Duncan Dam Project Water Use Plan

Lower Duncan River Argenta Slough Erosion Protection

Reference: DDMWORKS-01

2013 Argenta Slough Assessment Study

Study Period: August 20, 2013

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November 29, 2013

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Technical Memorandum

DATE: November 29, 2013

TO: Philip Bradshaw, BC Hydro

CC: Margo Dennis, BC Hydro

FROM: Erica Ellis, M.Sc., P.Geo.

RE: **2013 ARGENTA SLOUGH ASSESSMENT**
Final Report
Our File 0478.162-300

1. Introduction

Argenta Slough is located on the floodplain of the Duncan River, near an actively-eroding meander bend, close to the river's outlet at Kootenay Lake (Figure 1-1). Kerr Wood Leidal Associate Ltd. (KWL) was retained by BC Hydro (BCH) to provide an updated assessment of the potential impacts to the slough in the event that the erosion should break through the high ground immediately adjacent to the river.

The following questions have been posed by BCH:

1. Will a breach through the high ground adjacent to the river (i.e., at Argenta Bend) result in increased flow into Argenta Slough (i.e., overland flow northwards) such that flow from the Duncan River, on its own or in conjunction with high levels of Kootenay Lake, will:
   a) inundate the Argenta Slough to a water level that will flood new areas that are not normally flooded by hydrological fluctuations of the Argenta Slough, such areas with riparian vegetation or areas used for nesting by Western Painted Turtles; or
   b) create new flow patterns that would flood and then drain the Argenta Slough with the rise and fall of water levels in the Duncan River and Kootenay Lake?
2. Could any potential increased flow into the slough be mitigated by reinforcing the existing, remnant berms (locally referred to as "beaver dams") located near the south end of the slough?
3. If the breach has not already occurred, would there be any benefit to the slough if a deliberate breach were engineered at a more southerly location?

Based on our conversations with BC Hydro, it is our understanding that Argenta Slough provides Western Painted Turtle nesting habitat, as well as habitat for nesting birds, and that both these populations would potentially be vulnerable to changes in overland flow patterns and increased flooding.

The following technical memorandum summarizes our assessment.

2. Background Data

2.1 Topography

Topographic data were obtained from BC Hydro to characterize the floodplain elevations at and surrounding the slough. The most recent topographic for the Argenta Slough area was obtained in 2012; however, these data were collected under relatively high-water conditions, leaving gaps in the ground elevations where the land was under water. 2008 topography was collected under lower-water conditions, although the primary data source was photogrammetry rather than LiDAR, which yields a lower density of ground elevation points. Where there was spatial overlap between the 2008 and 2012 data, a comparison was made of the ground elevations to evaluate whether the data sets appeared to be comparable and could be used together. However, the comparison indicated relatively large elevation differences (> ±1 m) in certain areas and therefore it was decided to base the analysis solely on the 2008 topography data.

2.2 River Discharge and Lake Level

Discharge and lake level data were obtained from Water Survey of Canada. Stations are summarized in the following table.

Table 2-1: WSC Discharge and Lake Level Stations

Station	Period of Record	Notes
WSC 08NH118 Duncan River Below Lardeau River	1963 – present	• Data available up to 2011 • Drainage area = 4,070 km²
WSC 08NH064 Kootenay Lake at Queens Bay	1931 – present	• Data available up to 2012 • 1928 vertical datum

2.3 Argenta Slough

Argenta Slough is a long watercourse located on the very east extent of the Duncan River floodplain, running almost parallel to Argenta Road, as shown on Figure 1-1. Argenta Slough appears to be the receiving waters for the local mountainside tributaries; however, the origin of the channel may be associated with a former floodplain channel from Duncan River. The total length of Argenta Slough is more than 1.7 km, and the area of concern for this study involves the lower 800 m or so.

There are a number of earthen berm control structures along Argenta Slough that were constructed to increase annual water depths and area. These berms in the study area are no longer maintained, but some of the structures in the northern slough area may still maintained by land owners. In the study area the slough is more of a channel feature, relatively narrow with an observable velocity throughout. Upstream of the three berms in the study area, the slough is much more a series of large ponds, with a much larger habitat potential (i.e., water area, depth, and longer perimeter/fringe area).

