Park Rill Flood Response Feasibility Study

Presented To:

REGIONAL DISTRICT RDOS OKANAGAN-SIMILKAMEEN

Dated: April 30, 2019

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ENGINEERS & GEOSCIENTISTS BRITISH COLUMBIA

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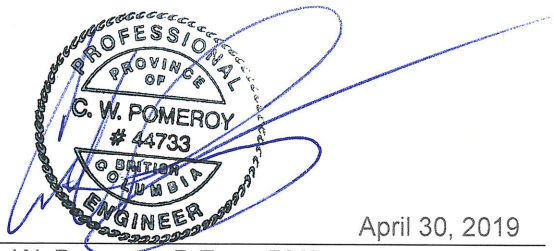

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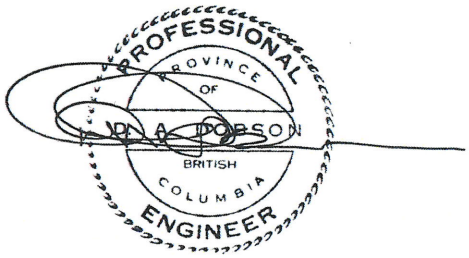

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Acronyms and Abbreviations

CSP	Corrugated Steel Pipe
Ecora	Ecora Engineering & Resource Group Ltd.
Dobson	Dobson Engineering Ltd.
EMBC	Emergency Management British Columbia
EOC	Emergency Operations Center
MoTI	Ministry of Transportation and Infrastructure
RDOS	Regional District of Okanagan-Similkameen
RTAC	Roads and Transportation Association of Canada

1. Introduction

Ecora Engineering & Resource Group Ltd. (Ecora) and Dobson Engineering Ltd. were retained by the Regional District of Okanagan-Similkameen (RDOS) to complete a flood response feasibility study to develop options for a long-term solution to flooding in the Park Rill Creek watershed. The purpose of this report is to review available information for Park Rill Creek and to develop alternatives to upgrade the watercourse to a design standard capable of handling a 1 in 200-year flood event. The alternatives proposed will be assessed in this report to determine cost and reliability of each alternative, and a Class D cost estimate will be prepared for each recommended option.

The report is arranged as follows:

- Section 1 provides project background information, including a summary of recent flooding events and temporary flood mitigation measures.
- Section 2 provides a desktop review of available information for Park Rill Creek, comprised a review publicly available information and reports and historical aerial photographs.
- Section 3 provides a summary of the site reconnaissance carried out as part of this study along with relevant findings.
- Section 4 summarizes the methods used to estimate the 1 in 200-year design flood event and the results;
- Section 5 feasible options for Park Rill Creek flood mitigation and an assessment of the advantages and disadvantages of each, including a list of potential constraints;
- Section 6: Provides the estimated quantities and construction costs to a Class D level for each alternative; and
- Section 7: Provides recommendations for supplemental studies and work to be carried out in support of detailed design.

Ecora and Dobson have also prepared a report summarizing a flood response feasibility study for Twin Lakes, which should be reviewed in conjunction to this report.

1.1 Project Background

In Spring 2018, the Park Rill Creek watershed experienced extensive flooding with the most heavily impacted areas being the Willowbrook area, Sportsmens Bowl Road area and properties along the stream channel downstream of Highway 97 to the confluence with the Okanagan River. The flooding caused damage to homes, public infrastructure, loss of property and numerous evacuations. The emergency response required an extensive effort to prevent floodwaters from damaging homes and overtopping public roads, most notably Secrest Hill Road nearly overtopped presenting a serious risk to public safety which required the mobilization of two emergency 8” pumps and the installation of an 800mm overflow pipe to prevent future risks of overtopping. As part of the emergency response works, the Ministry of Transportation and Infrastructure (MoTI) installed two 800mmØ culverts across Highway 97 to increase flow capacity downstream and the RDOS Emergency Operations Center (EOC) coordinated the mobilization pumps at the Park Rill Creek outlet to discharge water into the Okanagan River. Flooding in the Park Rill area resulted in considerable expenditure for pumping and temporary flood protection works, implemented by the RDOS EOC and funded by Emergency Management BC (EMBC). Repeated flooding of infrastructure in the Park Rill Creek watershed has been documented since the 1950’s (Botham 1973).

RDOS requested that Ecora provide a scoping document to summarize potential alternatives available for long-term flood mitigation in the Park Rill Creek watershed. A draft letter-report was submitted to RDOS on July 10, 2018,

presenting four potential alternatives for upgrading Park Rill Creek to handle the 1 in 200-year flood event. The Park Rill Creek watershed has been split into study reaches which represent three corridors where the physical attributes and hydraulics of the reach are distinct. Following is a breakdown of each study reach:

- Reach 1 is the lower reach of Park Rill Creek extending upstream from the Okanagan River to Highway 97. Reach 1 is located on the Okanagan River floodplain;
- Reach 2 extends upstream from Highway 97 to Secrest Hill Road and is a steep channel with high energy flows;
- Reach 3 extends upstream from Secrest Hill Road to the Park Rill Creek headwaters; and
- Horn Creek and Twin Lakes, a separate watershed, contributes water to Park Rill Creek during emergency pumping. This area is addressed in the Twin Lakes Response Feasibility Study (2019 Ecora/Dobson), and the recommended solution is summarized in this report.

2. Desktop Review

A review of publicly-available information was completed on the Park Rill Creek watershed, including a review of hydrology. The desktop review comprised a review of reports available from EcoCat Ecological Reports Catalogue (Government of British Columbia 2018), reports and memorandums previously completed by Ecora, and historical air photos for the area from the oldest available (1938) to the most current (2007). A site reconnaissance summarized in Section 3 below, was also carried out to confirm information and observations from the desktop review.

2.1 Creek History and Summary of 2018 Response

Based on a review of satellite imagery from Google Earth (2018) and historic air photos (University of British Columbia 2018), sections of Park Rill Creek appear to have been realigned over the years. Re-aligned channels typically consist of either:

- straightened sections following generally a similar flow direction as the original natural channel or full diversions; or
- diversions of the channel that generally consist of straight channels with severe bends with the original natural channel infilled.

The observations made from satellite imagery are consistent with reported channel diversion. Boom (1978) indicates that the main channel of Park Rill Creek has been diverted by a ditch within the Sportsmens Bowl area and that the old channel has been filled in. Boom (1978) also notes that surface flow has historically been observed only during freshet in this area. This discharge is suspected to be comprised groundwater discharges from the Myers Flat and Victoria Creek groundwater aquifers (Talbot 1966).

In 2014, 2016, 2017, and 2018, the Twin Lakes area experienced a higher than average runoff year, and water was pumped out of Lower Twin Lake into the Park Rill Creek watershed. It is suspected that pumping of water into Park Rill Creek has increase groundwater levels in the Park Rill catchment, indicated by an increase in groundwater level recorded in Groundwater Observation Well 282, located in Willowbrook, of approximately 1 m in peak elevation from 2014 to 2015. A letter report written by Nicole Pyett, regional hydrogeologist, indicates that there may be limited storage capacity in the Willowbrook aquifer to handle continued pumping from Twin Lakes, eluding that higher groundwater levels in Willowbrook may be a result of pumping discharge from Twin Lakes into the Park Rill Creek watershed; however, it is noted that this relationship is not well understood, and other factors, such as an overall increasing trend in regional aquifers, should also be considered (Pyett 2018). Botham (1973) mentions that

in 1951, pumping from Lower Twin Lake into Park Rill Creek caused flooding in the Park Rill Creek area. Water from Lower Twin Lake was pumped into Park Rill Creek in 2017 and again in 2018 with significant pumping occurring from April until November.

In 2018, Ecora and Dobson were retained by RDOS for engineering services in response to severe flooding in the Park Rill Creek watershed. RDOS and MoTI carried out the following emergency response during the 2018 flood event:

- Sandbagging and tiger dam deployment to protect vulnerable properties near Park Rill Creek in Reach 1;
- The removal of channel hydraulic restrictions in Park Rill Creek and continual removal of sediment and debris in Reach 1;
- The installation of four 12” diesel powered discharge pumps at the outlet of Park Rill Creek into Okanagan River;
- The installation of one 12” diesel powered discharge pump located at Park Rill Road;
- The installation of two 800mm culverts under Highway 97 discharging into a constructed emergency channel to increase flow capacity. This emergency channel, that discharged into the wetland area adjacent to Park Rill Creek, was removed later in 2018;
- Hesco bins, sandbags and tiger dams were installed along Sportsmens Bowl Road and on private property to protect key infrastructure and properties;
- Construction of a riprap roadside channel and installation of culverts along Sportsmens Bowl Road to contain flow to the channel and convey it downstream to the Highway 97 culverts;
- The removal of restrictions, including private culvert crossings and creek side vegetation and sediment from the Park Rill Creek channel;
- Replacement of riprap channel berms on Sportsmens Bowl Road with concrete road barriers to contain flow and re-establish 2-way traffic;
- Ditching improvements and upgrade of all crossings to 2-800mmØ culverts along the Sportsmens Bowl right-of-way and installation of a cattleguard which acts as a surface water intercept near Highway 97 to prevent flooding of Park Rill onto Highway 97;
- At Secrest Hill Road, an emergency overflow 800mmØ culvert was installed during the freshet to mitigate the road from overtopping and causing a debris flood. An 8” diesel pump was also installed on Secrest Hill Road during the freshet to keep water levels from cresting the road, which was sustained for several weeks;
- Pumping at Myers Road prior to removal of culvert;
- Sandbagging and installation of tiger dams to protect key infrastructure and property within the Willowbrook area;
- Removal of culverts in Willowbrook on Kearns Creek to increase flow capacity. These culverts were later upgraded in 2018 to box culverts;
- Replacement of existing culverts with concrete box culverts at Park Rill Creek crossings at Goldtau Road, Jones Way, Yellowbrick Road, and Willowbrook Road;
- Park Rill Creek at Secrest Hill Road, has been upgraded to 2-2700mmØ CSP culverts;
- Upgrades to Park Rill Dam to increase spillway capacities by the dam owner; and

- At Twin Lakes, pumping from Lower Twin Lake into the Park Rill Creek watershed and extensive sandbagging and flood wall construction.

2.2 Hydrological Overview

2.2.1 General

Ecora previously completed a high-level hydrological review of the Park Rill Creek watershed in 2018 as part of the flood risk and mitigation engineering recommendations (Ecora 2018). The watershed of Park Rill Creek includes the tributary watersheds of Kearns Creek, Victoria Creek, Orofino Creek, and McCaig Creek, generally capturing runoff from Orofino Mountain and Mount Parker. Based on Ecora's 2018 review, Park Rill Creek has a total catchment area of 165.2km2 as shown in Figure 1.

During the 2018 freshet, it was noted that Park Rill Creek and Kearns Creek were restricted at undersized culvert crossings, causing backwater and flooding into residential properties. Following the high-flow event, MoTI replaced numerous culverts along both creeks. Within the Park Rill Creek watershed there are several small earth-fill dams which regulate the flows in the system, but the live storage of the dams is relatively small and have little impact during a large flood event.

Based on the upgrades completed on culvert crossings in 2018 and 2019 by MoTI, it is expected that backwatering behind the culverts will no longer be an issue throughout the majority of the watershed. However, the Highway 97 crossing is currently undersized and should be upgraded. The Park Rill Creek outlet currently floods the Park Rill Creek mouth area during high flow events and when Okanagan River water levels are high, resulting in increased groundwater levels which has impacted homes and businesses in this area. Additionally, several residential culverts are located along the watershed which may not have the capacity to convey the design event discharges. Culvert sizes and capacities in residential properties has not been assessed for this report. A summary of hydrological characteristics for each Reach is provided in the sections below.

2.2.2 Reach 1 – Okanagan River to Highway 97

This lower reach of Park Rill Creek extends from the mouth of Park Rill Creek to Highway 97 and is bordered on the east by the Okanagan River. The local drainage area for this channel reach is approximately 6km2. The channel was historically the west arm of the Okanagan River and was cut off from the Okanagan River with the construction of the Okanagan Lake Regulation System (OLRS) which included channelization of the river in the 1950's and included the construction of the dikes. Following the OLRS construction project, areas along the inlet to the west arm of the Okanagan River were infilled and agricultural and residential development increased within Reach 1. The upstream end of this old west arm between Island Road and Highway 97 has become a wetland-type feature that collects local runoff and floodwater and backwater from the Park Rill Creek channel when the channel capacity is exceeded and is overtopped. Based on observations in 2018, numerous channel restrictions were present within this channel reach, primarily consisting of log debris constrictions. Additionally, beaver activity has been observed in the Park Rill channel throughout this reach, which may further restrict channel flow and result in undesired localized flooding. The 1992 floodplain mapping project shows the entire area of Reach 1 east of Park Rill Creek is within the Okanagan River Floodplain which was developed based on a 1 in 200-year daily flow of 119 m3/sec. The 1992 floodplain mapping for Reach 1 is provided in Appendix A.

Two hydraulic structures are located within Reach 1, shown on Figure 2, as follows:

- Park Rill Creek at Park Rill Road – Consists of a 1200mmØ corrugated steel pipe (CSP) culvert with beaver caging extended upstream from the culvert inlet. It is noted that this culvert did not have the capacity to discharge the 2018 freshet flows, which caused flooding on adjacent properties.

- Park Rill Creek outlet to Okanagan River – Consists of a 1200mmØ CSP culvert. It is noted that this culvert did not have the capacity to discharge the 2018 freshet flows and was in backwater from high flow in the river. Four diesel pumps were installed to pump into the Okanagan River. Additionally, it was noted that there is currently no flap gate on this outlet culvert, and during high flow events, the Okanagan River can backflow into Park Rill Creek.

Flooding in Reach 1 results for a rise in surface water levels due to limited capacity at the Okanagan River, Park Rill Road culvert crossings and within the channel. Groundwater is a significant source of flooding issues for residential properties as well, as shallow aquifer levels are further exacerbated by surface flooding or high water levels within Park Rill Creek and the Okanagan River.

2.2.3 Reach 2 - Highway 97 to Secrest Hill Road

This reach of Park Rill Creek extends from Highway 97 to the top of the Sportsmens Bowl Area at the Secrest Hill Road culvert crossing. The local drainage area for this channel reach is approximately 1.4km2. Just below Secrest Hill Road, Park Rill Creek discharges through several waterfall-type areas with extremely steep channel gradients interspersed between flat sections of channel. At the based of the slope, the channel runs through privately owned property before running into the Sportsmens Bowl Road roadside ditch. Based on the historic air photo review and anecdotal evidence provided by the Sportsmens Bowl residents, the primary channel until 2018 was the channel running along the base of the Sportsmens Bowl slope to the northeast of the residential properties. The secondary channel prior to 2018 was the irrigation ditch that runs through properties from 352 to 274 Sportsmens Bowl Road and discharges to the Sportsmens Bowl Road ditch. During the 2018 freshet, a channel avulsion occurred that diverted the entire flow into the irrigation ditch that now acts as the primary flow path for Park Rill Creek. This area was most severely impacted during the 2018 freshet, as the irrigation and roadside ditches did not have capacity for the high flows, causing flooding on private property and the roadway.

Two hydraulic structures are located within Reach 2, shown on Figure 2, as follows:

- Secrest Hill Road Crossing – Consists of two 2700mmØ CSP culverts with headwalls, installed in Spring 2019.
- Highway 97 Road Crossing – Consists of three 600mmØ CSP culverts with two overflow 800mmØ culverts, installed in 2018 that are currently blocked. The two 800mmØ are intended to be used only if the three 600mmØ culverts do not have the capacity to convey the Park Rill Creek flows, as they currently discharge directly towards a dwelling and a temporary channel must be constructed if they are to be used. It is noted that the combined capacity of these five culverts is less than the capacity of the upstream Secrest Hill Road culverts.

In addition to the hydraulic structures mentioned above, numerous smaller culverts are located along this reach that convey creek flows under private driveways located within private property and along the Sportsmens Bowl Road ditch. These culverts do not have capacity to discharge high-flow events.

2.2.4 Reach 3 – Secrest Hill Road to Headwaters

This reach extends upstream from Secrest Hill Road to the Park Rill Creek headwaters, which includes the Kearns Creek, Victoria Creek, Orofino Creek, and McCaig Creek watersheds. Orifino Creek and McCaig Creek watersheds have generally minor anthropogenic disturbances observe in satellite imagery, which primarily consist of forestry access roads. Orifino Creek has a watershed area of 13.3km2, and McCaig Creek has a watershed area of 6.9km2. Victoria Creek has been similarly impacted by forestry and is further impacted by road crossings for Willowbrook Road and Secrest Hill Road. Victoria Creek has a watershed area of 27.4km2 and several small lakes, including Ripley Lake, Madden Lake, and Burnell Lake area located within its upper watershed, which may partially attenuate flows and delay and reduce peak flow timing.

Kearns Creek has been heavily impacted by residential development in addition to the impact of forestry and the construction of White Lake Road. The creek runs through the community of Willowbrook where it discharges through four concrete box culverts. Additionally, two earthfill dams, Kitley Lake Dam and Kearns Creek Dam, located upstream of the Willowbrook community regulate flows through Kearns Creek. Flow regulation by these two dams is limited, especially during high-flow events, due to a low live storage volume, and both dams have significant deficiencies which are in the process of being addressed. The Kearns Creek watershed area is approximately 43.3km2 and includes several small lakes in the upper watershed, including Prather Lake, White Lake, and Mahoney Lake. The community of Willowbrook experienced flooding in 2017 and 2018 primarily from Kearns Creek. Flows in Kearns Creek overwhelmed the existing channel and culvert crossing in Willowbrook which impacted several residences. High groundwater also impacted the community, flooding basements and causing water quality issues in the public water supply well which triggered a boil water advisory.

From the upper watershed, Park Rill Creek flows through a series of culverts located along White Lake Road, Jones Way, and Goldtau Road. The confluence to Park Rill for McCaig Creek, Orofino Creek, and Kearns Creek all occur prior to Park Rill Creek dispersing into a wetland type area in Myers Flats that is mostly provincial park. At the downstream end of Myers Flats, Victoria Creek discharges into Park Rill Creek and the combined creek flows into a small reservoir at the Park Rill Dam, an earthfill/concrete gravity dam that can provide limited regulation of flows into the lower reaches of Park Rill Creek.

As described above, several hydraulic structures are located within Reach 3, shown on Figure 3, as follows:

- Concrete Box Culvert Crossings along Kearns Creek – Kearns Creek crossings at Johnson Crescent, Carr Crescent, and Myers Road. These culverts have been appropriately sized by MoTI to convey the estimated design event discharge in Kearns Creek.
- Kitley Creek Dam (private) – Located upstream of Kearns Creek Dam, water levels monitored and controlled by St. Andrews by the Lake strata community.
- Kearns Creek Dam (private) – Dam is structurally compromised by internal erosion in the embankment; therefore, reservoir siphoning has previously been implemented to mitigate potential for failure. It is understood this dam owner intends to lower the spillway to bring the stored volume under 10,000m3.
- Victoria Creek Crossing – An 1800mmØ CSP culvert has been installed at the Victoria Creek crossing under Secrest Hill Road.
- Concrete Box and CSP Culvert Crossings – Park Rill Creek crossings at Secrest Hill Road, Jones Way and Goldtau Road. These culverts have been appropriately sized by MoTI to convey the estimated design event discharge in Park Rill Creek.
- Park Rill Dam (private) – Consists of a concrete dam with broad crested weir spillway, with a secondary overflow spillway which passes through 1-1200mmØ CSP and 1-900mmØ CSP culverts. The natural overflow spillway was eroded in 2018 and has since been repaired.

2.2.5 Twin Lakes and Horn Creek

The Horn Creek watershed and Twin Lakes area is addressed in Ecora and Dobson's Twin Lakes Response Feasibility Study (2019) which should be reviewed in conjunction with this Park Rill Creek report.

2.3 Geologic Setting

2.3.1 Surficial Geology

The Geology Map "Surficial Geology, Kootenay Lake, British Columbia-Alberta, Open File 1084" (Fulton, Shetsen & Rutter 1984) indicates that the subsurface soils consist of the following:

- Ice contact glaciofluvial sand and gravel cover the eastern portion of the watershed, including the Kearns Creek watershed and the base of Orofino Mountain and Mount Parker;
- Sand loamy and loamy till generally covers the mountain ranges. This deposit is generally thin (i.e., less than 2 m) and discontinuous, moderately stony, compact, and massive containing lenses of stratified sediments; and
- Sandy till is present along the lower reaches of Park Rill Creek along the southwest portion of the watershed. The till is generally gravelly, cobbly, or boulder and occurs as a discontinuous blanket with thickness up to 2 m.

2.3.2 Bedrock Geology

The Geological Survey of Canada 1:100000 bedrock geology map "Okanagan Watershed" (Okulitch, 2011) indicates that the watershed is underlain by the numerous different bedrock formations, including the Marama Formation, Marron Formation, White Lake Formation, Yellow Lake Member, Skaha Formation, and Apex Mountain Group. Early and middle Jurassic diorite and Paleozoic and Mesozoic grandiorite, biotite, amphibolite, gneiss, feldspathic, and diorite are also mapped along the lower portion of the Park Rill Creek watershed. The watershed's bedrock is primarily comprised igneous rock with some sedimentary rock along the upper reaches and some metamorphic rock within the lower reaches.

2.3.3 Groundwater Aquifers

The presence of groundwater aquifers in the Park Rill Creek watershed may have a significant impact on surface runoff volumes, as available aquifer storage can increase or decrease quantities of groundwater seepage. Numerous groundwater aquifers are present in the Park Rill Creek watershed based on provincial mapping (Government of BC 2019) which are also shown in Figure 4:

- Aquifer 255 is an unconfined aquifer that is exposed at surface with an area of 14km2 and an average depth to water of 5.5m. It underlies the lower reaches of Park Rill Creek Secrest Hill Road to Okanagan River and extends south from the south lakeshore of Vaseux Lake to Tugulnuit Lake.
- Aquifer 257 is a confined surficial aquifer with an area of 8.5km2 and an average depth to water of 5.5m. It primarily underlies the Myers Flats area of the Park Rill Creek watershed, extending along the Park Rill Creek channel from upstream of the McCaig Creek confluence to Secrest Hill Road, including the Kearns Creek channel from just downstream of Mahoney Lake.
- Aquifer 1108 is a bedrock aquifer with an area of 62km2 and an average depth to water of 7.9m. It partially underlies Aquifers 255 and 257, extending south from Willowbrook to Oliver.
- Aquifer 1109 a bedrock aquifer with an area of 12km2 and an average depth to water of 15.2m. This aquifer partially underlies Aquifer 257, underlying a portion of the Kearns Creek watershed to the north and south of Willowbrook.

- Aquifer 1107 is a narrow, near surface aquifer within the surficial deposits with an area of 0.6km2 and an average depth to water of 0.3m. It is located along one of the headwater channels of Park Rill, near Grand Oro Road.
- Aquifer 261 is an unconfined aquifer within the surficial deposits with an area of 3.13km2 and an average depth to water of 18.9m. It underlies the Twin Lakes, extending from northeast from Upper Twin Lake to near Marron Lake.
- Aquifer 260 is a bedrock aquifer underlying Aquifers 1107 and 261 with an area of 62km2 and an average depth to water of 22.3m. It underlies the Twin Lakes and the headwaters of Park Rill Creek and Kearns Creek.

2.4 Air Photograph Review

Air photos obtained from BC (2018) for Park Rill Creek were reviewed as part of this study. Air photos from 1938, 1947, 1951, 1959, 1963, 1969, 1979, 1985, 1996, and 2007 were reviewed, as well as 2016 satellite imagery from Google Earth (Google 2018) for comparison with more current conditions. Select air photographs are provided in Appendix B of this report.

The air photo review is summarized by Reach, and the results of the review are presented in Table 2.1 to Table 2.3

Table 2.3. The air photo review for the Twin Lakes area is available in a separate report (Ecora/Dobson 2019) and has not been included in this report.

Table 2.1 Reach 1 Air Photo Summary

Year	Air Photo Details	Comments
1938	BC99:63. Medium Scale.	The two channels of the Okanagan River near Park Rill Creek are visible in 1938. Island Road has been constructed through the west arm of the river, and it is unclear as to whether there is a culvert or bridge installed to discharge water under this roadway.
1951	BC1243:106. Medium Scale.	Meander progression is noted in the Okanagan River with the channel becoming more straight within this time period.
1959	Details not available.	Significant channelization of the Okanagan River has occurred with construction of the OLRS which consists of straightening and widening the channel. Cut-offs are created in areas where meanders were previously present, including at the downstream end of Park Rill Creek where the channel splits into two sides of an old meander and appear to discharge into the Okanagan River.
1974	BC7581-207. 1:16,000. July 24, 1974.	There is a visible cut-off between the upstream end of the west arm and the channelized Okanagan River. There is a defined cut-off between the downstream east meander channel and the Okanagan River.
1985	BCC348-132. 1:15,000. July 8, 1985.	No significant changes are observed in this photo; however, ongoing development in this area is observed.
1996	BCC96023-178. 1:15,000. July 13, 1996.	Residential development has occurred within the upstream end of the historical channel alignment.
2007	BCD7038-191. 1:27,000. July 26, 2007.	No significant changes are observed in this photo.

Table 2.2 Reach 2 Air Photo Summary

Year	Air Photo Details	Comments
1938	BC99:13. Medium Scale.	Two channels through this reach are observed in the 1938 air photo, with the primary channel appearing to be the one that runs along the bottom of the north-eastern Sportsmens Bowl slope, and a secondary channel running along the bottom of the west slope.
1951	BC1243:10. Medium Scale.	Sportsmens Bowl Road has been constructed, and the secondary channel appears to still be present running along the roadway ditch area; however, it is unclear as to whether a culvert or bridge has been installed to discharge water under the roadway.
1963	BC4174-037. 1:16,000. August 16, 1963.	Sportmens Bowl Road has been re-aligned and the South Okanagan Sportsmens Association (SOSA) gun club has been expanded. The secondary channel of Park Rill Creek been realigned as an irrigation ditch such that it runs through properties from 352 to 274 Sportsmens Bowl Road. Areas around this secondary channel have been cultivated and buildings have been constructed on these properties.
1974	BC7581-206. 1:16,000. July 24, 1974.	Works appears to have been constructed just upstream of the SOSA to direct flow towards the irrigation ditch. Further cultivation around the irrigation ditch is observed.
1985	BCC348-176. 1:15,000. July 8, 1985.	A large parcel of land to the west of Sportsmens Bowl has been cultivated. The Park Rill Creek previously primary channel is no longer visible through the middle section of the reach, and cultivation extends east to the old alignment. An access trail has been constructed near the downstream end of the creek, near Highway 97.
1996	BCC96023-178. 1:15,000. July 13, 1996.	No significant changes are observed in this photo, and the channel is still not visible through a portion of this reach.
2007	BCD7039-038. 1:27,000. July 26, 2007.	Cultivation has been expanded and now extends across the old primary Park Rill Creek alignment. The channel is not visible through this cultivation.

Table 2.3 Reach 3 Air Photo Summary

Year	Air Photo Details	Comments
Near White Lake Ranch (see Figure 3)		
1938	BC101:26. Medium Scale.	The Park Rill Creek channel appears relatively undisturbed through this reach, with heavy vegetation along the alignment.
1963	BC4184:139. 1:16,000. August 30, 1963.	White Lake Road has been widened and re-aligned, north of the channel. New buildings have been constructed along the downstream end of the photos, and a new access trail has been constructed just south of the channel alignment.
1985	BCC363-038. 1:15,000. July 14, 1985.	New buildings and roads have been developed, including an access road constructed crossing the Park Rill Creek channel. There is ponding observed behind this access road.
2007	BCD07022-066. 1:27,000. July 1, 2007.	Another access road has been developed across Park Rill Creek, upstream of the one observed previously. Ponding is still present behind the further downstream access road.
Near Willowbrook Road (see Figure 3)		
1938	BC128:48. Medium Scale.	Park Rill Creek discharges through several channels in this area which meander through the fields west of White Lake Road.
1963	BC4174:078. 1:16,000. August 16, 1963.	Cultivation over the central channels in the upstream section is observed, and the channel is re-aligned and straightened through the remainder of this area.
1996	BCC96025-026. 1:15,000. July 13, 1996.	The upstream channels have been re-aligned and straightened, and the downstream channel has been re-aligned again with surrounding areas cultivated. A residential home and access road have been constructed, located within a historical flow path.
2007	BCD07040-219. 1:27,000. July 26, 2007.	One central, straightened Park Rill Creek channel has been constructed through this section.

Year	Air Photo Details	Comments
At Willowbrook (see Figure 3)		
1938	BC101:260. Medium Scale.	Multiple channels of Kearns Creek are observed that are not clearly defined. Park Rill Creek in this area is also not clearly defined.
1963	BC4184:044. 1:16,000. August 30, 1963.	Access roads have been constructed through this area, and the area has been cultivated. Park Rill Creek has been re-aligned and straightened, and Kearns Creek appears to be limited to only its southernmost existing channel.
1985	BCC363-191. 1:15,000. July 14, 1985.	The community of Willowbrook has been constructed, which includes roadways and residential development. The Park Rill Creek channel has been re-aligned and contains a 90-degree bend just east of the White Lake Road crossing. Kearns Creek has been straightened and re-aligned, and ponded water is observed just east of the community.
2007	BCD07040-221. 1:27,000. July 26, 2007.	Further cultivation and development have occurred in this area. Park Rill Creek has been re-aligned again downstream of Jones Way, and ponded water is still observed just east of the Willowbrook Community.

3. Site Reconnaissance

Numerous site visits were carried out by Ecora to review the hydrological features of the Park Rill Creek watershed and observe areas of interest, including areas of immediate concern. Visits to site were carried out on October 10, 23, and 30, and November 23, 2018, as well as on March 14, 2019. Photographs from the site visits are provided in Appendix C.

