform will remain as is in its present location and would function as an island in >3 yr floods. Access to the platform during

<3 yr floods would not be impeded as floodwaters would remain within the existing channel banks. If desired, access during floods up to a 200 yr recurrence interval could be possible through the construction of a raised (1 m high) boardwalk about 21 m long.

The potential effects of setback dykes on water levels and stream velocities were modeled using the HEC-RAS computer program (Gaboury et al. 2004). According to the modeling results, setback dyke construction does not result in a significant change in the hydrology of the river, and the current Casorso Bridge crossing remains as the main cause of backwatering effects during floods in this section of river.

4. Analysis of the 1939 channel

This section provides an analysis of the location, width, area and sinuosity of the Mission Creek channel in 1938. At this time the Mission Creek channel was mostly in a natural state, although some dyking had occurred and the channel may have been previously straightened. Even so, the 1938 aerial photographs provide the best example of the Mission Creek channel as it was naturally. The location of the 1938 channel may therefore be used as the first approximation of where the channel should be located following restoration. The location of the 1938 channel was mapped using a 1938 orthophoto that was georectified onto 2009 orthophotos. All mapping was therefore in the same reference system for analysis.

The location of the 1938 channel can be seen in Figure 4-1. The 1938 channel is generally wider and more sinuous than the 2009 channel. The sinuosity of the 1938 channel was greatest in sections 3, 4 and 5, the upstream sections that are now unstable (Table 4-1). The channel sinuosity ranged from 1.03 to 1.07. The sinuosity has decreased between 1 and 6 percent, with the greatest decrease occurring in section 4, the section that is currently showing evidence of degradation (Burge 2009).

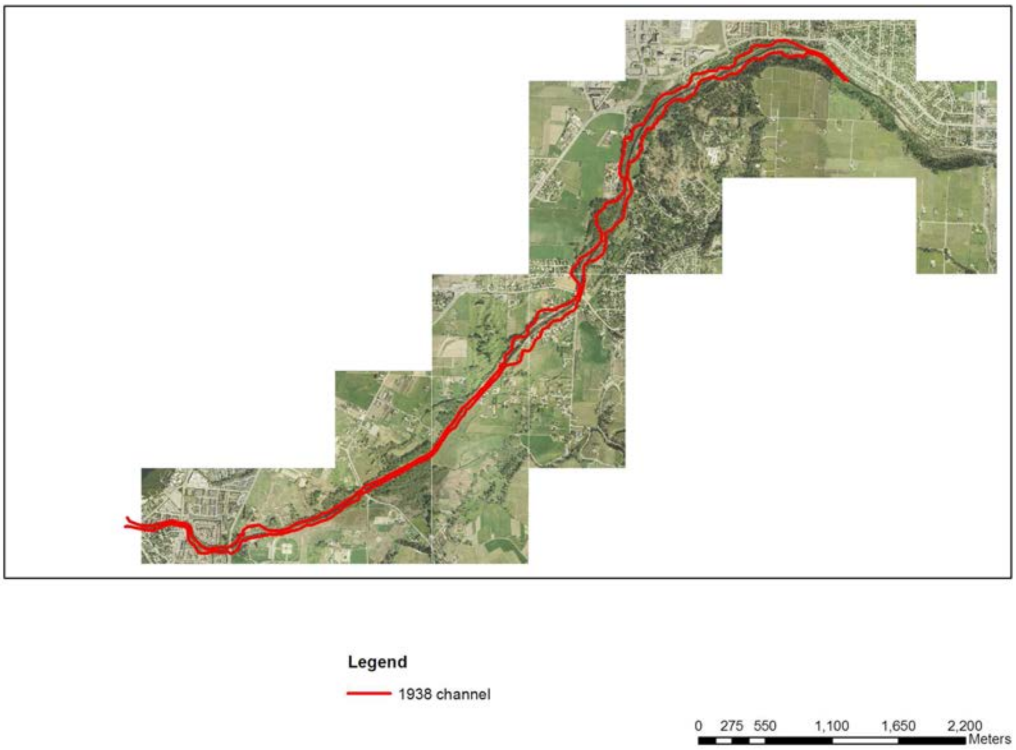


Figure 4-1. 1938 Mission Creek channel location.

Table 4-1. Channel sinuosity values for Mission Creek for 1938 and 2009.

	Valley length (m)	1938 length (m)	2009 Length (m)	1938 sinuosity	2009 sinuosity	Difference %
Section 1	1197	1246	1227	1.04	1.03	-1.59
Section 2	1300	1337	1323	1.03	1.02	-1.08
Section 3	1063	1150	1104	1.08	1.04	-4.33
Section 4	850	913	863	1.07	1.02	-5.88
Section 5	1558	1661	1600	1.07	1.03	-3.92

The Mission Creek channel has decreased in both area and width. Channel area has decreased between 14 and 68%, with the greatest change again occurring upstream in sections 3, 4 and 5 (Table 4-2). Average channel width was determined by dividing the channel area by the channel length. This method provides an accurate measurement of the channel width. The channel widths measured for each of the 20 cross-section sites is listed in Table 4-3. The average channel width has decreased between 5 and 52 m, again with the greatest changes occurring in sections 3, 4 and 5.

Table 4-2. Changes in the area and width of the Mission Creek channel for 1938 and 2009.

	1938 Channel area (m)	**2009 Channel area (m)**	**Change in area (%)**	**1938 Channel width (m)**	**2009 Channel width (m)**	**Change in width (m)**
Section 1	59556	50821	-15	47	41	-6
Section 2	38619	33212	-14	34	29	-5
Section 3	89076	46462	-48	66	36	-30
Section 4	79416	40522	-49	85	48	-38
Section 5	131124	41455	-68	78	26	-52

Table 4-3. Channel width measurements for the 1938 and 2009 channel at each of the 20 cross-section locations.

	Channel distance (m)	1938 Channel width (m)	2009 Channel width (m)	Change in width (m)
XS 1	6244.9	63	34	-29
XS 2	5753.1	80	22	-58
XS 3	5628.1	89	22	-67
XS 4	5384.3	59	22	-37
XS 5	4998.3	71	23	-48
XS 6	4612.3	183	28	-155
XS 7	4300.3	67	30	-37
XS 8	4030.3	104	31	-73
XS 9	3894.2	23	34	11
XS 10	3568.4	103	32	-71
XS 11	3160.5	104	33	-71
XS 12	2819.6	31	26	-5
XS 13	2305	36	25	-11
XS 14	2017.7	26	40	14
XS 15	1916.5	21	37	16
XS 16	1612	32	36	4
XS 17	802	44	25	-19
XS 18	587.4	32	24	-8
XS 19	273.2	30	33	3
XS 20	0	33	37	4

This analysis indicates that the greatest changes to the Mission Creek channel have occurred in sections 3, 4 and 5. These are also river sections that were identified as unstable by Burge (2009). Section 3 is an aggrading section while sections 4 and 5 have the potential for degradation. Surprisingly, sections 1 and 2 display few changes since 1938. These results indicate that sections 3, 4 and 5 have changed the most and are unstable and therefore they should receive priority in restoration.

5. Analysis of Dyke Setback location

The following section provides a discussion of how wide dykes should be set back to mimic a natural condition. Two terms are used to describe the width of the active floodplain. Williams (1986) uses the term meander belt width, while Ward et al. (2002) uses the term streamway to include the channel and the active floodplain. The report will use the term streamway width.

5.1. Criteria for location of dykes

When proposing the locations of new dykes, several outcomes can be managed for. This requires a set of criteria to be used to make decisions about the locations of new dykes. In its natural condition, Mission Creeks' floodplain included much of the low elevation portions of Kelowna, including downtown and the channel migrated throughout this area. Obviously, Mission Creek will never occupy its former floodplain. Therefore, a number of criteria and limitations were used to determine where the dykes should be set back. These include that:

1. Bridge locations cannot be changed;
2. Residential or other intensive land uses should not be within the dykes.
3. Where possible, only one dyke should be moved. This limits the expense of relocating dykes.
4. The 1938 channel or recently abandoned channels seen on the 1938 photos should be located within new dyke locations where possible. This would provide the greatest possibility of returning the creek to its predyked state.
5. The new floodplain located between the new dykes should be at an elevation that would be flooded regularly where possible. This would limit the expense of lowering the floodplain to a level that will become inundated regularly. Lowering of a floodplain can be done but it is expensive and is taken as a last resort.
6. The new floodplain within the dykes should be a maximum of 300 m wide where possible (see analysis below).
7. Forested areas should be located within the dykes where possible.
8. The dyke locations should follow property lines where possible to minimize small slivers of land.
9. Wetlands should be within the dykes where possible. This will allow wetlands to be hydrologically connected with the Mission Creek channel during overbank events.

5.2. How far should the dykes be set back?

There is little literature about how far dykes should be set back to create a new floodplain. Copland et al. 2001 provides a discussion of the characteristics of meandering channel geometry as it relates to river restoration. The most frequently cited work is Williams (1986) who investigated a number of empirical relationships among river planform variables including meander belt width and channel width (W). The meander belt width is defined as the width of the floodplain between an upstream outer channel bank at the apex of a meander and the downstream outer channel bank at the apex of the next meander (Figure 5-1). These relationships were developed from natural unconfined alluvial meandering river channels. These channels adjust their bankfull width and meander characteristics through deposition and erosion. Meander belt width (B) was found to be

$$B = 4.3\ W^{1.12} \qquad \text{(Williams 1986)} \qquad (1)$$

More recently, Ward (2001) and Ward et al. (2002) further investigated these empirical relationships as they apply to sizing stream setbacks. Ward et al. (2002) provides a reanalysis of Williams (1986) with the goal of determining sizing of dyke setbacks. The Williams (1986) analysis provides a best fit relationship between the variables. When applied as an estimate of the meander belt width, which he called streamway width (Sw) (Figure 5-2), the method generates a number of over and under estimates. Without modification, equation 1 will fail our setback requirements at least half the time (Ward et al. 2002). When sizing the streamway, over estimates are not a concern, however, underestimates decrease the margin of safety. Based on their analysis, the empirical relationship was found to be

$$Sw = 6.92\ W^{1.12} \qquad \text{(Ward et al. 2002)} \qquad (2)$$

The relationship presented by Ward et al. (2002) was used to size the channel streamway for Mission Creek. Mission Creek is not an unconfined alluvial river; therefore, the channel width must be estimated. There are a number of empirical relationships between bankfull discharge and bankfull channel width. The stream restoration toolbox by Parker (2006) was used because it incorporates bankfull discharge and the channel bed grain size into the estimate of channel width. The mean annual flood (52.1 m^3/s) for Mission Creek (Burge 2009) was used as the bankfull discharge. The restoration toolbox calculated different channel widths (26.5 to 29.25 m) depending on grain size. A range of streamway values (272 – 303 m) were calculated using the Ward et al. (2002) relationship. A conservative channel width of 29 m was used to determine the streamway width requirement for Mission Creek. The distance required to set back the dykes in Mission Creek was calculated to be 300 m.

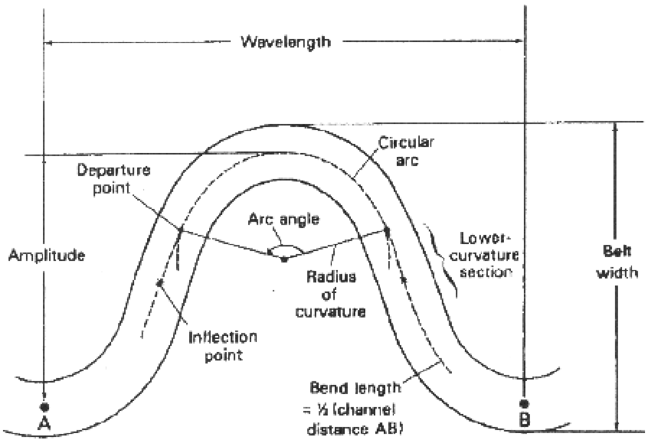


Figure 5-1. Plan view sketch of an idealized river meander (from Williams 1986).

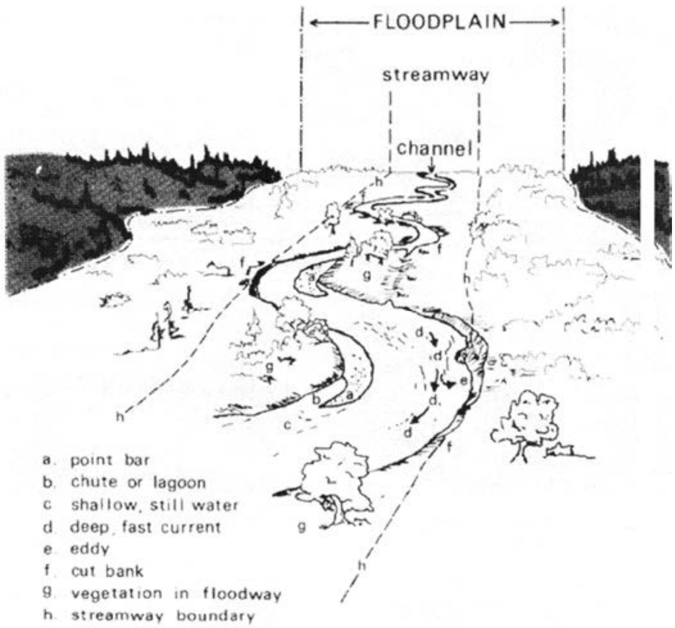


Figure 5-2. Floodplain characteristics including streamway width (from Ward et al. 2002)

5.3. Mapping

A number of variables were used to guide the recommendations for the best locations for the dykes to be setback. These variables included the topography, location of the channel in 1938, the present dyke location, the land use (residential, golf course, farmland), and the location of bridges.

The topography was characterized using a map with 1 m contour intervals provided by the City of Kelowna. The 1938 channel was mapped using a georectified orthomap of Kelowna created from 1938 aerial photographs. Recently abandoned channels seen on the 1938 orthophoto were also mapped. The current dyke location and current channel location were mapped from 2009 orthophotos provided by the City of Kelowna. The present land use could also be seen on these photos. The dyke location and channel location proposed by Gaboury et al. 2004 were also mapped. This allowed the overlay of the 1938 channel locations with the modern channel and dyke locations to aid in the determination of the best location for the setback dykes.

6. Proposed setback dyke locations

Mission Creek was divided into five sections for the analysis of the dyke setbacks (Figure 2-1). Working from downstream to upstream, these included section (1) Gordon Bridge and Casorso Bridge, (2) Casorso Bridge to Mission Creek Golf and Country, (3) Mission Creek Golf and Country and KLO Bridge, and (4) KLO bridge and Benvoulin woods, and (5) Benvoulin woods and the ECO centre

6.1. Section 1: Gordon Bridge to Casorso Bridge

Two dyke setback options are proposed for section 1. In the first option the dykes on the right bank are relocated. In the second option the left bank dykes are relocated. Both of these options differ from that presented in Gaboury et al. (2004) which relocated the dykes on both sides of the channel and impacts few properties while only setting back the dyke about 40 m.

6.2. Section 1: Burge dyke 1

Under the first option, the dykes are setback for 1035 m along the channel to provide a streamway width of up to 285 m. This option provides a much greater streamway width than the proposal by Gaboury et al. (2004). This is the preferred option because under this proposal, abandoned channels (natural wetlands) that can be seen in the 1938 aerial photographs will be located within the new dykes (Figure 6-1). Also, the most recently active floodplain, the predyked floodplain, will be within the dykes. It is unlikely that the course of the abandoned channels can be used entirely as the new meander geometry because these channels were unstable and were cut off. However, it may be possible to reconnect parts of the abandoned channels to the main channel. This would provide the abandoned channels to be hydrologically reconnected to the Mission Creek channel where they would experience annual inundation. This option also included a large portion of riparian forest in property 3034.