3. Overbank Flooding Assessment

3.1 Seasonal River Flow and Lake Level Regime

Argenta Slough is located near the outlet of Duncan River at Kootenay Lake. As such, water levels in the river adjacent to the slough are sensitive both to discharge but also to lake level. Kootenay Lake is regulated by Libby Dam, which was constructed in 1972. Duncan River flow at the mouth of the river is partially regulated: about half of the upstream drainage area is impounded by Duncan Dam (constructed in 1967).

Average Duncan River flow and Kootenay Lake level are shown on Figure 3-1, for the post-regulation period. As indicated in the figure, lake levels begin to rise in May and peak, on average, in June, and then begin to fall in July. Peak discharge tends to lag behind peak lake water level, with the annual freshet occurring in July or August. The following table summarizes average monthly discharge and lake level for summer months.

Table 3-1: Average Discharge and Lake Level for Summer Months

Month	Average Discharge[1] (m^3/s)	Average Lake Level[2] (m)
May	171	531.5
June	239	532.5
July	278	532.05
August	274	531.6

Notes:
1. Discharge scaled to represent drainage area at mouth (4,750 km^2).
2. 1928 vertical datum.

3.2 Ground Topography

As shown in Figure 1-1, Argenta Slough is located along the eastern margin of the Duncan River floodplain and is roughly 2 km long. Surface flow enters the slough from the adjacent eastern hillslope, and groundwater inputs are possible, but unknown. The outlet of the slough is to Kootenay Lake. The slough is intersected along its length by a number of remnant berms that were constructed likely as water management structures for agricultural development. One of the structures located about 300 m upstream of the eroding bend includes a culvert.

These structures act to control water levels in the slough, although they have varying degrees of effectiveness at retaining water, as they are no longer maintained. Water retention is generally achieved due to woody debris blockages on the low side of the berms. At high lake levels, the floodplain and the slough are completely under water, and the berms are overtopped.

Figure 3-2 shows ground elevations at a cross-section cut through the eroding bend of the Duncan River, and extended east across the slough. The high ground adjacent to the eroding bend has a maximum elevation of about 534.5 m. Should this portion of the bank be eroded, the ground behind has an elevation of about 532.5 m.

3.3 Field Visit

A one-day field visit was conducted on August 20, 2013 by David Matsubara (KWL) and Brenda Thomas (BCH-Castlegar). The field visit was used to collect site observations and confirm ground elevations at key locations around Argenta Slough.

Based on data obtained from the BCH website, lake level at the time of the visit was about 531.45 m, and discharge at the Duncan River below Lardeau station was about 224 m^3/s. These values are slightly below average conditions for both discharge and lake level.

Observations made during the field visit include:

- The lower slough and floodplain area are all situated in a large floodplain channel (bounded by the 534 m contour on Figure 4-1), and the contemporary slough is further incised into the feature;
- The large floodplain channel has been inactive for some time and may have been closed off with some man-made intervention as the head of the channel at the Duncan River channel could not be easily located in the field without entering private property;
- There were a total of three berms across the slough channel that maintain water levels (Figure 4-1) downstream in the lowest reach of slough near the eroding bend;
- The berms are relatively narrow, are no longer maintained, and are affected by wood debris accumulation on and around the structures. These berms can be crossed on foot, but would need upgrading for any other access or work;
- The Duncan River, Argenta bend, has further eroded, but has not yet broken through the area of higher ground. At the narrowest location the area of high ground was between 1 m and 2 m wide, and a distinct lower/incised spill location was noted near the end of curve (based on the 2012 aerial photo) at an elevation of about 534.4 m. It did not appear as though river discharge had passed over this area in 2013;
- The erosion at the Argenta bend is somewhat non-uniform with recent erosion at the upstream end, and further erosion near the downstream end, resulting in current two pockets of erosion;
- The low-lying area behind the high ground was wetted and supported a substantial number of small (2 cm to 3 cm) and some larger (7 cm to 10 cm) frogs. This area appears to offer habitat to amphibians; and
- The slough area downstream of Berm 1 appears to have relatively deep areas that persist through the year. The slough area between Berm 1 and 2 was quite broad but generally shallow, and appears to be transitory. The slough area between Berm 2 and is quite short and narrow, but deeper in nature, and the areas upstream of Berm 3 appear to be the highest quality for water depth and width.

Field observations were logged using a metre-accuracy (1 to 5 m horizontal) GPS unit, and elevations were collected using a laser grading level at GPS observation points. Approximate absolute observations were based on comparison to survey points collected as part of DDMWORKS #1, and compared against aerial mapping contours, which agreed quite well. Relative elevations are centimeter (1 cm to 2 cm) accuracy.