On October 10, 2018, Caleb Pomeroy, Sarah Nhan, and Michael Laws carried out a site visit to 4493 Willowbrook Road, where the property owner has noticed significant erosion in the Park Rill Creek channel that runs through his property. The property owner suspects that pumping from Twin Lakes in 2018 has created a significant gulley in his property, which was observed to be greater than 3m deep in areas and approximately 300m in length.

A site reconnaissance carried out on October 30, 2018 by Caleb Pomeroy and Sarah Nhan reviewed the existing channel along Sportsmens Bowl Road and culverts along Park Rill Creek and Kearns Creek as input to a 2019 flood response assessment. It was noted that the existing channel along Sportsmens Bowl Road was at approximately half capacity during the site visit, and in its current configuration is not likely to handle the 2019 freshet if it is higher than normal. Ecora prepared a 2019 flood response plan for the RDOS EOC which is attached in Appendix D. During this site visit, it also was noted that a concrete box culvert was installed under Myers Road to increase capacity of Kearns Creek; however, due to low existing Kearns Creek channel gradient, minimal cover on Myers Road and dimensions of the box culvert, the invert of the culvert was set significantly lower than the Kearns Creek downstream channel. In its current configuration the capacity of box culvert cannot be fully utilized. re-grading of the downstream channel is proposed to allow the full capacity of the culvert to be utilized, an application was made by the landowner with support from the Willowbrook residents but later was withdrawn due to the extensive permit requirements and the large financial cost of completing the supporting studies involved. Ecora assisted in preparation of a report and design drawings for the channel re-grading, attached in Appendix E.

On November 23, 2018, Caleb and Sarah completed a site reconnaissance of Park Rill Creek between the Southern Okanagan Sportsmens Association (SOSA) property and Secrest Hill Road. As summarized in Section 2.2.3, it is understood that the primary channel for Park Rill Creek was a channel at the base of the slope to the north and northeast of Sportsmens Bowl properties until 2018, when a channel avulsion occurred during the high flows that diverted the entire flow into the irrigation ditch that is now the primary flow path for Park Rill Creek. Upstream of the SOSA property to Secrest Hill Road, there are several waterfall-type areas with extremely steep channel gradients interspersed between flat sections of channel. Observations from this site reconnaissance found the canyon to be generally stable with areas of significant erosion near the west property boundary of the SOSA. A summary of the November site reconnaissance is provided in Appendix D in the addendum to the 2019 flood response assessment.

As per Ecora's recommendations in the 2019 flood response assessment, staff gauges to measure water levels were installed at several of the culvert crossings located along Park Rill Creek and Kearns Creek on March 14, 2019. These staff gauges were to be used as part of an ongoing flow monitoring program to collect data on stream flows during the spring freshet period.

4. Hydrology

4.1 Existing Hydrology Studies

Available hydrology studies and design reports were reviewed for their methods and resulting peak flow estimates for Park Rill Creek for potential incorporation into this report. The following work was reviewed:

- MoTI report titled "Infrastructure Damage and Recovery, Goldtau Road Hydrology and Culvert Sizing Report, June 2017 Flood Event, Goldtau Rd, Willowbrook, B.C." undated;
- MoTI draft report titled "Spring 2018 Freshet, Infrastructure Damage & Recovery, Hydrology & Culvert Sizing, Park Rill Watershed", dated January 22, 2019; and,
- Pages 16 to 18 from Interior Dams report titled "Park Rill Dam – Dam File No. D220177-00, Spillway Upgrade – Development Report", dated September 20, 2018

4.1.1 MoTI Reports Methods

In general, both MoTI reports use a similar approach, which compares the results of several design discharge estimating methods, which include regional frequency analysis, gauged hydrometric station transfer analysis, and the BC Streamflow Inventory analysis.

The MoTI report for Goldtau Road uses six select hydrometric stations from the Water Survey of Canada (WSC) which were chosen based on properties such as elevation, un-regulated, land use, and other properties. The unit flow rate for 100-year and 200-year return periods for each station were averaged, reduced using a factor based on 15% of the total watershed being storage area (i.e. swamps and lakes) and applied to a 97km^2 drainage area. Using this methodology, the high-end estimate used for the Goldtau Road culvert crossing design is the 100-year return period discharge plus 15% for climate change which equals 7.07m3/s.

The MoTI report for Park Rill generally applies two methods to derive the design discharges for Park Rill Creek at select locations. The first being a transfer analysis from WSC Station 08LF099 (Arrowstone Creek near the Mouth) based on similar watershed characteristics and then reduced by to account for storage area in the Park Rill Creek watershed. The second is the BC Streamflow Inventory. A summary of the derived discharges at the three Park Rill Creek locations is provided in Table 4.1.

Table 4.1 MoTI Park Rill Discharge Estimates

Location	Drainage Area (km^2)	Derived Design Discharge (m^3/s)	Return Period
Secrest Hill Road	159	11.55	100-year plus 15% for climate change
Willowbrook Road/Jones Way	71.1	6.6	100-year plus 15% for climate change
Yellowbrick Road/Sweetwater Ranch	58.0	5.58	100-year (no reduction for storage area)

4.1.2 Interior Dams Inc. Methods

Interior Dams Inc. applied a frequency analysis method on the discontinued WSC Station 08NM120 for Park Rill near Oliver and extended the record to include estimates of peak discharge in 2017 and 2018. The resulting value was then increased by variable factors to account for climate change and uncertainty in the dataset. Based on this method, the estimated 200-year discharge was 3.26 m^3/s.

4.2 Methodology

4.2.1 Design Event

In consideration of the potential loss of life due to Park Rill Creek watershed flooding, the risk is relatively low due to generally disbursed nature of homes in the area and small population living adjacent to Park Rill Creek and its tributaries. In accordance to the APEGBC Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate, a 200-year return period flow is considered suitable for the development of long-term flood mitigation measures.

4.2.2 Park Rill Creek Hydrometric Data

As mentioned above, a WSC hydrometric gauge station was seasonally in operation on Park Rill Creek, near Secrest Hill Road, from 1951 to 1970. Flood frequency analyses were carried out on the dataset for the Park Rill Creek using the HYFRAN software Version 2.2 to estimate 100-year to 200-year return period discharges. Results of flood frequency analyses are summarized in Table 4.2.

Table 4.2 Flood Frequency Analysis Results

Station ID	Station Name	Location	Drainage Area (km^2)	100-year Discharge (m^3/s)	200-year Discharge (m^3/s)
08NM120	Park Rill near Oliver	49°14'10" N 119°34'20" W	160	1.82	2.47

As describe in sections above, there are numerous culverts located along the length of Park Rill Creek that were not previously sized to the appropriate return period event; therefore, peak flows in the creek would have been limited by the capacity of these culverts. Additionally, historical flood years of 1972, 2012, 2017 and 2018 have not been captured within the available period of record which will have a significant impact on the estimated return period flows, likely increasing them significantly. A comparison of these results to Ecora's observations during the 2018 freshet indicates that these estimated return period events are too low; and an alternate method should be considered to calculate design discharges.

4.2.3 Regional Hydrometric Data

Due to the unique nature of the Park Rill Creek watershed, available nearby regional hydrometric stations were assessed for suitability for use in a regional analysis. Selected stations were generally within about 20km of the reach and collect runoff from the same mountains (e.g. Orofino Mountain, Mount Kobau) or similar nearby mountain ranges. Water yields for each station from April to September was calculated and compared. The results of this comparison are presented in Table 4.3.

Table 4.3 Regional Water Yields

Station ID	Station Name	Location	Drainage Area (km^2)	Water Yield (mm)
08NM120	Park Rill near Oliver	49°14'10" N 119°34'20" W	160	7.91
08NL045	Keremeos Creek below Willis Intake	49°15'32" N 119°49'33" W	181	99.2
08NL014	Keremeos Creek above Marsel Creek	49°19'60" N 119°49'0" W	68.6	67.2
08NM164	Testalinden Creek in Canyon	49°7'17" N 119°35'53" W	13	59.7
08NM147	Horn Creek near Olalla	49°18'11" N 119°45'13" W	15	32.3
08NL040	Richter Creek near Osoyoos	49°3'16" N 119°37'58" W	15.3	15.0

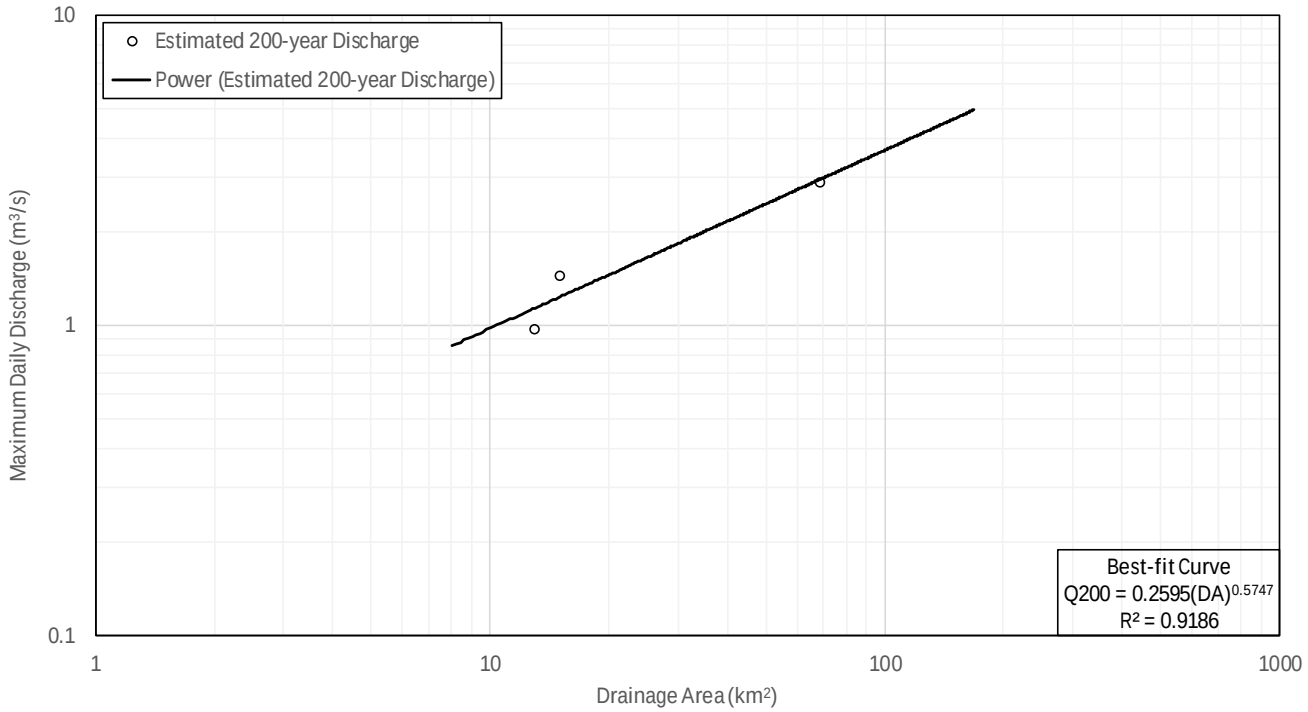
A review of the resulting water yields indicates that the Park Rill Creek station water yield is significantly less than stations on Keremeos Creek, Testalinden Creek, and Horn Creek which source their runoff from the same snowpack along the Mount Kobau and Orofino Mountain ridge. Richter Creek sources it's runoff from lower elevations along the southern end of Mount Kobau, which may explain its lower water yield.

Due to the inconsistency in water yields between Park Rill Creek and the nearby regional stations, it is possible that the Park Rill Creek WSC station does not capture the true water yield for the catchment, particularly upstream of Park Rill Dam when flows have not yet been attenuated. A lower annual water yield is expected for the Park Rill Creek downstream of Park Rill Dam due to the attenuation of flows throughout the year. However, in large runoff events, a conservative approach should consider that the dam reservoir is full and therefore flows are not attenuated and overflow downstream. Regional hydrometric data from WSC Stations 08NL014, 08NM164, and 08NM147 were therefore used to derive the design discharge, as the watersheds and water yields for the stations are generally similar.

4.2.3.1 Regional Analysis

The 200-year design discharge was estimated by completing a regional analysis on the three selected regional stations on Keremeos Creek, Testalinden Creek, and Horn Creek. Keremeos Creek and Horn Creek stations did not have peak flow data; therefore, annual maximum daily flow data were used for the regional analysis. Flood frequency analyses were conducted for the selected regional hydrometric stations using the HYFRAN software Version 2.2 to estimate 1 in 200-year maximum daily flows for each station.

The 1 in 200-year maximum daily flows were plotted against drainage area to derive a best-fit curve between the two variables. Limited scatter is observed in the plotted results. The results of the regional analysis are shown in Plot 1.



Plot 1 1 in 200-year Maximum Daily Discharge Regional Analysis Results

The 1 in 200-year annual maximum daily flow estimate for Park Rill Creek at the mouth is 4.9 m3/s, corresponding to a drainage area of 165km2. It should be noted that the period of record available for the selected regional stations is short, with only 8 years of data available for Keremeos Creek; however, frequency analysis of the available data generally indicated well-fitting trendlines and these stations are expected to best represent hydrological conditions at Park Rill Creek. Based on Ecora's observations of Park Rill Creek in 2018, the resulting 1 in 200-year maximum daily flow estimate appears to be reasonable.

4.3 Results

4.3.1 1 in 200-year Peak Flow Estimates

For design, the 1 in 200-year peak instantaneous flow was estimated. As per the Figure 2.5.2 of the Roads and Transportation Association of Canada (RTAC) Drainage Manual, the expected peak to daily discharge ratio is estimated to be about 1.1:1. This ratio is typically higher in small, high runoff watersheds and lower in retentive, high storage watersheds. A conservative factor of 1.1 has been applied to daily maximum estimates derived from regional analysis. The effect of climate change was also considered by adding a factor of 10% to the peak flow in accordance with current Engineers and Geoscientists BC recommendations. The resulting peak flow estimates for the sub-watersheds in Park Rill Creek and along Park Rill Creek are summarized in Table 4.4.

Table 4.4 1 in 200-year Peak Flow Estimates

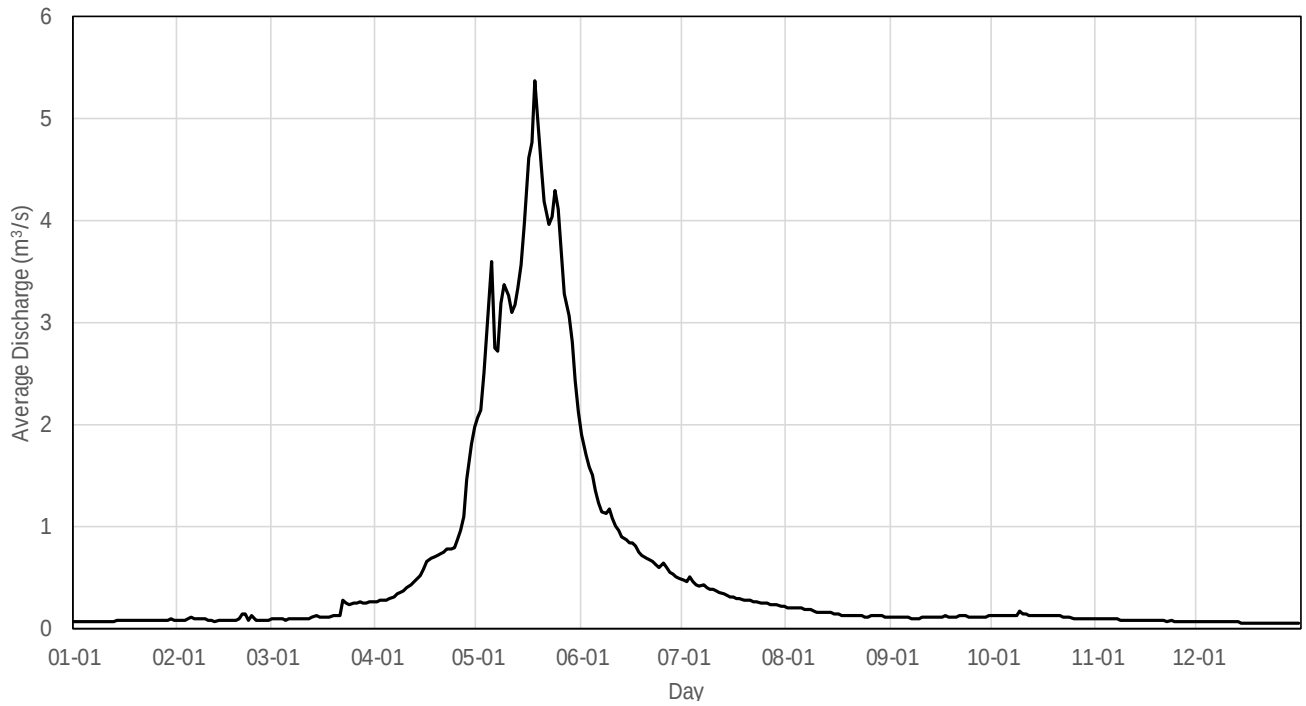
Watershed	Drainage Area	1 in 200-year Peak Flow (m^3/s)
Twin Lakes*	24.0	2.85
McCaig Creek	6.90	0.95
Orofino Creek	13.3	1.4

Watershed	Drainage Area	1 in 200-year Peak Flow (m^3/s)
Victoria Creek	27.4	2.1
Kearns Creek	43.3	2.7
Park Rill above McCaig Creek	60.5	3.3
Park Rill above Kearns Creek	67.4	3.5
Park Rill above Park Rill Dam	157	5.7
Park Rill above Park Rill Dam – with Twin Lakes Discharge	181	6.2
Park Rill at the Mouth	165	5.9
Park Rill at the Mouth – with Twin Lakes Discharge	189	6.4

* Note that Twin Lakes watershed has been included as potential options for flood mitigation in this area include discharging water into the Park Rill Creek watershed. The effect of Twin Lakes discharge will be dependent on the option chosen; however, for the purpose of this report, the watershed area has been added onto the regional analysis to provide a simplified estimate for peak discharge if Twin Lakes is discharged into Park Rill Creek.

4.3.2 Annual Hydrograph

As discussed above, Keremeos Creek sources a portion of its runoff from Orofino Mountain, similar to Park Rill Creek. Station 08NL045, Keremeos Creek at Willis Intake, is the only active WSC station that is expected to provide an appropriate representative hydrograph when applied to Park Rill Creek. The 2018 daily flow data, provided by WSC, was supplemented by 1972 daily flow data from October 24 to December 31 for days missing from the 2018 record. Daily flows were estimated for Park Rill Creek at the mouth by multiplying by a factor equivalent to the maximum daily flow from 2018 for Keremeos Creek to the estimated maximum daily flow estimate (plus 10% for climate change) for Park Rill Creek. The resulting hydrograph for the mouth of Park Rill Creek is presented in Plot 2.



Plot 2 Estimated 200-year Annual Hydrograph for Park Rill Creek Mouth

5. Option Development

5.1 General

The following sections summarize option development and analysis for potential upgrade options that can be utilized to improve the Park Rill Creek watershed drainage to handle a 1 in 200-year flood event. The options included in this report focus on reducing flood risk in key areas of development, where numerous properties and residents are currently impacted by recurrent flooding. Proposed options for each study reach of the Park Rill Creek watershed are described in the sections below, and cost estimates for the recommended options are provided in Section 6.

For the proposed works to be implemented, a drainage service area would need to be established through public consent under the jurisdiction of the RDOS which would define the hydraulic structures and channel reaches where maintenance and repair works would be the responsibility of the RDOS and financed through annual taxation. Consultation with the private property owners that would be affected by the proposed works would be required to discuss responsibilities of all parties and inform residents of the potential financial impacts that these upgrades would impose.

Considering spatial constraints along the creek alignment and the extensive upgrades that will be required to mitigate flooding, two main options were considered to mitigate flooding within the Park Rill Creek watershed:

Option 1: Upgrade Park Rill Creek to handle the 1 in 200-year event which will include channel improvements within Willowbrook and Sportsmens Bowl Road, upgrades to public road crossings and increased capacity at Okanagan River with the construction of an eclectic pump station; or

Option 2: Provide storage to attenuate peak flows up to a 1 in 200-year event in Myers Flats and maintain a peak discharge equivalent to the existing channel capacity downstream of the dam. The construction of a dam directly downstream of Myers Flats could provide the necessary attenuation to maintain manageable peak flows which would significantly reduce the cost of channel and crossing upgrades and works required at the outlet to Okanagan River would be significantly reduced as a result of a lower peak flow rate. Channel and road crossing upgrades would still be required upstream of the dam in this option.

The analysis provided is a high-level review based on available information and is not based on a detailed engineering design. Prior to selecting an option, a detailed engineering study is recommended to confirm assumptions and collect necessary site-specific data for detailed design.

5.2 Reach 1 – Okanagan River to Highway 97

5.2.1 Option 1 – Upgrade to 1 in 200-year Capacity

The calculated peak flows for a 1 in 200-year event for Park Rill Creek is 5.9m3/s at the Okanagan River, or 6.4m^3/s if Twin Lakes is discharged into the watershed. The following recommendations are presented for key infrastructure along the alignment of Park Rill Creek. A detailed review of every property was not completed and is outside of the scope of this report. The analysis completed was to ensure that critical infrastructure is upgraded to handle the design event and it is expected that some response costs would still result during the 1 in 200-year flood event. The recommended options deal specifically with mitigating surface water flood damage and risk. During the design event, groundwater will also be a significant source of damage but due to the location on the floodplain, a feasible solution to this flood risk has not been developed and should be investigated in further studies. The following upgrades are recommended for Reach 1:

1. Increased performance at the outlet into Okanagan River is required to manage the peak flows, At the location of the outlet there are several residential properties that would be affected during the 200-year event. A storage-area-elevation-curve was developed using available LiDAR data to estimate the inundation zone during the 1 in 200-year flood event if the existing outlet is not upgraded. It is assumed that the flap gate would be repaired, and in a 1 in 200-year flood event, the flap gate would be closed for a large portion of the freshet event as the water elevation in the Okanagan River is expected to be higher than the top of the existing culvert. This assumption is based on the estimated water elevations presented in the Okanagan Lake Regulation System Hydrologic & Hydraulic Capacity Review (WaterSmith and Streamworks 2014). Timing of the peak discharge in the Okanagan River cannot be estimated without further analysis; however, 2018 water level data for WSC Station 08NM247, Okanagan River below McIntyre Dam, indicates that the water level was generally highest from mid-May to mid-June. For simplicity, it was therefore assumed that inflows into Park Rill Creek and outflows into the Okanagan River were equivalent until May 15 when the flap gate is fully closed, which results in an accumulated volume in Park Rill Creek of 8,030,000m^3 by June 15 using the estimated 1 in 200-year hydrograph. The available storage in Reach 1 prior to overtopping of the Okanagan River dike is approximately 180,000m^3; therefore, the dike will be overtopped, and the inundated area will be that area that lies below the dike elevation as shown in Figure 6. There are several options available to upgrade this outlet as follows:

   – Construct an electric low-head pump station capable of maintaining water levels at the designed elevation;
   – Continue to manage high-flow events with temporary pumping; or
   – Purchase the low-lying properties and allow the floodwaters rise behind the dike.

   An engineering study should be undertaken to further understand the hydrology and hydraulics of Reach 1 to explore the further possibilities to improve the hydraulics at the Park Rill outlet in order to minimize the area of inundation. A possible option that could be explored further includes constructing a dike on the east side of Park Rill Creek and installing gravity outlet pipes; however, the analysis required understand the feasibility of this option and the associated costs is beyond this scope of work.

2. Park Rill Road currently has 1-1200mm CSP culvert which will require upgrading. Should this upgrading option be selected, this work would fall under MoTI jurisdiction and would be funded separately. A short span bridge or box culvert is recommended in this location to increase crossing capacity to discharge the 1 in 200-year flood event;

3. The property located a 7841 Highway 97 is recommended to be purchased for the re-alignment of the creek and construction of a sediment basin.t The channel at this location will require significant channel improvements which will impact the existing structures on the property, as extensive work will be required for upgrading the creek channel and upgrading the Highway 97 crossing. In addition to channel upgrades, this property could serve as a sediment capture basin for bed load in Park Rill Creek. Heavy machinery access is available at this property and the channel gradient is flat, allowing sediment to deposit before entering the low gradient reach of Park Rill Creek. Following upgrades to the channel on this property, the property will likely no longer be suitable for development due to the required riparian setbacks.

4. The property located a 7823 Highway 97 would be significantly impacted during a peak flow event, and mitigation in the future could be achieved by the installation of a permanent setback berm or temporary flood wall (i.e., tiger dams)

5. The existing Park Rill Creek crossing under Highway 97 is 3-600mmØ CSP culverts. Highway 97 would require an upgrade to pass the designed flow with a 6.0m short span bridge or a 4200mm (span) x 1500mm (rise) concrete box culvert.

Channel upgrades in Reach 1 are not currently recommended along Park Rill Creek. The existing channel is a low gradient stream located on the Okanagan River floodplain and upgrades would significantly impact private properties along the alignment and be environmentally disruptive. Further hydraulic capacity assessment, outside of this report's scope of work, should be completed on this channel reach to establish feasible alternatives for flood protection for existing private property, which could include setback berms or temporary flood walls. However, beaver activity along this reach has been an historic issue and it is recommended that beavers be controlled in this area to prevent construction of dams that cause local flooding.

The recommended flood mitigation plan for Reach 1 is presented in Figure 5. Details on cost considerations and affected infrastructure are provided in Section 6.0.

5.2.2 Option 2 – Upgrade for Flood Storage in Myers Flats

The proposed location of the dam was identified in the natural bedrock canyon directly downstream of the confluence of Victoria Creek and Park Rill Creek. The advantage of a dam in this location is the is a natural canyon with bedrock which narrows to a width of approximately 25 meters in the location of the dam. The location where dam construction would be most feasible due to the width of dam required, geology and existing topography. The proposed dam is on private property District Lot 20S, SDYD, Except Plan 14400, civic address 197 Pampas Grass Way. The noted property currently has an existing water resource dam that is used for irrigation. For the dam storage solution to be feasible, an agreement with the landowner would be required to secure an easement and access for maintaining and monitoring the structure. The new dam would replace the existing small private irrigation dam.

A storage-area-elevation curve for Myers Flats upstream of the dam was developed based on a field survey completed by Ecora on April 11, 2019 and supplemented with Provincial contour data. Analysis was carried out to assess the minimum required outflow from the dam such that the 1 in 200-year flood event could be attenuated by the available storage in Myers Flats. The analysis assumed an earthfill embankment dam with a maximum height of 10 m and a low-level outlet culvert with a diameter of 1000mm and a slope of 1%. The derived 1 in 200-year hydrograph scaled to include the Twin Lakes discharge was applied as inflow to the dam reservoir. The outflow from the dam reservoir through the low-level outflow was estimated using the HY-8 Culvert Hydraulic Analysis Program, available from the U.S. Department of Transportation Federal Highway Administration, which calculates culvert discharge based on headwater height behind the culvert. An hourly timestep was used to calculate inflow volume, calculate reservoir volume and reservoir water level, and then calculate outflow volume. A maximum storage volume of approximately 2,620,000m3 is available in Myers Flats based on the derived storage-area-elevation curve. Based on the analysis, the construction of a flood attenuation dam directly downstream of Myers flats would allow peak flows to be attenuated to the designed maximum regulated outflow of $3m^3/s$. The corresponding required dam height is estimated at 9.6m.

Observations of the Park Rill Creek channel downstream of Myers Flats indicates that the current channel does not have the capacity to handle a discharge of 3m3/s; therefore, upgrades to the channel downstream of the dam would still be required for this option, similar to Option 1. Costs associated with dam construction on top of channel upgrade construction is expected to far exceed the cost of Option 1; therefore, Option 2, which includes dam construction for flood storage in Myers Flats, is not discussed further in this report as it is not economically viable.

5.3 Reach 2 – Highway 97 to Secrest Hill Road

The challenges with a solution in Sportsmens Bowl area include overall space constraints and limitations in the available road right-of-way to accommodate a channel sized to the 1 in 200-year event. The following two main alignment options were reviewed which will impact private property regardless of which alignment is chosen:

Alignment A: Maintain the current alignment and purchase the necessary right-of-way along Sportsmens Bowl Road to construct a channel. This option would require stabilization of the current alignment, the relocation of two homes, significant property dedication and the re-alignment of the lower 300m of Sportsmens Bowl Road to accommodate the upgraded channel, or,

Alignment B: Re-align the creek to the channel along the north edge of the Sportsmens Bowl by constructing a new alignment within properties 352 & 340 Sportsmens Bowl Road and expanding the existing abandoned channel to accommodate the design flood. The upgraded channel in this location will still significantly impact private property but the impact will be limited to the cultivated areas on the Sportsmens Bowl properties. This alignment also allows dedication to be limited to the northern portion of the properties rather than intersecting the majority of properties. Some re-alignment of the creek is required for this option to maintain acceptable offset and freeboard from the dwellings located at 194 & 168 Sportsmens Bowl Road.

The two options selected are based on maintaining open channel flow. A piped system was not analyzed due to the sediment load and maintenance concerns. Several options were considered which include a concrete flume, utilization of Sportsmens Bowl Road as emergency overflow, re-aligning the channel at the SOSA access down Sportsmens Bowl Road, but were eliminated based on preliminary costs being impractical relative to the two selected alternatives. The recommended flood mitigation option for Reach 2 is presented in Figure 7.