Option 1 would require property from three lots on the right channel bank (Figure 6-2, Table 6-1). These were properties of interest identified by the Mission Creek Habitat Restoration project with scores of >15.

This proposal also includes a dyke setback on the left channel bank just downstream of the Casorso Bridge. If possible the dyke should be relocated to the property line of IR8 so that the floodplain can be reconnected with the channel. Therefore, a small pie shaped area is also needed from LOT 1829 (Figure 6-2, Table 6-1). This would disturb far less forest than the Gaboury et al. (2004) proposal to move the dykes back within the forest. It will also increase the streamway width just downstream of the Casorso Bridge.

Table 6-1. Potential areas for purchase for Section 1: Burge Dyke 1 option.

Section 1: Burge Dyke 1

Plan #	Area (ha)
3034	7.38
1829	0.16
41675 Lot A	2.64
41675 Lot B	2.46

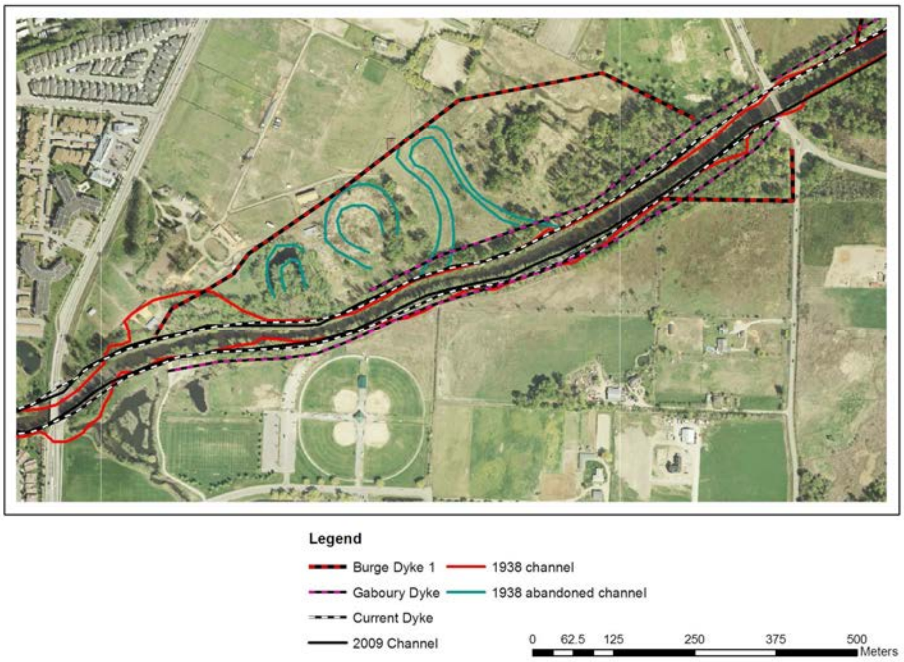


Figure 6-1. Setback dyke locations for section 1 for Burge Dyke 1 option.

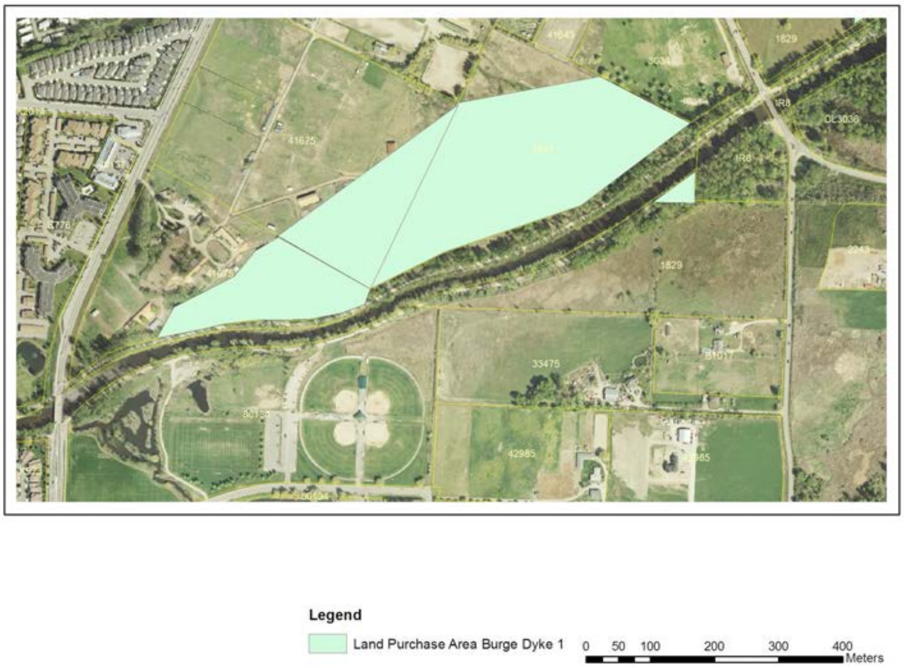


Figure 6-2. Areas to purchase for Section 1: Burge Dyke 1 option.

6.3. Section 1: Burge Dyke 2

Under the second option, the dykes are setback for 760 m to provide a streamway width of up to 190 m (Figure 6-3). This proposal only deals with the dyke on the left bank. This option does not include the abandoned channels that can be seen in the 1938 aerial photographs within the new dykes and therefore these wetlands will remain cut off from the Mission Creek channel. This option also has less riparian forest within the streamway. Also, under option 2 the benefit of setting back the dykes affects 275 m less channel distance than option 1.

This option affects four lots (Figure 6-4, Table 6-2), two of which are listed in Gaboury et al. (2004). The dyke would be setback to the property line of IR8 and portions just downstream of the Casorso Bridge. Again, if possible the dyke should be relocated to the IR 8 property line so that the floodplain can be reconnected with the channel. This option would also disturb far less forest than the Gaboury et al. (2004) proposal and only setback one dyke. It will also increase the streamway width just downstream of the Casorso Bridge. The dyke would be setback to reconnect the floodplain on the left bank which would then be planted with riparian vegetation. The channel could be relocated within this new streamway with a new meander or island constructed.

Table 6-2. Areas to purchase for section 1: Burge Dyke 2 option.

Section 1: Burge Dyke 2

Plan #	Area (ha)
33475	1.30
80134	0.74
1829	5.19
IR8	

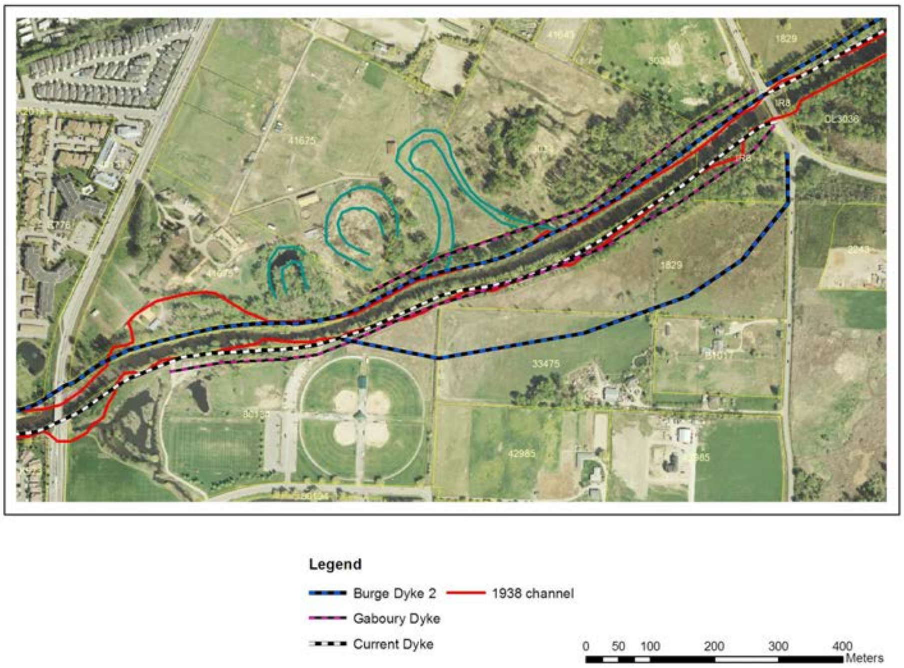


Figure 6-3. Setback dyke locations for section 1: Burge Dyke 2 option.

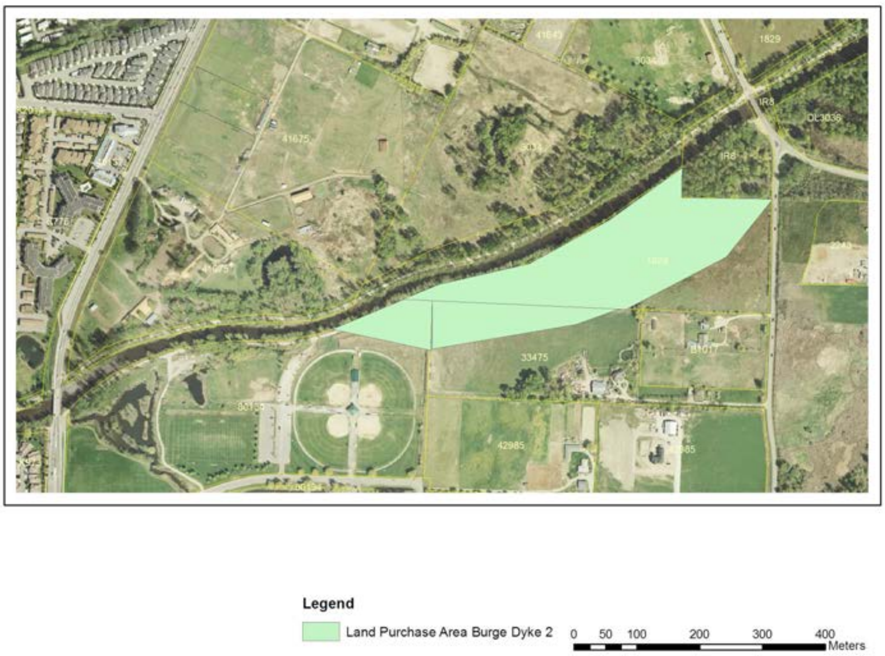


Figure 6-4. Areas to purchase for section 1: Burge Dyke 2 option.

6.4. Section 2: Casorso Bridge to Mission Creek Golf and Country

Two options are presented for section 2: one where the dykes are setback on the right bank and a second option where the dykes are setback less on the right bank and land is purchased to plant a riparian forest on the left bank. Both options differ from the recommendations in Gaboury et al. (2004).

6.5. Section 2: Burge dyke 1

Under the first option, the dykes are setback up to 240 m on the right bank (Figure 6-5). Since there is no dyke on the left bank there is no need to relocate a dyke. This option differs significantly from Gaboury et al. (2004). The proposed streamway between the dykes include mature riparian forest that would be reconnected hydrologically to the Mission Creek channel.

Four properties will be affected (Figure 6-6,Table 6-3). The dyke should be relocated to the north property line of 60920. The proposed dyke location then surrounds the mature forest and then bends so that buildings on lot 2021 are not located within the streamway. The dyke then surrounds a wetland located on 81588. This would connect this wetland with the Mission Creek channel. This proposal allows for space within the streamway to construct new meanders.

Table 6-3. Areas to purchase for section 2: Burge dyke 1 option.

Section 2: Burge Dyke 1

Plan #	Area (ha)
1829	1.43
81566	5.67
2021	0.60
60919	2.82

6.6. Section 2: Burge Dyke 2

Option 2 is similar to the proposal by Gaboury et al. (2004). The stream channel is setback to the property line of 1829 and 81588 on the right bank (

Figure 6-7). Option 2 differs from Gaboury et al. (2004) in that it is proposed that property also be purchased on the right bank to plant a new riparian forest and allow room for channel meanders. No new dyke should be built on the right bank. The dykes should be set back to the property line of 60920 on the right bank. This proposal affects two properties (

Table 6-4, Figure 6-8).

This proposal forms a much narrower streamway of only 145 m when compared with option one. This narrower streamway does not provide much room for the channel to meander. No new wetlands are reconnected with the channel and little riparian forest is reconnected to the channel.

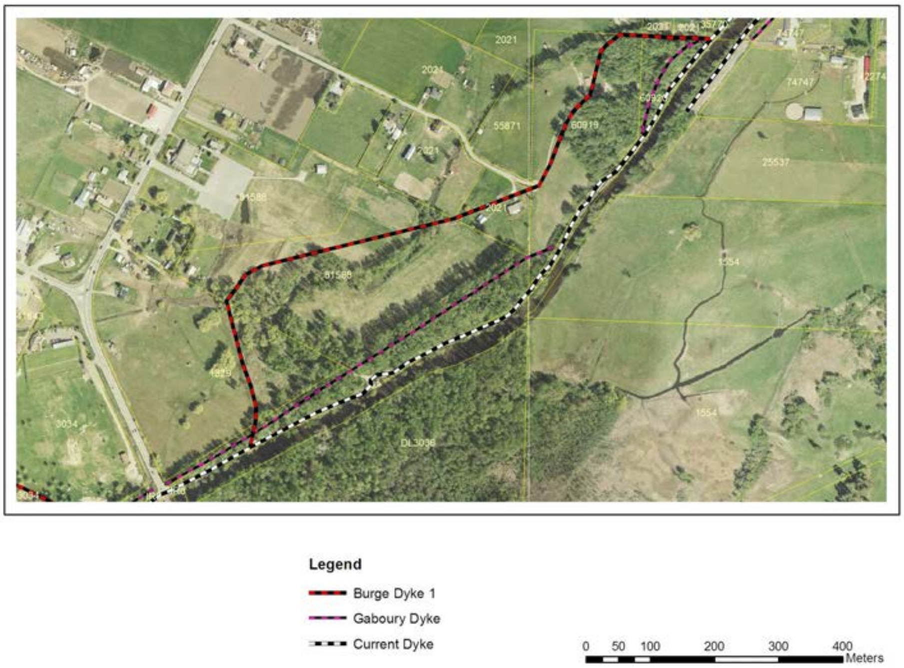


Figure 6-5. Setback dyke locations for section 2: Burge Dyke 1 option.

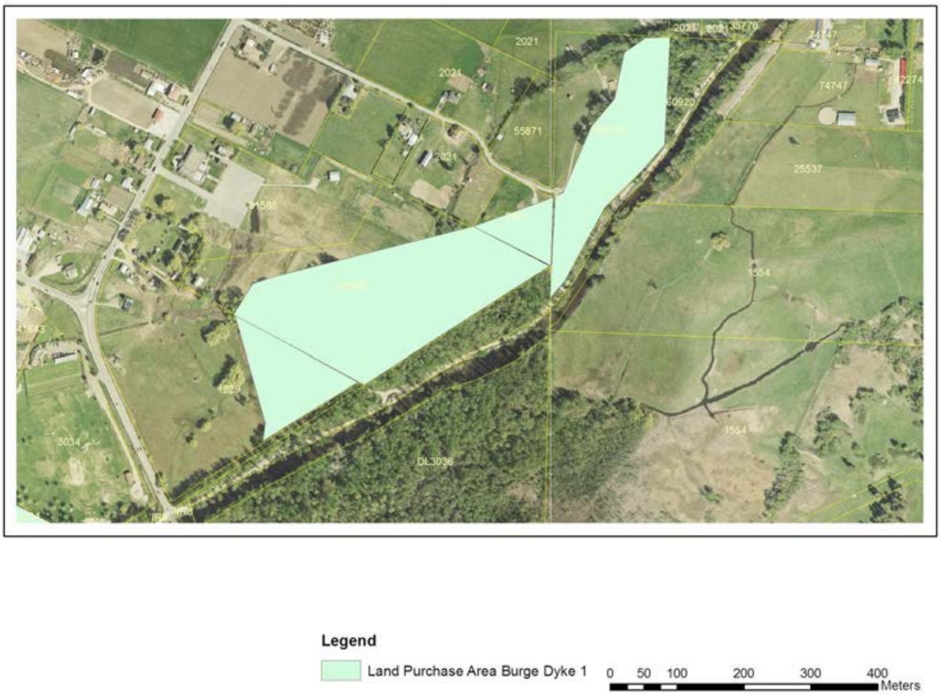


Figure 6-6. Areas to purchase for section 2: Burge dyke 1 option.