3.4 Hydraulic Model

KWL has developed a one-dimensional (HEC-RAS) hydraulic model of the lower Duncan River for a previous BCH project (DDMWORKS #1). This model represents the downstream-most 3.5 km of the river, terminating at Kootenay Lake (Figure 3-3). Within this reach there are multiple secondary and distributary channels that carry flow; these are represented in the model as lateral weirs that convey flow once the water level exceeds the ground elevation estimated to represent the channel entrance invert.

The hydraulic model was used to estimate the river water level at the eroding bend for different discharge and lake level conditions. Monthly average conditions for May through August (Table 3-1) were simulated first.

At high lake level the lake elevation governs and the floodplain and slough are completely inundated by the lake. However, the concern with respect to the eroding bend is for overland flooding resulting solely from Duncan River flow: high river discharge but low lake level. Based on the topography at the eroding bend, river levels would need to exceed about 532.5 m for overland flooding to occur once the higher ground adjacent to the channel has been eroded.

Model results for summer average month conditions are summarized in Table 3-2. Only the June scenario resulted in a modelled water level that was equal to 532.5 m; water levels in all other monthly average scenarios were lower. The modelling results also suggest that the discharge input results only in a small increase in water level above the lake level.

Table 3-2: Modelled Water Level At Duncan River Eroding Bend For Summer Month Scenarios

Month	Average Discharge[1] (m^3/s)	Average Lake Level[2] (m)	Modelled Water Level[3] (m)
May	171	531.5	531.6
June	239	532.5	532.5
July	278	532.05	532.06
August	274	531.6	531.7

Notes:
1. Discharge scaled to represent drainage area at mouth (4,750 km^2).
2. 1928 vertical datum.
3. Results at HEC-RAS XS 3.

The sensitivity of water level at the eroding bend to different lake and discharge scenarios was investigated further using the hydraulic model. The goal of the modelling was to assess, at a range of typical summer lake levels, the impact of larger flows on river water level. The flood series presented in M. Miles and Associates (2002[1]) was selected for modelling, ranging from a 2-year return period (523 m^3/s) to 200-year return period (1,047 m^3/s).

Results of the peak flow modelling exercise are summarized in Table 3-3.

[1] M. Miles and Associates, 2002. Channel Stability Assessment Lower Duncan River. Report prepared for BC Hydro. 27 pp + figures, tables and appendix.

Table 3-3: Modelled Water Level At Duncan River Eroding Bend[3] For Peak Flow[1] Scenarios

Lake Level[2] (m)	Q_2 523 m^3/s[1] Modelled Water Level[3] (m)	Q_5 641 m^3/s[1] Modelled Water Level[3] (m)	Q_{10} 719 m^3/s[1] Modelled Water Level[3] (m)	Q_{50} 894 m^3/s[1] Modelled Water Level[3] (m)	Q_{100} 970 m^3/s[1] Modelled Water Level[3] (m)	Q_{200} 1047 m^3/s[1] Modelled Water Level[3] (m)
531.5	531.77	531.83	531.88	531.99	532.04	532.09
532	532.06	532.1	532.12	532.19	532.22	532.26
532.5	532.51	532.52	532.52	532.55	532.56	532.58

Notes:
1. Peak flow discharges from Miles (2002).
2. 1928 vertical datum.
3. Results at HEC-RAS XS 3.

As indicated in Table 3-3, the addition of increasingly large river flows has a modest effect on the water level at the eroding bend. At a lake level of 531.5 m, increasing discharge from the Q_2 to the Q_{200} results in a water level increase of only 0.32 m (a maximum change for a doubling of the discharge). Also, as the downstream lake level is increased, the river level response is increasingly damped such that there is only a 0.07 m change in water level from Q_2 to Q_{200}.

4. Results

The following sections address the management questions presented in Section 1.

4.1 Question 1

Will a breach through the high ground adjacent to the river (i.e., at Argenta Bend) result in increased flow into Argenta Slough (i.e., overland flow northwards) such that flow from the Duncan River, on its own or in conjunction with high levels of Kootenay Lake, will:

a) inundate the Argenta Slough to a water level that will flood new areas that are not normally flooded by hydrological fluctuations of the Argenta Slough, such areas with riparian vegetation or areas used for nesting by Western Painted Turtles; or

b) create new flow patterns that would flood and then drain the Argenta Slough with the rise and fall of water levels in the Duncan River and Kootenay Lake?