The calculated design flood event for Sportsmens Bowl Road is 5.7 m^3/s, or 6.2 m^3/s including Twin Lakes discharge. Preliminary order of magnitude cost was estimated for both alignment options and indicated that the costs associated with Alignment B were significantly lower due to the elimination of 9 channel crossings upgrades and the re-alignment of 300m of Sportsmens Bowl Road from the Highway 97 intersection. Considering this cost comparison, Alignment B is recommended, and the cost estimate is provided in Section 6. The following tasks are recommended for Reach 2:

- Purchase the required easement to accommodate the required channel and access road across the properties from 352 Sportsmens Bowl Road to Highway 97. Assuming a 15m wide easement or SROW, this would total ~1.6 hectares of land;
- Channel bank stabilization works to excavate the eroded channel on 352 Sportsmens Bowl Road (SOSA property) to a safe slope. Due to erosion in 2018, the Park Rill Creek channel on the SOSA property has eroded down leaving vertical walls that are a continual risk for sloughing and depositing sediment in the channel. Removal of vegetation, sloping the channel banks based on geotechnical recommendations, and channel armouring or re-vegetation of channel banks is required;
- Construct 150 m of new channel on 352 and 340 Sportsmens Bowl Road to direct Park Rill Creek back to its historic alignment on the north side of the Bowl complete with riprap armouring and access for maintenance. Based on the estimated 1 in 200-year peak flow of 6.2 m3/s and an approximate channel slope of 1.2%, a trapezoidal channel with 2H:1V side slopes, 2 m bottom width, and 1.2 m depth would be suitable;
- Repair the damages to 274 to 340 Sportsmens Bowl Road from the channel avulsion in 2018. The avulsion channel is eroded and unsafe and should be infilled and the property restored to the pre-2018 flood condition. Re-use of excavated material from the new channel alignment may be possible depending on direction from qualified geotechnical personnel;

- Increase the capacity of 900m of channel to accommodate the design flood and armour the channel with riprap to prevent erosion. Add an access road along the channel for maintenance; and
- Replace the existing Highway 97 Park Rill Creek Crossing with either a 6.0m span bridge or a 4200mm x 1500mm concrete box culvert.

The recommended alignment is further discussed in Section 5.2 which would route Park Rill Creek along the northern channel to the location of the two emergency 800mm CSP culverts on Highway 97. The proposed alignment is shown in Figure 7. The new channel should be sized to handle the 1 in 200-year design flow plus freeboard.

To increase the capacity of the existing channel to accommodate the design flow will include major earthworks which may impact stability of adjacent slope. A geotechnical assessment should be carried out to assess the feasibility of this re-alignment and provide recommendations for design and construction.

It is important to note that the entire area where works are proposed in Reach 2 are located within a registered archeological site and a Heritage Conservation Act Permit and Site Alteration Permit would be required prior to any works proceeding. The Osoyoos Indian Band (OIB) Referrals office should be notified prior to any planned works for an early consultation for any proposed works to develop a work plan.

5.4 Reach 3 – Secrest Hill Road to Upper Watershed

Since 2017, the MoTI has been working to upgrade all MoTI crossings in this watershed and as of April 2019, larger culverts have been installed at the following locations for the identified creeks:

- Park Rill Creek: Secrest Hill Road, Goldtau Road, Jones Way, Willowbrook Road, Yellowbrick Road and 4493 Fairview White Lake Road
- Kearns Creek: Myers Road, Carr Crescent West, Carr Crescent East and Johnson Road
- Victoria Creek: Secrest Hill Road

The following upgrades are recommended for Reach 3 and are shown in Figure 8:

- A hydraulic study of the Kearns Creek channel through the community of Willowbrook is recommended to develop detailed recommendations for all water crossings;
- It is recommended that the channel cross-section be upgraded between the Myers Road culvert crossing and the Goldtau Road crossing by deepening the channel to the same depth as the elevation of the outlet of the box culvert (~1 m lower) and re-shaping the channel. A 1 in 100-year event was previously used for the report and design drawings by Ecora for pre-freshet preparation in 2019; however, these should be reviewed and revised for the 1 in 200-year flood event. The report and design drawings are provided in Appendix E;
- A detailed analysis of channel upgrades that should result from the construction of the Twin Lakes gravity overflow is recommended to identify areas where high peak flows may damage the channel or properties adjacent to the creek;
- Significant erosion damage occurred at 4493 Willowbrook Road throughout the 2017 and 2018 freshet due to high stream flows and the additional water from pumping at Twin Lakes. Stabilization and restoration of this property is required which should consist of increasing channel capacity to accommodate the design flow and stabilize the channel banks.

On April 11, 2019 Ecora surveyed the Park Rill Creek channel from Goldtau Road to Myers Canyon to better estimate the Park Rill Creek channel gradient and determine if any upgrades within the BC Parks boundary would improve drainage for Willowbrook. The length of the Park Rill Creek Channel surveyed was 2.8km with an average gradient of 0.46%. Myers flats is an important hydrologic storage and attenuation feature within the Park Rill system. Any change in the channel hydraulics to increase the velocity and conveyance of floodwater would significantly impact the scale of the proposed flood protection works in Reach 1 and Reach 2. It is not recommended to complete any channel improvement works in Myers Flats directly downstream of Goldtau Road.

5.5 Twin Lakes & Horn Creek

Recommendations have been discussed and analysed in the 2019 Twin Lakes Flood Response Feasibility Assessment by Ecora and Dobson. This document should be reviewed and is summarized below.

The most feasible option for a long-term solution for lower Twin Lake is the construction of a 1000mm overflow gravity discharge pipe to Park Rill Creek. The peak outflow from the diversion pipe is ~1.6m^3/s. During the 1 in 200-year flood event, flows would be routed through the diversion pipe for approximately61 days with an average flow rate of 0.45m^3/s. The Lower Twin Lake discharge to Park Rill Creek is expected to have an impact downstream of the discharge location, primarily in the Park Rill Creek headwaters where the overall proportional increase to discharge is significant and there is insufficient channel capacity. As suggested in Reach 3 recommendations above, a detailed analysis of channel will be required to identify areas where peak flows may damage the channel and adjacent private property.

6. Cost Estimates

The following cost estimates are provided based on the upgrading recommended in Section 5.0 for the key identified portions of channel and crossings to handle the 1 in 200-year peak flow in the Park Rill Creek watershed. A summary of costs for all areas assessed is included in Table 6.1 below:

Table 6.1 Summary of Park Rill Creek Watershed Costs for Recommended Solution

No.	Description of Required Works	Cost ($)
1.1	Reach 1 Upgrades	$7,980,000
1.2	Reach 2 Upgrades	$1,650,000
1.3	Reach 3 Upgrades	$115,000
1.4	Twin Lakes Upgrades	$1,338,000
	Total	**$11,083,000**

6.1 Reach 1 – Okanagan River to Highway 97

The cost estimate for Reach 1 summarized below includes the estimated cost for a permanent electric pumping station capable of handling a 1 in 200-year flood event for the purpose of understanding the cost magnitude of permeant infrastructure costs. Recent dike pump station upgrades cost estimates in the Fraser Valley with a similar peak flow capacity were used in the development of the pump station costs. It should be noted that the construction of a pump station capable of passing a 1 in 200-year event is not a recommended practice due the low probability the infrastructure will see the designed flow within its operation lifespan. Due to high costs, pump stations are typically designed to a maximum of a 1 in 50-year event. Considering that the 1 in 200-year peak flow is an order of magnitude above what has been recorded historically in Park Rill Creek and the likely infrequent use this infrastructure would get if installed, it is recommended that an additional study be undertaken to arrive at a flood management solution that is economically feasible for the service area. The detailed analysis required to develop further hydrotechnical recommendation was beyond the scope of this study.

It is recommended that temporary emergency pumping be utilized on an as-and-when required basis until a more detailed analysis can be completed for hydraulic improvements in Reach 1.

Table 6.2 Reach 1 Class D Cost Estimate

No.	Description of Required Works	Cost ($)
1.1	Construct a 3-phase electric pump station at the outlet of Park Rill	$5,000,000
1.2	Upgrade Park Rill Road crossing to 4200 x 1500mm box culvert1	$450,000
1.3	Local channel improvements	$100,000
1.4	Purchase 7841 Highway 97 and remove all existing buildings	$800,000
1.5	Construct channel improvements and sediment basin at 7841 Highway 97	$150,000
1.6	Environmental and Archaeological assessments and monitoring	$150,000
1.7	Engineering and Contingency 20%	$1,330,000
	Total	**$7,980,000**

Notes:

(1) Infrastructure on MoTI ROW is included in the budget but funding, design and construction would be under the direction of MoTI.

(2) Annual operation and maintenance costs will depend on the design of the pump station and should be determined during detailed design. Not enough information is available at this time to estimate these costs.

6.2 Reach 2 – Highway 97 to Secrest Hill Road

Table 6.3 Reach 2 Class D Cost Estimate

No.	Description of Required Works	Cost ($)
1.1	Channel stabilization on SOSA property and removal of debris	$50,000
1.2	Construct 150m of new channel to route flows to north channel c/w riprap armouring and access	$100,000
1.3	Restore properties along the current avulsion channel to Sportsmens Bowl Rd.	$100,000
	Construct bridge or install larger culvert to access 340 & 352 Sportsmens Bowl Road	$60,000
1.4	Increase capacity on 900m of the north channel to Hwy. 97 c/w riprap armouring and maintenance access	$315,000
	Purchase ~1.5 hectares for 15m wide stream corridor @175,000/ha + legal costs	$300,000
1.5	Upgrade Highway 97 crossing to 4200mm x 1500mm box culvert	$550,000
1.6	Environmental Management Plan and monitoring and Archeological assessments and monitoring	$100,000
1.7	Engineering and contingency 20%	$225,000
	Total	**$1,800,000**
2.0	Annual operation and maintenance costs	$2,500

Note:

(1) Infrastructure on MoTI ROW is included in the budget but funding, design and construction would be under the direction of **MoTI**

6.3 Reach 3 – Secrest Hill Road to Upper Park Rill Creek Watershed

Table 6.4 Reach 3 Class D Cost Estimate

No.	Description of Required Works	Cost ($)
1.1	Complete a detailed hydrotechnical study of Kearns Creek drainage in Willowbrook	$50,000
1.2	Regrade Kearns Creek from Myers Road to Goldtau Road including permitting	$20,000
1.3	Identify impacts on Park Rill Creek channel from Lower Twin Lake pumping and recommend remedial works	$45,000
	Total	**$115,000**

6.4 Twin Lakes & Horn Creek

The details for the Twin Lakes and Horn Creek cost estimate and the methodology used to develop the identified costs are provided in the Twin Lakes Flood Response Feasibility Assessment report (Ecora/Dobson 2019).

Table 6.5 Class D Cost Estimate using Trenchless Methods Only

No.	Description of Required Works	Cost ($)
1.1	Mobilization and Demobilization	$5,000
1.2	Clear & Grubbing	$10,000
1.3	Trenching & Backfilling	$550,000
1.4	1000 mm Dia. Fused HDPE Supply & Installation	$250,000
1.5	Inlet screen and slide gate	$50,000
1.6	Environmental protection & dewatering	$20,000
1.7	Site Restoration	$50,000
	2-1000mm culvert upgrades and channel improvements(1)	$100,000
1.8	Archaeological and Environmental Reporting, & Monitoring	$50,000
1.9	Engineering Cost and Contingency (20%)	$223,000
	Total	**$1,308,000**
2.0	Annual operation and maintenance costs	$2,500

Note:

(1) Channel improvements are based on excavating a suitable channel to safely convey the design flow and revegetating. No armoring was assumed, and appropriate measures will be developed during detailed design.

Prior to selecting this option, a study to determine what the appropriate measures are for downstream impact mitigation and the operation of the slide gate during a 1 in 200-year event will need to be addressed.

7. Recommendations

All future development within the Park Rill Creek watershed should be required to complete a flood hazard assessment in accordance with Engineer and Geoscientists British Columbia's Legislated Flood Assessments in a Changing Climate in BC and local government legislation and bylaws.

As suggested in the recommended options in Section 5 above, the following supplemental studies or work are recommended:

- A flood hazard assessment, including a hydraulic capacity assessment, of Reach 1 should be completed to establish potential flood mitigation options that can be applied to protect existing private properties within the Okanagan River floodplain. Environmental constraints within this Reach are expected to impact the feasibility of mitigation alternatives and qualified environmental professionals should be consulted as part of this assessment.
- A geotechnical assessment of the north channel in Reach 2 and adjacent slopes should be completed by qualified geotechnical personnel. Due the presence of a large slope adjacent to the recommended Park Rill Creek alignment, the impact of these earthworks and surface water presence on overall slope stability should be assessed. Geotechnical input for design and construction of the works should also be provided.
- As Reach 2 is located on a registered archeological site, a Heritage Conservation Act Permit and Site Alteration Permit would be required prior to any works proceeding. The Osoyoos Indian Band (OIB) Referrals office should be notified prior to any planned works for an early consultation for any proposed works to develop a work plan.
- A flood hazard assessment, including a hydraulic capacity assessment of Kearns Creek at Willowbrook should be carried out to provide flood mitigation options, that may consist of channel upgrades or potential channel berms.
- A detailed analysis of the Park Rill Creek channel from the point of diversion from Lower Twin Lake into Park Rill Creek to Willowbrook should be carried out to assess the impacts of diverting water from Lower Twin Lake into Park Rill Creek during periods of high water levels in Lower Twin Lake, specifically in locations where the creek channel or adjacent property is susceptible to damage.

Sources of funding for the proposed options should be discussed with all parties involved, which should include affected residents and property owners, RDOS, MoTI, MFLNRORD and EMBC. Maintenance and repair responsibilities for the proposed works should also be established to ensure the long-term success of the project.

References

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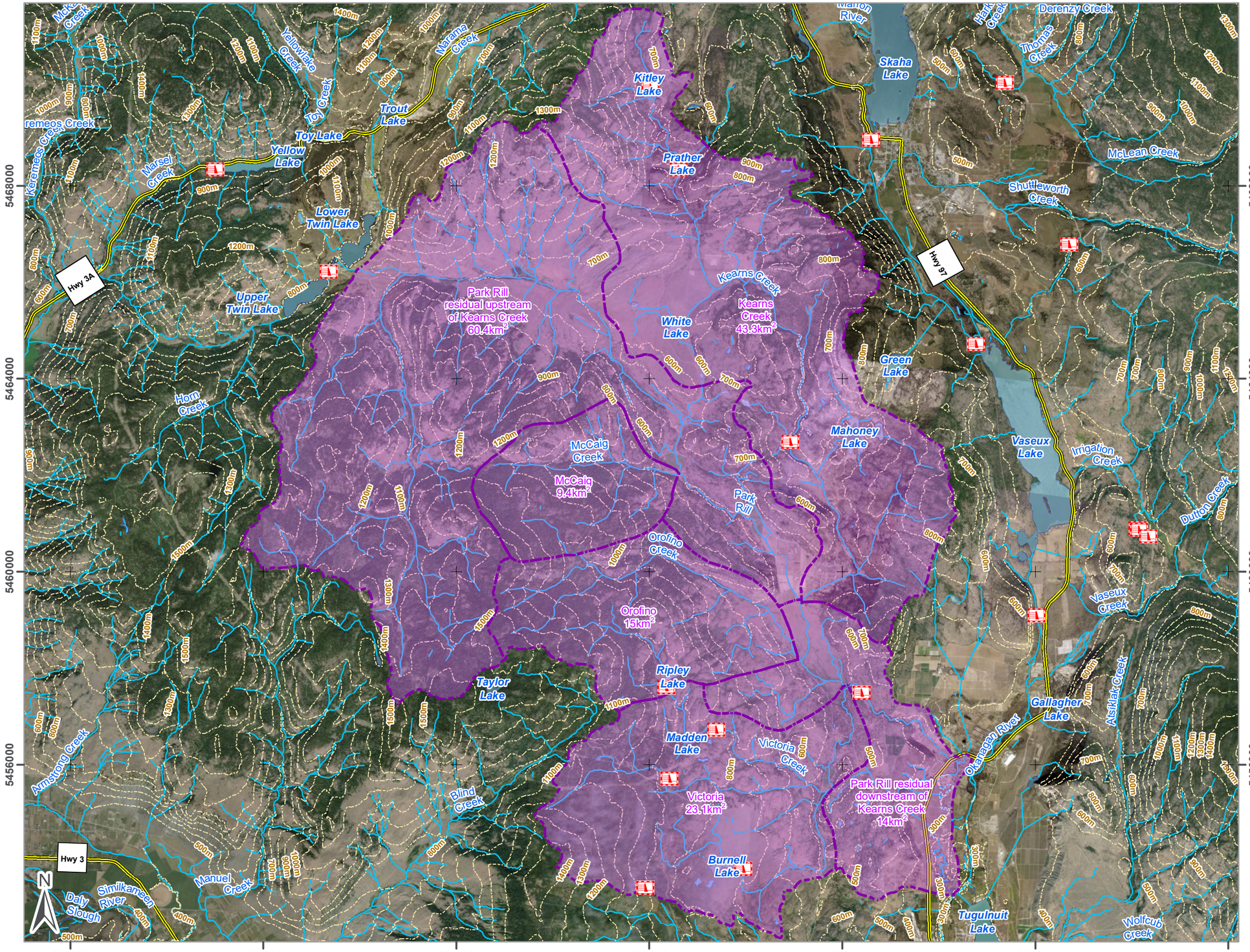
Figures

PARK RILL WATERSHED OVERVIEW

ecora™

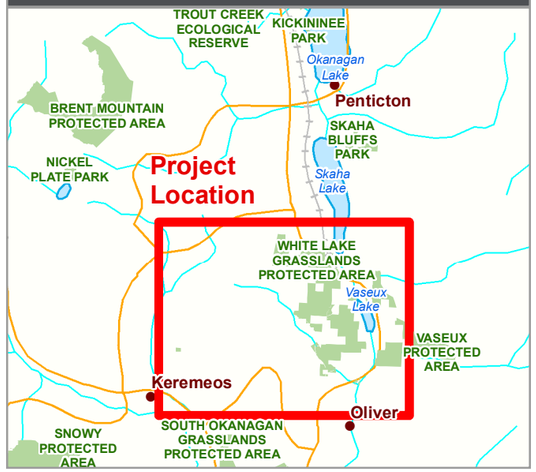


PARK RILL FLOOD RESPONSE FEASIBILITY STUDY OLIVER, BC

Legend

- Dam Locations
- 100m TRIM Contour Lines
- Fresh Water Atlas Streams
- Highways
- Park Rill Sub-Watershed Catchments

LOCATION MAP



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Project No.: CP-18-568-RDO
Client: Regional District of Okanagan-Similkameen
NAD 1983 UTM Zone 11N

Date: 2019/04/29
Drawn: MT Check: CP

Figure 1.0

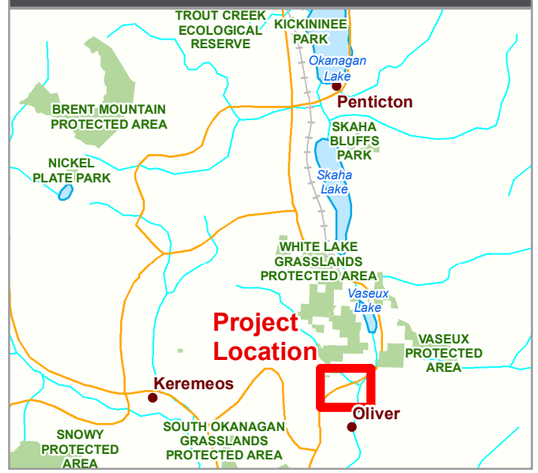
HYDRAULIC STRUCTURES IN REACH 1 AND REACH 2

PARK RILL FLOOD RESPONSE FEASIBILITY STUDY OLIVER, BC

Legend

- Hydraulic Structures
- 20m TRIM Contour Lines
- Fresh Water Atlas Streams
- Digital Atlas Roads
- Highways
- Current Alignment of Park Rill Creek

LOCATION MAP



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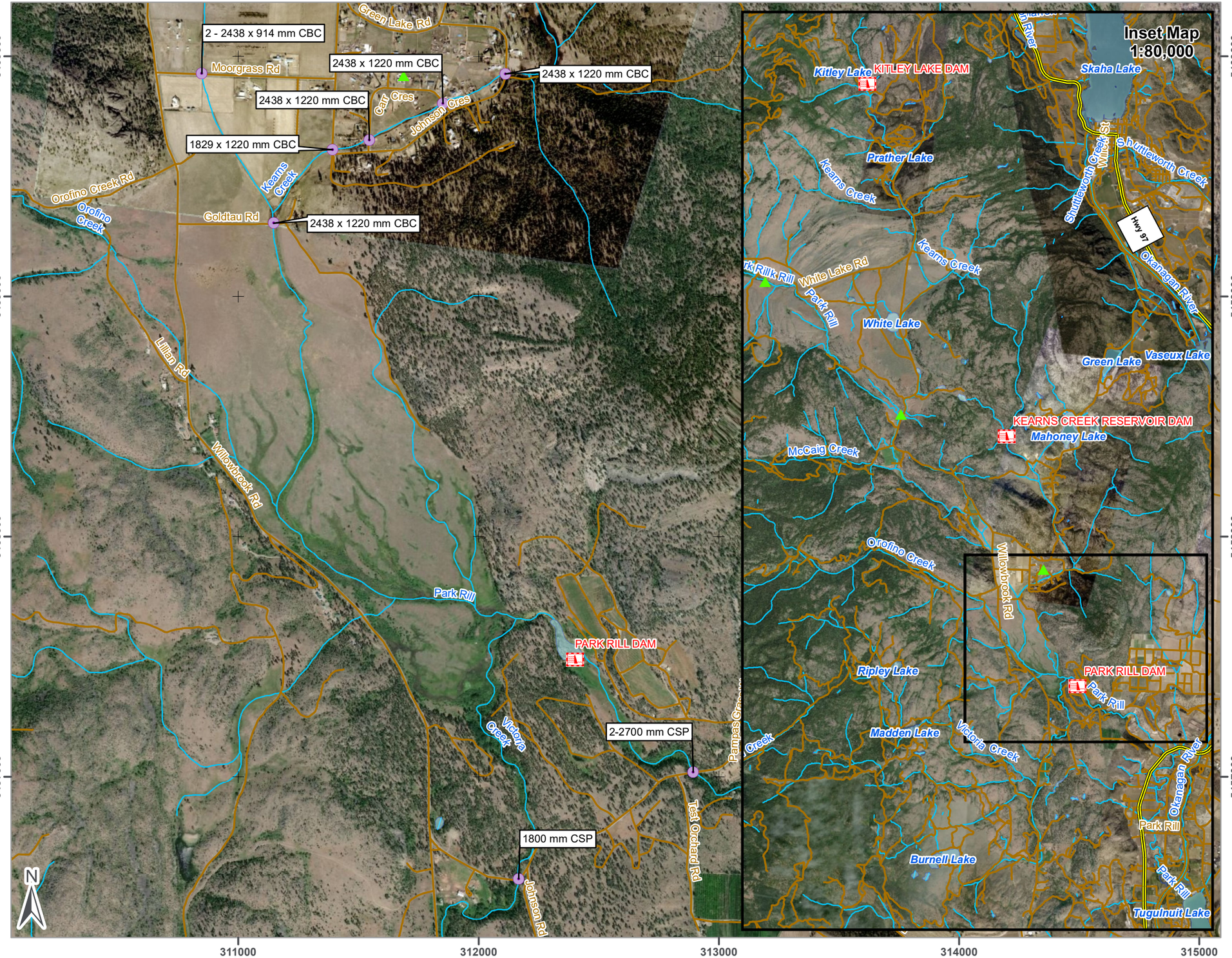
Project No.: CP-18-568-RDO
Client: Regional District of Okanagan-Similkameen
NAD 1983 UTM Zone 11N

Date: 2019/04/29
Drawn: MT Check: CP

Figure 2.0

HYDRAULIC STRUCTURES IN REACH 3

ecora™

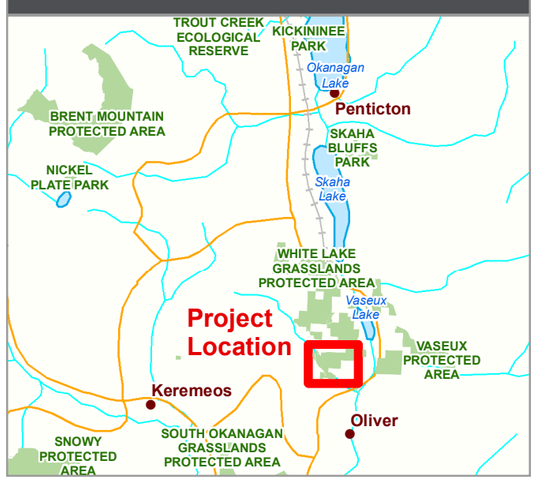


PARK RILL FLOOD RESPONSE FEASIBILITY STUDY OLIVER, BC

Legend

- Air Photo Area of Interest (See Appendix B)
- Hydraulic Structures
- Dam Locations
- Fresh Water Atlas Streams
- Digital Atlas Roads
- Highways

LOCATION MAP



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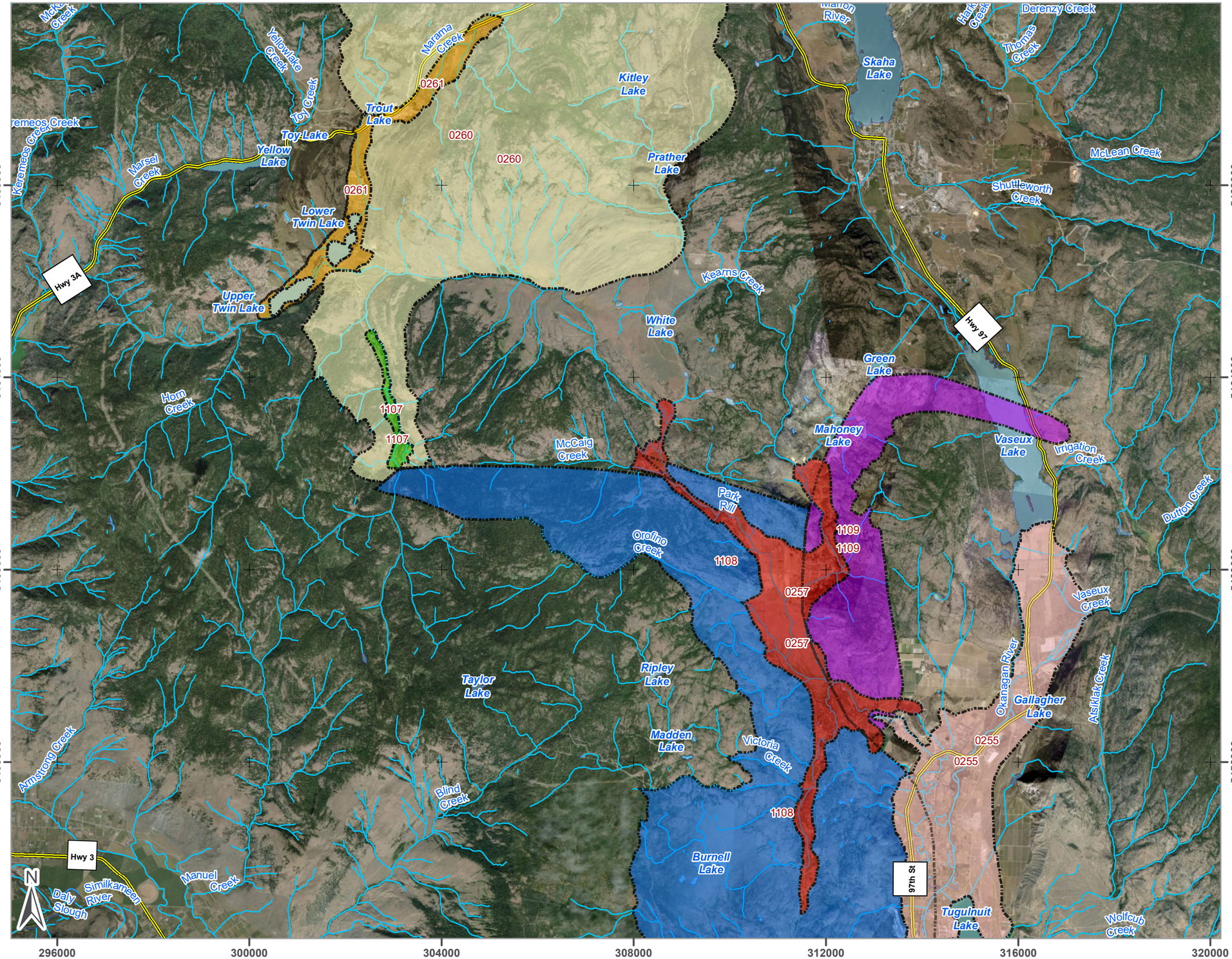
Project No.: CP-18-568-RDO
Client: Regional District of Okanagan-Similkameen
NAD 1983 UTM Zone 11N