Table 6-4. Areas to purchase for section 2: Burge Dyke 2 option.

Section 2: Burge Dyke 2

Plan #	Area (ha)
25537	0.47
1554	2.56

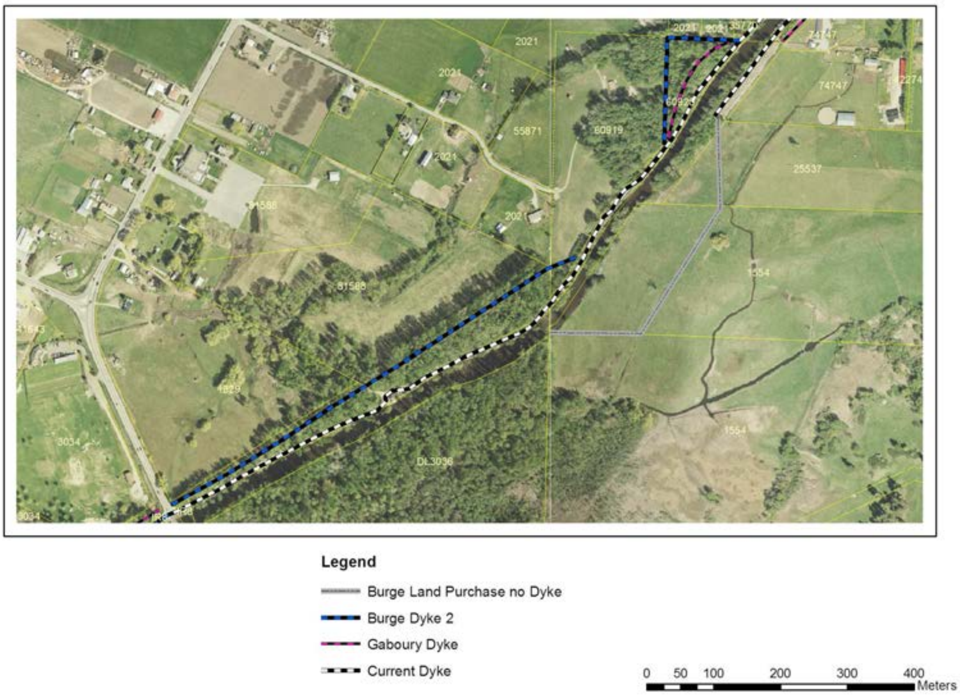


Figure 6-7. Setback dyke locations for section 2: Burge Dyke 2 option.

Figure 6-8. Areas to purchase for section 2: Burge Dyke 2 option.

6.7. Section 3: Mission Creek Golf and Country and KLO Bridge

Two options are proposed for section 3: option 1 with a more extensive streamway and option 2 with a more restricted streamway. The options in the section are limited because of the residential land use on the left bank and the golf course and buildings on the right bank. Both options affect two properties on the right bank and one property on the left bank. The golf course was excluded from the proposed dyke relocation. Both options differ significantly from the recommendations by Gaboury et al. (2004).

This is the location of the sedimentation zone discussed in Burge (2009). One option is to build a sediment trap in this section. The setback locations provide space to build a wide channel to enhance sediment deposition as discussed in Burge (2008).

6.8. Section 3: Burge Dyke 1

Under option 1 the stream channel is setback 85 m on the right bank (

Figure 6-9) and 95 m on the left. This will create a streamway width of between 130 and 160 m. It preserves riparian forest on the right channel bank. The option also provides enough room to redesign the channel to allow for sediment extraction if necessary as discussed in Burge (2009). This option affects 3 properties (Figure 6-10, Table 6-5).

Table 6-5. Areas to purchase for section 3: Burge Dyke 1 option

Section 3: Burge Dyke 1

Plan #	Area(ha)
39954	1.35
39954	1.51
12010	3.06

6.9. Section 3: Burge Dyke 2

Under this option the streamway is only between 95 and 116 m wide and is much below optimum (300 m) (Figure 6-11). It is proposed that the dykes are set back to include a strip of the mature riparian forest on the right bank so that the dykes exclude buildings from the streamway. Then the streamway meanders to the left bank where the dykes are setback on 12010. This creates a streamway of approximately the same width through the section. Three properties are affected in this option (Table 6-6, Figure 6-12).

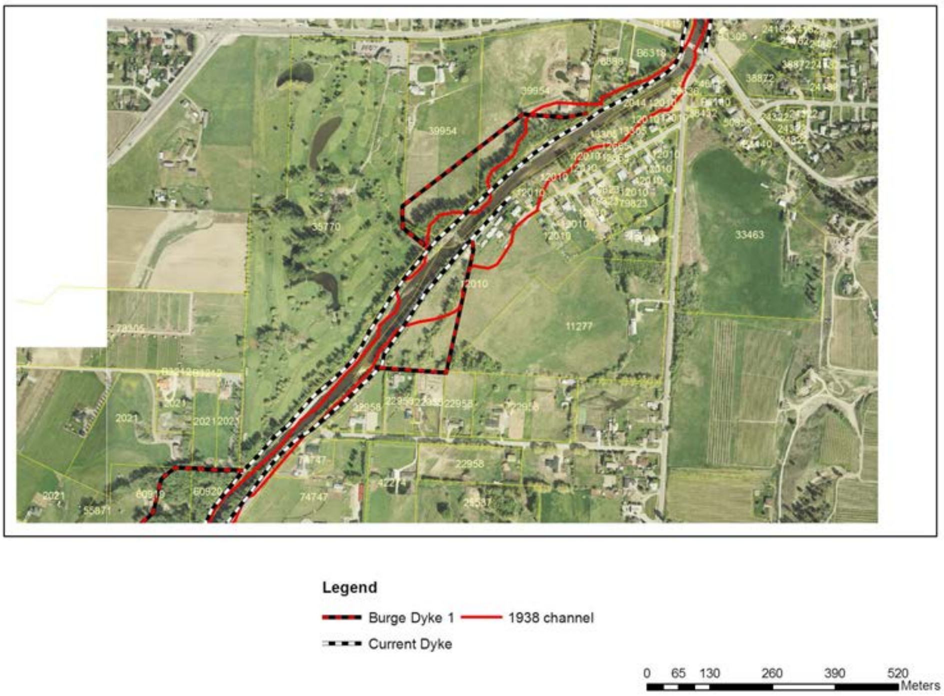


Figure 6-9. Setback dyke locations for section 3: Burge Dyke 1 option.

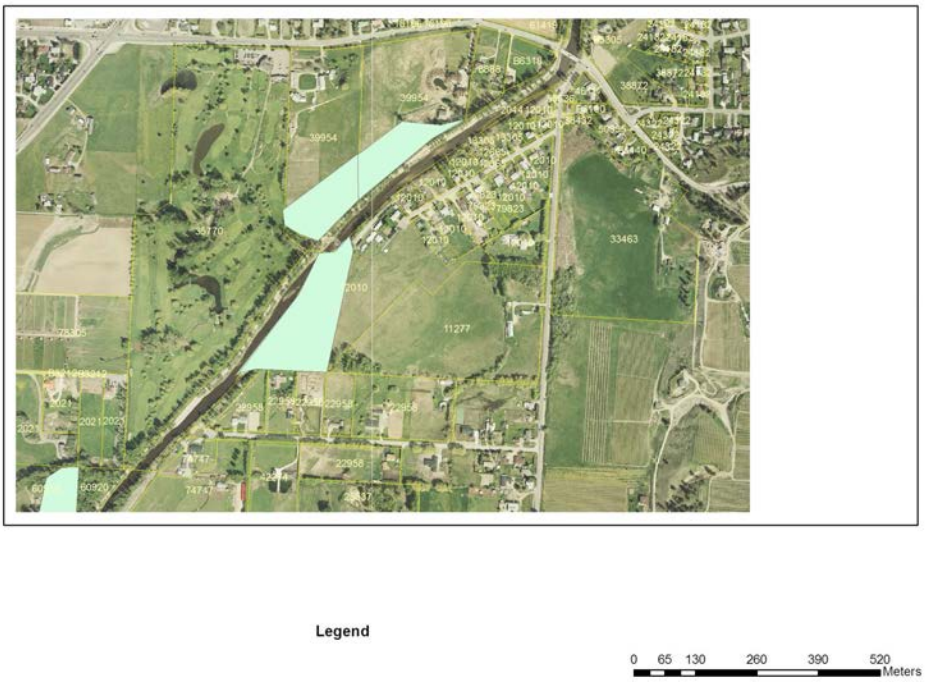


Figure 6-10. Areas to purchase for section 3: Burge Dyke 1 option.

Table 6-6. Areas to purchase for section 3: Burge Dyke 2 option.

Section 3 Burge Dyke 2	
Plan #	Area (ha)
39954	0.85
39954	0.66
12010	2.32

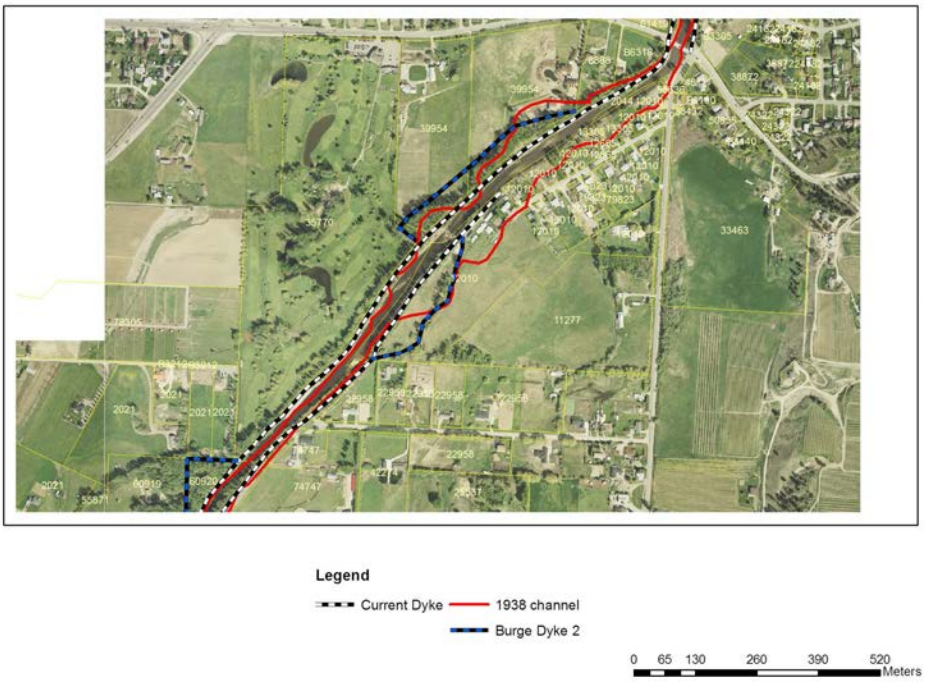


Figure 6-11. Setback dyke locations for section 3: Burge Dyke 2 option.

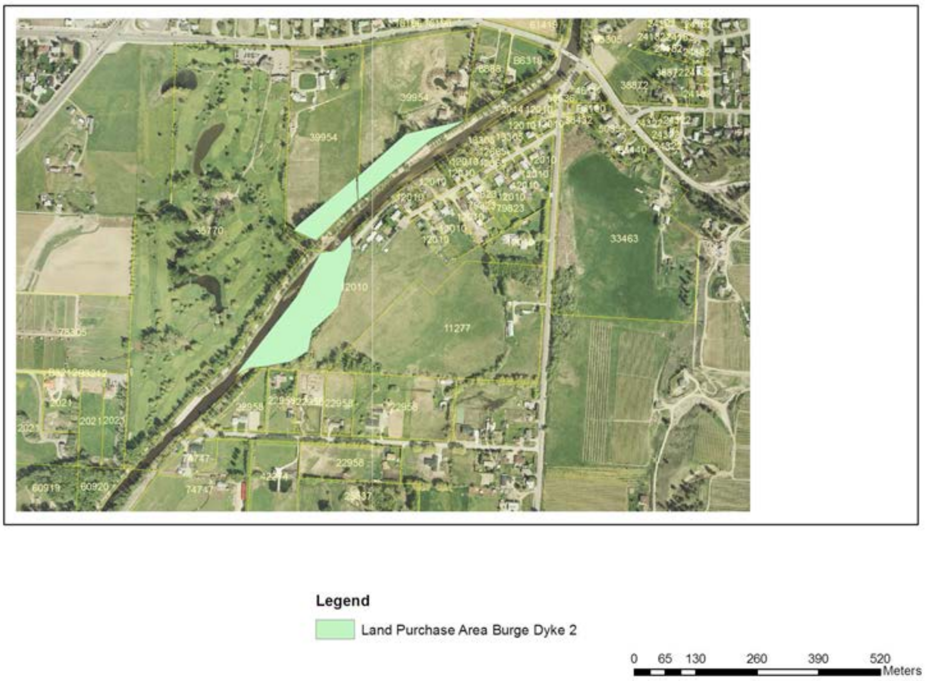


Figure 6-12. Areas to purchase for section 3: Burge Dyke 2 option.

6.10. Section 4: KLO Bridge to Benvoulin woods

Only one option is presented for section 4. This section includes the Benvoulin woods where Mission Creek was located, as seen in the 1938 aerial photographs. Under this option the dykes are set back up to 195 m, providing a streamway width of up to 245 m. This option affects eight properties (Table 6-7, Figure 6-13).

Section 4 includes areas that are unstable and have degraded (Burge 2009). Channelization is known to cause the channel bed to erode and channel degradation to occur (Brooks 1989, Talbot and Lapointe 2002a, Talbot and Lapointe 2002b). Channel degradation has been exacerbated by gravel extraction downstream of section 4 (Burge 2009). Evidence of channel bed degradation in Section 4 has been identified in the field (Epp 2008, Epp 2009) including an increase in channel slope and grain size (Burge 2009). The plan for this area is to increase the channel length by creating meanders. Currently, the channel slope is too high and degradation is probable. Increasing the channel length will decrease the channel slope and decrease the sediment transport and degradation through this section.

If shear stresses within the channel are decreased by decreasing the slope through lengthening the channel, it is logical to conclude that the grain size on the bed will decrease. This should improve the spawning habitat for Kokanee salmon within this section. This section should therefore be considered a priority section for restoration.

Table 6-7. Areas to purchase for section 4: Burge Dyke 1 option.