The low level floodplain area adjacent to the Argenta bend is at about 532.5 m elevation. This area is bounded at the upstream by ground at about 533 m and would naturally drain to the south towards Kootenay Lake. Once the Duncan River breaks through, the channel level will initially be limited to water levels at about 532.5 m.

The hydraulic modelling indicates that it is relatively difficult to generate a 'high flow/low lake level' scenario that would result in water levels greater than 532.5 m, and therefore overland flooding at the eroding bend. The only modelled scenarios with river levels greater than 532.5 m were ones in which the downstream lake level was set to 532.5 m already, implying that lake water would have flowed northward into the slough and inundated the floodplain up to that elevation. As shown in Table 3-3, the addition of Duncan River peak flow on top of this boundary condition results in relatively little increase in river level, and therefore little hydraulic gradient to drive overland flows northward.

Figure 4-1 shows the floodplain topography between the river and the slough, with low areas (between 531.75 m and 533 m) highlighted in pink. As indicated, from the eroding bend the existing floodplain topography would tend to route overland flow toward the south-east, into the southern portion of the slough and from there back to the lake. Therefore, this low area could potentially see river-related overland flooding as a result of erosion of Argenta Bend. These low areas are already seasonally inundated when the lake level exceeds 531.75 m, but the river-caused flooding could potentially occur at lower lake levels. However, based on our understanding of the project, the area of greatest habitat concern and potential vulnerability to overland flooding is the ponded area to the north/north-north-west of the eroding bend (indicated on Figure 4-1), and not this lower elevation area.

The "ponded area" is between 533 m and 534 m in elevation. In general, a comparison of modelled river water elevations and the ground topography indicates that floodwaters are unlikely to reach the ponded area, since even Q_{200} modelled water levels did not exceed 533 m.

Although the slough channel appears to provide a potential hydraulic connection that could route overland flow northward into the pond, field observations of the three berms on the slough suggests that these structures would tend to block flow conveyance northward.

The following water surface elevation differences between upstream and downstream were measured during the field visit:

- Berm 1: 0.1 m difference;
- Berm 2: 0.4 m difference; and
- Berm 3: 0.27 m difference.

The low level overflow at Berm 1 is estimate to be about 532.85 m.

Based on the fieldwork and evaluation of water levels:

1. River discharge or lake levels would have to exceed 533.5 m to inundate above Berm 3;
2. Highest deposition of woody debris exceeds 534 m in the area of Berm 3;
3. The maximum lake operating level 536.4 m, while the higher of the lake levels during freshet are about 533 m; and
4. Below Berm 1 the water levels are about 532.75 (versus a lake level of 531.45 m), and would be only influenced by discharges occurring on typical June lake level, but would be dominated by lake backwater.

Consequently, the most likely evolution of the floodplain due to the erosion will be overtopping and widening of a breach at the bend only to a level of 532.5 m (base elevation). This breach could result in some lateral erosion in the narrow section of overland flood route (Figure 4-1), and deposition of eroded soil in the lower reaches of the slough. This breach will likely only be active for a short period annually in June and could result in backwatering upstream of Berm 1. A flushing flow upstream of Berm 1 is not expected at this time, and no effect above Berm 2 is foreseen.

If the bend migration continues, eventually the Duncan River could breach Berm 1 (over a period of decades), the upper slough would drain into the Duncan River directly, and the lower slough would be cut off. Mitigation of such an event would be costly and not required for some time.

In the shorter term, floodplain flow could degrade the quality of the downstream slough habitat through sediment deposition or increased conveyance and less perennial slough area.

None of the effects of the erosion and floodplain flow will change the dominant lake backwater effect which inundates the areas downstream of Berm 3 annually.

4.2 Question 2

Could any potential increased flow into the slough be mitigated by reinforcing the existing berm located near the south end of the slough?

The downstream-most remnant berm (Berm 1) appears to be the least hydraulically-effective structure of the three berms reviewed in the field. The effectiveness of this structure could be improved by augmenting and reinforcing the existing material; however, it should be noted that modifications to prevent flow northwards could also affect water levels and the passage of water southwards.