Date: 2019/04/29
Drawn: MT Check: CP

Figure 3.0

GROUNDWATER AQUIFERS

ecora™



PARK RILL FLOOD RESPONSE FEASIBILITY STUDY OLIVER, BC

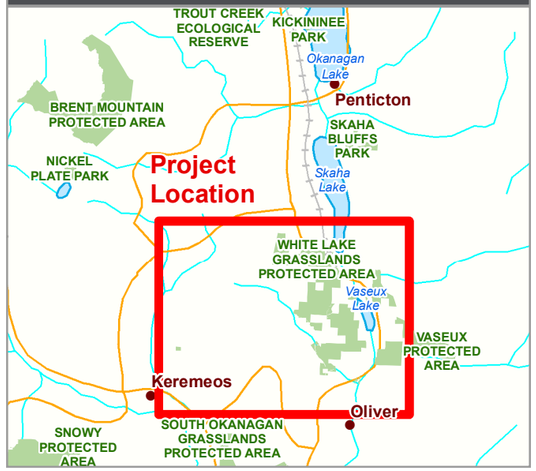
Legend

- Fresh Water Atlas Streams
- Highways

AQUIFER NUMBER

- 0255
- 0257
- 0260
- 0261
- 1107
- 1108
- 1109

LOCATION MAP



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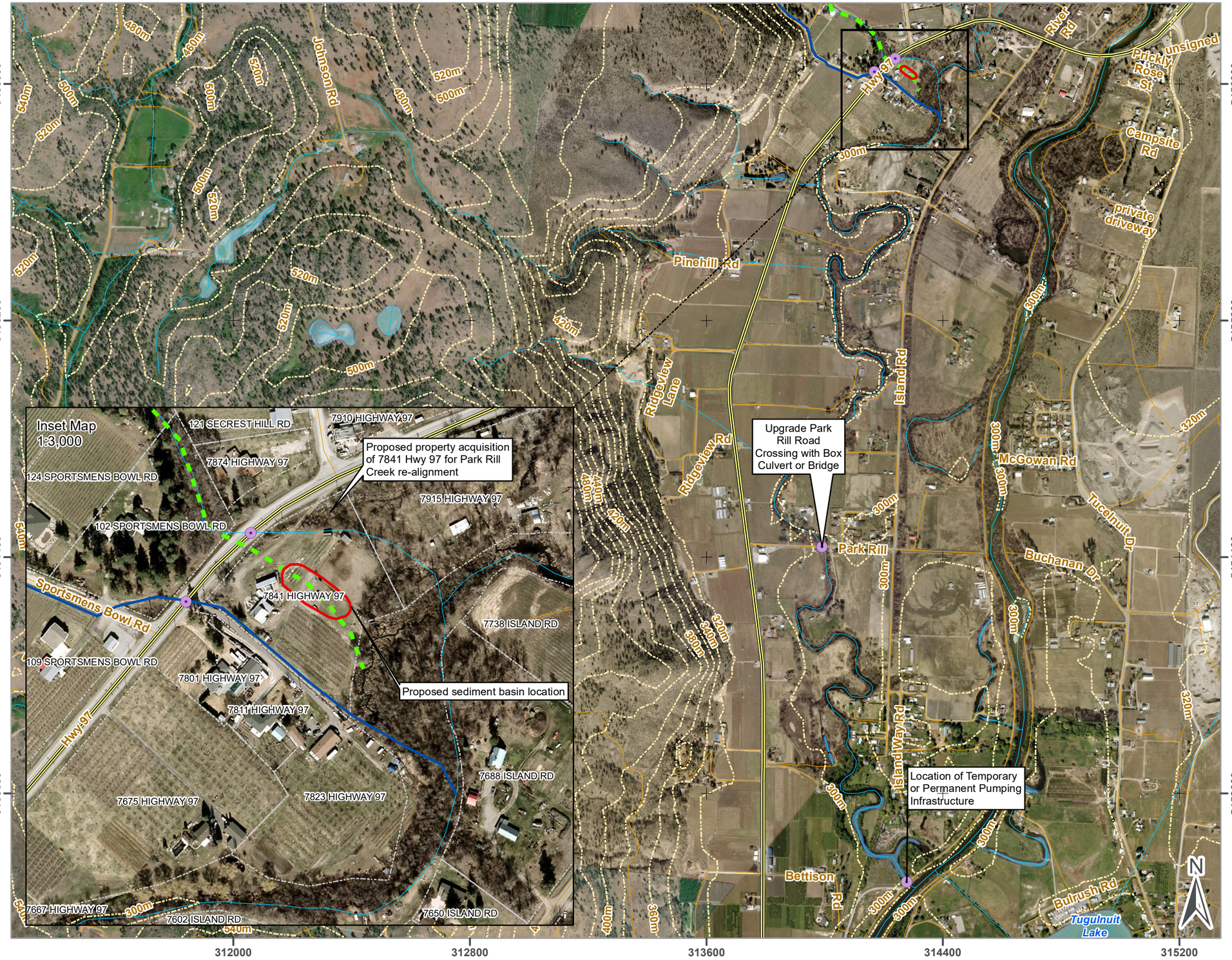
Project No.: CP-18-568-RDO
Client: Regional District of Okanagan-Similkameen
NAD 1983 UTM Zone 11N

Date: 2019/04/29
Drawn: MT Check: CP

Figure 4.0

REACH 1 RECOMMENDED UPGRADES

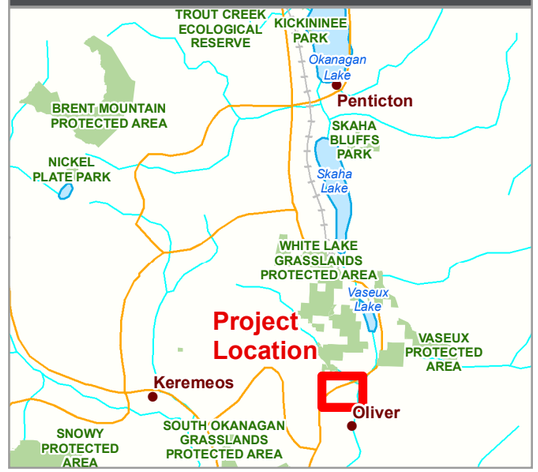


PARK RILL FLOOD RESPONSE FEASIBILITY STUDY OLIVER, BC REACH 1

Legend

- Hydraulic Structures
- Current Alignment of Park Rill Creek
- Proposed Re-alignment of Park Rill Creek
- Digital Road Atlas
- Highways
- Fresh Water Atlas Streams
- 20m TRIM Contours
- Proposed Sediment Basin Location
- RDOS Legal Parcels

LOCATION MAP



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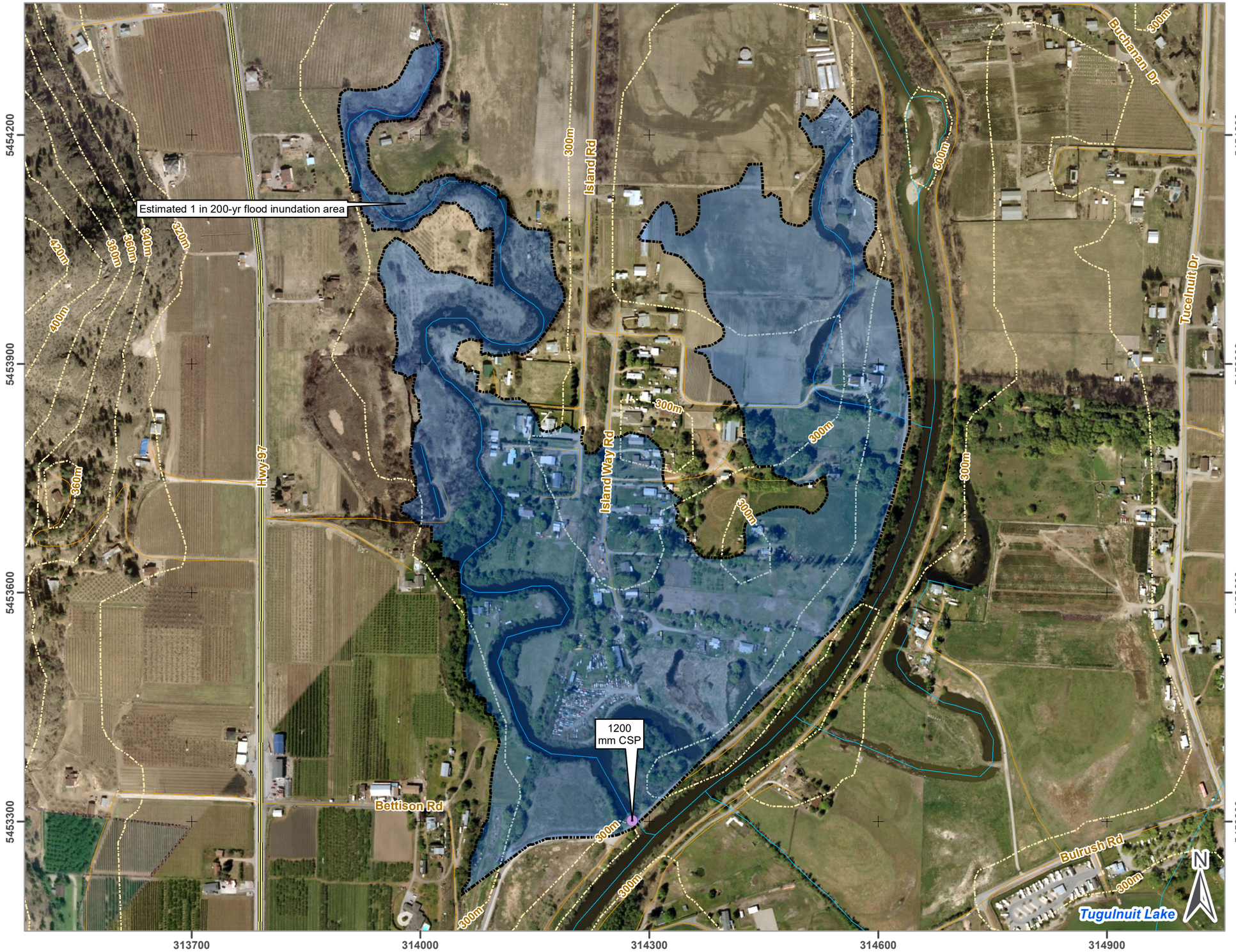
Project No.: CP-18-568-RDO
Client: Regional District of Okanagan-Similkameen
NAD 1983 UTM Zone 11N

Date: 2019/05/01
Drawn: MT Check: CP

Figure 5.0

REACH 1 INUNDATION AREA FOR EXISTING PARK RILL CREEK OUTLET

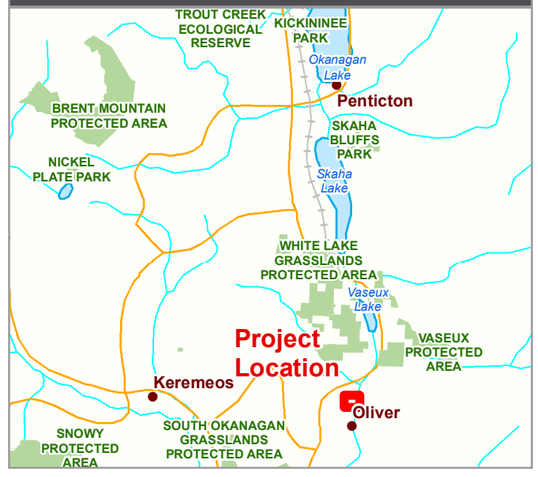


PARK RILL FLOOD RESPONSE FEASIBILITY STUDY OLIVER, BC REACH 2

Legend

- Hydraulic Structures
- Digital Road Atlas
- Highways
- Fresh Water Atlas Streams
- 20m TRIM Contours
- 1 in 200-yr Flood Inundation Area (0.36km^2)

LOCATION MAP



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Project No.: CP-18-568-RDO
Client: Regional District of Okanagan-Similkameen
NAD 1983 UTM Zone 11N

Date: 2019/05/01
Drawn: MT Check: CP

Figure 6.0

REACH 2 RECOMMENDED UPGRADES

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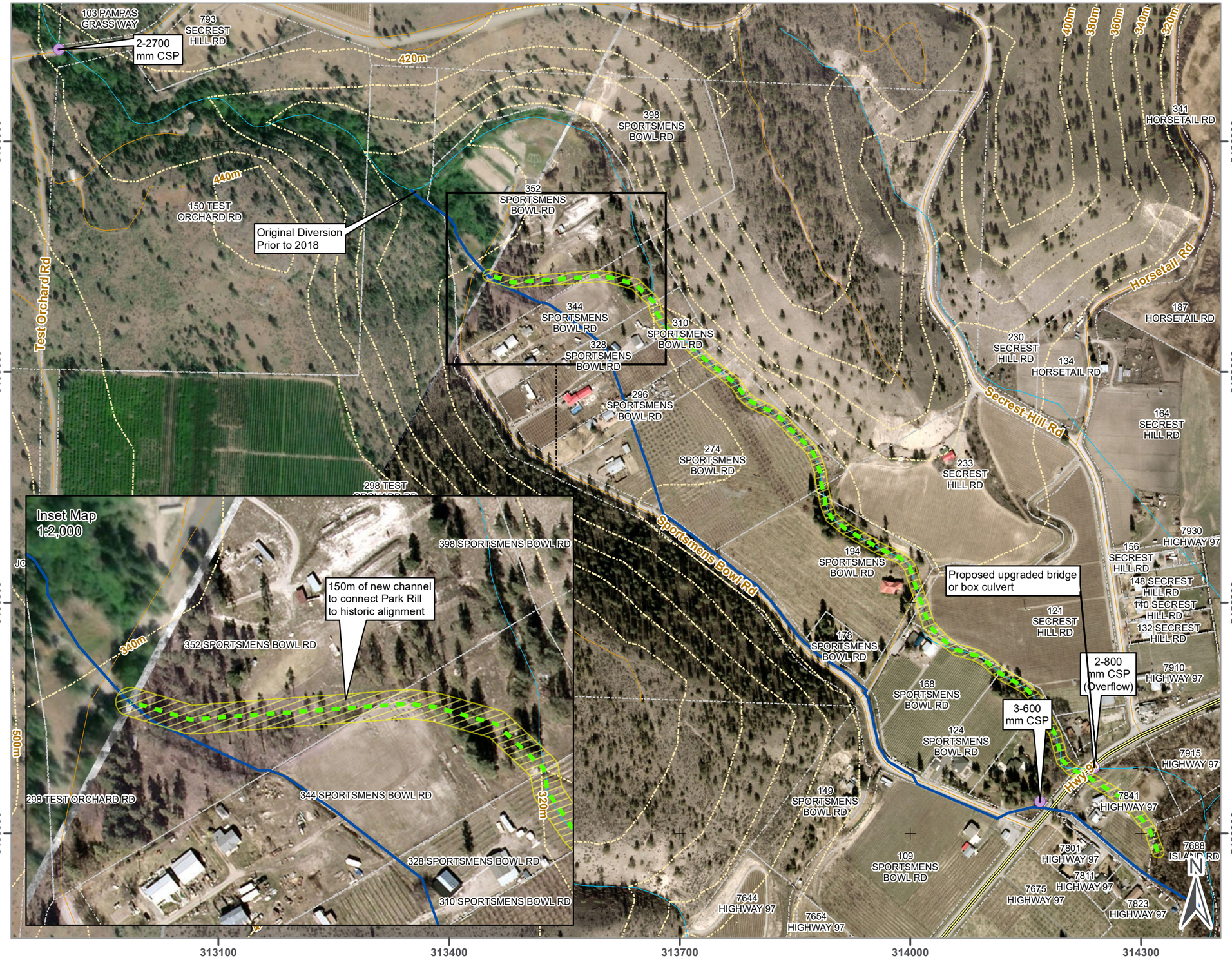


PARK RILL FLOOD RESPONSE FEASIBILITY STUDY OLIVER, BC REACH 2

Legend

- Hydraulic Structures
- Current Alignment of Park Rill Creek
- Proposed Re-alignment of Park Rill Creek
- Digital Road Atlas
- Highways
- Fresh Water Atlas Streams
- 20m TRIM Contours
- 15m Wide Creek Right-of-Way
- RDOS Legal Parcels

LOCATION MAP

1:5,000

0 150 300 Meters

Project No.: CP-18-568-RDO

Client: Regional District of Okanagan-Similkameen

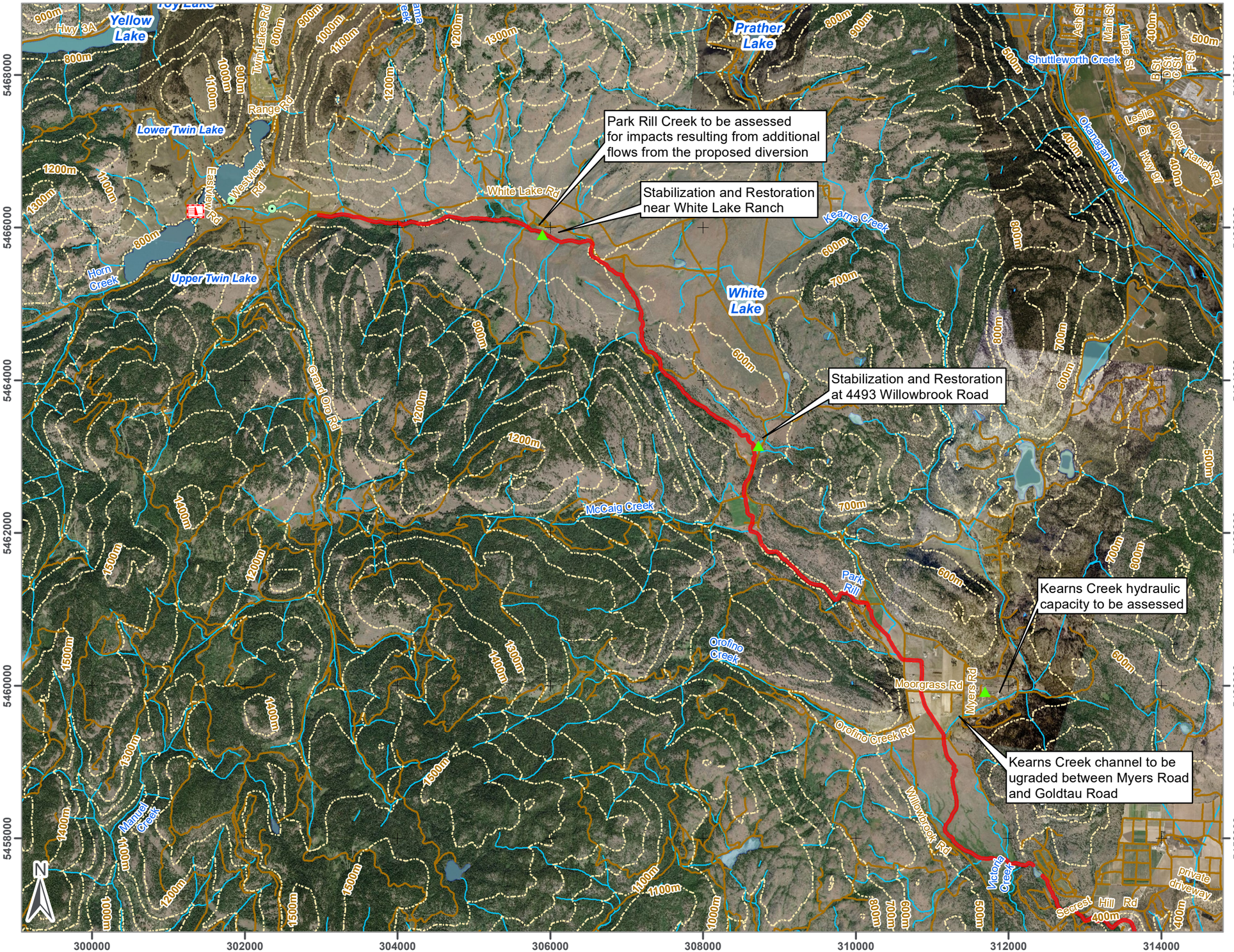
NAD 1983 UTM Zone 11N

Date: 2019/04/29

Drawn: MT Check: CP

Figure 7.0

REACH 3 RECOMMENDED UPGRADES

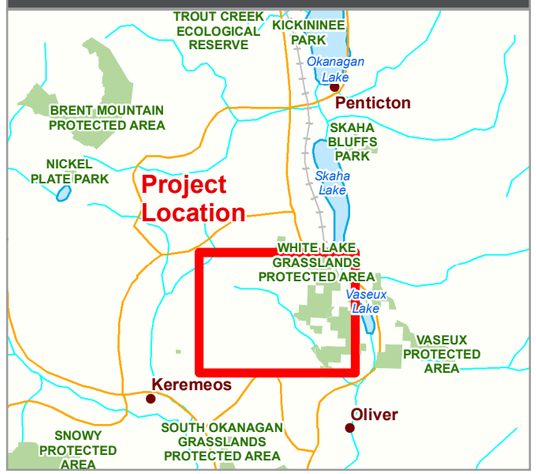


PARK RILL FLOOD RESPONSE FEASIBILITY STUDY OLIVER, BC REACH 3

Legend

- Area of Interest
- Upper Twin Lake Dam
- LNID Electric Pump Inlet and Outlet
- 100m TRIM Contour Lines
- Fresh Water Atlas Streams
- Digital Atlas Roads
- Channel Impact Assessment Study Area

LOCATION MAP



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0 1 2 KM

Project No.: CP-18-568-RDO
Client: Regional District of Okanagan-Similkameen
NAD 1983 UTM Zone 11N

Date: 2019/04/30
Drawn: MT Check: CP

Figure 8.0

Appendix A

1992 Floodplain Mapping

SEE SHEET 8

SEE SHEET 6

L 2710

Gallagher Lake

Vaseux Creek

L 2855

L 2845

VASEUX CREEK ALLUVIAL FAN
The fan area may be subject to special flood hazard related to channel avulsion and erosion caused by channel accretion and/or debris jamming. Floodplain limits not determined.

I R 1
"OSOYOOS"

NOTE :
The floodplain limits as shown are within the accuracy of the base mapping. Site specific ground elevations should be confirmed by field survey.

LIMIT OF STUDY

L 2475S

L 916S

L 1043S

L 117S

L 1761

L 2450S

McALPINE BRIDGE

CANADA NATIONAL RAILWAY

OKANAGAN RIVER

ISLAND ROAD

SECRET COVE

Standard Dykes

FLOOD LEVEL ISOGRAMS
within standard dyked areas are dashed as indicated.

Use and Limitations of Floodplain Maps

- Users must note the dates of base mapping, aerial photography, river surveys and issue of mapping relevant to dates of development in the map area. Subsequent developments or changes within the floodplain or channel (natural or constructed) will affect flood levels and render site-specific map information obsolete.
- Floodplain maps are administrative tools which depict minimum flood elevations and floodplain boundaries. Flooding may occur outside of the designated floodplain boundary.
- Floodplain maps do not provide information on site-specific flood hazards such as, land erosion or high water velocity, sudden shifts in the channel of the watercourse, or alluvial and debris flow fan areas.
- Other sources of water, roads, railways or other barriers can restrict water flow and affect local flood levels. As well, obstructions such as ice and debris, flooding in surrounding areas, channel deposition, groundwater or other phenomena can cause flood levels to exceed those indicated on the map. Land adjacent to a floodplain may be subject to flooding from tributary watercourses.
- Floodplain maps do not indicate or locate legal survey boundaries. A site survey is required to reconcile property location, ground elevations, and designated flood level information.
- The accuracy of the location of a floodplain boundary as shown on this map is limited by the base topography. It is generally assumed to be plus or minus one-half the increment of the ground contours.
- Professional assistance and detailed engineering analysis are required to address any of the above considerations.

NOTES

Produced by: British Columbia Water Management Branch, Special Projects Section, Floodplain Mapping Program.

Survey: River survey done by Surveys, Mapping and Remote Sensing Branch, MSR&T 79-COMP-2, 1978 and 1980.
a) Horizontal control based on provincial control.
b) Elevations are in metres and are referred to Geodetic Survey of Canada datum, (◉ Indirates Survey Monument)

Cadastral: Reference Map Series 1 : 20 000, Surveyor General Branch, 1992.

Mapping: Base mapping done by Map Production Division, Surveys and Resource Mapping Branch, Project 79-1261-D, NAD 27. Air photography date: June 1979.
a) Contour intervals 5 metres and greater; spot elevations shown to 0.1 metres, with accuracy to ± 0.3 metres, except where noted.
b) Grid ordinates referred to U.T.M. Projection Zone 10 .

FLOODPLAIN DATA

1. The floodplain areas as depicted on this map have been interim designated pursuant to the Canada/British Columbia Floodplain Mapping Agreement (1988) by the Ministers of the Environment for Canada and the Minister of Environment, Lands and Parks for British Columbia.
   Flooding may still occur outside of the interim designated floodplain areas. The Ministers do not assume any liability by reason of the interim designation or failure to interim designate areas on this map.
2. The designated flood has a statistical frequency of occurrence of once every 200 years.
3. The flood levels were computed using a standard step method modelling technique, assuming open water flow conditions.
4. The floodplain limits assume the absence of all dykes.
5. The floodplain limits and flood levels include an allowance for freeboard.
6. The floodplain limits are not established on the ground by legal survey.
7. The floodplain limits are not delineated for side streams and tributaries.
8. The required setback of buildings from the natural boundaries of lakes and watercourses to allow for the passage of floodwaters and possible bank erosion is not shown. This information is available either through local municipalities or the Ministry of Environment, Lands and Parks.
9. MAPS AVAILABLE FROM MAPS B.C., MAP AND AIR PHOTO SALES, VICTORIA, B.C.
10. For detailed description of Water Resources Service reference monuments, see drawing A-8221-INDEX and drawing A-8221-1 to -16.

LEGEND

DESIGNATED FLOODPLAIN LIMITS

FLOOD LEVEL

200 Year Frequency

(METRES G.S.C. DATUM)

KEY MAP

SCALE 1:600 000

REVISIONS

No.	DESCRIPTION	DATE

ISSUE OF MAPPING DATE

DRAWN T. C. E.

CHECKED

RIVER SURVEY B. R. S.

DESIGNED B. R.

ENGINEER

RECOMMENDED

APPROVED

ENVIRONMENT CANADA INLAND WATERS
ENVIRONNEMENT CANADA EAUX INTÉRIEURES

BRITISH COLUMBIA MINISTRY OF ENVIRONMENT
COLOMBIE-BRITANNIQUE MINISTÈRE DE L'ENVIRONNEMENT

CANADA BRITISH COLUMBIA FLOODPLAIN MAPPING AGREEMENT
ACCORD CANADA COLOMBIE-BRITANNIQUE SUR LA CARTOGRAPHIE DES PLAINES D'INONDATION

FLOODPLAIN MAPPING
OKANAGAN RIVER
OSOYOOS TO PENTICTON

100m 0 100 200 300 400 600m
Scale in metres

FILE No. 310-0000

N.T.S. MAP No. 82E

SCALE 1 : 5 000

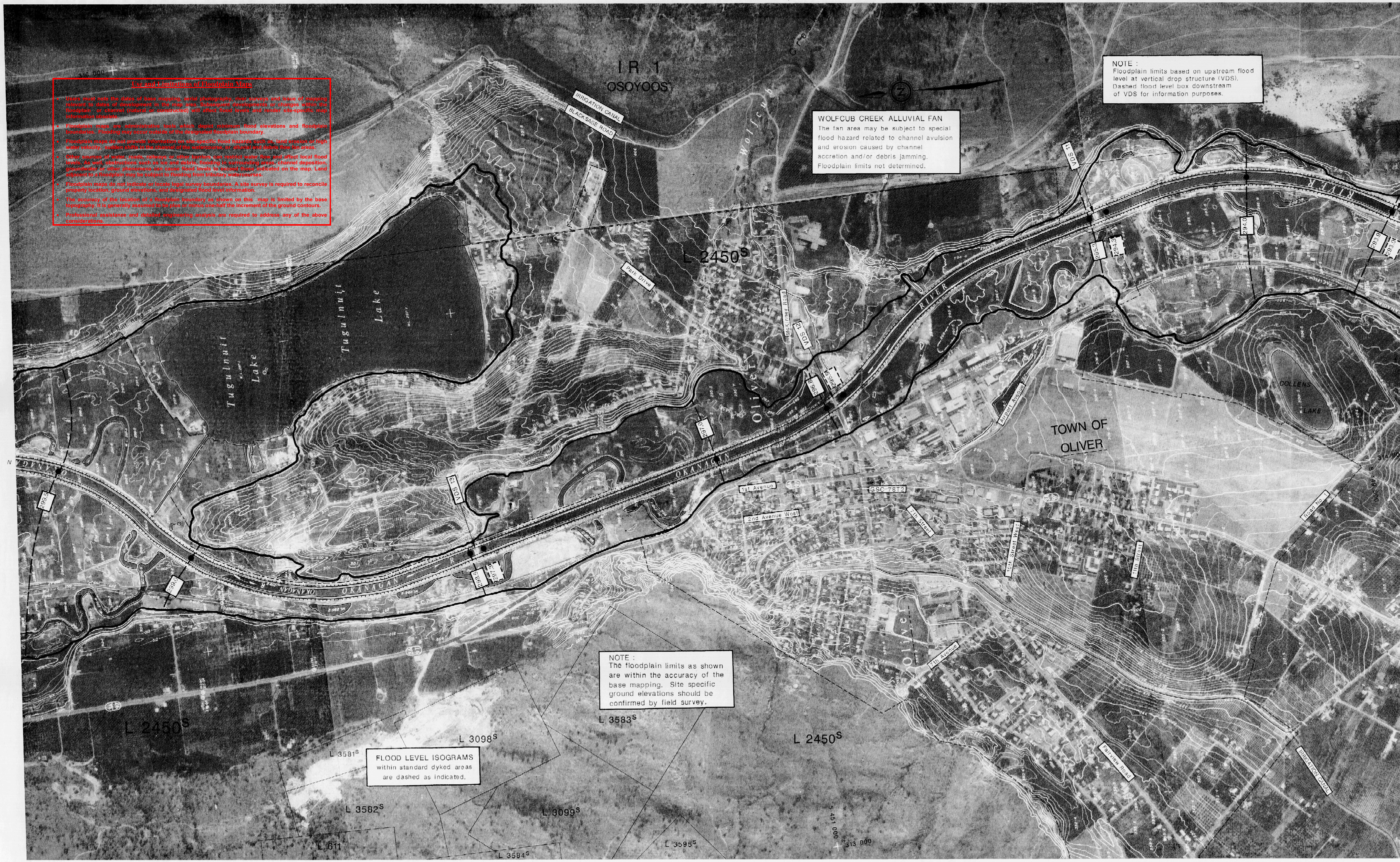
NEGATIVE No.

DRAWING No. 89-12-7

REV.