Section 4: Burge Dyke 1

Plan #	Area (ha)
20240 Lot 11	0.66
1920	0.47
20240 Lot 10	0.14
2332	4.86
86233	0.21
20240 Lot 12	0.50
61419	0.23
18628	0.03

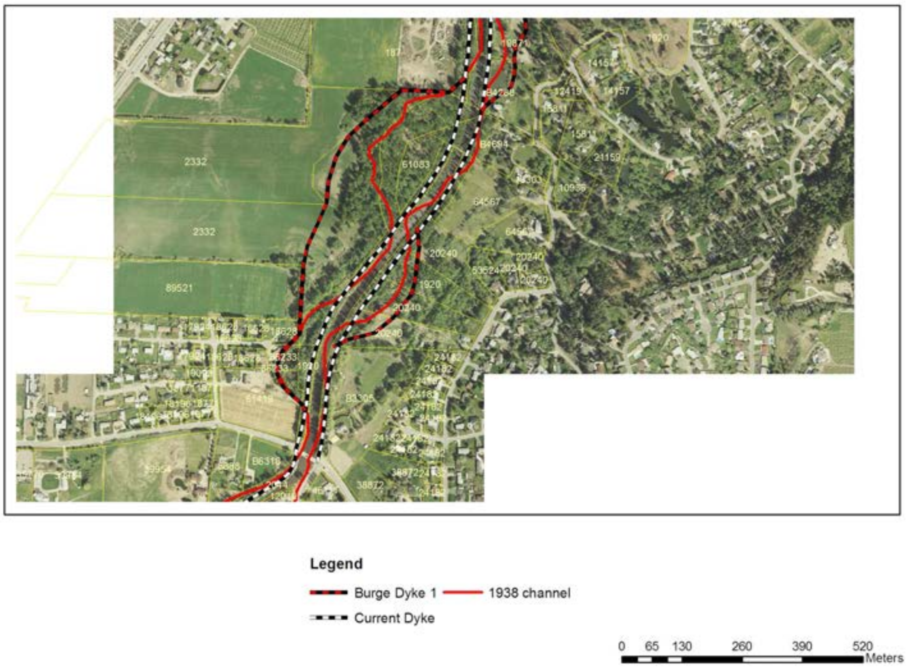


Figure 6-13. Setback dyke locations for section 4: Burge Dyke 1 option.

Figure 6-14. Areas to purchase for section 4: Burge Dyke 1 option.

6.11. Section 5: Benvoulin woods to ECO Centre

Only one option is presented for section 5. This section includes the land owned by the regional district in the Mission Creek Regional Park. Under this option the dykes are set back up to 100 m on both sides of the Mission Creek channel, providing a streamway width of up to 200 m (Figure 6-15). This option affects four properties (Table 6-8, Figure 6-16).

In 1938 the Mission Creek channel was much more sinuous than it is today. As in section 4, this has caused the channel bed slope to increase. The increase in slope caused an increase in channel bed shear stresses and the sediment transport rate. This has caused the sediment on the bed of the Mission Creek channel to become too large for Kokanee to use for spawning. As with section 4, the plan for this area is to increase the channel length by creating meanders. Currently, the channel slope is too high and degradation is probable. Increasing the channel length will decrease the channel slope and decrease the sediment transport and degradation through this section.

This section should also be considered a priority section for restoration. The dyke on the left bank is currently protecting the floodplain with the park between the dyke and the valley wall. There is no infrastructure in this location. It is likely that the dyke within the park from the end of the spawning channel to the end of the regional district property could be removed immediately with no ill effects. This would allow flooding onto the floodplain lands adjacent the channel. A small dyke could be constructed to protect 1920 Lot N from flooding until the dyke setback could be extended. The valley wall protects any of the properties at higher elevations from flooding on the left bank. I do not understand why this dyke was constructed in this location in the first place.

Table 6-8. Areas to purchase for section 5: Burge Dyke 1 option.

Section 5: Burge Dyke 1

Plan #	Area (ha)
1920 Lot N	3.89
19871	1.07
B4288	0.87
B15221	4.99

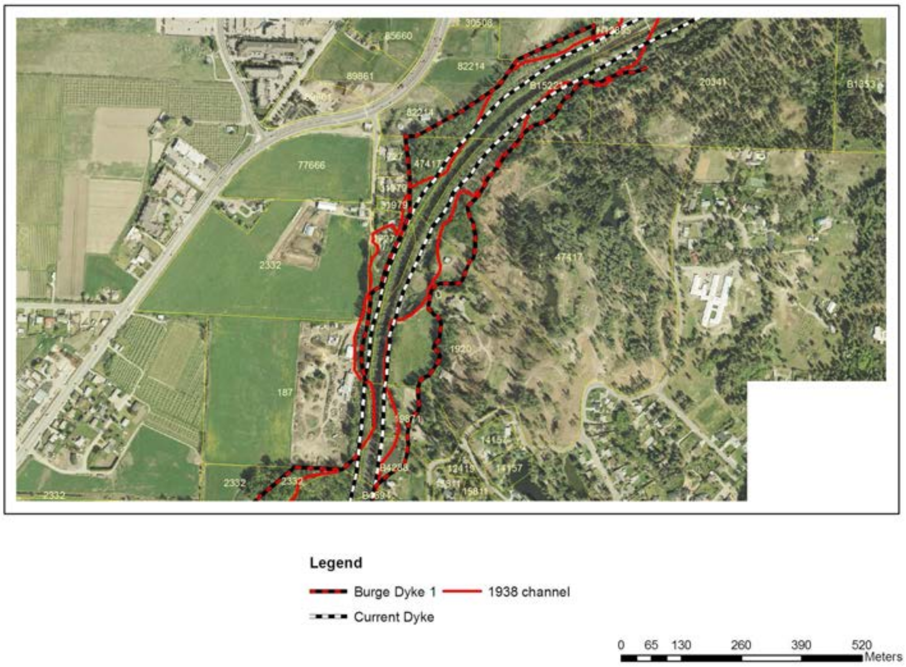


Figure 6-15. Setback dyke locations for section 5: Burge Dyke 1 option.

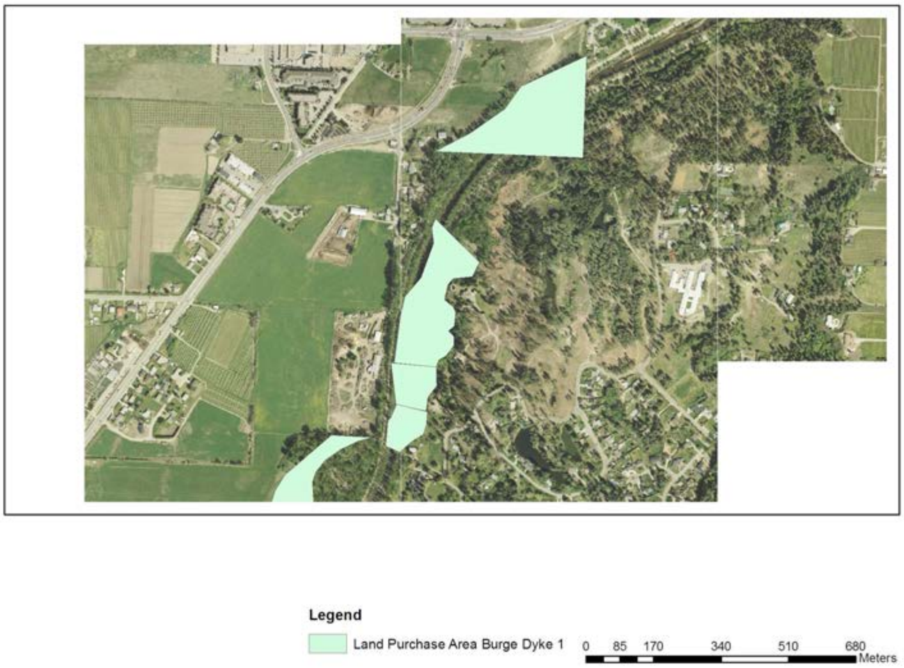


Figure 6-16. Areas to purchase for section 5: Burge Dyke 1 option.

7. HEC RAS Modelling

The HEC-RAS computer model was used to assess the potential for floodplain erosion during the bankfull, 100 year and 200 year floods. The purpose of these modelling experiments was to determine the susceptability of the new floodplain within the setback dykes to erosion and the probable depth of the flooding on the floodplain.

7.1. HEC-RAS Boundary Conditions

Boundary conditions for the model mean annual flood (52.1 m^3/s), 100 yr flood (95.8 m^3/s) and the 200 yr flood (104 m^3/s) are shown in Figure 7-1. These are similar values to those used in Gaboury et al. (2004) of 40, 107 and 115 for the 2 year, 100 year and 200 year floods respectively.

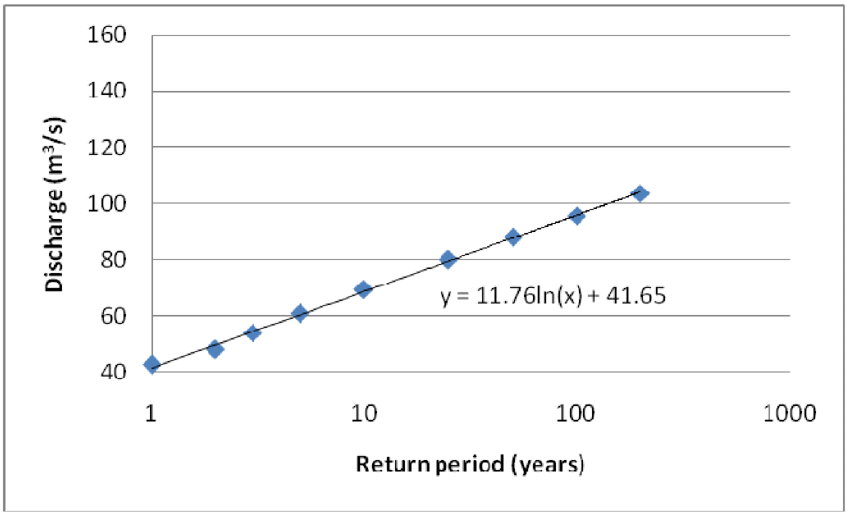


Figure 7-1. Flood frequency analysis for Mission Creek from 1949-2006 (from Burge 2009)

7.2. Model Cross-Sections

Twenty channel cross sections were measured in the field during the summer of 2007 by Okanagan College students working as research assistants (Zoe Masters and Ryan Morgan). The cross-sections were surveyed with a lazer level and hip chain and an arbitrary datum was used. These were the most recent channel data that the author had access to. The locations of these cross sections can be seen in Figure 7-2. In addition to the surveyed channel cross-sections, grain size measurements were made on Mission Creek using pebble counts (Wolman 1954).

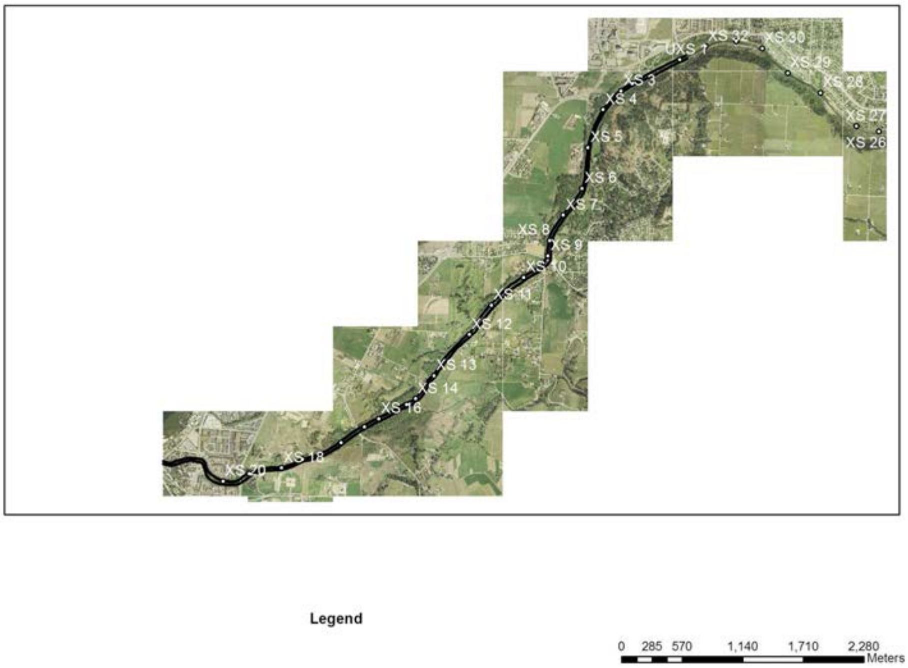


Figure 7-2. Location of field measured cross-sections.

Floodplain elevations were determined from a 1m contour resolution map provided by the City of Kelowna. The two datasets were merged to form the channel and floodplain cross sections used in the HEC-RAS model. The new floodplain level simplified when necessary to reflect the probable floodplain construction elevations. Therefore, the new floodplain used in the modelling represents an over simplification of the floodplain geometry.

The cross-sections are an important input variable for HEC-RAS modeling. Therefore several steps were completed to produce the final cross-sections. First, the maximum floodplain width was mapped. This represents the maximum possible floodplain extent. The maximum floodplain width was used as the beginning and end of the floodplain cross sections input into HEC-RAS. Alternative dyke locations were superimposed on these cross sections. Colour orthophotos and a 1m resolution contour map were used to determine the location of the modern floodplain. This represents the absolute maximum possible floodplain width given the constraints of modern land use including housing. The maximum possible floodplain width was determined by angling the floodplain away from constrictions such as bridges. Benvoulin Road was used as the furthest possible point from Mission Creek that the floodplain could extend on the right bank. The Mission Creek Golf and Country club was excluded from the floodplain as were any subdivisions. The high banks (>3m tall) delineated the extent of the floodplain on the left bank where they occurred. The extent of the cross-sections can be seen in Figure 7-3.