We understand from BC Hydro that D.L. 7828, the approximate boundaries of which are shown on Figure 4-1, is private property and no works could be constructed on this parcel. However, the Crown Land to the east, and the property recently acquired by a Provincial Land Conservancy (also shown on Figure 4-1) are both areas on which works could be constructed.

Improvement of Berm 1 could benefit the upstream habitat, providing more perennial slough channel, and could reduce the duration of backwatering by raising the structure to about 533 m, and providing a controlled overflow weir and/or low level culvert.

As well, the lateral ground downstream of Berm 1 between the slough and the river could be raised slightly (about 1 m – lateral berm) to better separate the potential overland flow and existing slough areas. This would have limited applicability and could be feasibly constructed for 100 m to 150 m to contain and separate the areas. The type of structure could be on the order of 4 m wide and 1 m high (a total of 8 to 10 m^3/m) or between about 1,000 m^3 and 1,500 m^3.

In order to construct these works we anticipate a cost to access the sites (including clearing) of up to $10,000, upgrades to Berm 1 ($5,000), and the lateral berm construction in the order of $20,000 to $30,000 depending on material sources.

There would be incremental benefit for constructing the downstream berm.

4.3 Question 3

If the breach has not already occurred, would there be any benefit to the slough if a deliberate breach were engineered at a more southerly location?

If desired, an engineered breach located somewhat to the south of the bend, in conjunction with an excavated overland channel and berm, could be constructed to more deliberately route overland river flow southward, back to the slough channel. This would have the advantage of providing a greater degree of control over the route taken by overland floodwaters, and could provide the option to isolate a greater degree of the southern slough from the effects of the overland flooding. However, the construction is likely to have an associated disturbance that would have to be weighed against the potential benefit.

An engineered breach would not vastly improve habitat or provide substantially more protection to the slough. If the work described in Question 2 where undertaken, excavating a breach would not be excessively expensive (likely $5,000 to $7,000 once on-site), and the material would be then used for the adjacent berm resulting in a cost savings.

5. Closure

The work conducted finds that the large and deep slough areas upstream of Berm 3 are only affected by very high Kootenay Lake levels, and would not be affected by the Duncan River breaching to the floodplain at the eroding bend. The downstream section of slough between Berm 1 and 3 is of moderate quality and could be improved (e.g. higher depths) with upgrades at Berm 1. The slough area downstream of Berm 1 is at most risk to possible degradation associated with a river breach, and could be protected to some degree by further separating the two areas with a long north-south lateral berm.

In the event that no mitigative work is conducted at this site, no dramatic change to any of the slough areas (even downstream of Berm 1) is foreseen for the immediate future.

We trust that the work summarized herein usefully addresses the management questions posed by BC Hydro at the outset of this project. Do not hesitate to contact the undersigned should you have any questions regarding this assessment.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

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Nov. 29, 2013

Erica Ellis, M.Sc., P.Geo.
Fluvial Geomorphologist

Reviewed by:

PROFESSIONAL PROVINCE OF D. T. MATSUBARA #27759 BRITISH COLUMBIA ENGINEER

Nov 29, 2013

David Matsubara, M.Eng., P.Eng.
Project Manager

EE/sk

Encl.