SHEET 7 of 15

DDI mm



Use and Limitations of Floodplain Maps
• Users must note the dates of base mapping, aerial photography, river surveys and issue of mapping relevant to dates of development in the map area. Subsequent developments or changes within the floodplain or channel (natural or constructed) will affect flood levels and render site-specific map information obsolete.
• Floodplain maps are administrative tools which depict minimum flood elevations and floodplain boundaries. Flooding may occur outside of the designated floodplain boundary.
• Floodplain maps do not provide information on site-specific flood hazards such as, land erosion or high water velocity, sudden shifts in the channel of the watercourse, or alluvial and debris flow fan areas.
• Other sources of water, roads, railways or other barriers can restrict water flow and affect local flood levels. As well, obstructions such as ice and debris, flooding in surrounding areas, channel deposition, groundwater or other phenomena can cause flood levels to exceed those indicated on the map. Land adjacent to a floodplain may be subject to flooding from tributary watercourses.
• Floodplain maps do not indicate or locate legal survey boundaries. A site survey is required to reconcile property location, ground elevations, and designated flood level information.
• The accuracy of the location of a floodplain boundary as shown on this map is limited by the base topography. It is generally assumed to be plus or minus one-half the increment of the ground contours.
• Professional assistance and detailed engineering analysis are required to address any of the above considerations.
I R 1
OSOYOOS
IRRIGATION CANAL
BLACKSAGE ROAD
WOLFCUB CREEK ALLUVIAL FAN
The fan area may be subject to special flood hazard related to channel avulsion and erosion caused by channel accretion and/or debris jamming. Floodplain limits not determined.
NOTE :
Floodplain limits based on upstream flood level at vertical drop structure (VDS). Dashed flood level box downstream of VDS for information purposes.
L 2450S
Tugulnuit Lake
Park Drive
McKinney Road
VDS 11
VDS 12
VDS 13
VDS 9
OKANAGAN RIVER
TOWN OF OLIVER
COLLENS LAKE
Airport Avenue
1st Avenue
2nd Avenue West
Standard Dykes
SEE SHEET 5
SEE SHEET 7
NOTE :
The floodplain limits as shown are within the accuracy of the base mapping. Site specific ground elevations should be confirmed by field survey.
FLOOD LEVEL ISOGRAMS
within standard dyked areas are dashed as indicated.
L 3583S
L 3098S
L 3581S
L 3582S
L 3099S
L 3595S
L 3584S
L 611
Fairview Road
IRRIGATION CANAL

NOTES

Produced by: British Columbia Water Management Branch, Special Projects Section, Floodplain Mapping Program.

Survey: River survey done by Surveys Section, Water Management Branch, Project 79-OBIP-2, 1979 and 1980.
a) Horizontal control based on provincial network.
b) Elevations are in metres and are referred to Geodetic Survey of Canada datum. (◉ indicates Survey Monument.)

Cadastral: Reference Map Series 1 : 20 000, Surveyor General Branch, 1992.

Mapping: Base mapping done by Map Production Division, Surveys and Resource Mapping Branch, Project 79-1261-0, NAD 27.
Airphotography date: June 1975
a) Contour interval 1 metre and greater; spot elevatons shown to 0.1 metres, with accuracy to ± 0.3 metres, except where noted.
b) Grid origin referred to U.T.M. Projection Zone 10 .

FLOODPLAIN DATA

1. The floodplain areas as depicted on this map have been interim designated pursuant to the Canada/British Columbia Floodplain Mapping Agreement (1988) by the Minister of the Environment for Canada and the Minister of Environment, Lands and Parks for British Columbia.

   Flooding may still occur outside of the interim designated floodplain areas. The Ministers do not assume any liability by reason of the interim designation or failure to interim designate areas on this map.
2. The Designated Flood has a statistical frequency of occurrence of once every 200 years.
3. The flood levels were computed using a standard step method modelling technique, assuming open water flow conditions.
4. The floodplain limits assume the absence of all dykes.
5. The floodplain limits and flood levels include an allowance for freeboard.
6. The floodplain limits are not established on the ground by legal survey.
7. The floodplain limits are not delineated for side streams and tributaries.
8. The required setback of buildings from the natural boundaries of lakes and watercourses to allow for the passage of floodwaters and possible bank erosion is not shown. This information is available either through local municipalities or the Ministry of Environment, Lands and Parks.
9. MAPS AVAILABLE FROM MAPS B.C., MAP AND AIR PHOTO SALES, VICTORIA, B.C.
10. For detailed description of Water Resources Service reference monuments, see drawing A-5221-INDEX and drawing A-5221-1 to -19

LEGEND

DESIGNATED FLOODPLAIN LIMIT

RIVER

FLOOD LEVEL
200 Year Frequency

Standard Dykes

Vertical Drop Structure
VDS 5

(METRES G.S.C. DATUM)

KEY MAP

SCALE 1 : 500 000

REVISIONS

No.	DESCRIPTION	DATE

ISSUE OF MAPPING
DATE

ENVIRONMENT CANADA INLAND WATERS / ENVIRONNEMENT CANADA EAUX INTÉRIEURES

BRITISH COLUMBIA MINISTRY OF ENVIRONMENT / COLOMBIE-BRITANNIQUE MINISTÈRE DE L'ENVIRONNEMENT

CANADA BRITISH COLUMBIA FLOODPLAIN MAPPING AGREEMENT / L'ACCORD CANADA COLOMBIE-BRITANNIQUE SUR LA CARTOGRAPHIE DES PLAINES D'INONDATION

DRAWN T. C. E.
CHECKED
RIVER SURVEY B. R. S.
DESIGNED B. B.

FLOODPLAIN MAPPING
OKANAGAN RIVER
OSOYOOS TO PENTICTON

100m 0 100 200 300 400 500m
Scale in metres

ENGINEER [signature] RECOMMENDED [signature] APPROVED [signature]

FILE No. 310-0000
N.T.S.MAP No. 82E
SCALE 1 : 5 000
NEGATIVE No.
DRAWING No. 89-12-6 REV.
SHEET 6 of 15

DDflmg

Appendix B

Aerial Photos

Reach 1 – Lower Park Rill Creek from Highway 97 to Okanagan River

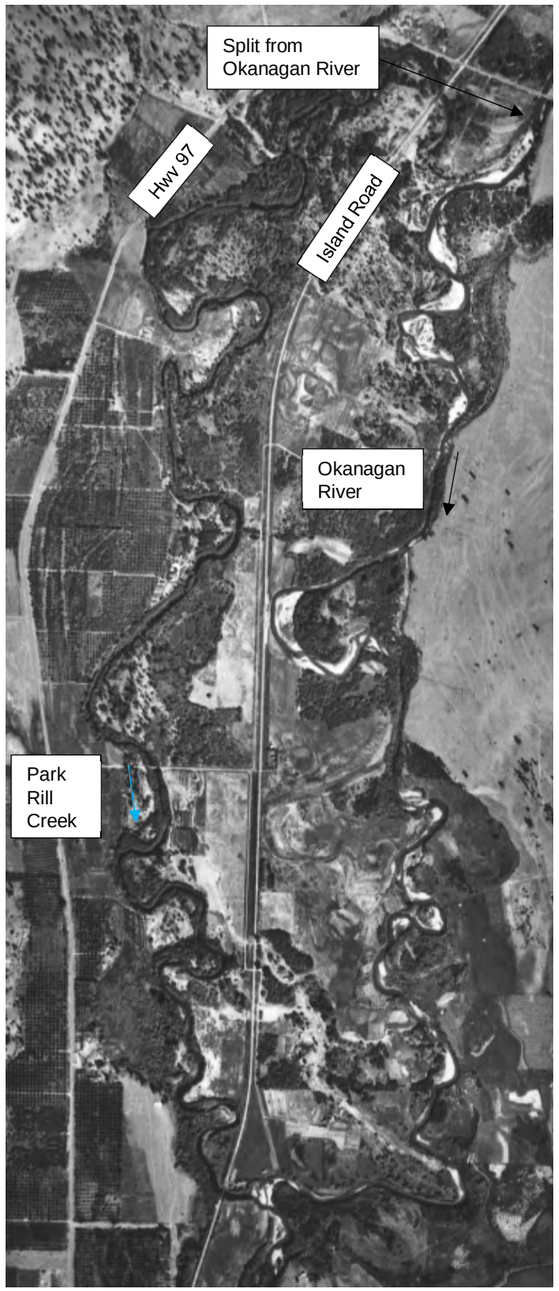


Photo 1: 1938 (BC99:63)

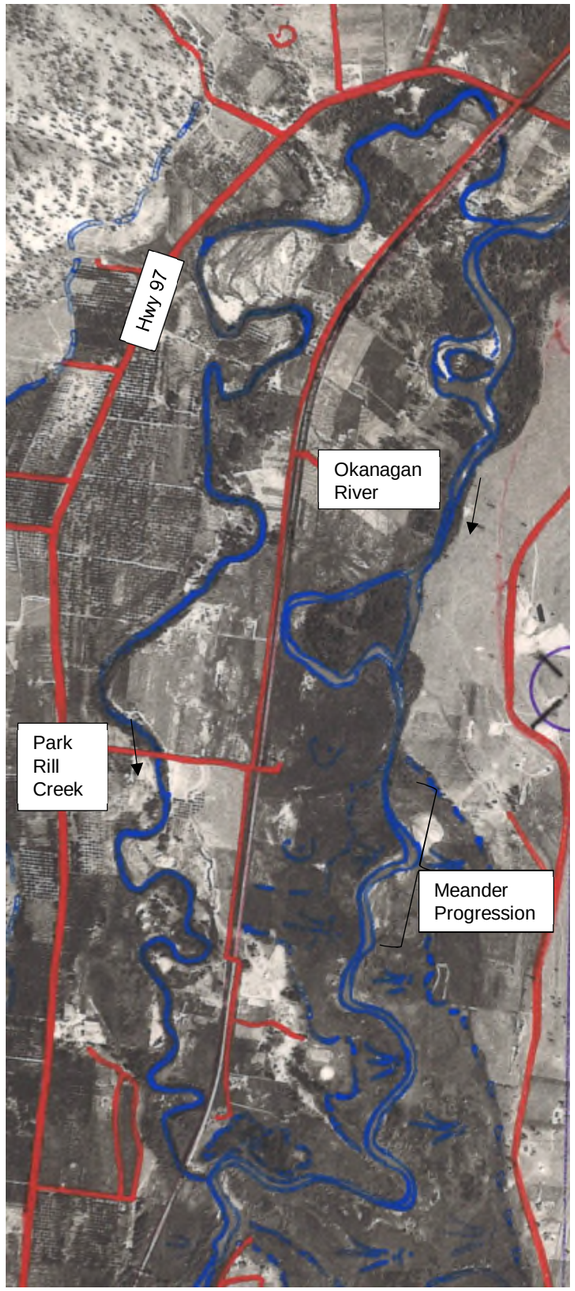


Photo 2: 1951 (BC1243:106)

Photo 3: 1959 (Photo Information Not Available)

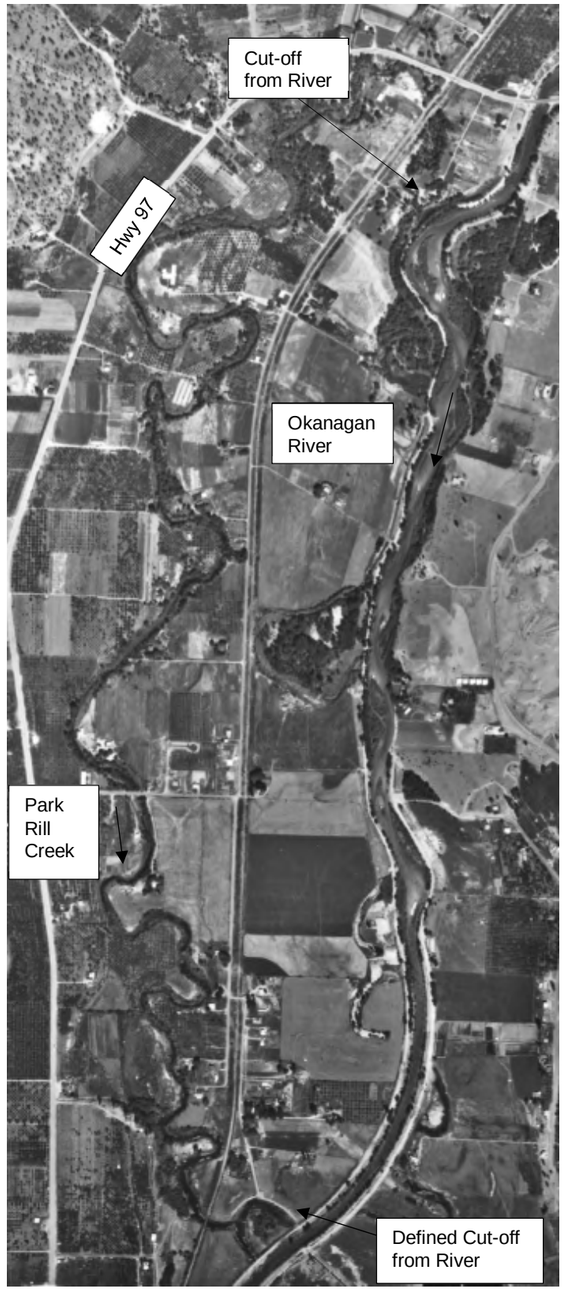


Photo 4: 1974 (BC7581-207)

Photo 5: 1985 (BCC348-132)

Photo 6: 1996 (BCC96023-178)

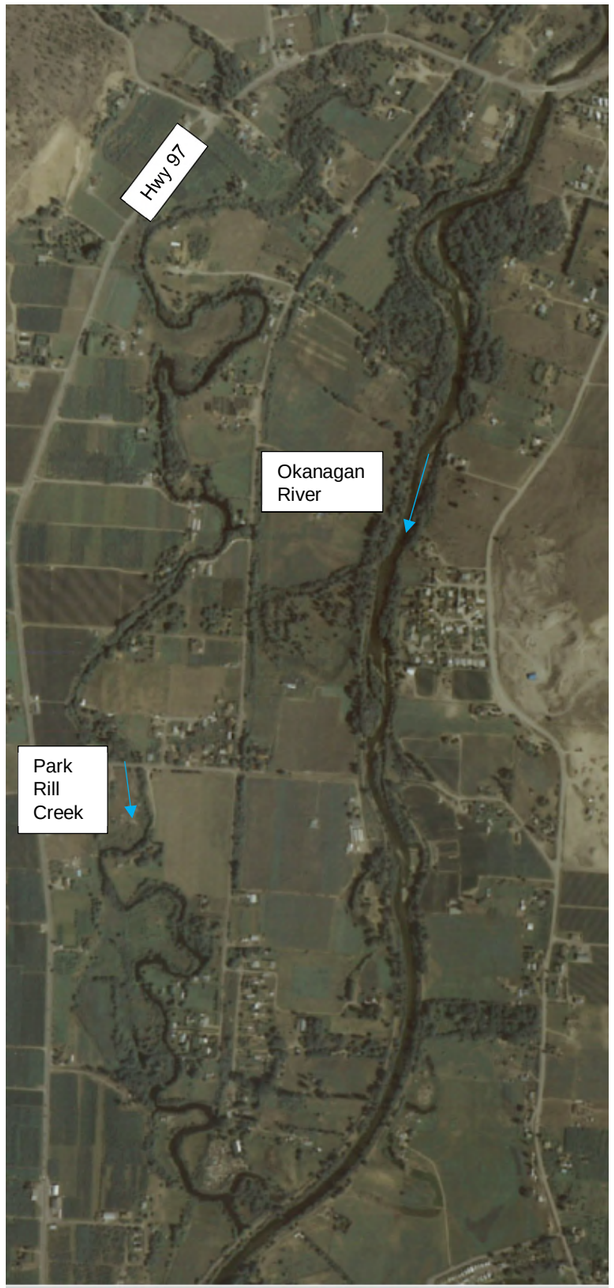


Photo 7: 2007 (BCD7038-191)

Reach 2 – Park Rill Creek from Secrest Road to Highway 97

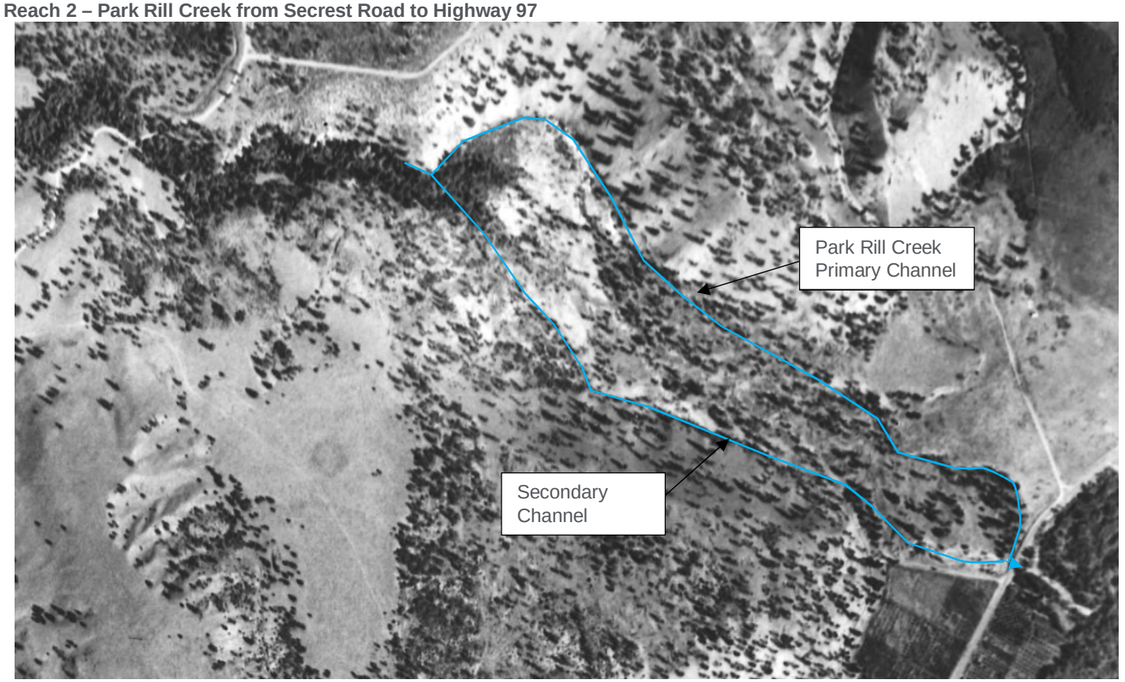


Photo 8: 1938 (BC99:13)

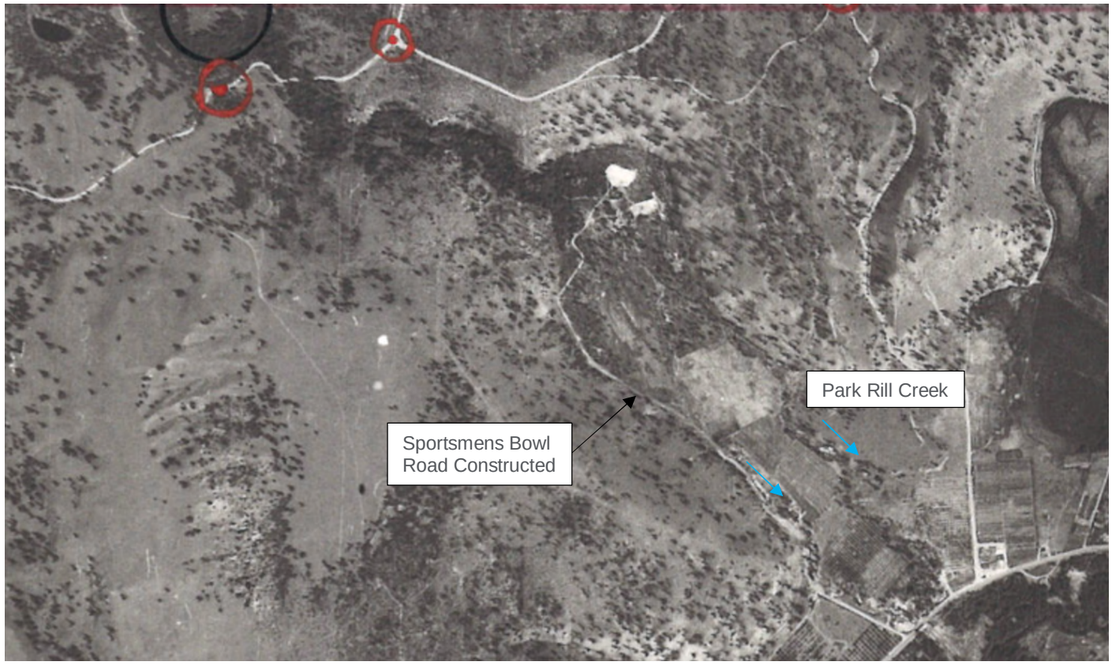


Photo 9: 1951 (BC1243:10)

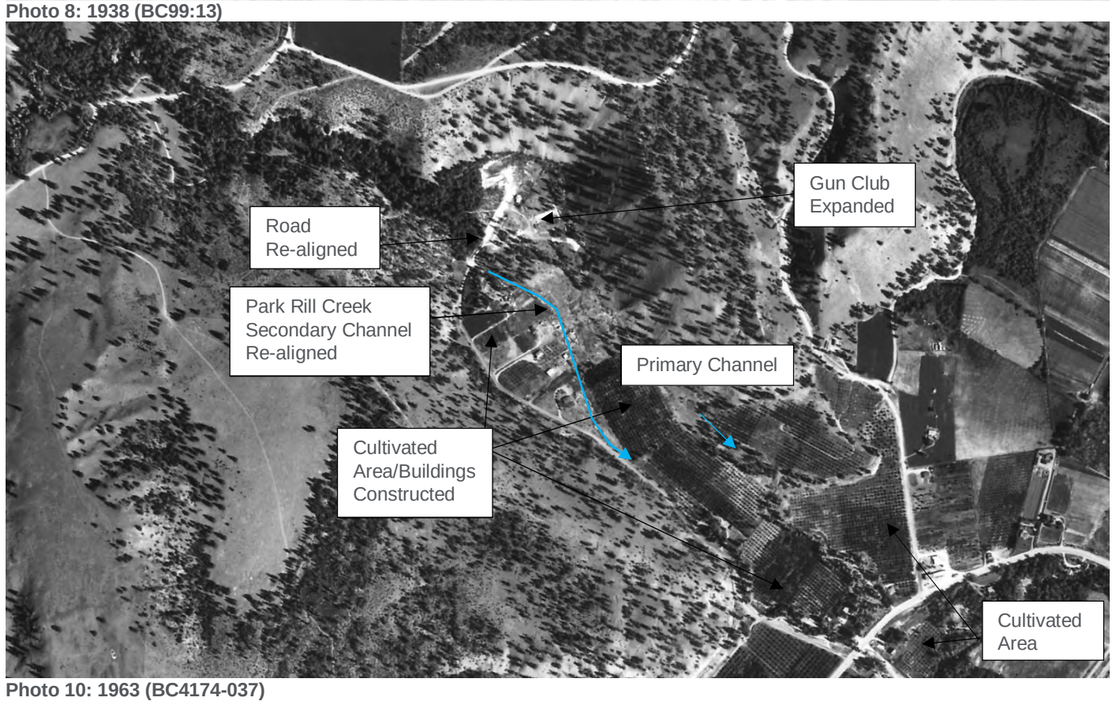


Photo 10: 1963 (BC4174-037)

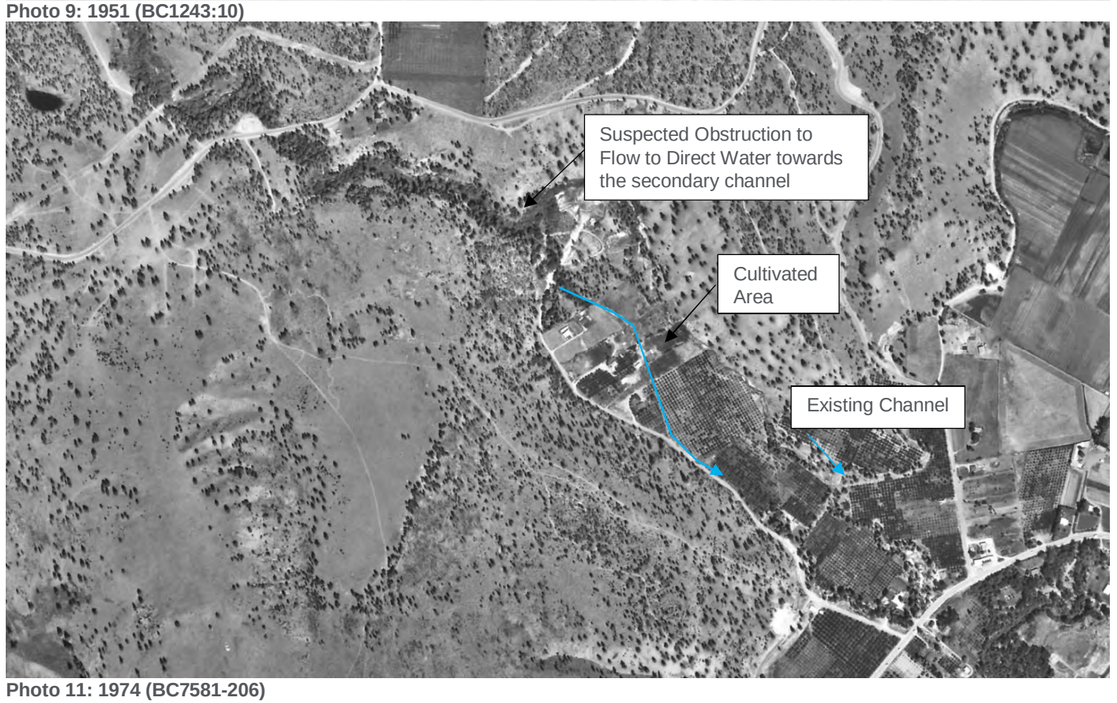


Photo 11: 1974 (BC7581-206)

Photo 12: 1985 (BCC348-176)

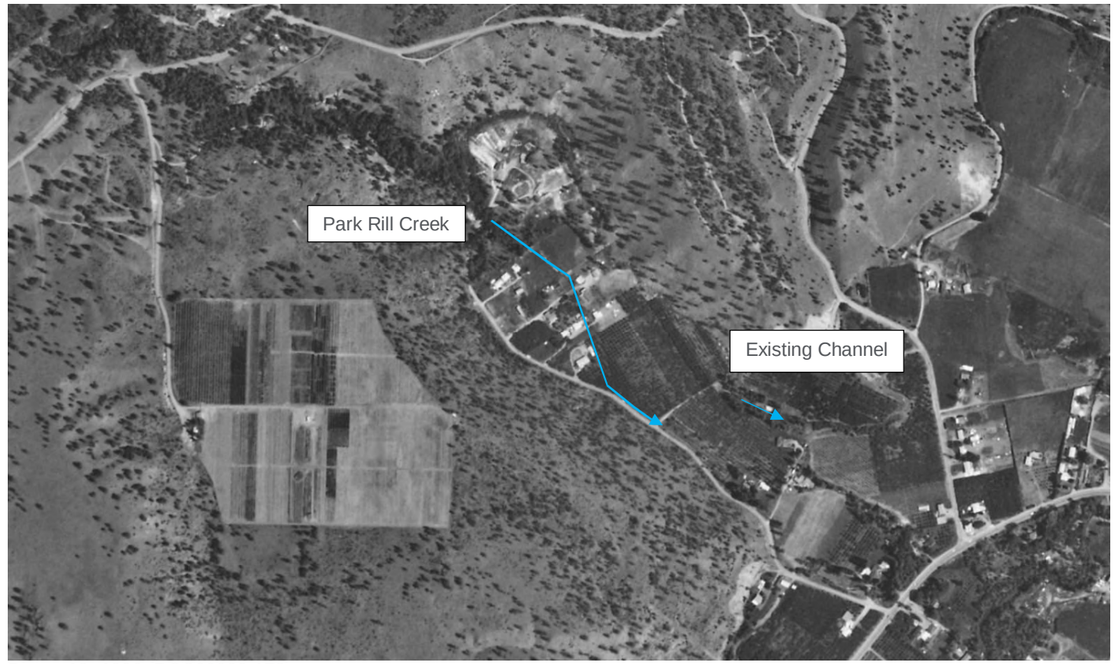


Photo 13: 1996 (BCC96023-178)

Photo 14: 2007 (BC7039-038)

Reach 3 – Upper Park Rill Watershed (Select Locations and Photos only) – Near White Lake Ranch

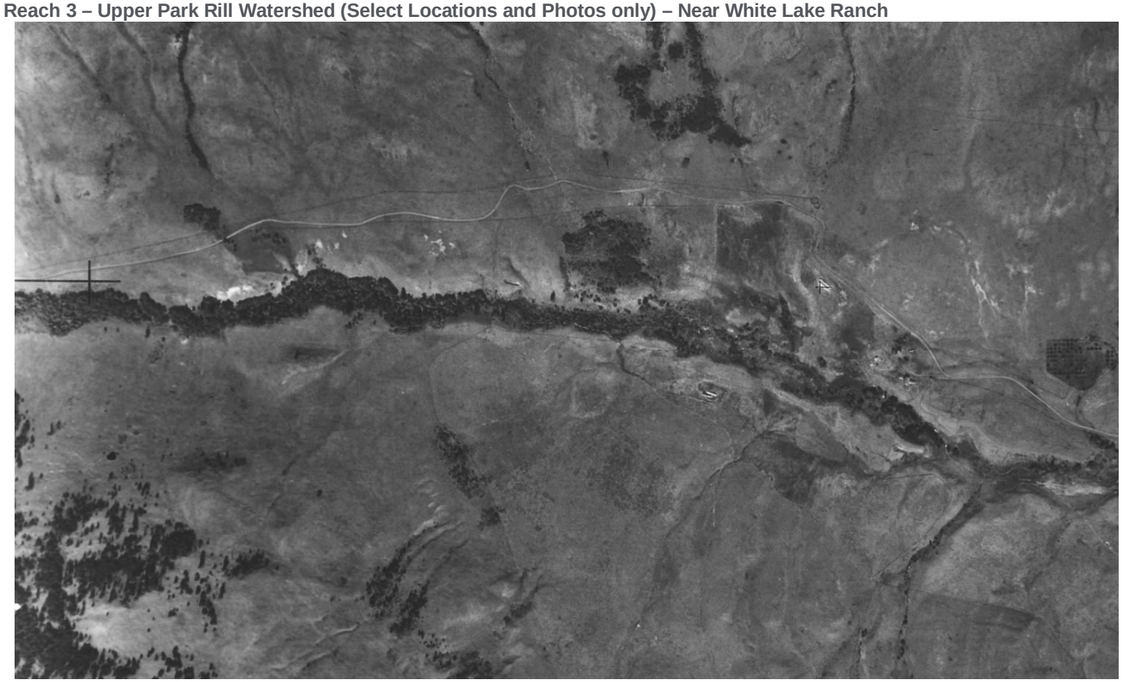


Photo 15: 1938 (BC101:26)