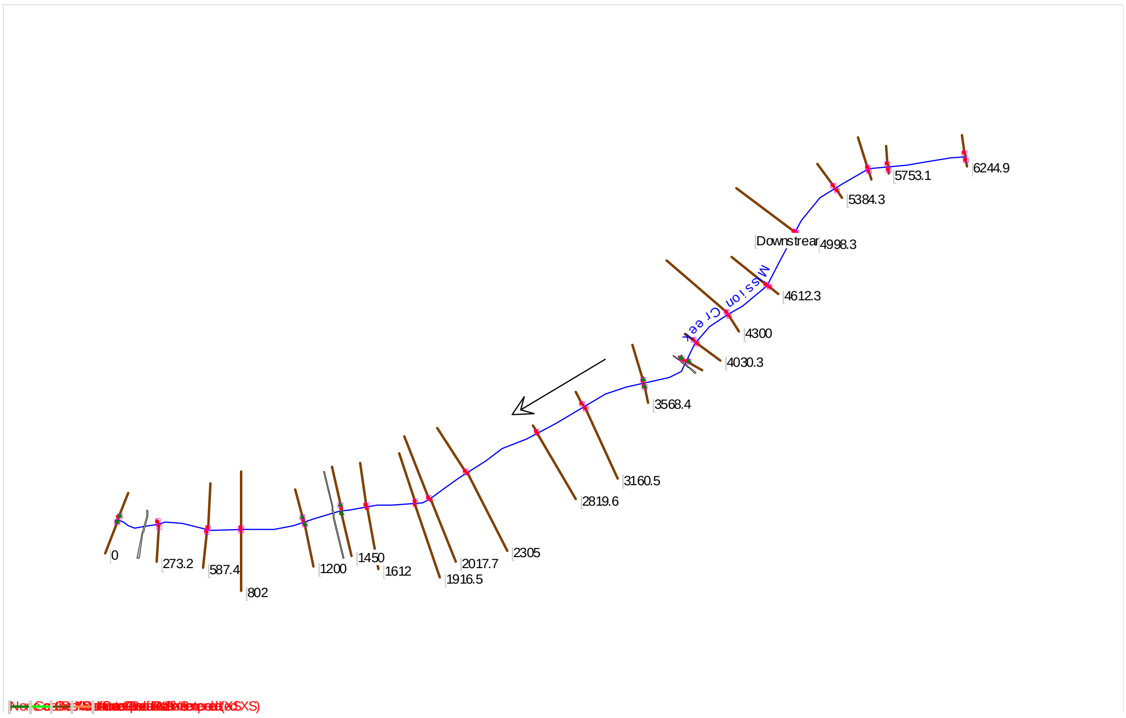
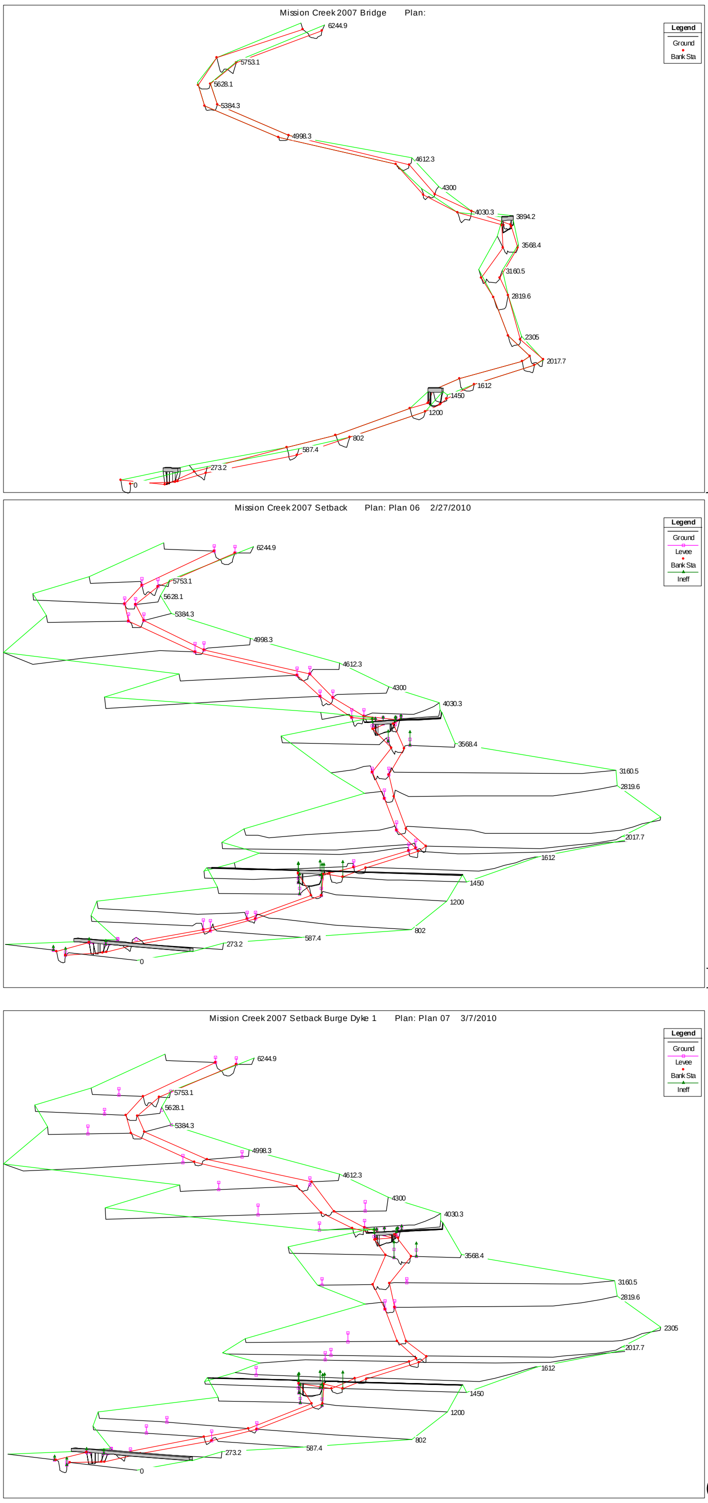


Figure 7-3. HEC-RAS Cross Sections and Bridges.

Three bridges occur within the study reach: KLO Bridge, Casorso Bridge, and Gordon Bridge. The bridge cross-section underneath each bridge was measured in the field and input into HEC-RAS, including the location of piers.

7.3. Model Restored Channel and Floodplain

The shape of the field measured cross-sections, the combined field channel cross-sections and the floodplain cross-sections obtained from the contour map and the final model input cross-sections can be seen in Figure 7-4.



A

B

C

Figure 7-4. Cross sections for HEC-RAS (A) field measured cross-sections, (B) Burge Dyke 1 locations super imposed on field measured cross-sections merged with floodplain elevations obtained from 1m contour map, (C) Burge Dyke 2 locations superimposed on same cross sections as B.

7.4. HEC-RAS Model Validation

The HEC-RAS model results were validated by comparing water level elevations measured in the field to water level elevations modelled using HEC-RAS (Figure 7-5). The boudary conditions included the peak daily flow for 2007 (39.1 cm) and the known water surface elevations for the first and last cross sections. The elevation of organic detritus deposited during the last freshet was used as high water markers in the field (Burge 2004). Where possible, a water level was measured on both banks and averaged. The average difference between the two water levels was 27.5 cm.

The model did quite well in estimating the water surface elevation (Figure 7-6). The averege difference between the HEC-RAS modelled water surface elevation and the field measured water surface elevation was 36.3 cm. This value is within the same range as the error in determing the water surface elevation in the field. As seen in Figure 7-6, the model did the worst at around 2000 m downstream and at the upstream end.

The model was run again with the cross sections including the floodplain. This decreased the difference between the model water level elevations and the field measured elevations to 0.29 cm. This was mostly due to the addition of the floodplain where no dykes exist upstream of the Casorso Bridge.

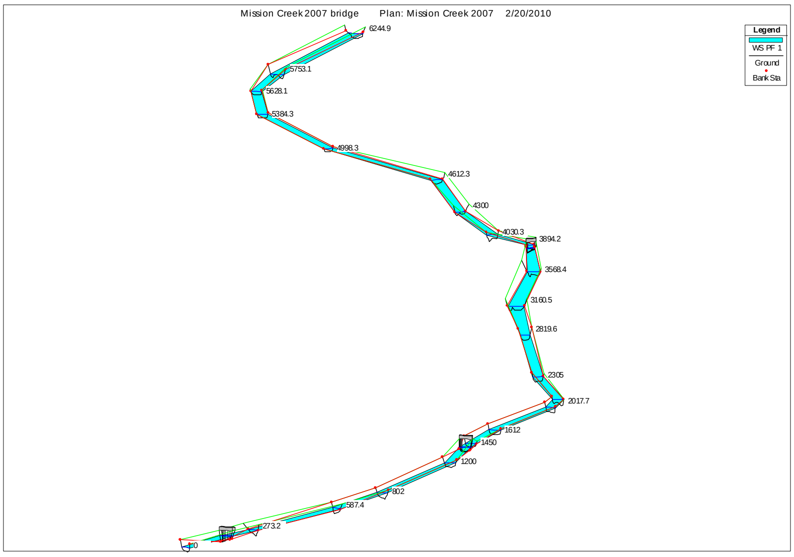
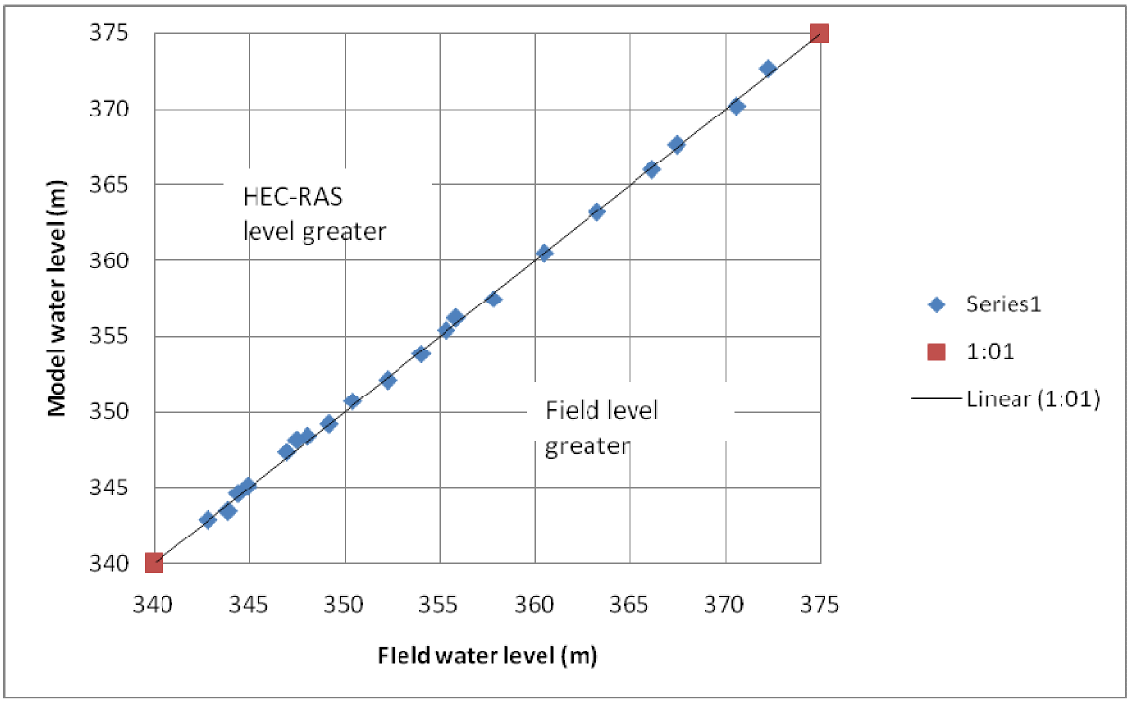


Figure 7-5. HEC-RAS model of field cross-sections at a discharge of 39.1 m^3/s.

A



B

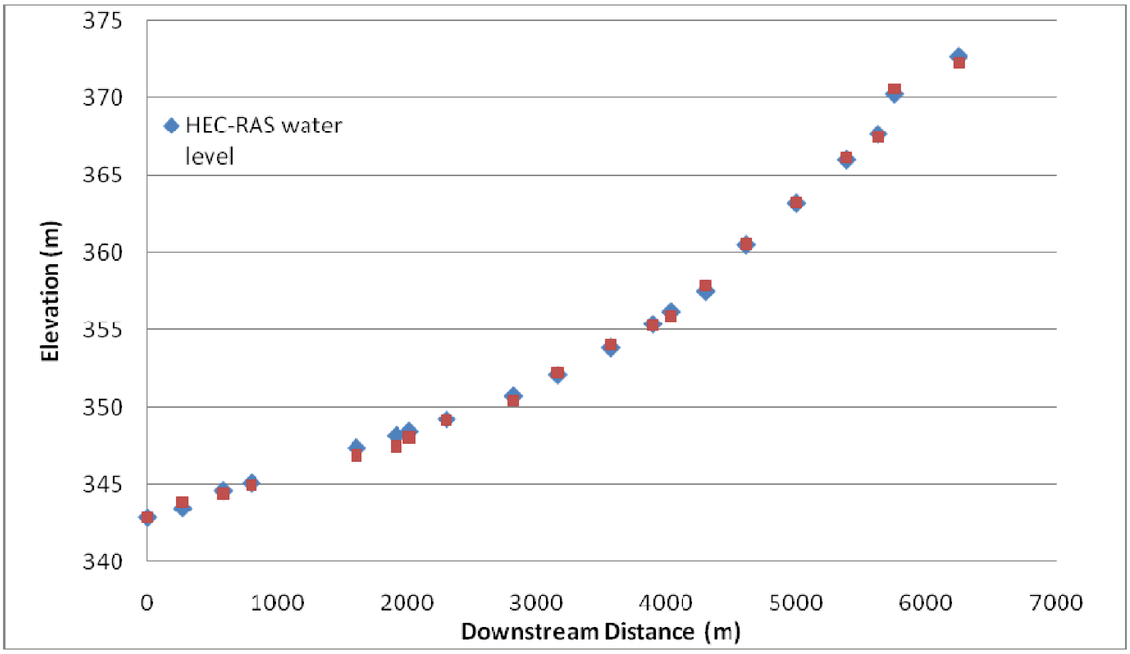


Figure 7-6. Comparison of modelled and field measured water level elevations. A) displays the modelled elevations plotted against the field measeured water levels, while B) shows the elevations plotted downstream.

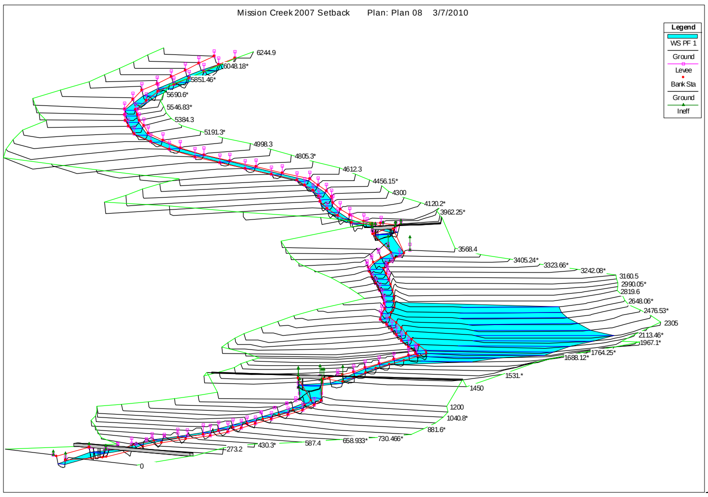
7.5. Modeling Experiments

Three dyke configurations were modeled at three discharges (the mean annual flood, the 100 year flood and the 200 year flood). First, the model was run with the current dyke locations to investigate the range of bed shear stress values that the channel bed would experience under the three discharge scenarios. Second, the dykes were set back to the distance proposed under the Burge Dyke 1 option. Finally, the model was run using the dyke locations proposed under the Burge Dyke 2 option.

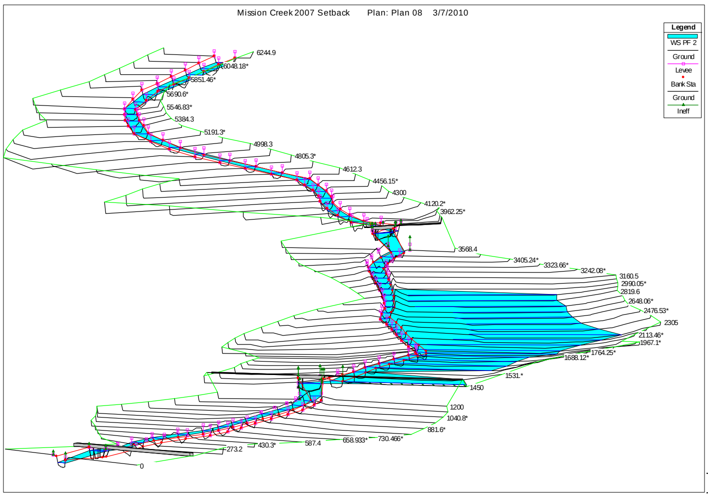
7.6. Model 1: Current Dyke Locations

The model was run with the current dyke locations superimposed upon the floodplain. The flow is contained within the banks except where the dykes are absent from the left bank upstream of the Casorso Bridge (Figure 7-7). The effect of the bridges can be seen on the water surface elevation plot, with each bridge creating a back water upstream of the restriction (Figure 7-8). The backwater effect becomes more pronounced with increasing discharge, a result that was also found by Gaboury et al. (2004).

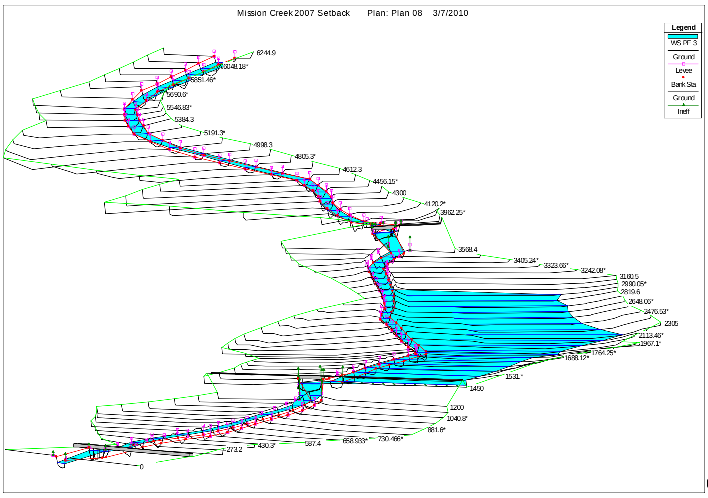
The channel top width is very low in every section except section 3 and 4 where dykes are present only on one bank (Table 7-1). The shear stress values generally decrease downstream and increase significantly from the mean annual flood to the 200 year flow. The highest shear stress value (110 Pa) occurred in section 4. This site shows evidence of recent degradation (Burge 2009). There are very few overbank shear stress values because the dyke location. Froude numbers are below one, increase with increasing discharge and decrease downstream. The largest overbank shear stress values occurred in section 3 with the 200 year flood.