Statement of Limitations

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This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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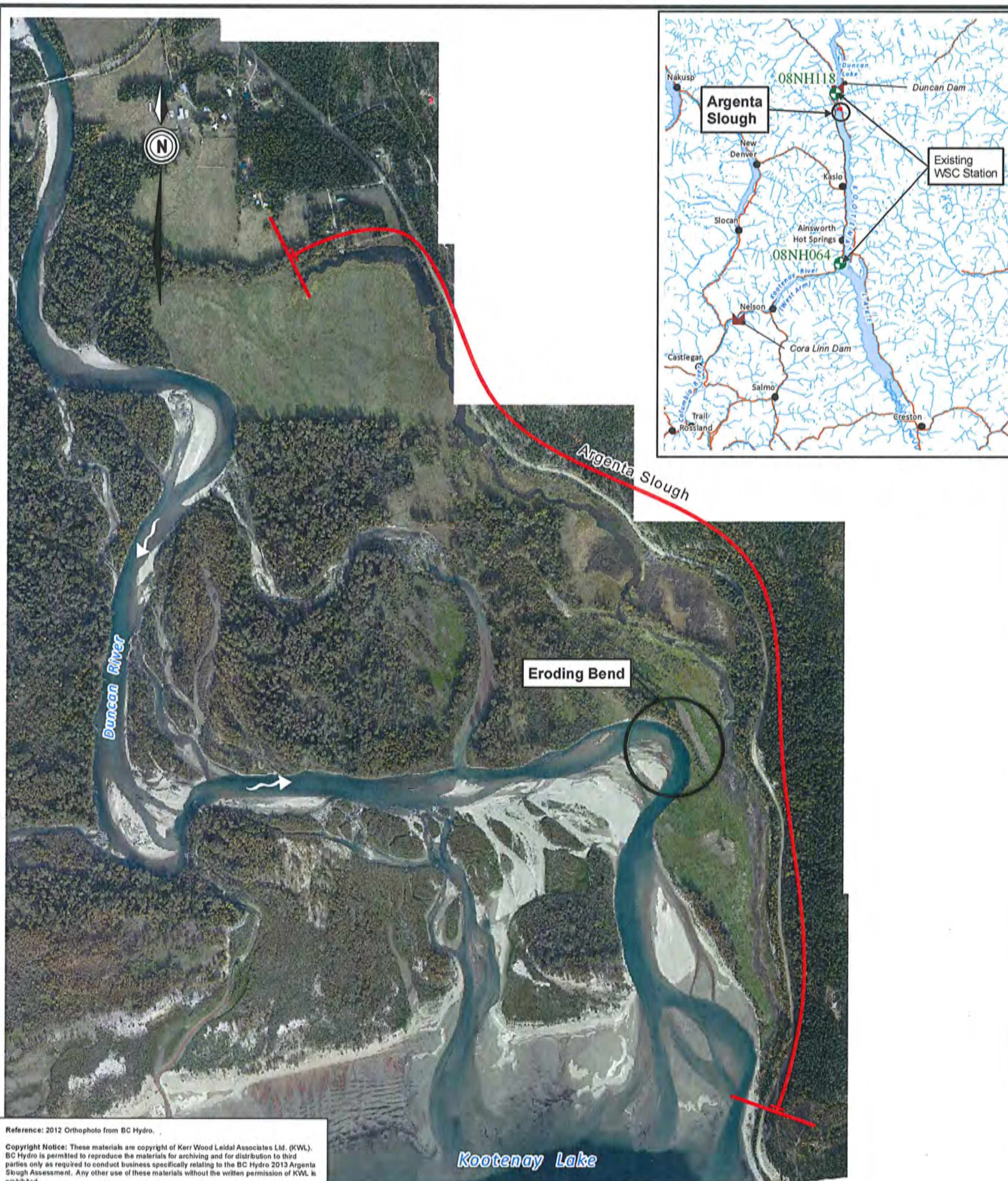
Revision History

Revision #	Date	Status	Revision	Author
0	September 3, 2013	Draft	Draft report for internal review.	EE
1	November 29, 2013	Final	Final report.	EE/DTM



Reference: 2012 Orthophoto from BC Hydro.

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BC Hydro
2013 Argenta Slough Assessment