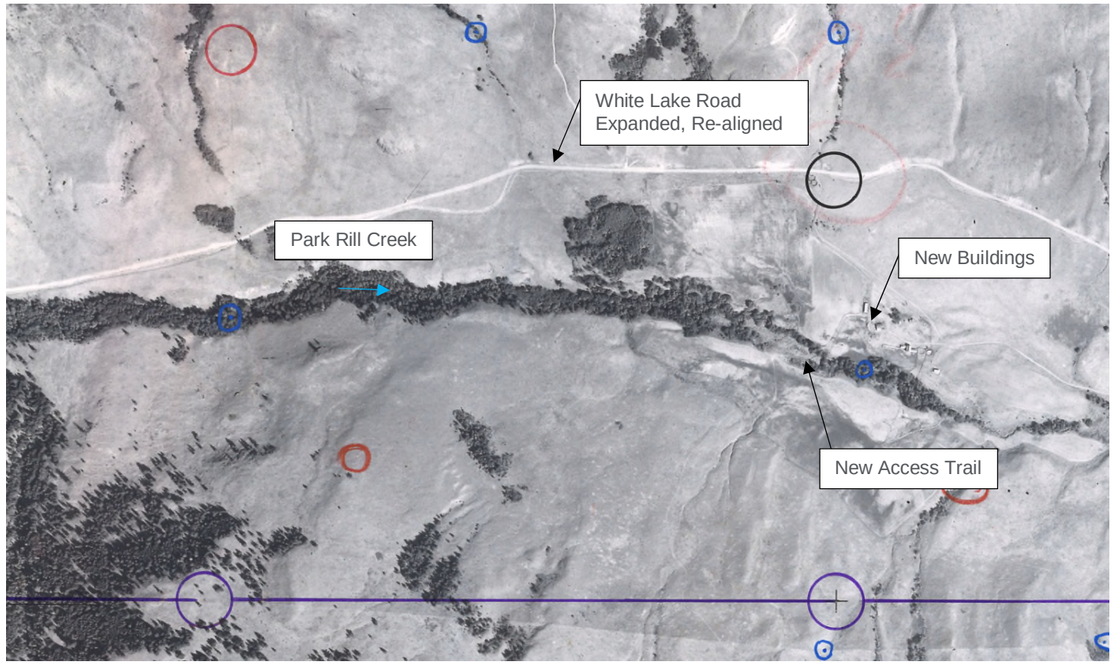


Photo 16: 1963 (BC4184-139)

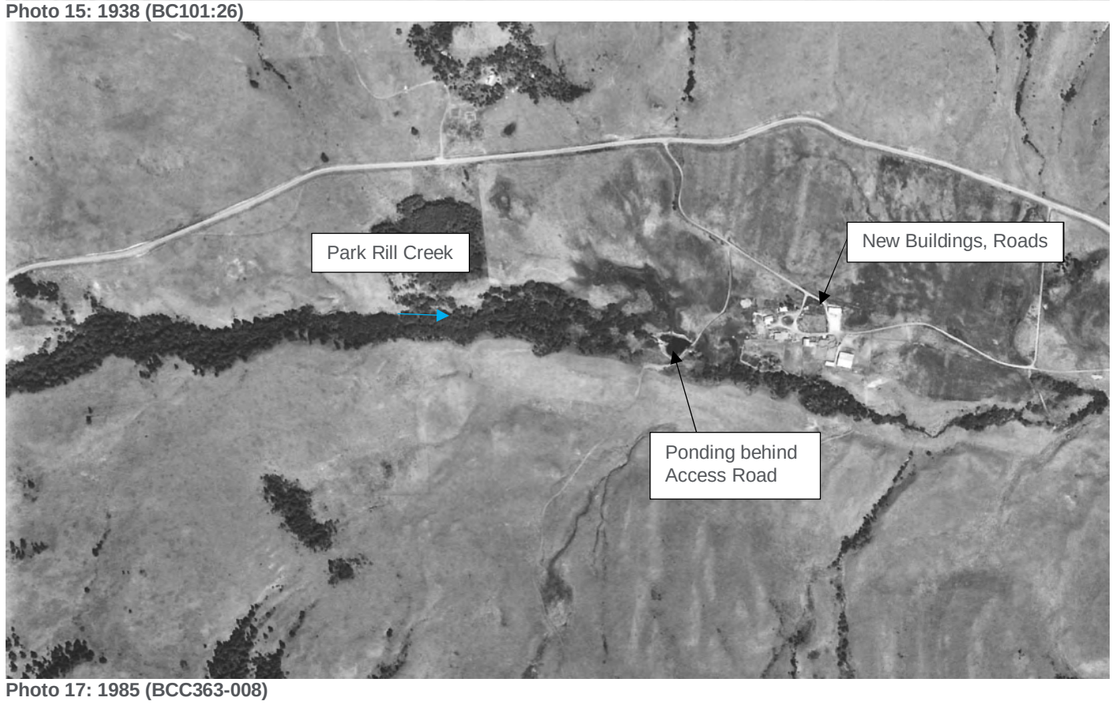


Photo 17: 1985 (BCC363-008)

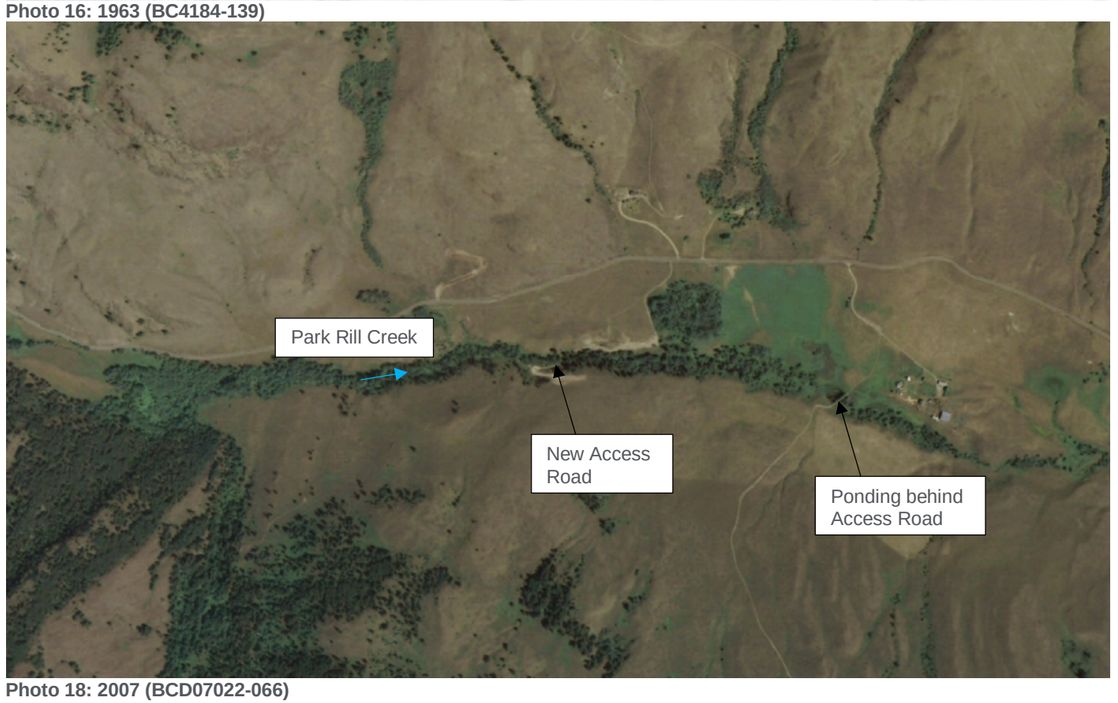


Photo 18: 2007 (BCD07022-066)

Reach 3 – Upper Park Rill Watershed (Select Locations and Photos only) – Near Willowbrook Road

Photo 19: 1938 (BC128:48)

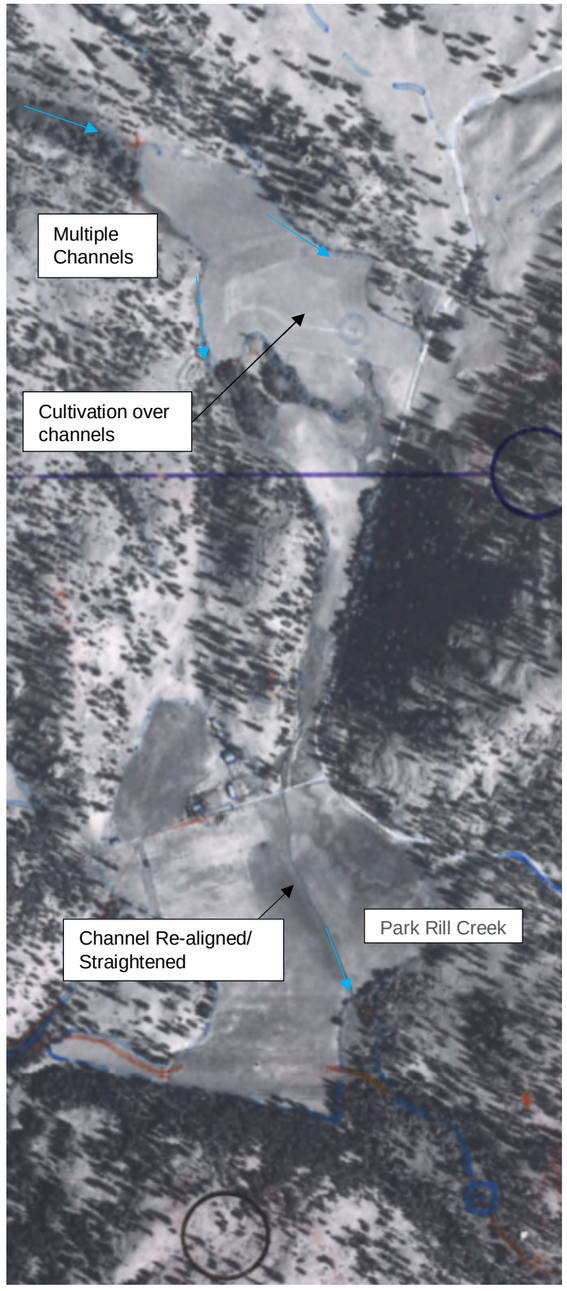


Photo 20: 1963 (BC4174-078)

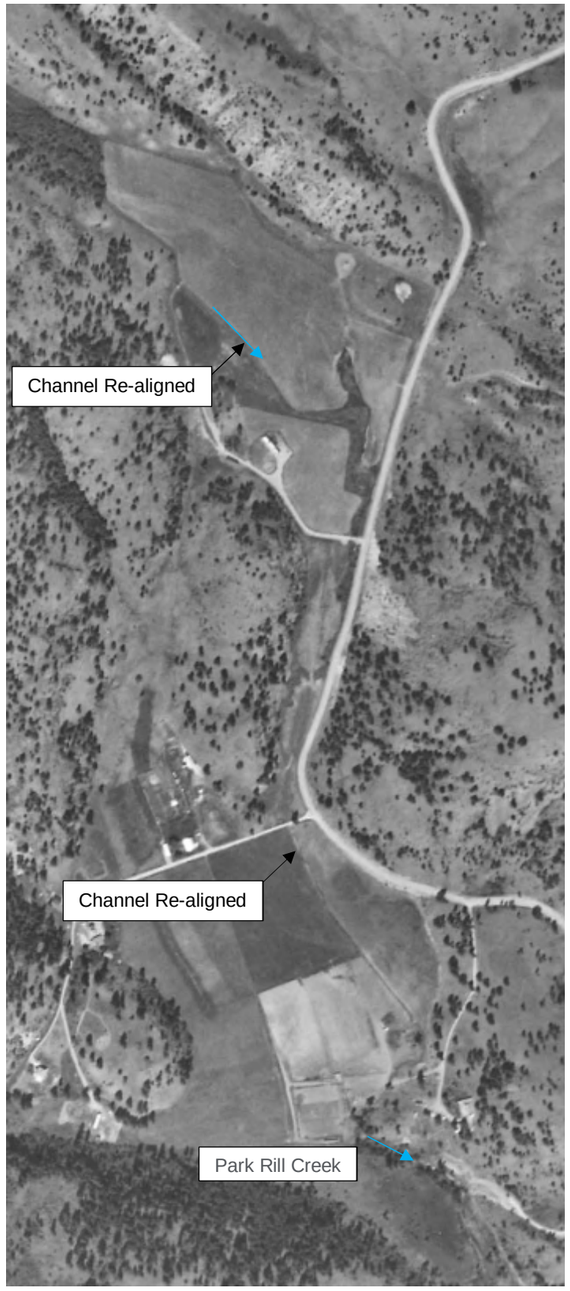


Photo 21: 1996 (BCC96025-026)

Photo 22: 2007 (BCD07040-219)

Reach 3 – Upper Park Rill Watershed (Select Locations and Photos only) – At Willowbrook

Photo 23: 1938 (BC101:26)

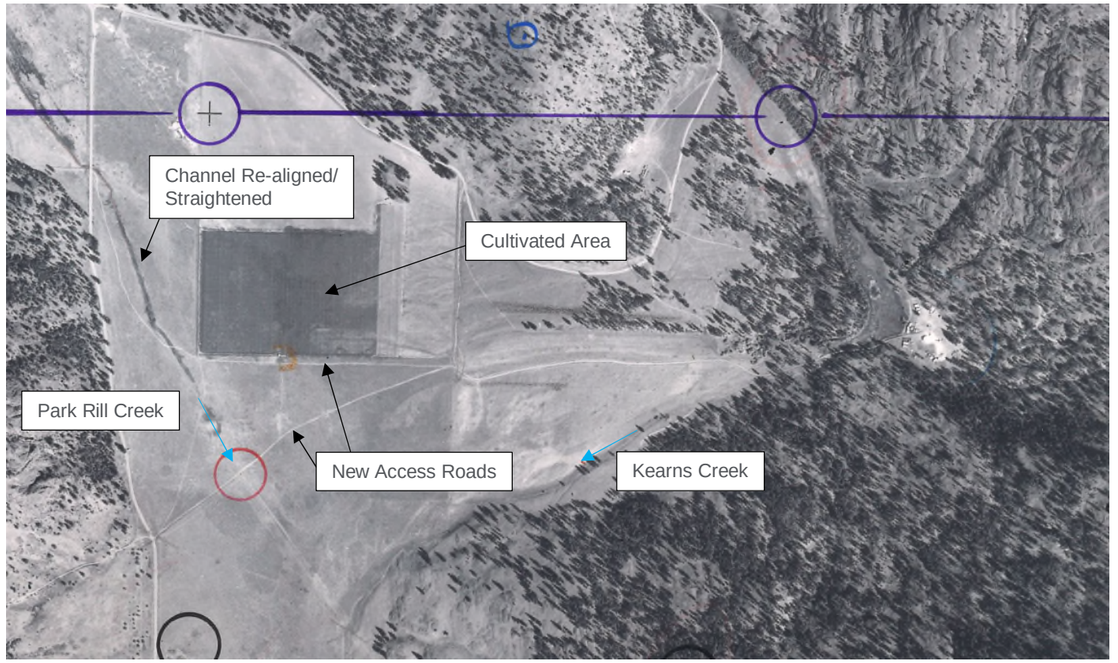


Photo 24: 1963 (BC4184-044)

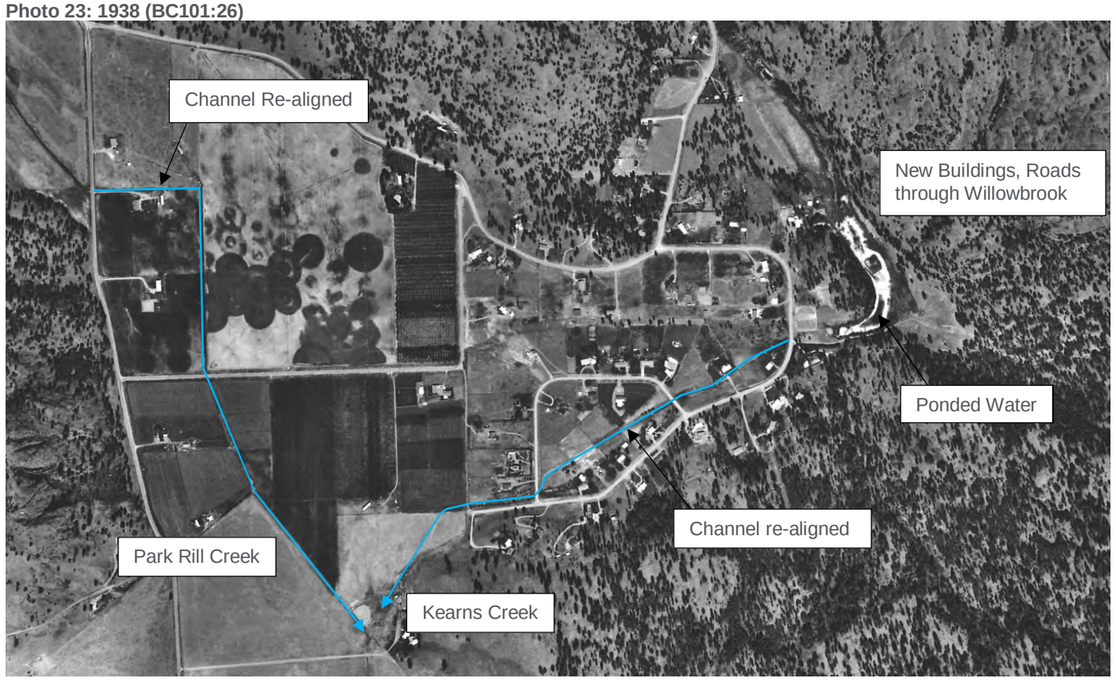


Photo 25: 1985 (BCC363-191)

Photo 26: 2007 (BCD07040-221)

Appendix C

Site Photographs

Study Area 1 – Okanagan River to Highway 97

Photo 1 View of Okanagan River and Park Rill Culvert Outlet (March 14, 2019)

Photo 2 Looking upstream at Park Rill Creek from outlet culvert (March 14, 2019)

Photo 3 Inlet of Park Rill Outlet Culvert with Grate and Headwall (March 14, 2019)

Photo 4 Looking at Inlet to Park Rill Creek at Park Rill Road Culvert (March 14, 2019)

Photo 5 Looking at Outlet of Park Rill Creek culvert at Park Rill Road (March 14, 2019)

Photo 6 Looking downstream from Park Rill Road at Park Rill Creek (March 14, 2019)

Photo 7 Looking downstream from Highway 97 at Park Rill Creek (March 14, 2019)

Photo 8 Looking at outlet of 2-800 mmØ culverts at Highway 97 (October 23, 2018)

Study Area 2 – Highway 97 to Secrest Hill Road – More photos in Addendum 1 of 2019 Flood Response Memo

Photo 9 Looking downstream at 3-800 mmØ culverts at Highway 97 (March 14, 2019)

Photo 10 Inlet of 2-800 mmØ culverts at Highway 97 (March 14, 2019)

Photo 11 Looking downstream along Park Rill Creek running along Sportsmen's Bowl Road (October 23, 2018)

Photo 12 Looking downstream along Park Rill Creek at 10368 Sportsmen's Bowl Road (November 23, 2018)

Photo 13 Looking at culvert inlet at SOSA access road (October 23, 2018)

Photo 14 Inlet of 2-2700 mmØ culverts at Secrest Hill Road

Study Area 3 – Secrest Hill Road to Headwaters

Photo 15 Looking East across Park Rill Creek just upstream of Park Rill Dam (November 23, 2018)

Photo 16 Looking downstream at Park Rill Dam reservoir (November 23, 2018)

Photo 17 Looking downstream at Park Rill Creek through Myers Flats area from Goldtau Road (April 1, 2019)

Photo 18 Looking downstream at Kearns Creek from Myers Road culvert in Willowbrook (October 30, 2018)

Photo 19 Looking downstream at Kearns Creek from Carr Crescent (October 30, 2018)

Photo 20 Inlet of Victoria Creek culvert at Secrest Hill Road (March 14, 2019)

Photo 21 Looking downstream at Park Rill Creek after 2018 erosion at 4493 Willowbrook Road (October 10, 2018)

Photo 22 Looking downstream at Park Rill Creek near White Lake Ranch (October 23, 2018)

Photo 23 Looking downstream at Park Rill Creek upstream of Lower Horn Lake confluence (October 23, 2018)

Study Area 4 – Horn Creek Watershed and Twin Lakes – For site photographs, refer to Twin Lakes Flood Response Assessment (Ecora/Dobson 2019)

Appendix D

2019 Flood Response Plan

December 17, 2018 Ecora File No.: CP-18-568-RDO

Regional District of Okanagan Similkameen (RDOS)
101 Martin Street
Penticton, BC V2A 5J9

Attention: **Mark Woods – RDOS Emergency Management Program Director**

Reference: **Addendum #1 – Park Rill Creek 2019 Flood Response Assessment**

Ecora Engineering and Resource Group Ltd. (Ecora) submitted a report to the Regional District of Okanagan-Similkameen (RDOS) on November 26, 2019 providing recommendations to the RDOS Emergency Operation Centre (EOC) for 2019 flood mitigation within the Park Rill Creek watershed to minimize risk to public safety and damage to infrastructure. This addendum presents additional recommendations to those provided in Ecora's November 26th report based on further consideration of previous site observations and observations made during Ecora's recent site reconnaissance to the Willowbrook on October 30, 2018 and the Sportsmen's Bowl areas on November 23, 2018.

1. Kearns Creek at Myers Road in Willowbrook –Recommended Improvements

During a site visit on October 30, 2018, Ecora observed that the channel downstream of the new Kearns Creek box culvert crossing at Myers Road in Willowbrook is constricting the flow and will very likely cause further backwatering and flooding on Kearns Creek upstream of the new culvert unless the channel capacity downstream is improved. When the new large box culvert was installed, it was set significantly lower than the original culvert so the outlet elevation is lower than the Kearns Creek channel downstream (refer to Photos 1 & 2). A review of the channel between Myers Road and Goldtau Road by Ecora confirmed that if the channel was lowered and the capacity was increased, it would allow the Kearns Creek freshet flows to pass through Willowbrook with limited obstruction and would significantly reduce the risk of backwatering and localized flooding upstream of Myers Road, as occurred in 2018.

To improve channel capacity, it is recommended that the channel cross section be improved between the Myers Road culvert crossing and the Goldtau Road crossing by deepening the channel to the same depth as the elevation of the outlet of the box culvert (~1 m lower) with a bottom width of 1 m and side slopes of 1.5:1.

It is understood that when MoTI replaced the former metal culvert with the new box culvert, construction was restricted to work within the right-of-way (ROW). The recommended channel improvements are situated on private land, outside MoTI's authority.

Considerations for the Kearns Creek channel improvements from Myers Road to Goldtau Road include:

1. A Section 11 Notification will be required to complete these works, which should be submitted to the Province as soon as possible.

2. The estimated cost for permitting and excavation, with disposal on-site is approximately $10,000. This cost will be far less than the 2018 response costs and likely those costs incurred should flooding occur again in 2019, if nothing is done.
3. The proposed work would occur on two private parcels where the landowners would be required to agree to the work and sign off on the proposed channel changes.

Photo 1. Myers Road new box culvert outlet, looking north

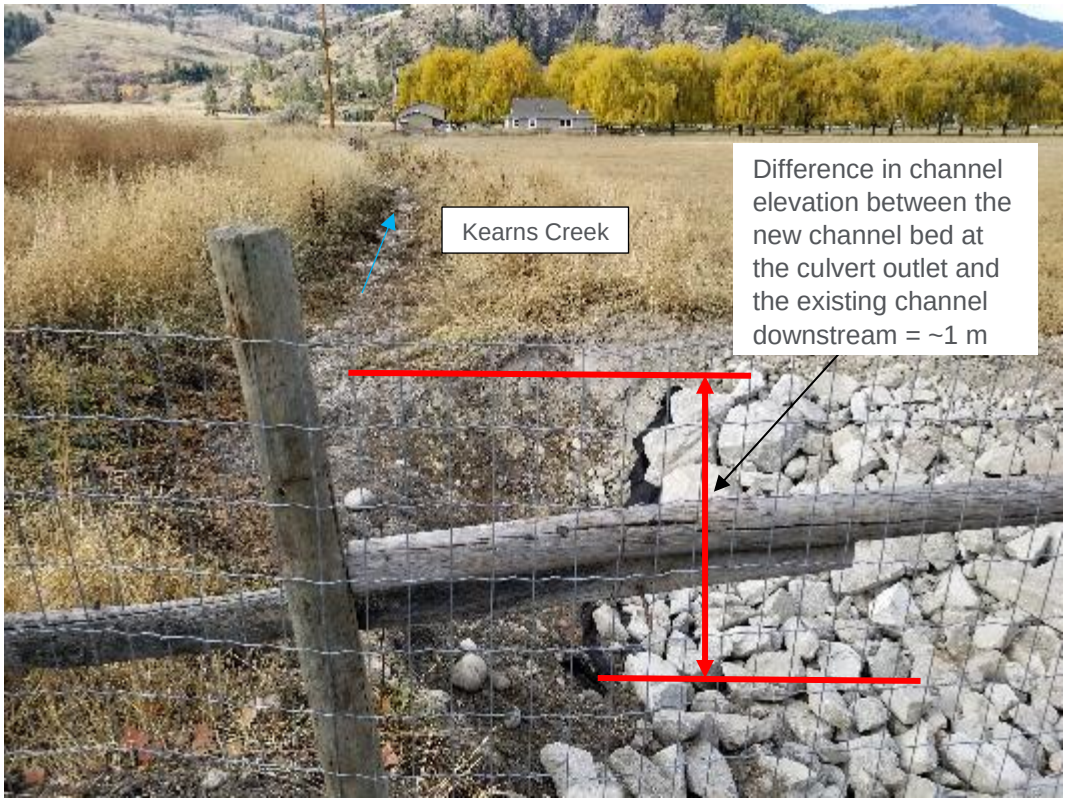


Photo 2. Looking downstream from Myers Road Culvert at Kearns Creek

2. Park Rill Creek channel from Sportsmen's Bowl Road to Secrest Hill Road Recommendations

On November 23, 2018, Ecora completed a site reconnaissance of Park Rill Creek between the Southern Okanagan Sportsmen's Association (SOSA) property and Secrest Hill Road. Ecora also met with Brian Amos of SOSA who provided some anecdotal information regarding Park Rill Creek near Sportsmen's Bowl. The site reconnaissance was carried out to assess potential permanent flood mitigation alternatives and to identify potential immediate hazards that could affect downstream residents during the 2019 freshet.

During the site reconnaissance, the following observations were made:

- Brian commented that prior to 2018, the primary channel for Park Rill Creek was a channel at the base of the slope to the north and northeast of Sportsmen's Bowl properties. The secondary channel prior to 2018 was the irrigation ditch that runs through properties from 352 to 274 Sportsmen's Bowl Road and discharges to the Sportsmen's Bowl Road ditch. During the freshet in 2018, a channel avulsion occurred during the high flows that diverted the entire flow into the irrigation ditch that is now the primary flow path for Park Rill Creek.
- The channel avulsion created a deep new channel (~3m deep) leading to the culvert that flows under the SOSA access road. Photo 3 shows the creek just upstream from the SOSA access road.
- At the channel avulsion site, a willow is located within the channel and the channel has undermined the tree roots. The willow will eventually fall over blocking the channel and could initiate a debris flow. Photo 4 shows a view of the willow and the channel.
- The former northeast channel is now permanently cut off from flows, except during very high flow periods, due to the downcutting of the avulsion channel, as shown in Photo 5.

- Along this reach, there are several waterfall-type areas with extremely steep channel gradients interspersed between flat sections of channel. Some of these steep reaches appear to be caused by debris build-up within the channel. Photo 6 shows a waterfall where channel appears to be controlled by a debris build-up, and Photo 7 shows a flat area just upstream of the drop-off.
- Based on the existing conditions within this reach of the creek, high flow events have potential to cause debris flows through the channel when the debris jams wash out. If debris is washed downstream, it is expected that it will be trapped in the narrower sections of the channel, specifically in the gulley near the SOSA access road.
- The terrain is comprised steep slopes with some flatter sections with dense vegetation throughout, and the creek is restricted by steep valley walls on both sides. Due to the nature of this terrain, access by heavy machinery and personnel is generally not recommended.

Photo 3. Park Rill Creek channel – post 2018 flood, upstream of SOSA access road

Photo 4. Willow located within channel

Photo 5. View of Northeast Channel looking north that is now cut off anddry

Photo 6. Breach with flow retained by debris

Photo 7. Flat creek channel upstream of the breach

Based on the observations made during the site reconnaissance, there does not appear to be an imminent threat to life in the section of Park Rill Creek downstream of Secrest Hill Road to Sportsmen's Bowl Road. Although debris flows may occur in response to future high flow events, the volume of debris and sediment is not expected to be large enough to cause life-threatening hazards. Debris is expected to be restricted by the narrow channel gully upstream of the SOSA access road. The channel reach should be monitored by Ecora on a semi-monthly basis leading up to spring freshet for new hazards or worsened conditions that may increase potential for debris flow; however, at this time, no immediate action is recommended for Park Rill Creek between the Seacrest Hill Road Crossing and the south boundary of the SOSA property.

We trust that this addendum meets your present requirements. If you have any questions or comments, please contact the undersigned.