A



B



C

Figure 7-7. Water surface locations for the current dyke locations for the (A) mean annual flood, (B) 100 year flood and (C) 200 yr flood.

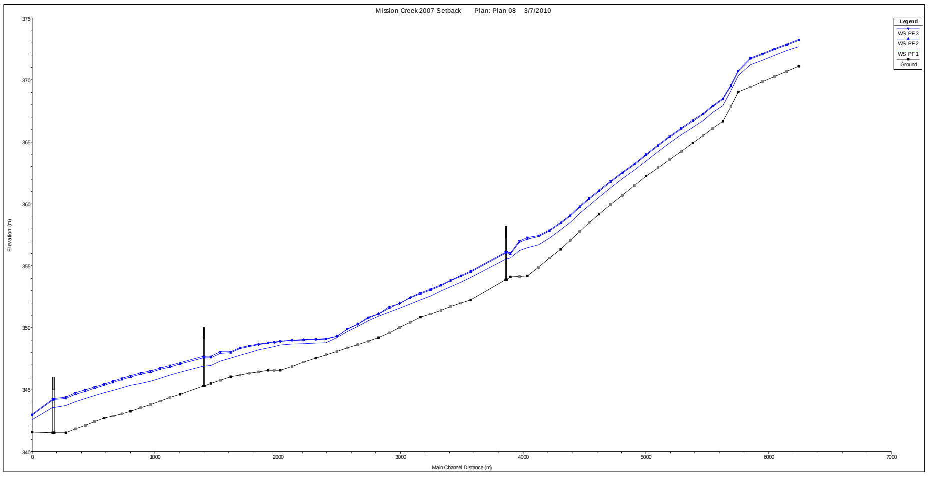


Figure 7-8. Water surface profile for current dyke locations for mean annual flood, 100 year flood and 200 year flood.

Table 7-1. Results from the HEC-RAS model of the current channel with the present dyke locations.

	Discharge (m^3/s)	W.S. Elev (m)	Top Width (m)	Froude # Ch	Shear Ch (Pa)	Shear LOB (Pa)	Shear ROB (Pa)
Section 5	52.1	368.1	27	0.68	71.2		
Section 5	95.8	368.6	30	0.71	97.2		
Section 5	104	368.7	30	0.72	101.7		
Section 4	52.1	357.6	23	0.62	68.1		
Section 4	95.8	358.1	26	0.70	105.1		
Section 4	104	358.2	26	0.71	109.6		
Section 3	52.1	352.4	28	0.51	44.4		
Section 3	95.8	352.8	137	0.56	66.3		
Section 3	104	352.8	137	0.59	73.3	7.4	
Section 2	52.1	348.1	171	0.33	23.4	8.7	
Section 2	95.8	348.4	252	0.34	30.4	2.6	
Section 2	104	348.5	307	0.33	31.3	3.3	
Section 1	52.1	344.6	23	0.57	59.6	3.6	
Section 1	95.8	345.1	26	0.59	81.6		
Section 1	104	345.2	26	0.58	83.9		
Overall average	52.1	354.2	58	0.54	53.5		
Overall average	95.8	354.6	93	0.58	75.7	2.6	11.9
Overall average	104	354.6986	106	0.58	79.2	4.1	13.3

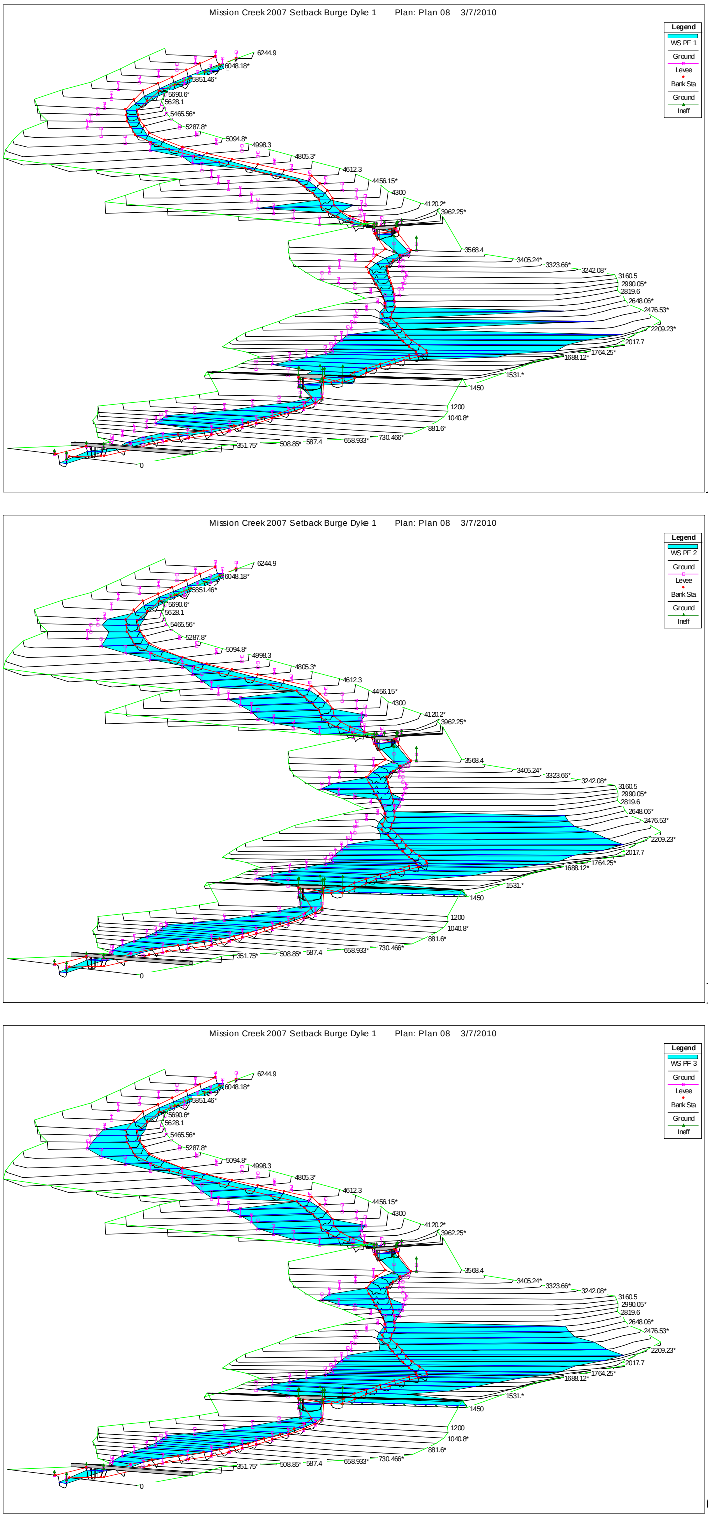
7.7. Model 2: Burge Dyke 1 locations

The model was run with the Burge dyke 1 locations superimposed upon the modified floodplain. The flow is now unconstrained by the dykes and flows freely over the floodplain (Figure 7-9). Inundation of the floodplain even occurs under the relatively low discharges at the mean annual flow. Again, the effect of the bridges can be seen on the water surface elevation plot, with each bridge creating a back water upstream of the restriction (Figure 7-10). The model becomes unstable between Casorso and KLO bridges as indicated by the oscillation of the water surface profile at higher flows. These results should therefore be interpreted with this in mind.

The channel top width is high in every section except section 3 and 4 where dykes are present only on one bank (Table 7-2). The shear stress values generally decrease downstream and increase significantly from the mean annual flood to the 200 year flow. The highest shear stress value (110 Pa) still occurred in section 4. Over bank shear stress values range from 18 Pa in section 5 to 8 Pa in section 2 and 3 at the 200 year flow. Again, Froude numbers are below one.

As would be expected the water width increased significantly in all sections (Table 7-3). The water surface elevation decreased by up to 20 cm when compared to the current dyke levels. Shear stress values within the channel decreased between 0.3 and 15.5 Pa. The overbank shear stresses generally increased because of the introduction of flow onto the floodplain. The highest increase in shear stress levels was 11 Pa in section 5.

The overbank shear stress values can be compared to permissible shear stress values for bar soil and shear strength values for soil with vegetation growing on it. This provides an estimate of the erosion potential of the new floodplain. The typical permissible shear stress values for bare soil and stone lined channels from Kilgore and Cotton (2005) (Table 7-4) was used to estimate the shear stress needed for the floodplain to remain stable during a flood. With cohesive sand sediment, shear stress should not exceed 4.5 Pa. It therefore appears that the floodplain is likely to experience some erosion even under mild flows over a newly constructed floodplain. However, shear strength increases significantly following colonization by vegetation (Micheli and Kirchner 2002). Shear strength values of greater than 40 Pa are not uncommon. Therefore, areas that mature riparian vegetation exists and after riparian forest grows in newly constructed floodplain should be quite resistant to erosion even during the 200 year flood.



A

B

C

Figure 7-9. Water surface locations for the Burge dyke 1 location for the (A) mean annual flood, (B) 100 year flood and (C) 200 year flood.

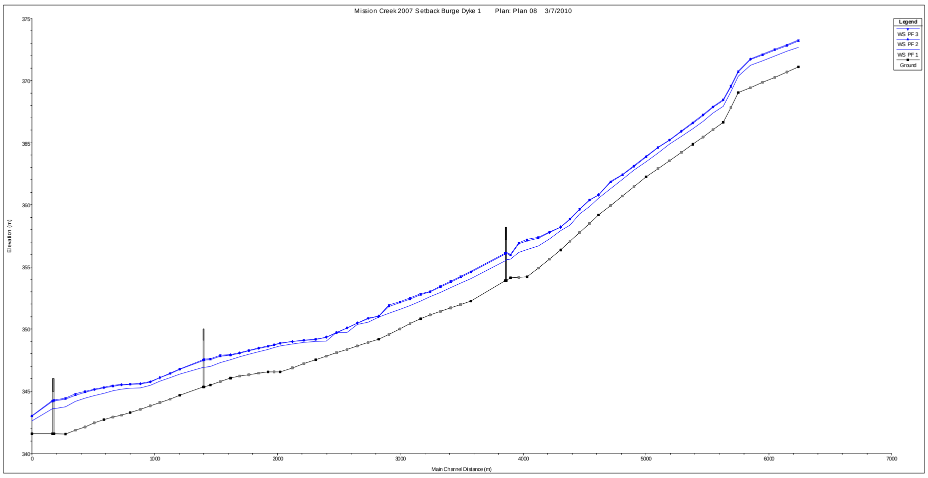


Figure 7-10. Water surface profile for Burge dyke 1 setback locations for mean annual flood, 100 year flood and 200 year flood.

Table 7-2. Results from the HEC-RAS model of the Burge Dyke 1 proposed dyke locations. (LOB = Left overbank; ROB = right overbank).

	Discharge (m^3/s)	W.S. Elev (m)	Top Width (m)	Froude # Ch	Shear Ch (Pa)	Shear LOB (Pa)	Shear ROB (Pa)
Section 5	52.1	368.1	32	0.68	70.9		7.3
Section 5	95.8	368.5	58	0.73	95.8	8.6	14.8
Section 5	104	368.6	68	0.74	100.4	10.5	18.3
Section 4	52.1	357.6	72	0.61	63.1	0.7	8.0
Section 4	95.8	358.0	100	0.69	102.7	8.2	10.2
Section 4	104	358.1	100	0.71	109.9	10.1	12.7
Section 3	52.1	352.4	28	0.51	43.8	0.2	
Section 3	95.8	352.8	68	0.61	78.6	8.6	7.2
Section 3	104	352.8	68	0.62	87.3	9.9	8.2
Section 2	52.1	348.1	328	0.38	29.2	1.3	1.0
Section 2	95.8	348.4	419	0.36	29.3	6.3	7.1
Section 2	104	348.4	439	0.35	29.1	6.4	7.7
Section 1	52.1	344.5	63	0.53	53.9		1.2
Section 1	95.8	345.0	100	0.53	66.3		9.8
Section 1	104	345.0	100	0.53	68.4		11.0
Overall average	52.1	354.2	113	0.54	52.5	1.0	2.3
Overall average	95.8	354.5	159	0.57	72.9	7.3	9.8
Overall average	104	354.6	166	0.58	76.9	8.3	11.5

Table 7-3. Differences between the HEC-RAS model results for the current channel conditions and the model of the Burge Dyke 1 locations. (LOB = Left overbank; ROB = right overbank).

	Discharge (m^3/s)	W.S. Elev (m)	Top Width (m)	Froude # Ch	Shear Ch (Pa)	Shear LOB (Pa)	Shear ROB (Pa)
Section 5	52.1	0.00	5	0.00	-0.3	0.0	1.5
Section 5	95.8	-0.04	28	0.01	-1.4	1.7	8.9
Section 5	104	-0.05	38	0.02	-1.3	2.1	11.0
Section 4	52.1	-0.02	49	-0.02	-5.0	0.2	2.0
Section 4	95.8	-0.13	74	-0.01	-2.3	6.2	7.7
Section 4	104	-0.15	74	0.00	0.3	7.6	9.5
Section 3	52.1	0.01	0	-0.01	-0.6	0.1	0.0
Section 3	95.8	-0.01	-68	0.04	12.3	0.4	2.4
Section 3	104	-0.01	-68	0.04	14.0	0.4	2.7
Section 2	52.1	0.06	157	0.05	5.8	-0.5	1.0
Section 2	95.8	-0.05	167	0.02	-1.1	3.6	7.1
Section 2	104	-0.06	132	0.02	-2.2	3.6	7.7
Section 1	52.1	-0.01	40	-0.04	-5.8		0.7
Section 1	95.8	-0.17	75	-0.06	-15.3		7.8
Section 1	104	-0.20	74	-0.06	-15.5		8.8
Overall average	52.1	0.01	55	0.00	-1.0	-0.1	1.1
Overall average	95.8	-0.09	66	0.00	-2.8	2.4	7.1
Overall average	104	-0.10	60	0.00	-2.4	2.7	8.4

Table 7-4. Typical Permissible Shear Stresses for Bare Soil and Stone Linings (from Kilgore and Cotton 2005).

		Permissible Shear Stress	
Lining Category	Lining Type	N/m^2	lb/ft^2
Bare Soil Cohesive (PI=10)[1]	Clayey sands	1.8-4.5	0.037-0.095
	Inorganic silts	1.1-4.0	0.027-0.11
	Silty sands	1.1-3.4	0.024-0.072
Bare Soil Cohesive[1] (PI≥20)	Clayey sands	4.5	0.094
	Inorganic silts	4.0	0.083
	Silty sands	3.5	0.072
	Inorganic clays	6.6	0.14
Bare Soil Non-cohesive[2] (PI<10)	Finer than coarse sand D_{75}<1.3 mm (0.05 in)	1.0	0.02
	Fine gravel D_{75}=7.5 mm (0.3 in)	5.6	0.12
	Gravel D_{75}=15 mm (0.6 in)	11	0.024
Gravel Mulch[3]	Coarse gravel D_{50}=25 mm (1 in)	19	0.4
	Very coarse gravel D_{50}=50 mm (2 in)	38	0.8
Rock Riprap[3]	D_{50}=0.15 m (0.5 ft)	113	2.4
	D_{50}=0.30 m (1.0 ft)	227	4.8

[1]Based on Equation 4.6 assuming a soil void ratio of 0.5.
[2]Based on Equation 4.5
[3]Based on Equation 6.7 with Shields' parameter equal to 0.047.