Project No.	Date
478-162	September 2013

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Project Location

Figure 1-1

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Author: JLau

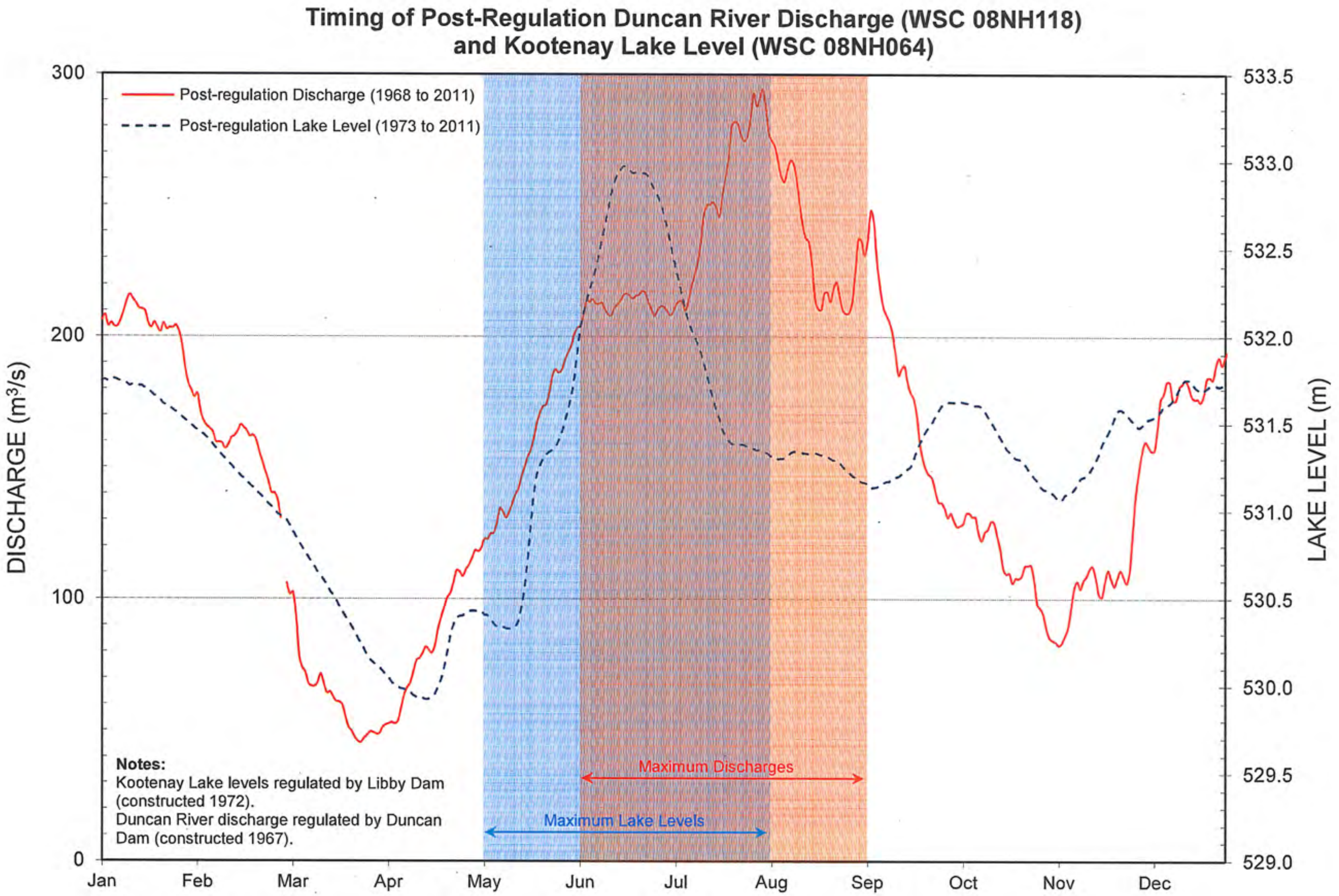

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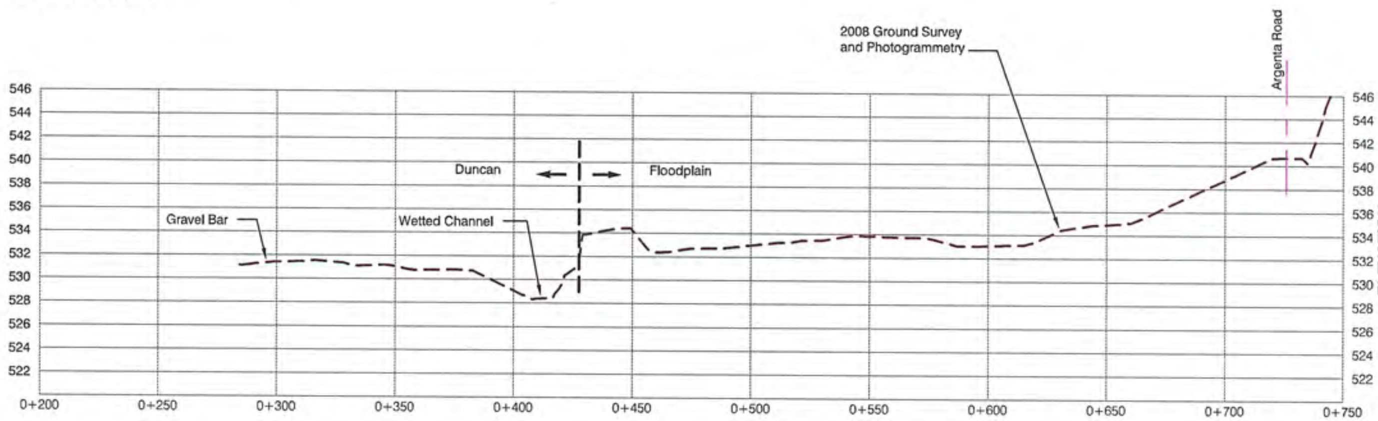
Figure 3-1