Prepared By:

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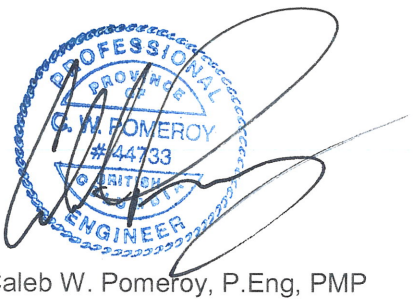

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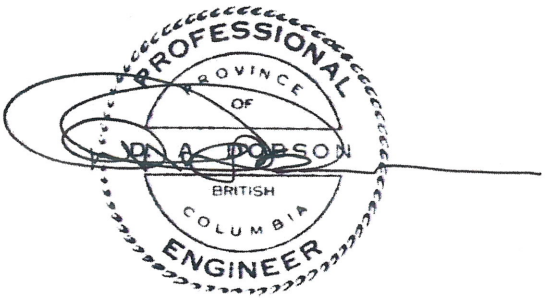
caleb.pomeroy@ecora.ca

Reviewed By:



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November 26, 2018 Ecora File No.: CP-18-568-RDO

Regional District of Okanagan Similkameen (RDOS)
101 Martin Street
Penticton, BC V2A 5J9

Attention: **Mark Woods – RDOS Emergency Management Program Director**

Reference: **Park Rill Creek 2019 Flood Response Assessment**

The Regional District of Okanagan-Similkameen requested Ecora Engineering and Resource Group Ltd. (Ecora) and Dobson Engineering Ltd. to prepare a response assessment for the Park Rill Creek watershed to prepare for flooding expected during the upcoming 2019 freshet event. In 2018, Willowbrook and Sportsmen's Bowl Road were severely impacted by flooding that caused risk to public safety and damage to public infrastructure and private properties. Groundwater levels are currently higher than normal due to the wet conditions experienced in 2017 and 2018, creating an increased potential for flooding during freshet in 2019.

The purpose of this flood response assessment is to provide recommendations to the RDOS Emergency Operation Centre (EOC) to control flooding to minimize risk to pubic safety and damage to public and private infrastructure in 2019. The Park Rill watershed has been split into four study areas for this report as follows:

- Study Area 1 is the lower reach of Park Rill Creek extending upstream from the Okanagan River to Highway 97;
- Study Area 2 extends upstream from Highway 97 to Secrest Hill Road;
- Study Area 3 extends upstream from Secrest Hill Road to the Park Rill Creek headwaters; and,
- Study Area 4 includes the headwaters of Park Rill Creek and Twin Lakes.

For each study area, a summary of 2018 flood response and restoration and upgrade activities carried out by the RDOS EOC and Ministry of Transportation and Infrastructure (MoTI) is provided followed by Ecora's recommendations for flood response for 2019. The recommendations provided in this report are activities that should be completed prior to the freshet event of 2019 (i.e., during this winter), with the exception of monitoring which is recommended to be completed both prior to and during the freshet event.

Study Area 1 – Okanagan River to Highway 97

Study Area 1 extends from the outlet of Park Rill Creek into Okanagan River up to the culvert crossing at Highway 97. Flooding in this study area was worsened by the Okanagan River culvert outlet structure that allows flow into the river at low river levels but allows flow back into the creek at high river levels. During the 2018 flood, Park Rill Creek could not discharge into Okanagan River as the river water level was high.

Flood response and upgrades in 2018 in Study Area 3 included:

- Sandbagging and tiger dam deployment to protect vulnerable properties near Park Rill Creek;
- The removal of channel hydraulic restrictions in Park Rill Creek and continual removal of sediment and debris;
- The installation of four 12” diesel powered discharge pumps at the outlet of Park Rill Creek into Okanagan River;
- The installation of one 12” diesel powered discharge pump located at Park Rill Road; and,
- The installation of two 800 mm culverts under Highway 97 discharging into a constructed emergency channel to increase flow capacity. This emergency channel, that discharged into the wetland area adjacent to Park Rill Creek, was removed later in 2018.

Recommended 2019 flood response actions for Study Area 1 includes:

1. Installing a flap gate on the Park Rill Creek outlet culvert to prevent Okanagan River from backwatering into Park Rill Creek. During a site visit on November 9, 2018, it was discovered that the flap gate was missing and the water from the Okanagan River can freely backwater into Park Rill Creek. This item should be requested to be completed by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development as it is part of the Okanagan Lake Regulation System and a regular maintenance item;
2. Monitoring water levels in Park Rill Creek and Okanagan River at the Park Rill Creek outlet, Park Rill Creek Road and key restriction points during the freshet and develop a trigger point for pumping from Park Rill Creek into Okanagan River. Trigger point elevations would be set based on when surface water flooding is imminent that impacts homes and public infrastructure. Under response, periodic weekly monitoring would be completed by a contractor with the frequency increasing as flows and water levels increase;
3. The existing Park Rill Creek crossing under Highway 97 is 3-600 mmØ CSP culverts. During inspection of these culverts on November 9, 2018, two of the three culverts were completely blocked by debris lodged in the upstream end. These culverts need to be cleaned and maintained through the freshet to prevent any blockage during peak flows. The immediate upstream area should be cleared of any remaining debris to mitigate blocking. In the absence of the activation of the two emergency 800 mmØ culverts, a trash rack could be installed to maintain operation of these pipes.
4. Re-establishing the emergency channel that conveys discharge from the two 800 mmØ culverts installed in 2018. This emergency channel can be constructed using 150 lineal meters of 36” tiger dams. Based on discussions with MoTI, MoTI plans to temporarily block the 800 mm culvert inlets as these culverts currently discharge towards a resident’s house. As soon as the emergency channel is installed, MoTI will be requested to remove the temporary pipe blocks to increase capacity under Highway 97.
5. Have 36” tiger dams ready for immediate deployment to protect the residences located directly downstream of Highway 97. 200 lineal meters of tiger dams are required.
6. It is understood that the Secrest Hill Road culvert crossing will be upgraded in late 2018 or early 2019 by MoTI with a 2700 mm csp. The Highway 97 culverts will not have equal capacity to Secrest Hill and as part of response, daily monitoring will be required once the water depth has reached a level where the existing 3-600 mm Ø culverts are submerged on the upstream side of Highway 97.

The recommended flood mitigation plan for Study Area 1 is presented in Figure 1.0.

Study Area 2 – Highway 97 to Secrest Hill Road

Study Area 2 extends from the Highway 97 culvert crossing to the Secrest Hill Road culvert crossing. During flooding in 2018, the residents on Sportsmen's Bowl Road were heavily impacted, many suffering significant damage to their property and loss of access to their homes for several weeks. The existing channel through the emergency culvert crossings on private and public property are currently at 50% capacity. Based on monitoring over the past three weeks, it appears that increased runoff is not experienced until the rainfall depth over 24 hours is greater than 10 mm. **Any rainfall event beyond 10 mm has the potential to immediately overwhelm the existing works**. In addition, recent upgrades upstream of Secrest Hill Road have removed attenuation (experienced in 2018) by the formerly undersized culverts, increasing the risk of higher peak flows downstream in 2019.

Flood response and upgrades in 2018 in Study Area 2 included:

- Hesco bins, sandbags and tiger dams were installed along Sportsmen's Bowl Road and on private property to protect key infrastructure and properties;
- Construction of a riprap roadside channel and installation of culverts along Sportsmen's Bowl Road to contain flow to the channel and convey it downstream to the Highway 97 culverts;
- The removal of restrictions, including private culvert crossings and creek side vegetation and sediment from the Park Rill Creek channel;
- Replacement of riprap channel berms on Sportsmen's Bowl Road with concrete road barriers to contain flow and re-establish 2-way traffic;
- MoTI has been working to re-establish two lanes of traffic on Sportsmen's Bowl Road for the winter season which includes ditching improvements and upgrading all crossings to 2-800 mmØ culverts along its right-of-way. There are also plans for installation of a cattleguard which will act as a surface water intercept near Highway 97 to prevent flooding of Park Rill onto Highway 97; and,
- At Secrest Hill Road, an emergency overflow 800 mmØ culvert was installed during the freshet to mitigate the road from overtopping and causing a debris flood. An 8" diesel pump was also installed on Secrest Hill Road during the freshet to keep water levels from cresting the road, which was sustained for several weeks.

Recommended 2019 flood response actions for Study Area 2 includes:

1. A late winter assessment by Ecora and Dobson Engineering to review MoTI temporary works constructed in 2018 for their potential to increase flooding of adjacent properties. Recommendations will be provided, if necessary, for removal or modification of these temporary works.
2. Installation of 700 lineal meters of 36" tiger dams, prior to the 2019 spring freshet, to protect low-lying private properties on both sides of the creek. Access to dwellings could be maintained by installing road crush berms (or similar well-draining, drivable material) to an equivalent height and alignment to the tiger dam and sloped to allow vehicular traffic.
3. Two temporary accesses were installed on 296 and 322 Sportsmen's Bowl Road which were designed to fail in a flood event. A swale was designed to allow floodwater to overtop the road fill and make its way back into the creek should flows exceed the culvert capacity. These swales have since been leveled off which poses a risk to downstream properties since floodwaters could develop new flow paths and/or channels through downstream properties instead of flowing through the creek channel. These accesses need to be modified to re-establish the flood swale to allow for a controlled failure prior to the 2019 freshet. If extreme flows should occur in 2019, these driveway culverts should be removed to restore full channel capacity until the freshet passes.

4. As an extension of the monitoring at Highway 97, once the trigger point has been reached where the upstream end of the culverts at Highway 97 have been submerged, weekly inspections should be completed by a contractor to monitor water levels and remove private culvert crossings as required to increase flow capacity. Frequency of inspections should be increased to daily once the two 800 mmØ emergency overflow culverts under Highway 97 are in service.
5. Identify an area upstream of the Highway 97 ditch, between Sportsmen's Bowl Road and the Highway where a sediment catchment area (approximately 500 m^2) can be excavated. This area would allow coarse sediment to settle out prior to discharging through the culverts and minimize the accumulation of sediment in areas where access is difficult.
6. Ecora will complete a stability, erosion and debris assessment of the Park Rill Creek channel between the Southern Okanagan Sportsmen's Association property and Secrest Hill Road to determine if there are any unknown risks in this area that could trigger a debris flow and provide any necessary response recommendations.
7. Secrest Hill Road is a risk to public safety. If the culverts are not replaced by MoTI, it is recommended that this crossing be monitored daily for signs of seepage and piping failure once the culvert inlets are submerged, as the consequence of failure includes the likely loss of life for downstream residents. If the crossing is upgraded, an understanding of the maximum flows that could occur through the upgraded crossing should be quantified to be included in the response plan as part of the late winter assessment identified in the first bullet. The potential for increased peak flows in the lower system has increased due to upgrades to most of the upstream crossings, which has removed the attenuation of peak flows in the system that was present in 2018 due to undersized culverts.

The recommended flood mitigation plan for Study Area 2 is presented in Figure 2.0.

Study Area 3 – Secrest Hill Road to Park Rill Creek Headwaters

Study Area 3 extends from the culvert crossing at Secrest Hill Road to the Park Rill Creek headwaters and includes the Kearns Creek watershed. Severe flooding in Willowbrook due to high flows in Kearns Creek led to an evacuation alert for residents in 2018.

Flood response and upgrades in 2018 in Study Area 3 included:

- Pumping at Myers Road prior to removal of culvert;
- Sandbagging and installation of tiger dams to protect key infrastructure and property;
- Removal of culverts in Willowbrook to increase flow capacity. These culverts were later upgraded in 2018 to box culverts;
- Replacement of existing culverts with concrete box culverts at Park Rill Creek crossings at Goldtau Road, Jones Way, Yellowbrick Road, and Willowbrook Road (currently in progress);
- Proposed upgrades to existing Park Rill Creek culverts under Secrest Hill Road, which are expected to be constructed later this year; and,
- Upgrades to Park Rill Dam to increase spillway capacities.

Recommended 2019 flood response actions for Study Area 3 includes:

1. As part of the phase 2 of this study, the upgrades to Kearns Creek and Park Rill Dams will be confirmed and estimated dam spillway capacities will be obtained from the Province.
2. Confirming upgrades to culverts under Secrest Hill Road and assessing total capacity.

3. Ecora has assessed the box culvert at Myers Road in Willowbrook. Based on recent field observations, the capacity of this culvert does not appear to be optimized and may cause increased flooding around the adjacent properties. Ecora will develop a plan with MoTI to assess this culvert and mitigate flooding at this crossing.
4. Complete a detailed inspection of deficiencies in Park Rill Creek and Kearns Creek in Willowbrook area and, if necessary, install sandbags and/or tiger dams along selected reaches of Kearns Creek to protect low-lying properties where channel capacity has not been improved. Sandbags may be required in areas where the topography is not appropriate for tiger dams. The 2018 Davies Wildfire Response Plan provides detail on where works are required.
5. Monitoring of flow rates in Kearns Creek, Victoria Creek and Park Rill Creek weekly at start of freshet to provide flow rate information for emergency response managers and crews. Details on the proposed locations are provided below.

The recommended flood mitigation plan for Study Area 3 is shown in Figure 3.0.

Study Area 4 – Park Rill Creek Headwaters and Twin lakes

Study Area 4 includes the Park Rill Creek headwaters and Twin Lakes. Flood response in 2018 in Study Area 4 included the pumping of lower Twin Lake into the Park Rill Creek watershed and extensive sandbagging and flood wall construction. Flooding in the Twin Lakes area is expected again for 2019, and therefore it is likely that pumping into Park Rill Creek will be required again. At the time of writing this report, Lower Twin Lake was at a level of 16.18 feet (local datum), and it is expected that pumping will soon be suspended due the freezing temperatures. In 2018, Lower Twin Lake rose approximately 10 feet with flooding starting at 19.5 feet (local datum), with the 2018 peak water level reaching a level of 27 feet (local datum).

Recommended flood response actions for Study Area 4 includes:

1. Prior to the 2019 freshet, estimate the snow water equivalent in the Horn Creek watershed, based on snow pack data available at the Mount Kobau snow course (2F12) to estimate inflow into Twin Lakes to plan the required response.
2. Ecora and Dobson Engineering are currently preparing a report on flooding at Twin Lakes to develop and estimate costs for a permanent solution to flooding which is expected to be completed by late December 2018.

General Recommendations

In addition to the recommendations listed above for each study area, the following items are also recommended:

- Store critical emergency response materials such as tiger dams locally, e.g. RDOS Penticton, prior to the 2019 freshet, for quick access during emergency response and have arrangements made for works that are known to be required. Materials and equipment that will be required including additional tiger dams, sandbags, heavy machinery and pumps should be pre-planned, prior to the 2019 freshet, for rapid deployment, based on the risks of flooding predicted by the BC River Forecast Centre.
- Preplan the number of BC Wildfire crews and contractors required based on the risks of flooding predicted by the BC River Forecast Centre so availability and funding can be planned.
- RDOS should establish a protocol with the BC River Forecast Centre for timely 2019 updates on flood risks in the RDOS area.
- Manual hydrometric stations are recommended to be installed at several locations in the Park Rill Creek and Kearns Creek catchments so that water levels and discharge monitoring can be carried prior to, during and following significant rainfall events and during the 2019 freshet. Staff gauge readings should

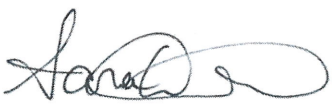
be completed by an RDOS contractor or MoTI staff or maintenance contractor. Staff gauge installation is recommended at:

- Kearns Creek at Johnson Crescent,
- Park Rill Creek at Secrest Hill Road,
- Park Rill Creek at Park Rill Road,
- Park Rill Creek at the outlet, and
- Okanagan River at Park Rill Creek outlet.

Stage-discharge rating curves will be developed by Ecora for each of these locations to estimate discharge based on the staff gauge reading. Monitoring results will be used to estimate whether culvert capacities will be exceeded and may result in recommendations for additional flood mitigation which may include removal of culverts or installation of pumps.

We trust that this report meets your requirements at this time. Please contact the undersigned should you have any questions

Prepared By:



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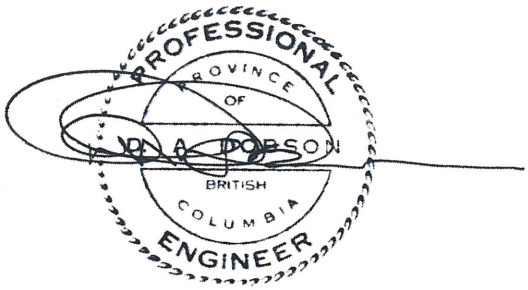

Don Dobson, P.Eng.
Senior Water Resources Consultant
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ddobson@dobsoneng.com

PROPOSED 2019 PARK RILL FLOOD RESPONSE PLAN

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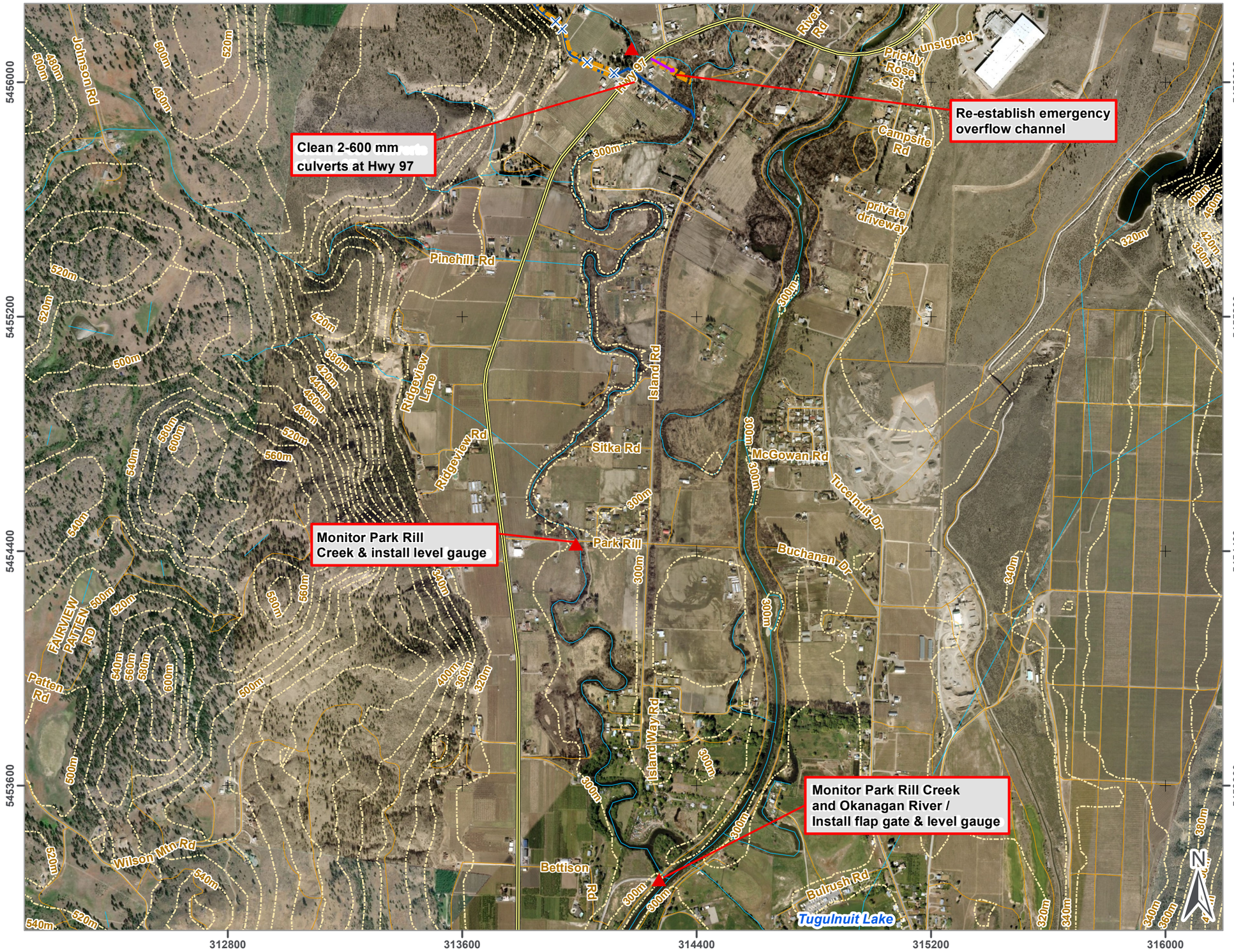


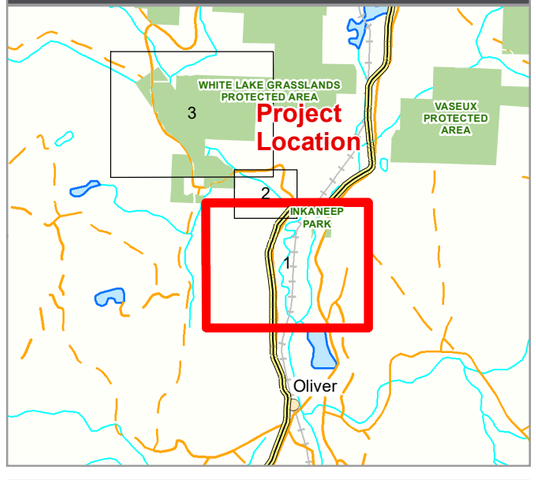
PARK RILL CREEK 2019 FLOOD RESPONSE PLAN
OLIVER, BC
STUDY AREA 1

Legend

- Access Location
- Monitoring Location
- Dam Locations
- Outlet Channel to Wetland
- Tiger Dams/Sandbags
- Current Alignment of Park Rill
- Digital Road
- Highways
- Fresh Water Atlas
- 20m TRIM Contours

DRAFT

LOCATION MAP



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Project No.: CP-18-568-RDO
Client: RDOS
NAD 1983 UTM Zone 11N

Date: 2018/11/16
Drawn: MT Check:

Figure 1.0

PROPOSED 2019 PARK RILL FLOOD RESPONSE PLAN

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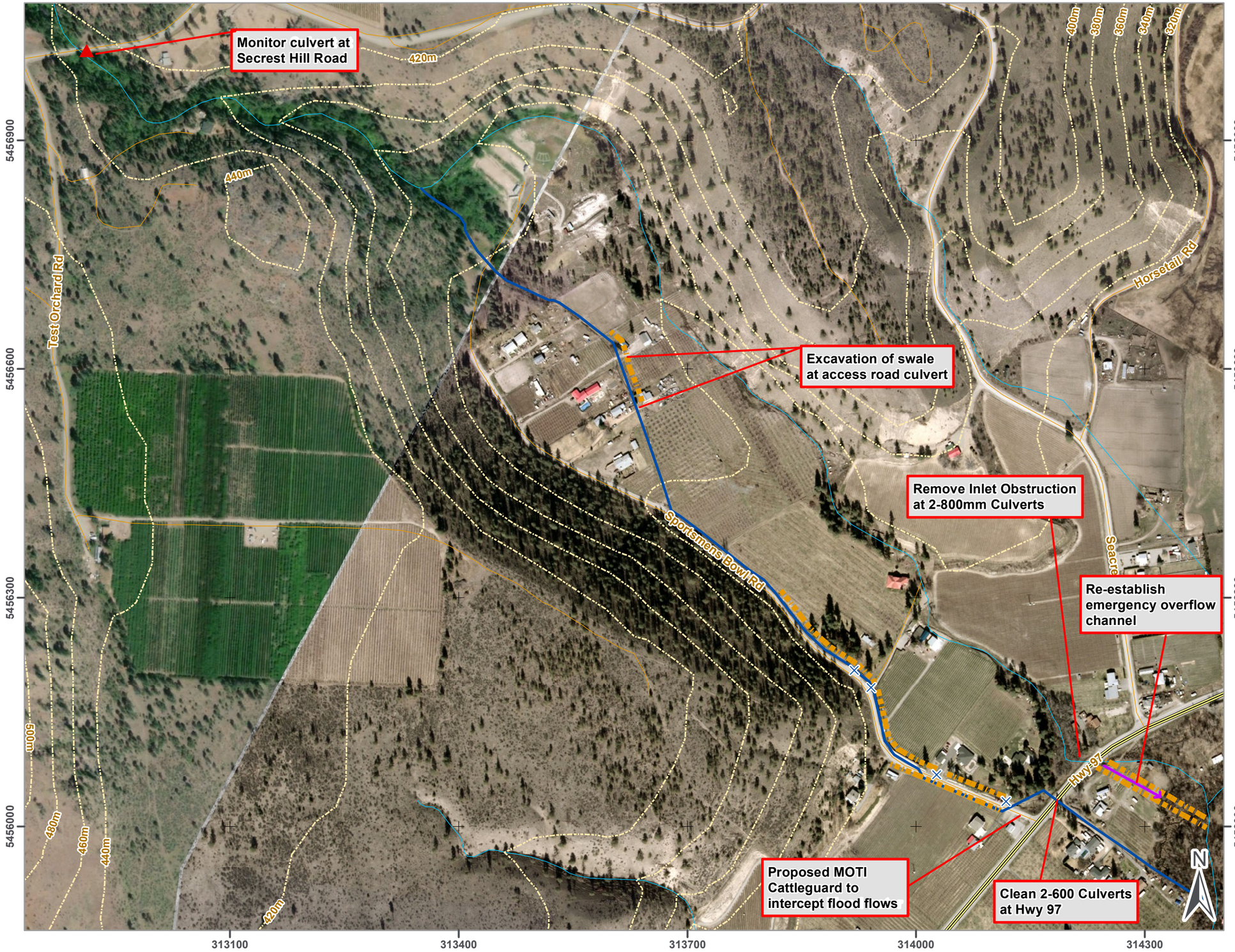


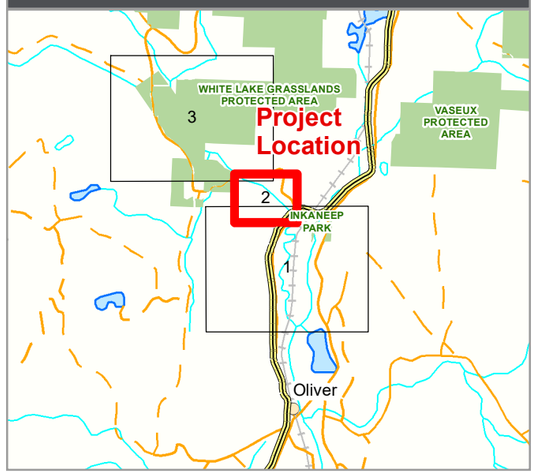
PARK RILL CREEK 2019 FLOOD RESPONSE PLAN
OLIVER, BC
STUDY AREA 2

Legend

- Access Location
- Monitoring Location
- Dam Locations
- Outlet Channel to Wetland
- Tiger Dams/Sandbags
- Current Alignment of Park Rill
- Digital Road
- Highways
- Fresh Water Atlas
- 20m TRIM Contours

DRAFT

LOCATION MAP



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Project No.: CP-18-568-RDO
Client: RDOS
Date: 2018/11/16
Drawn: MT Check:

NAD 1983 UTM Zone 11N

Figure 2.0

PROPOSED 2019 PARK RILL FLOOD RESPONSE PLAN

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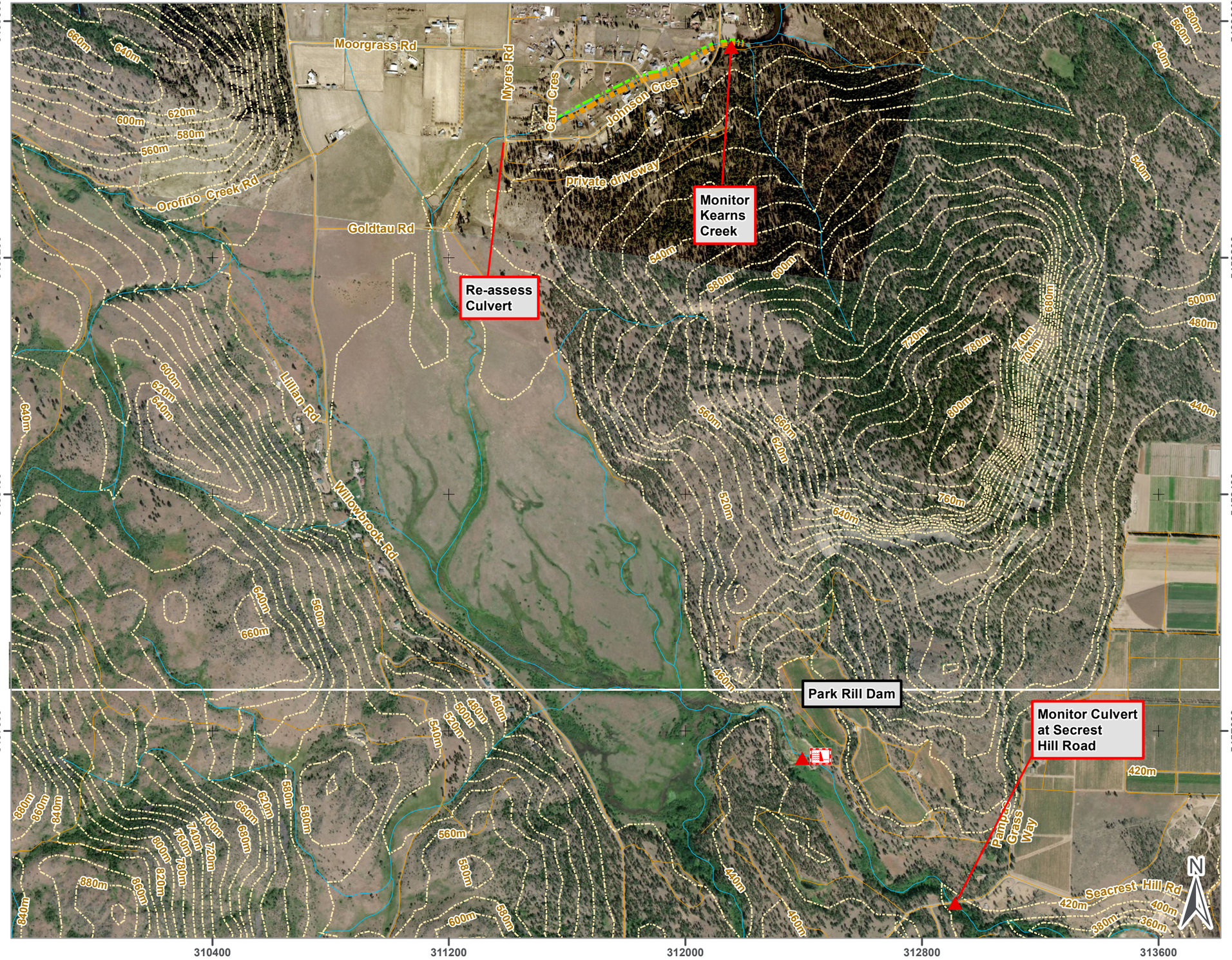