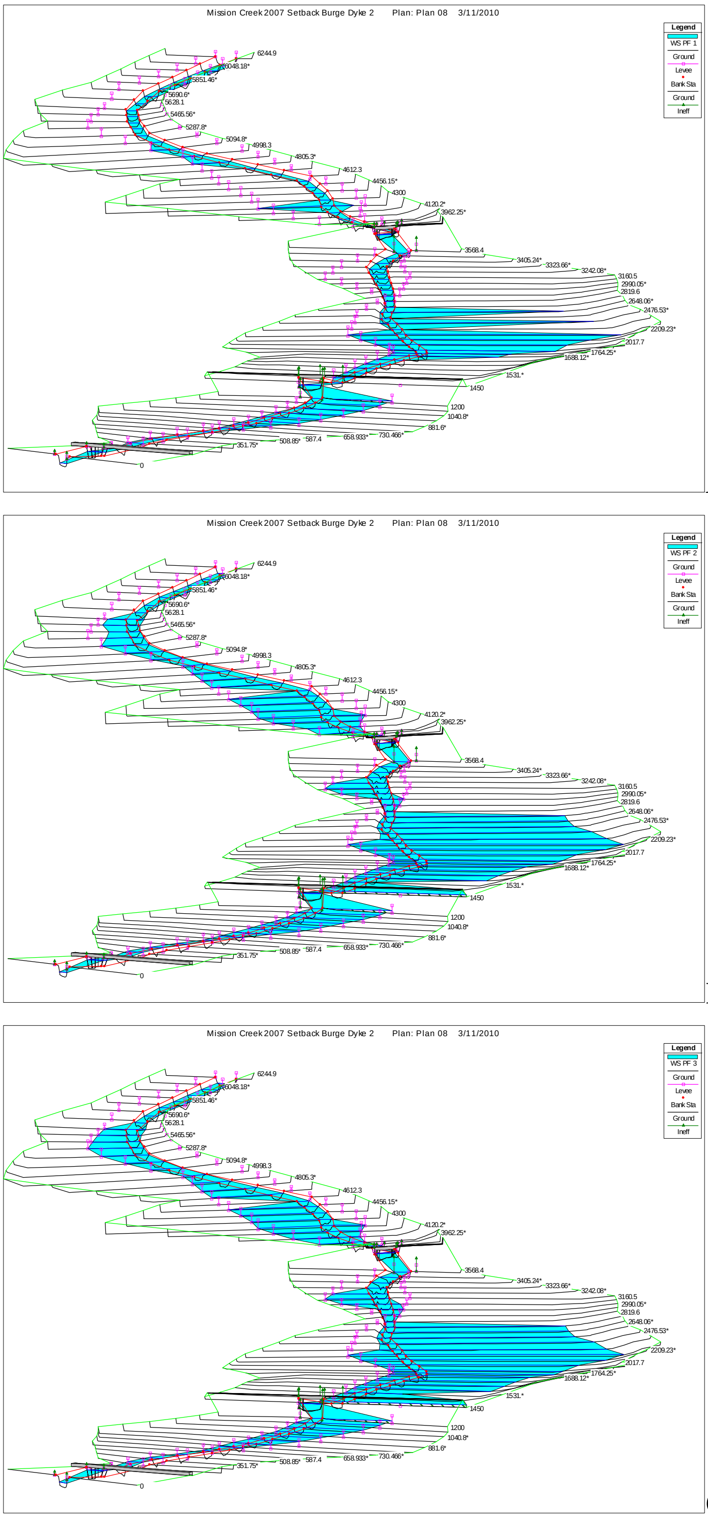
7.8. Model 3: Burge Dyke 2 locations

Finally, the model was run with the Burge dyke 2 locations superimposed upon the floodplain. The flow was constrained by dykes that are more narrow than the Burge Dyke 1 option but setback compared to the current condition (Figure 7-11). The Burge dyke 2 locations differ from the Burge dyke 1 locations only in sections 1, 2 and 3. Only these sections will be discussed. Inundation of the floodplain again occurs under the relatively low discharges at the mean annual flow. Again, the effect of the bridges can be seen on the water surface elevation plot, with each bridge creating a back water upstream of the restriction (Figure 7-12). The model becomes unstable between Casorso and KLO bridges as indicated by the oscillation of the water surface profile at higher flows. These results should again be interpreted with this in mind.

As would be expected, the water surface width is narrower than in the Burge dyke 1 option (Table 7-5). The shear stress values generally decrease downstream and increase significantly from the mean annual flood to the 200 year flow. Over bank shear stress values in sections 1, 2 and 3 range from 1 Pa to 11 Pa in section 3 through the three discharge values. Again Froude numbers are below one.

Under the Burge dyke 2 option, water surface elevations decreased by up to 25 cm when compared to the current dyke levels (Table 7-6). This is a 5 cm greater decrease in the flow compared to Burge dyke 1, since the Burge dyke 1 option creates a greater area for overbank flooding than the Burge dyke 2 option, this result is suspect. Shear stress values within the channel again decreased between 0.3 and 15.5 Pa. The overbank shear stresses generally increased because of the introduction of flow onto the floodplain. Again, the highest increase in shear stress levels was 11 Pa in section 5.

As with Burge dyke 1, the overbank shear stress values were compared to permissible shear stress values for bar soil (Kilgore and Cotton 2005) and shear strength values for soil with vegetation growing on it (Micheli and Kirchner 2002). Overbank shear stress values exceeded the limit for cohesive sand sediment of 4.5 Pa. However, the values were still below the 40 Pa shear strength value for sediment which vegetation has colonized. Therefore, under this option areas where mature riparian vegetation exists and after a riparian forest grows in newly constructed flood plain should be quite resistant to erosion even during the 200 year flood.



A

B

C

Figure 7-11. Water surface locations for the Burge dyke 2 locations for the (A) mean annual flood, (B) 100 year flood and (C) 200 year flood.

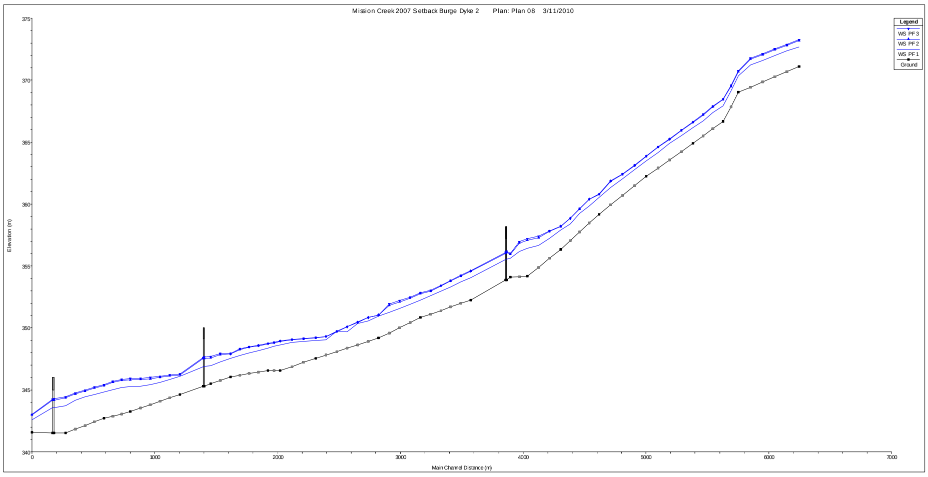


Figure 7-12. Water surface profile for Burge dyke 2 setback locations for mean annual flood, 100 year flood and 200 year flood.

Table 7-5. Results from the HEC-RAS model of the Burge Dyke 2 proposed dyke locations. (LOB = Left overbank; ROB = right overbank).

Profile	***Discharge (m^3/s)***	***W.S. Elev (m)***	***Top Width (m)***	***Froude # Ch***	***Shear Cha (Pa)***	***Shear LOB (Pa)***	***Shear ROB (Pa)***
Section 5	52.1	368.1	32	0.68	70.9		7.3
Section 5	95.8	368.5	58	0.73	95.8	8.6	14.8
Section 5	104	368.6	68	0.74	100.4	10.5	18.3
Section 4	52.1	357.6	72	0.61	63.1	0.7	8.0
Section 4	95.8	358.0	100	0.69	102.7	8.2	10.2
Section 4	104	358.1	100	0.71	109.9	10.1	12.7
Section 3	52.1	352.4	28	0.51	43.8	0.2	
Section 3	95.8	352.8	66	0.61	78.9	8.6	7.4
Section 3	104	352.8	66	0.63	87.7	9.9	8.5
Section 2	52.1	348.1	260	0.38	29.3	1.4	1.1
Section 2	95.8	348.4	330	0.38	34.6	6.9	8.7
Section 2	104	348.5	336	0.38	36.2	6.5	9.8
Section 1	52.1	344.5	63	0.53	53.9		1.2
Section 1	95.8	345.0	100	0.53	66.3		9.8
Section 1	104	345.0	100	0.53	68.4		11.0
Overall average	52.1	354.2	98	0.54	52.5	1.0	2.4
Overall average	95.8	354.6	138	0.58	74.1	7.6	10.3
Overall average	104	354.6	142	0.59	78.5	8.3	12.2

Table 7-6. Differences between the HEC-RAS model results for the current channel conditions and the model of the Burge Dyke 2 locations. (LOB = Left overbank; ROB = right overbank).

Profile	*Discharge (m^3/s)*	*W.S. Elev (m)*	*Top Width (m)*	*Froude # Ch*	*Shear Ch (Pa)*	*Shear LOB (Pa)*	*Shear ROB (Pa)*
Section 5	52.1	0.00	5.5	0.00	-0.3	0.0	2.4
Section 5	95.8	-0.04	28.2	0.01	-1.4	8.6	14.8
Section 5	104	-0.05	38.2	0.02	-1.3	10.5	18.3
Section 4	52.1	-0.02	48.5	-0.02	-5.0	0.3	2.7
Section 4	95.8	-0.13	74.1	-0.01	-2.3	8.2	10.2
Section 4	104	-0.15	73.9	0.00	0.3	10.1	12.7
Section 3	52.1	0.01	0.3	-0.01	-0.6	0.2	0.0
Section 3	95.8	-0.01	-71.0	0.04	12.5	1.2	7.4
Section 3	104	-0.01	-71.0	0.04	14.3	1.2	8.5
Section 2	52.1	0.06	89.2	0.05	5.9	-0.5	1.1
Section 2	95.8	-0.01	77.5	0.04	4.2	4.3	8.7
Section 2	104	-0.02	29.4	0.04	5.0	3.6	9.8
Section 1	52.1	-0.01	40.0	-0.05	-5.8		0.9
Section 1	95.8	-0.17	74.7	-0.06	-15.3		9.8
Section 1	104	-0.25	93.0	-0.07	-15.5		11.0
Overall average	52.1	0.01	39.5	0.00	-1.0	-0.2	1.5
Overall average	95.8	-0.07	44.8	0.00	-1.6	5.6	10.3
Overall average	104	-0.10	37.7	0.01	-0.7	6.0	12.2

7.9. Priorities for Construction

The following discussion provides recommendation for the priority of dyke setbacks on Mission Creek and is guided by the results from Burge (2009) and the preceding analyses. Please note that the dykes do not have to be setback in the sequence described below if land becomes available and is purchased the dykes within that section should be setback.

Gaboury et al. (2004) suggested that construction of the setback dykes should generally proceed from the downstream to upstream sections in Mission Creek. Results from Burge (2009) indicate that the section between the ECO centre and the KLO Bridge (sections 4 and 5 of this report) is susceptible to vertical bed degradation and that the section immediately downstream of the KLO Bridge (section 3 of this report) is susceptible to aggradation. Construction activities should not proceed from downstream to upstream but should begin where the channel is unstable and disturbed to gain the greatest benefit from the construction. These three sections should therefore be given priority for construction because the restoration should return the channel to a more stable state.

Under the prioritized order of restoration works from Gaboury et al. (2004), they recommend that the dyke on the right bank of the Mission Creek channel upstream of Casorso Road be set back first. I disagree with this recommendation. As cited in Gaboury et al. (2004) this site is highly utilized by Kokanee for spawning. Also, no dyke currently exists on the left bank. This section also has the greatest amount of riparian vegetation shading the channel and has some shallow riffles and pools developed. This section therefore represents the most natural section of the lower section of Mission Creek. I therefore recommend that this section be left alone and the restoration of this section of Mission Creek not be a priority.

I recommend that the dykes on the left bank within Mission Creek Regional Park be set back first. As discussed above, the dyke on the left bank is currently protecting the floodplain with the park between the dyke and the valley wall. There is no infrastructure in this location. It is likely that the dyke within the park from the end of the spawning channel to the end of the regional district land could be removed immediately with no ill effects. This would allow flooding onto the floodplain lands adjacent to the channel. A small dyke could be constructed to protect 1920 Lot N from flooding until the dyke setback could be extended. The valley wall protects any of the properties at higher elevations from flooding on the left bank.

Section 4 should be considered a priority. The Benvoulin woods should be utilized as floodplain surrounded by the dykes. The channel can be lengthened through this section to decrease degradation of the channel bed. This should allow smaller grain size sediment to be deposited and this will increase Kokanee spawning habitat. Restoring this section should solve a number of important problems on Mission Creek.

Great improvement can be made to Section 1 by setting the dykes back as proposed in Burge dyke 1. Setting back the dykes to surround the oxbow lakes would increase wetland habitat, hydrologically connect the riparian vegetation on the floodplain to the channel, and create space to build meanders.

Sedimentation currently occurs within Section 3. Burge (2009) recommended that this section be used to collect sediment and gravel extraction continue in this section. Sections 4 and 5 should be restored before section 3. Hopefully, the new geometry of the channel within sections 4 and 5 will decrease the sediment being delivered to section 3. Channel sections upstream of the ECO center should also be restored first to decrease the amount of sediment delivered to section 3.

As discussed in Burge (2009), the channel design must take into account the sediment passing through the river channel to engineer a stable channel (Shields et al. 2008). The design variables width, depth and slope can be calculated using analytical methods that use computer models using the input variables discharge, sediment inflow and bed material composition. The stable channel design routine in the hydraulic design software SAM (Copland 1994, Thomas et al. 1999, SAM Hydraulic 2005, Parker 2006) can be used to determine channel depth and slope for a sediment input rate.

Before a channel restoration design is begun, a sediment budget for Mission Creek should be conducted to aid in the channel design. The stable channel design routine SAM (SAM Hydraulic 2005) could be used.

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9. Appendix One

Current levee locations

River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	Top Width (m)	Froude # Chl	Shear Chan (N/m2)	Shear LOB (N/m2)	Shear ROB (N/m2)
6244.9	PF 1	52.1	372.7	31.79	0.45	33.47		
6244.9	PF 2	95.8	373.19	38.04	0.5	47.77		
6244.9	PF 3	104	373.26	38.89	0.5	49.82		
5753.1	PF 1	52.1	370.35	30.29	1	118.37		
5753.1	PF 2	95.8	370.7	31.75	1	152.15		
5753.1	PF 3	104	370.75	31.99	1	158.02		
5628.1	PF 1	52.1	367.95	22.9	0.65	69.56		
5628.1	PF 2	95.8	368.44	24.97	0.69	96.97		
5628.1	PF 3	104	368.51	24.97	0.7	102.33		
5384.3	PF 1	52.1	366.17	25.02	0.61	59.92		
5384.3	PF 2	95.8	366.67	29.83	0.65	80.99		
5384.3	PF 3	104	366.75	30.57	0.66	84.46		
4998.3	PF 1	52.1	363.46	22.71	0.68	74.61		
4998.3	PF 2	95.8	363.92	23	0.72	108.2		
4998.3	PF 3	104	364	23	0.73	113.99		
4612.3	PF 1	52.1	360.55	25.86	0.69	71.81		
4612.3	PF 2	95.8	361.02	30.56	0.72	93.43		
4612.3	PF 3	104	361.09	31.01	0.72	96.82		
4300	PF 1	52.1	357.91	23.04	0.66	70.63		
4300	PF 2	95.8	358.4	25.45	0.7	97.6		
4300	PF 3	104	358.48	25.84	0.71	101.57		
4030.3	PF 1	52.1	356.48	26	0.37	27.13		
4030.3	PF 2	95.8	357.17	28.13	0.38	36.76		
4030.3	PF 3	104	357.28	28.26	0.39	38.31		
3894.2	PF 1	52.1	355.62	17.17	0.77	102.9		
3894.2	PF 2	95.8	355.96	18.27	0.99	192.44		
3894.2	PF 3	104	356.03	18.52	1	201.88		
3860		Bridge						

3568.4	PF 1	52.1	354.05	28.94	0.53	44.87		
3568.4	PF 2	95.8	354.51	31.44	0.57	65.44	9.23	9.24
3568.4	PF 3	104	354.58	31.84	0.57	68.98	10.73	10.86
3160.5	PF 1	52.1	352.25	34.5	0.5	37.79		
3160.5	PF 2	95.8	352.74	35.9	0.5	50.07		
3160.5	PF 3	104	352.81	36.08	0.51	52.56		
2819.6	PF 1	52.1	350.92	20.09	0.51	50.62		
2819.6	PF 2	95.8	351.13	342.6	0.62	83.44	7.37	
2819.6	PF 3	104	351.13	342.58	0.68	98.46	8.68	
2305	PF 1	52.1	348.76	320.4	0.12	1.91	1.47	
2305	PF 2	95.8	349.04	350.54	0.13	2.81	2.24	
2305	PF 3	104	349.08	357.46	0.13	3	2.39	
2017.7	PF 1	52.1	348.58	299.81	0.24	10.89	2.82	
2017.7	PF 2	95.8	348.87	313.83	0.22	10.25	4	
2017.7	PF 3	104	348.91	315.79	0.22	10.45	4.23	
1916.5	PF 1	52.1	348.38	181.07	0.33	21.93	3.44	
1916.5	PF 2	95.8	348.74	264.87	0.29	19.9	5.27	
1916.5	PF 3	104	348.78	272.17	0.29	20.44	5.62	
1612	PF 1	52.1	347.56	25.9	0.44	36.1		
1612	PF 2	95.8	347.99	28.31	0.53	62.18	1.67	
1612	PF 3	104	348.05	284.36	0.53	64.23	2.02	
1450	PF 1	52.1	346.97	25.46	0.52	45.98		
1450	PF 2	95.8	347.6	303.36	0.51	56.9		
1450	PF 3	104	347.7	303.53	0.5	58.27		
1400		Bridge						
1200	PF 1	52.1	346.39	27.2	0.44	37.91		6.56
1200	PF 2	95.8	347.07	33.18	0.43	47.85		12.94
1200	PF 3	104	347.18	34.44	0.43	49.09		13.63
802	PF 1	52.1	345.33	20	0.39	33.48		
802	PF 2	95.8	346.02	20	0.42	51.18		
802	PF 3	104	346.13	20	0.43	54.27		

587.4	PF 1	52.1	344.73	20.98	0.45	40.92		
587.4	PF 2	95.8	345.35	20.98	0.49	62.22		
587.4	PF 3	104	345.44	20.98	0.49	66.15		
273.2	PF 1	52.1	343.72	22.69	0.56	55.52	6.22	1.49
273.2	PF 2	95.8	344.3	27.2	0.57	75.03	15.66	13.51
273.2	PF 3	104	344.39	27.89	0.57	78.63	17.17	15.35
178		Bridge						
0	PF 1	52.1	342.58	24.92	1.01	130.39		
0	PF 2	95.8	342.96	26.19	1.02	171.5		
0	PF 3	104	343.04	26.46	1	171.48		

Burge Dyke 1

River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	Top Width (m)	Froude # Chl	Shear Chan (N/m2)	Shear LOB (N/m2)	Shear ROB (N/m2)
6244.9	PF 1	52.1	372.7	31.78	0.45	33.53		
6244.9	PF 2	95.8	373.18	38.03	0.5	47.85		
6244.9	PF 3	104	373.26	38.89	0.51	49.91		
5753.1	PF 1	52.1	370.36	30.44	0.99	117.36		
5753.1	PF 2	95.8	370.7	31.87	0.99	151.17		
5753.1	PF 3	104	370.75	32.1	1	156.79		
5628.1	PF 1	52.1	367.94	22.76	0.66	70.07		
5628.1	PF 2	95.8	368.42	79.35	0.7	95.89	8.61	4.89
5628.1	PF 3	104	368.48	89.08	0.7	100.53	10.54	7.8
5384.3	PF 1	52.1	366.14	24.62	0.63	63.68		
5384.3	PF 2	95.8	366.58	81.47	0.71	94.22		1.49
5384.3	PF 3	104	366.63	121.88	0.72	100.69		3.86
4998.3	PF 1	52.1	363.47	50.55	0.66	70.02		7.26
4998.3	PF 2	95.8	363.84	57.78	0.73	89.99		38.06
4998.3	PF 3	104	363.88	58.71	0.75	93.97		43.11
4612.3	PF 1	52.1	360.53	25.76	0.71	74.67		
4612.3	PF 2	95.8	360.79	28.61	0.94	144.59		
4612.3	PF 3	104	360.81	28.82	1	163.59		
4300	PF 1	52.1	357.93	217.61	0.55	44.46	0.65	7.97
4300	PF 2	95.8	358.19	243	0.44	34.03	7.86	12.45
4300	PF 3	104	358.21	243	0.45	35.39	8.78	13.45
4030.3	PF 1	52.1	356.41	25.82	0.39	29.91		
4030.3	PF 2	95.8	357.1	109	0.39	37.91	1.86	2.14
4030.3	PF 3	104	357.22	109	0.38	35.78	2.65	4.1
3894.2	PF 1	52.1	355.62	17.07	0.77	103.48		
3894.2	PF 2	95.8	355.95	18.09	0.98	194.35	14.94	16.11
3894.2	PF 3	104	356.02	18.32	0.99	204.85	18.91	20.55
3860		Bridge						

3568.4	PF 1	52.1	354.06	28.99	0.52	44.01		
3568.4	PF 2	95.8	354.56	37.25	0.56	57.68		
3568.4	PF 3	104	354.63	37.38	0.56	60.29		
3160.5	PF 1	52.1	352.24	34.45	0.5	38.66		
3160.5	PF 2	95.8	352.75	146.98	0.43	35.61		7.24
3160.5	PF 3	104	352.83	147.19	0.4	33.19		8.23
2819.6	PF 1	52.1	350.95	20.85	0.5	48.75	0.17	
2819.6	PF 2	95.8	351.04	20.85	0.83	142.41	8.56	
2819.6	PF 3	104	351.03	20.85	0.91	168.55	9.89	
2305	PF 1	52.1	348.99	592.63	0.21	7.73	1.97	1.81
2305	PF 2	95.8	349.15	597.03	0.22	8.6	2.99	2.85
2305	PF 3	104	349.18	597.68	0.22	8.79	3.17	3.03
2017.7	PF 1	52.1	348.65	488.82	0.34	22.2	2.07	1.97
2017.7	PF 2	95.8	348.83	497.87	0.32	21.62	4.28	4.29
2017.7	PF 3	104	348.86	499.12	0.32	21.91	4.61	4.64
1916.5	PF 1	52.1	348.37	380.46	0.4	33.41	0.72	0.68
1916.5	PF 2	95.8	348.6	422.65	0.38	33.42	4.78	5.33
1916.5	PF 3	104	348.63	427.67	0.38	33.97	5.23	5.89
1612	PF 1	52.1	347.55	110.7	0.45	36.75		0.12
1612	PF 2	95.8	347.87	251.96	0.39	32.7	2.59	6.84
1612	PF 3	104	347.94	344.18	0.37	29.55	0.34	7.13
1450	PF 1	52.1	346.97	66.24	0.52	45.96	0.37	0.19
1450	PF 2	95.8	347.52	327	0.48	50.38	16.76	16.21
1450	PF 3	104	347.6	327	0.47	51.16	18.69	18.04
1400		Bridge						
1200	PF 1	52.1	346.36	25.12	0.46	40.44		0.11
1200	PF 2	95.8	346.74	48.53	0.55	68.54		14.28
1200	PF 3	104	346.79	48.53	0.56	73.6		17.17
802	PF 1	52.1	345.21	218	0.2	8.31		2.71
802	PF 2	95.8	345.53	218	0.2	9.44		4.3
802	PF 3	104	345.58	218	0.2	9.66		4.57

587.4	PF 1	52.1	344.83	23.07	0.42	34.54	
587.4	PF 2	95.8	345.24	170.18	0.37	31.97	7.54
587.4	PF 3	104	345.3	170.18	0.36	31.14	8.19
273.2	PF 1	52.1	343.73	24.68	0.58	56.03	0.63
273.2	PF 2	95.8	344.35	37.94	0.53	56.01	13.07
273.2	PF 3	104	344.45	38.54	0.52	56.45	14.2
178		Bridge					
0	PF 1	52.1	342.58	25.07	1.01	130.06	
0	PF 2	95.8	342.97	26.24	1	165.41	
0	PF 3	104	343.04	26.46	1	171.27	

Burge Dyke 2

River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	Vel Chnl (m/s)	Top Width (m)	Froude # Chl	Shear Chan (N/m2)	Shear LOB (N/m2)	Shear ROB (N/m2)
6244.9	PF 1	52.1	372.7	1.48	31.78	0.45	33.53		
6244.9	PF 2	95.8	373.18	1.84	38.03	0.5	47.85		
6244.9	PF 3	104	373.26	1.89	38.89	0.51	49.91		
5753.1	PF 1	52.1	370.36	2.55	30.44	0.99	117.36		
5753.1	PF 2	95.8	370.7	3.08	31.87	0.99	151.17		
5753.1	PF 3	104	370.75	3.16	32.1	1	156.79		
5628.1	PF 1	52.1	367.94	2.13	22.76	0.66	70.07		
5628.1	PF 2	95.8	368.42	2.62	79.35	0.7	95.89	8.61	4.89
5628.1	PF 3	104	368.48	2.7	89.08	0.7	100.53	10.54	7.8
5384.3	PF 1	52.1	366.14	2.02	24.62	0.63	63.68		
5384.3	PF 2	95.8	366.58	2.56	81.47	0.71	94.22		1.49
5384.3	PF 3	104	366.63	2.66	121.88	0.72	100.69		3.86
4998.3	PF 1	52.1	363.47	2.12	50.55	0.66	70.02		7.26
4998.3	PF 2	95.8	363.84	2.43	57.78	0.73	89.99		38.06
4998.3	PF 3	104	363.88	2.49	58.71	0.75	93.97		43.11
4612.3	PF 1	52.1	360.53	2.15	25.76	0.71	74.67		
4612.3	PF 2	95.8	360.79	3.07	28.61	0.94	144.59		
4612.3	PF 3	104	360.81	3.27	28.82	1	163.59		
4300	PF 1	52.1	357.93	1.65	217.61	0.55	44.46	0.65	7.97
4300	PF 2	95.8	358.19	1.51	243	0.44	34.03	7.86	12.45
4300	PF 3	104	358.21	1.54	243	0.45	35.39	8.78	13.45
4030.3	PF 1	52.1	356.41	1.45	25.82	0.39	29.91		
4030.3	PF 2	95.8	357.1	1.73	109	0.39	37.91	1.86	2.14
4030.3	PF 3	104	357.22	1.69	109	0.38	35.78	2.65	4.1
3894.2	PF 1	52.1	355.62	2.62	17.07	0.77	103.48		
3894.2	PF 2	95.8	355.95	3.73	18.09	0.98	194.35	14.94	16.11
3894.2	PF 3	104	356.02	3.86	18.32	0.99	204.85	18.91	20.55
3860		Bridge							
3568.4	PF 1	52.1	354.06	1.69	28.99	0.52	44.01		

3568.4	PF 2	95.8	354.56	1.99	37.25	0.56	57.68		
3568.4	PF 3	104	354.63	2.05	37.38	0.56	60.29		
3160.5	PF 1	52.1	352.24	1.56	34.45	0.5	38.66		
3160.5	PF 2	95.8	352.75	1.61	138.98	0.43	36.48		7.4
3160.5	PF 3	104	352.83	1.57	139.19	0.41	34.19		8.48
2819.6	PF 1	52.1	350.95	1.85	20.85	0.5	48.75	0.17	
2819.6	PF 2	95.8	351.04	3.19	20.85	0.83	142.41	8.56	
2819.6	PF 3	104	351.03	3.47	20.85	0.91	168.55	9.89	
2305	PF 1	52.1	349.01	0.68	593.15	0.2	7.02	1.84	1.7
2305	PF 2	95.8	349.19	0.7	597.89	0.2	7.14	2.6	2.49
2305	PF 3	104	349.22	0.71	598.65	0.19	7.21	2.72	2.62
2017.7	PF 1	52.1	348.66	1.3	361.21	0.35	23.69	2.33	2.46
2017.7	PF 2	95.8	348.91	1.22	373.45	0.3	20.03	4.65	4.85
2017.7	PF 3	104	348.94	1.23	375.09	0.3	20.15	4.97	5.19
1916.5	PF 1	52.1	348.38	1.54	243.04	0.4	32.93	0.9	1.08
1916.5	PF 2	95.8	348.72	1.47	304.13	0.34	28.05	5.17	6.11
1916.5	PF 3	104	348.75	1.48	310.98	0.34	28.41	5.59	6.66
1612	PF 1	52.1	347.55	1.58	34.86	0.45	36.7		0.14
1612	PF 2	95.8	347.87	2.23	45.96	0.56	67.36	5.33	13.92
1612	PF 3	104	347.91	2.35	68.68	0.58	74.28	0.36	16.71
1450	PF 1	52.1	346.97	1.75	66.24	0.52	45.96	0.37	0.19
1450	PF 2	95.8	347.52	1.95	327	0.48	50.38	16.76	16.21
1450	PF 3	104	347.6	1.98	327	0.47	51.16	18.69	18.04
1400		Bridge							
1200	PF 1	52.1	346.36	1.67	25.12	0.46	40.44		0.11
1200	PF 2	95.8	346.74	2.27	48.53	0.55	68.54		14.28
1200	PF 3	104	346.79	2.36	48.53	0.56	73.6		17.17
802	PF 1	52.1	345.21	0.78	218	0.2	8.31		2.71
802	PF 2	95.8	345.53	0.85	218	0.2	9.44		4.3
802	PF 3	104	345.58	0.87	218	0.2	9.66		4.57
587.4	PF 1	52.1	344.83	1.56	23.07	0.42	34.54		

587.4	PF 2	95.8	345.24	1.56	170.18	0.37	31.97	7.54
587.4	PF 3	104	345.3	1.55	170.18	0.36	31.14	8.19
273.2	PF 1	52.1	343.73	1.91	24.68	0.58	56.03	0.63
273.2	PF 2	95.8	344.35	1.99	37.94	0.53	56.01	13.07
273.2	PF 3	104	344.45	2.02	38.54	0.52	56.45	14.2
178		Bridge						
0	PF 1	52.1	342.58	2.74	25.07	1.01	130.06	
0	PF 2	95.8	342.97	3.29	26.24	1	165.41	
0	PF 3	104	343.04	3.37	26.46	1	171.27	