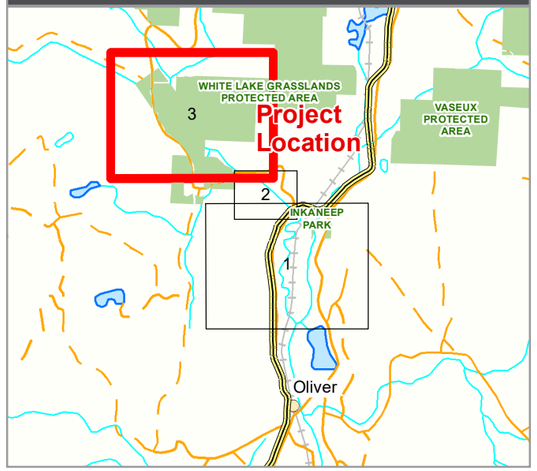
PARK RILL CREEK 2019 FLOOD RESPONSE PLAN
OLIVER, BC
STUDY AREA 3

Legend

- Crush Berm
- Monitoring Location
- Dam Locations
- Outlet Channel to Wetland
- Tiger Dams/Sandbags
- Current Alignment of Park Rill
- Digital Road
- Highways
- Fresh Water Atlas
- 20m TRIM Contours

DRAFT

LOCATION MAP



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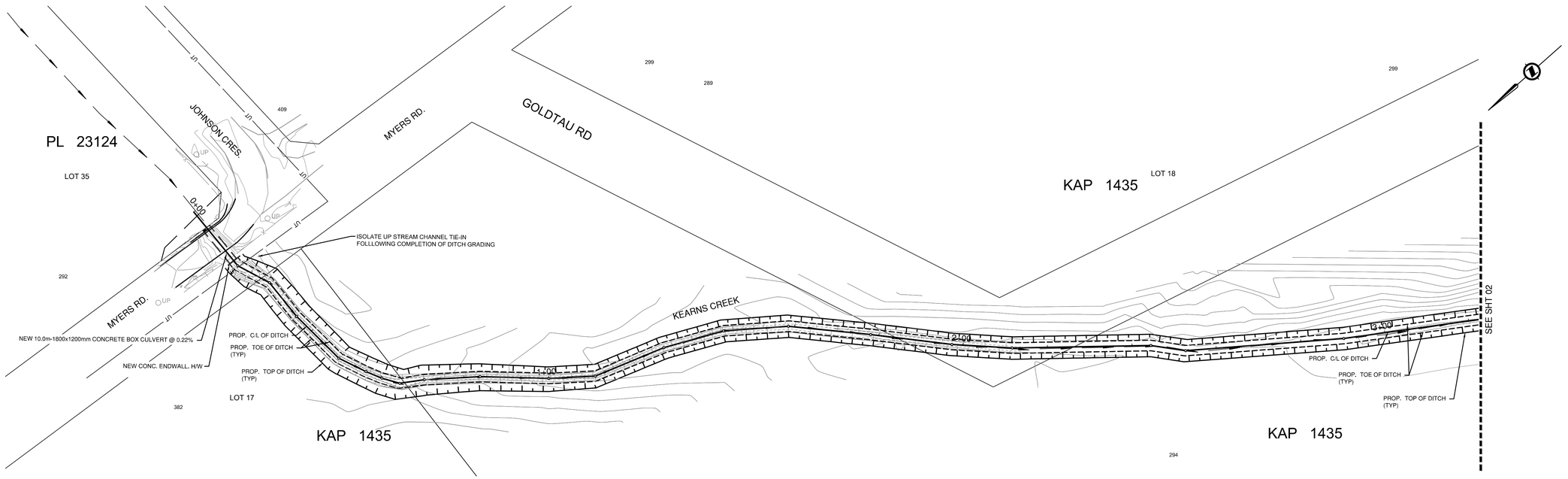
Project No.: CP-18-568-RDO
Client: RDOS
NAD 1983 UTM Zone 11N

Date: 2018/11/16
Drawn: MT Check:

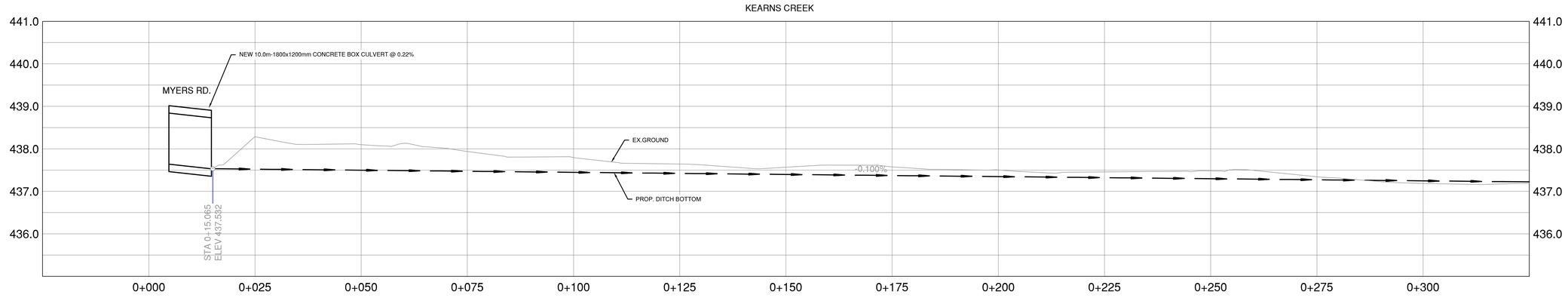
Figure 3.0

Appendix E

Myers to Goldtau Ditch Re-grade Design



DITCH RE-GRADING PLAN STA: 0+015 - 0+325
SCALE 1:500



DITCH RE-GRADING PROFILE STA: 0+015 - 0+325
SCALE 1:500H 1:50V

LEGEND

	PROP	EX
PROP. CULVERT		
PROP. DITCH		
EXIST. DITCH		
DITCH TOP/BOTTOM		
BERM LIMITS		
PROP. EASEMENT		
EOA		
WATER		
MANHOLE	●	○
CATCH BASIN		
WATER VALVE	WV	WV
CURB STOP	●	○
HYDRANT	FH	FH
IC	●	○
POWER POLE	P.P.	PP
LAMP STANDARD	L.S.	L.S.
DRYWELL	●	○

NO.	DATE (MM/DD/YY)	DRN	REVISION	CH'KD
1	04/04/2019	DH	ISSUED FOR APPROVAL	CP

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SEAL

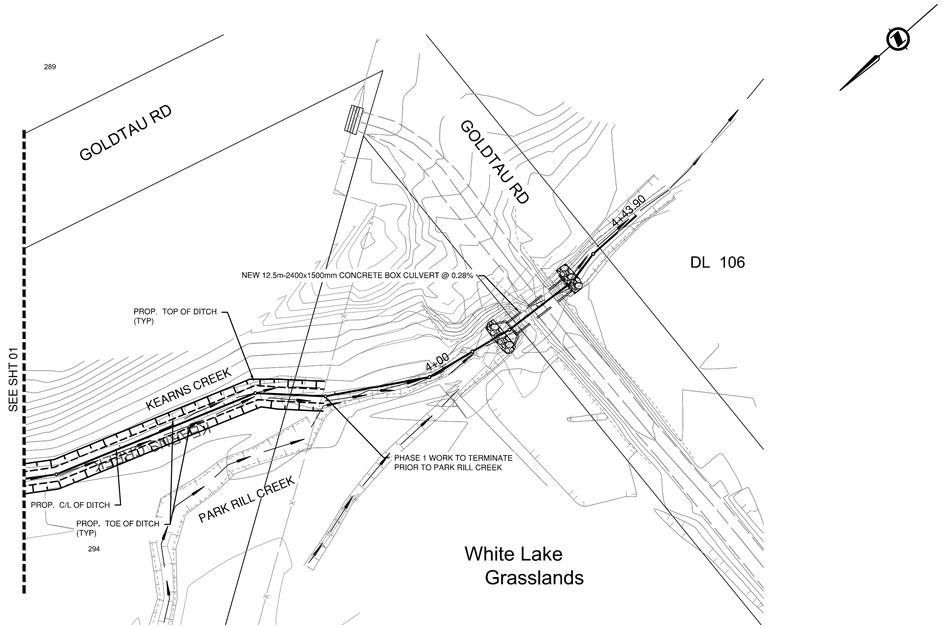
DESIGN:	SH
DRAWN:	DH
CHECKED:	CP
DATE:	04/04/2019
SCALE:	AS SHOWN

REGIONAL DISTRICT OKANAGAN-SIMILKAMEEN

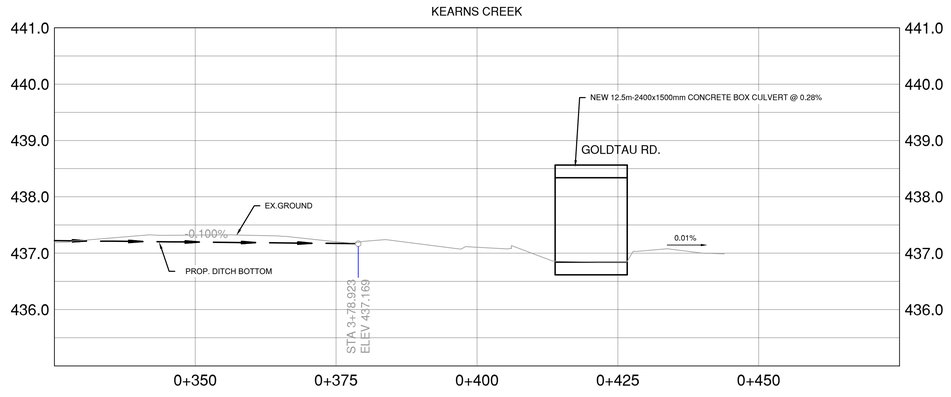
KEARNS CREEK RE-GRADING
MYERS RD. TO GOULDTAU RD.
PLAN & PROFILE

Drawing No. CP-18-568-P-02

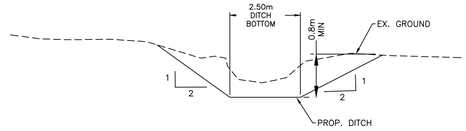
Rev.No 1



DITCH RE-GRADING PLAN STA: 0+325 - 0+405
SCALE 1:500



DITCH RE-GRADING PROFILE STA: 0+325 - 0+405
SCALE 1:500H 1:50V



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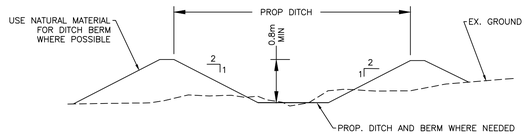

TYP. SECTION PROP. DITCH WHERE BERM REQUIRED
SCALE 1:100

LEGEND

	PROP	EX
PROP. CULVERT	MANHOLE	
PROP. DITCH	CATCH BASIN	
EXIST. DITCH	WATER VALVE	WV
DITCH TOP/BOTTOM	CURB STOP	
BERM LIMITS	HYDRANT	FH
PROP. EASEMENT	IC	
EOA	POWER POLE	P.P.
WATER	LAMP STANDARD	L.S.
	DRYWELL	

NO.	DATE (MM/DD/YY)	DRN	REVISION	CH'KD
1	04/04/2019	DH	ISSUED FOR APPROVAL	CP

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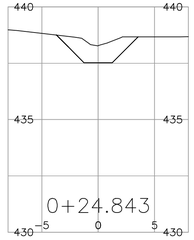
DESIGN:	SH
DRAWN:	DH
CHECKED:	CP
DATE:	04/04/2019
SCALE:	AS SHOWN

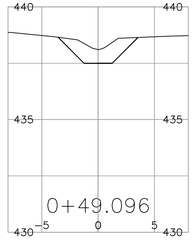
REGIONAL DISTRICT OKANAGAN-SIMILKAMEEN

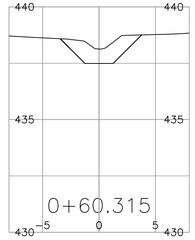
KEARNS CREEK RE-GRADING
MYERS RD. TO GOULDTAU RD.
PLAN & PROFILE

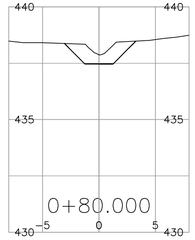
Drawing No. CP-18-568-P-02

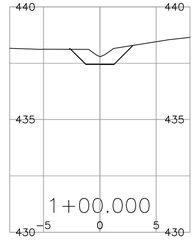
Rev.No 1

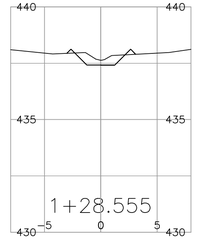


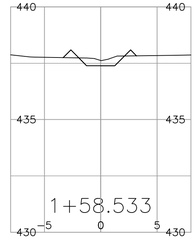


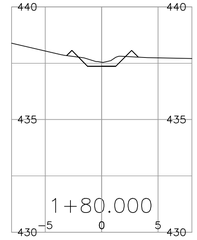


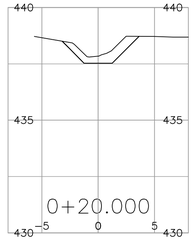


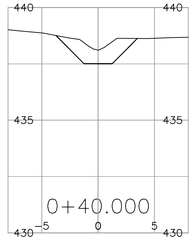


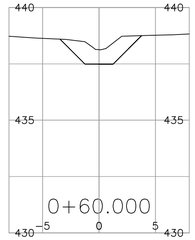


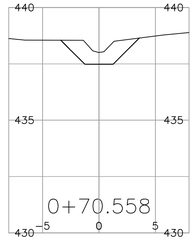


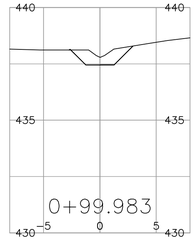


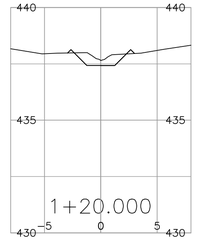


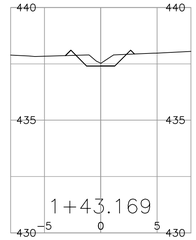


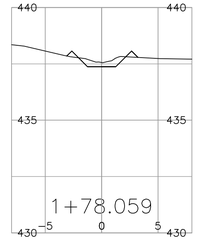


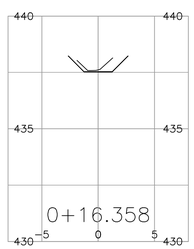


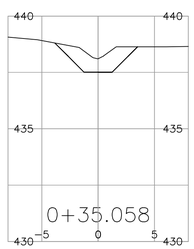


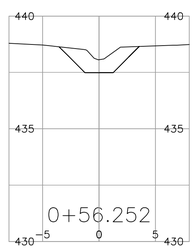


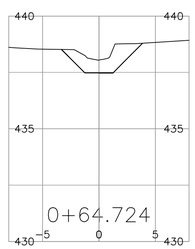


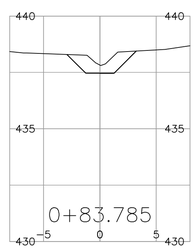


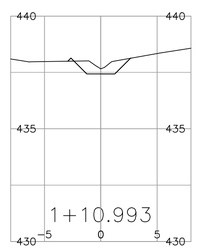


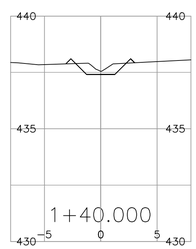


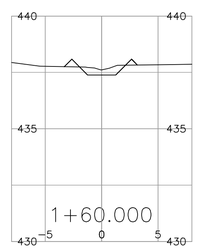












LEGEND

		PROP	EX
PROP. CULVERT	MANHOLE	●	○
PROP. DITCH	CATCH BASIN		
EXIST. DITCH	WATER VALVE		WV
DITCH TOP/BOTTOM	CURB STOP	●	●
BERM LIMITS	HYDRANT	FH	FH
PROP. EASEMENT	IC	●	●
EOA	POWER POLE	P.P.	PP
WATER	LAMP STANDARD	L.S.	L.S.
	DRYWELL		

NO.	DATE (MM/DD/YY)	DRN	REVISION	CH'KD
1	04/04/2019	DH	ISSUED FOR APPROVAL	CP

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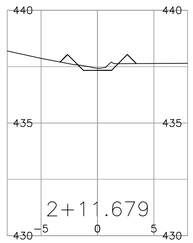
SCALE:	1:250

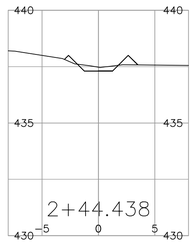
REGIONAL DISTRICT OKANAGAN-SIMILKAMEEN

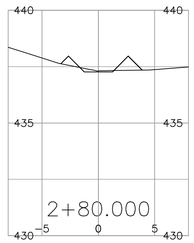
KEARNS CREEK RE-GRADING
MYERS RD. TO GOULDTAU RD.
SECTIONS

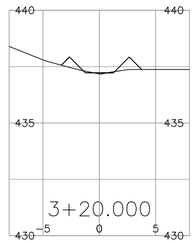
Drawing No. CP-18-568-P-03

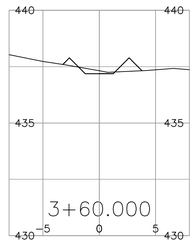
Rev.No 1

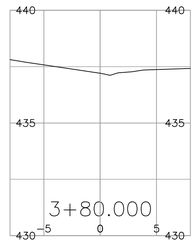


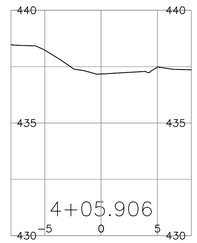


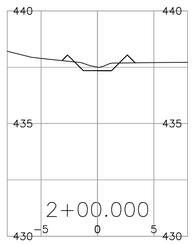


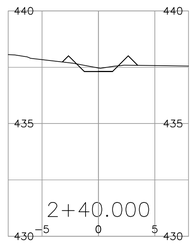


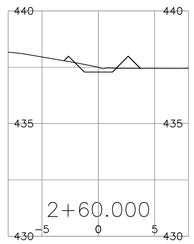


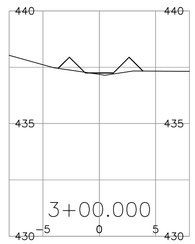


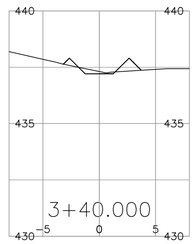


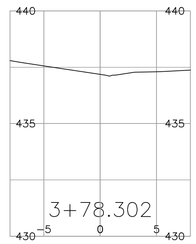


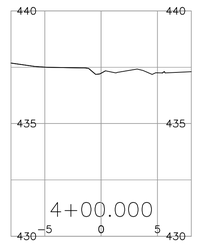


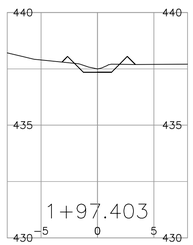


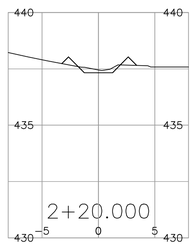


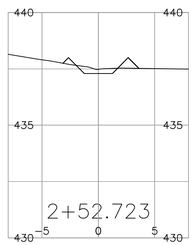


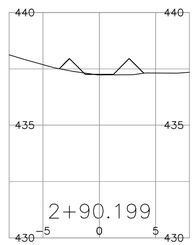


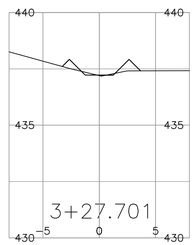


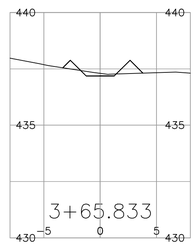


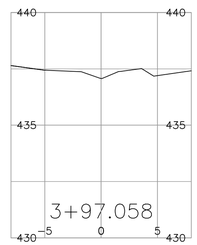












LEGEND

PROP. CULVERT
PROP. DITCH
EXIST. DITCH
DITCH TOP/BOTTOM
BERM LIMITS
PROP. EASEMENT
EOA
WATER

	PROP	EX
MANHOLE	●	○
CATCH BASIN		
WATER VALVE	⊗	⊗WV
CURB STOP	●	●
HYDRANT	●FH	⊗FH
IC	●	●
POWER POLE	●P.P.	●PP
LAMP STANDARD	□L.S.	□L.S.
DRYWELL	●	●

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REGIONAL DISTRICT OKANAGAN-SIMILKAMEEN

KEARNS CREEK RE-GRADING
MYERS RD. TO GOULDTAU RD.
SECTIONS

Drawing No.
CP-18-568-P-04

Rev.No
1

April 3, 2019 Ecora File No.: NF-19-123-KEX

Willowbrook Residents c/o Michelle Weisheit

Attention: **Michelle Weisheit – Chair of Willowbrook Water Advisory Committee**

Reference: **Kearns Creek Channel Re-grade – Myers Road to Park Rill Confluence near Goldtau Road**

1. Introduction

Ecora Engineering and Resource Group Ltd. (Ecora) was requested by Michelle Weisheit, on behalf of Willowbrook residents, to provide a design for the proposed Kearns Creek channel re-grading from downstream of Myers Road to the Park Rill confluence near Goldtau Road. In 2018, a concrete box culvert was installed under Myers Road to increase capacity of Kearns Creek; however, due to low existing Kearns Creek channel gradient, minimal cover on Myers Road and dimensions of the box culvert, the invert of the culvert was set significantly lower than the Kearns Creek downstream channel. For the recently upgraded box culvert to be fully utilized, the downstream channel requires re-grading to allow water to efficiently move through the system. This existing configuration results in a limitation to channel capacity, which in turn will create backwatering upstream through Willowbrook during a significant runoff event. Photos from March 22 and 25, 2019, attached at the end of this report, indicate that localized ponding of water within the culvert area has been observed this year, and Willowbrook flooding may be exacerbated if the channel downstream is not re-graded and reshaped. Channel re-grading will allow the full capacity of the Myers Road culvert to be utilized, thereby increasing overall Kearns Creek channel capacity which will reduce flood potential in Willowbrook. This letter report addresses the design of channel re-grading and environmental recommendations for the proposed construction.

2. Channel Capacity

2.1 Survey

Ecora carried out a survey of the existing channel from the outlet of the Myers Road culvert to just downstream of Goldtau Road. Results of the survey indicated the following:

- The Myers Road culvert outlet invert elevation is approximately 0.75 m below the Kearns Creek channel bed elevation immediately downstream from the culvert;
- The slope of the existing channel is generally reverse graded for the first 50 m downstream of the Myers Road culvert; and,
- The length of the channel between Myers Road and Goldtau Road is approximately 365 m with an elevation difference of 0.68 m, which is equal to a slope of approximately 0.19%.

The dimensions of the culvert at Myers Road are estimated to be 1800 mm x 1200 mm.

2.2 Estimated Discharge

Based on hydrology analysis completed for the Park Rill Creek watershed, regional analysis results using available nearby Water Survey of Canada stations can be used to derive the estimated 1 in 100-year maximum daily flow for Kearns Creek.

The 1 in 100-year annual maximum daily flow estimate for Kearns Creek at the project area, corresponding to a drainage area of 43.3 km^2, is 2.04 m^3/s. The effect of climate change was also considered by adding a factor of 10% to the peak flow in accordance with current Engineers and Geoscientists BC recommendations. The resulting 1 in 200-year peak flow estimate for the channel is therefore 2.24 m3/s.

2.3 Channel Slope and Geometry

A simple hydraulic capacity model was carried out using the U.S. Department of Transportation Federal Highway Administration's software Hydraulic Toolbox using an estimated slope 0.1% and a Manning's n value of 0.030, suitable for clean, straight channels. A bottom width of 2.5 m was chosen based on the culvert span with side slopes of 2 horizontal to 1 vertical (2H:1V).

Based on the estimated discharge, the depth of water for 1 in 200-year event is 0.8 m. Minimal infrastructure is located adjacent to the creek along the project reach and therefore minimal to no freeboard is expected to be required along this channel.

The proposed design for the channel is therefore a trapezoidal channel with a bottom width of 2.5 m, sides slopes of 2H:1V, a depth of 0.8 m, and a constant slope of 0.1%. Cross-sections taken during the survey indicate that the original ground elevations along the channel reach may not be adequate to achieve a channel depth of 0.8 m. In these areas, excavated material will be used to build channel berms such that a 0.8 m channel depth is constructed.

Design drawings for the proposed channel re-grading are attached.

3. Environmental Recommendation

3.1 Construction Timing

It is understood that the proposed channel re-grading and reshaping will be carried out when the Kearns Creek channel is dry. At the time of this report, the project reach is dry and construction is proposed to start as soon as possible, based on receipt of a Section 11 approval from the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD). Ecora and Michelle Weisheit have been in contact with Yi Li, P.Eng., from MFLNRORD to discuss this project and the Section 11 approval. It is expected that construction is not possible if the creek is flowing due to the following restrictions:

- Diversion requirements to re-direct flow around the work area, which would be costly; and,
- Fish potential – Ecora's experience in this area indicates that fish have previously been observed in Kearns Creek. If water is flowing through this channel reach, fish may be present and proper isolation and fish salvage will be required, which will require a fish permit and would delay construction.

3.2 Best Management Practices

At this time, the proposed channel re-grade and reshape will be carried out to reduce flood potential in Willowbrook as part of flood preparation planning. It is understood that additional work will be required to rehabilitate the channel such that it is adequate from an environmental perspective in terms of fish habitat and vegetation and that additional studies may be required for this purpose. If required, rehabilitation work would be carried out following the 2019 freshet.

Channel construction will need to be environmentally managed such that it does not have a detrimental effect downstream at Park Rill Creek. The following best management practices, from the BC Ministry of Environment's Standards and Best Practices for Instream Works, should be adhered to:

- A Qualified Environmental Professional (QEP) should be consulted prior to, and if required, during construction to mitigate environmental concerns;
- Ensure that equipment and machinery are in good operating condition, clean, free of leaks, excess oil, and grease. Refueling must occur at least 30 m of the watercourse;
- Remove excavated material and debris and place in a stable area away from the watercourse (unless it is being used for the channel berm);
- Use mitigative measures to protect excavated material from being eroded and re-introduced into the watercourse;
- Minimize the disturbance area by limiting access activities along the construction reach; and,
- Restore disturbed areas to pre-construction condition or better.

The upstream end of the channel nearest Myers Road should remain isolated such that Kearns Creek flow cannot enter the construction reach. This may be achieved by blocking off the channel reach using poly-lined sand bags or pre-cast concrete blocks. The upstream end of channel construction should be completed last when the remaining downstream reach has been reviewed by a QEP to approve flow release into the channel.

Based on observations of Kearns Creek, flows from summer through spring are generally low and slow through this channel reach and there is minimal potential for erosion. The current creek consists of lightly vegetated channel with exposed soil. During freshet, flow velocities are expected to be high enough that even with the existing light vegetation, the channel will experience erosion and sediment generation. Therefore, channel re-grading and reshaping are not anticipated to significantly change the amount of sediment entering Park Rill Creek from Kearns Creek. In addition, sediment entering Park Rill Creek is settled out naturally by the flat, undefined area in Myers Flat just downstream of Goldtau Road.

4. Downstream Impact

In 2018 and 2019, the BC Ministry of Transportation and Infrastructure (MOTI) upgraded numerous culverts in the Park Rill Creek watershed that were observed to be undersized during the 2018 freshet. These upgrades were completed to improve overall watershed drainage and reduce flooding upstream of culverts and allow the creeks to convey water as they would naturally in the absence of anthropogenic infrastructure. Because the culverts are now appropriately sized, it is expected that higher peak flows, unrestricted by culvert capacities, will enter Myer's Flats just downstream of Goldtau Road which would be considered the natural hydraulic regime for the Kearns watershed.

The proposed re-grading of Kearns Creek downstream of Myers Road will not change the hydraulic regime of Kearns creek beyond the loss of the initial attenuation that occurs as a result of the backwater at Myers Road. Once the water behind Myers Road is able to build up the necessary hydraulic grade line to route all incoming flood waters, the inflows and outflows in Kearns Creek, within Willowbrook will be the same, ignoring any minor losses

to groundwater. Considering this, the downstream impact is considered minimal and the benefit is alleviation of flooding for Willowbrook residents. Due to the low gradient on both Park Rill Creek and Kearns Creek, it is likely there will be some ponding at the inlet of the Goltau Road culvert, but the capacity of the culvert has been upgraded to handle a 1 in 100-year event for both creeks. Downstream of Goldtau Road, Myers Flats within BC Parks provides considerable attenuation for freshet flows.

5. Closure

We trust this letter meets your present requirements. If you have any questions or comments, please contact the undersigned.

Sincerely

Ecora Engineering & Resource Group Ltd.

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Geotechnical and Hydrotechnical Consultant
Sarah.Nhan@ecora.ca

Caleb Pomeroy, P.Eng., PMP
Civil/Hydrotechnical Engineer
Caleb.Pomeroy@ecora.ca

Attachment: Site Photos from Michelle Weisheit – Received April 2, 2019
Design Drawings

Site Photos (Received from Michelle Weisheit on April 2, 2019)

Kearns Creek at Myers Road culvert - view from upstream (flow goes from right to left). March 22, 2019.

Pooling just downstream of the Myers Road culvert where flow is currently obstructed. March 22, 2019.

Looking upstream at the Myers Road outlet – water appears to seep into the ground. March 22, 2019.

Looking upstream at Myers Road outlet – water has seeped into ground and the area is now dry. March 25, 2019.