Scale: 1:7,500

Cross-section Location



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BC Hydro
2013 Argenta Slough Assessment

Cross-section through Eroding Bend of Duncan River, near Argenta Slough

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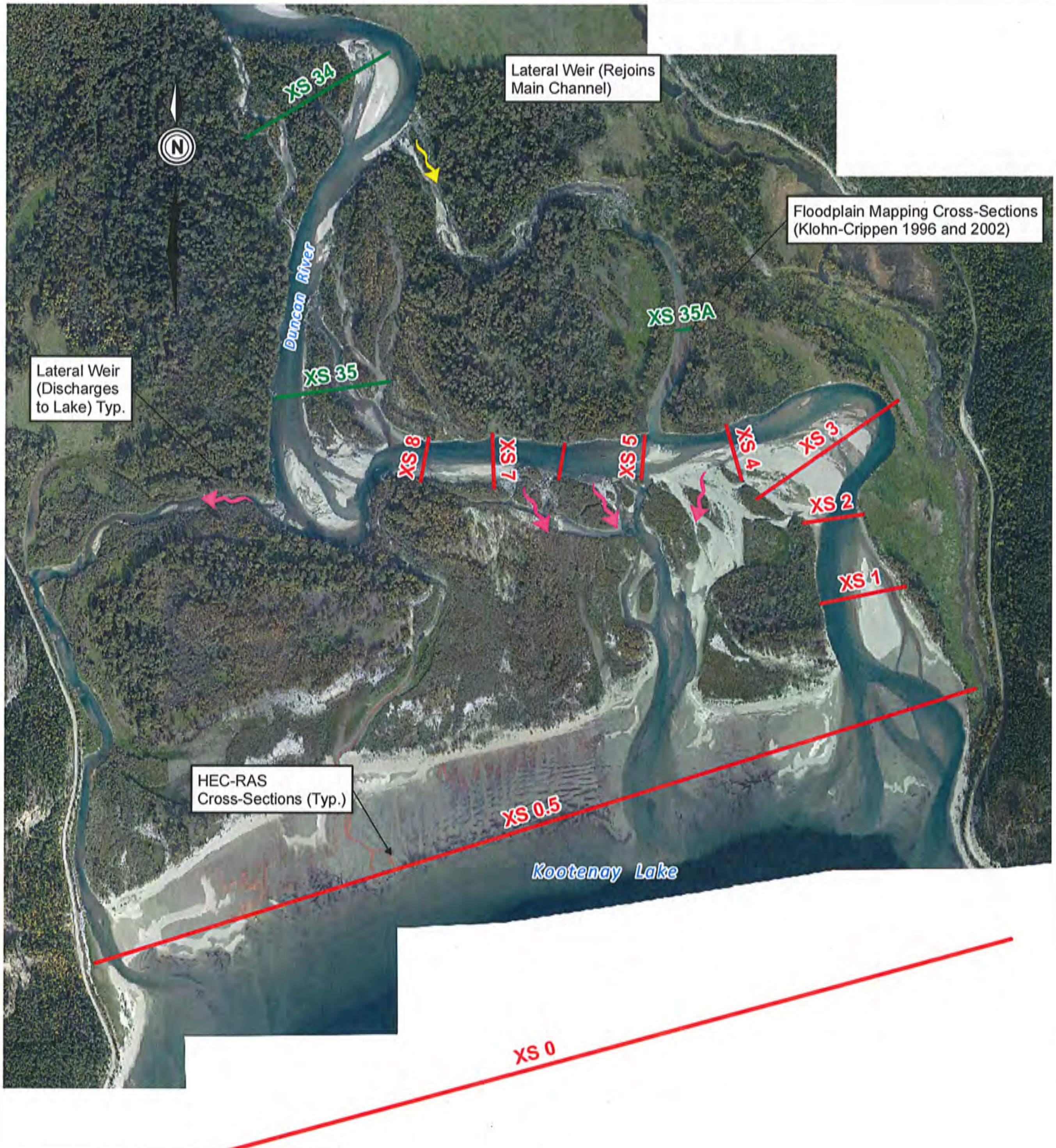
Figure 3-2



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Date September 2013

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Hydraulic Model of Lower Duncan River

Figure 3-3

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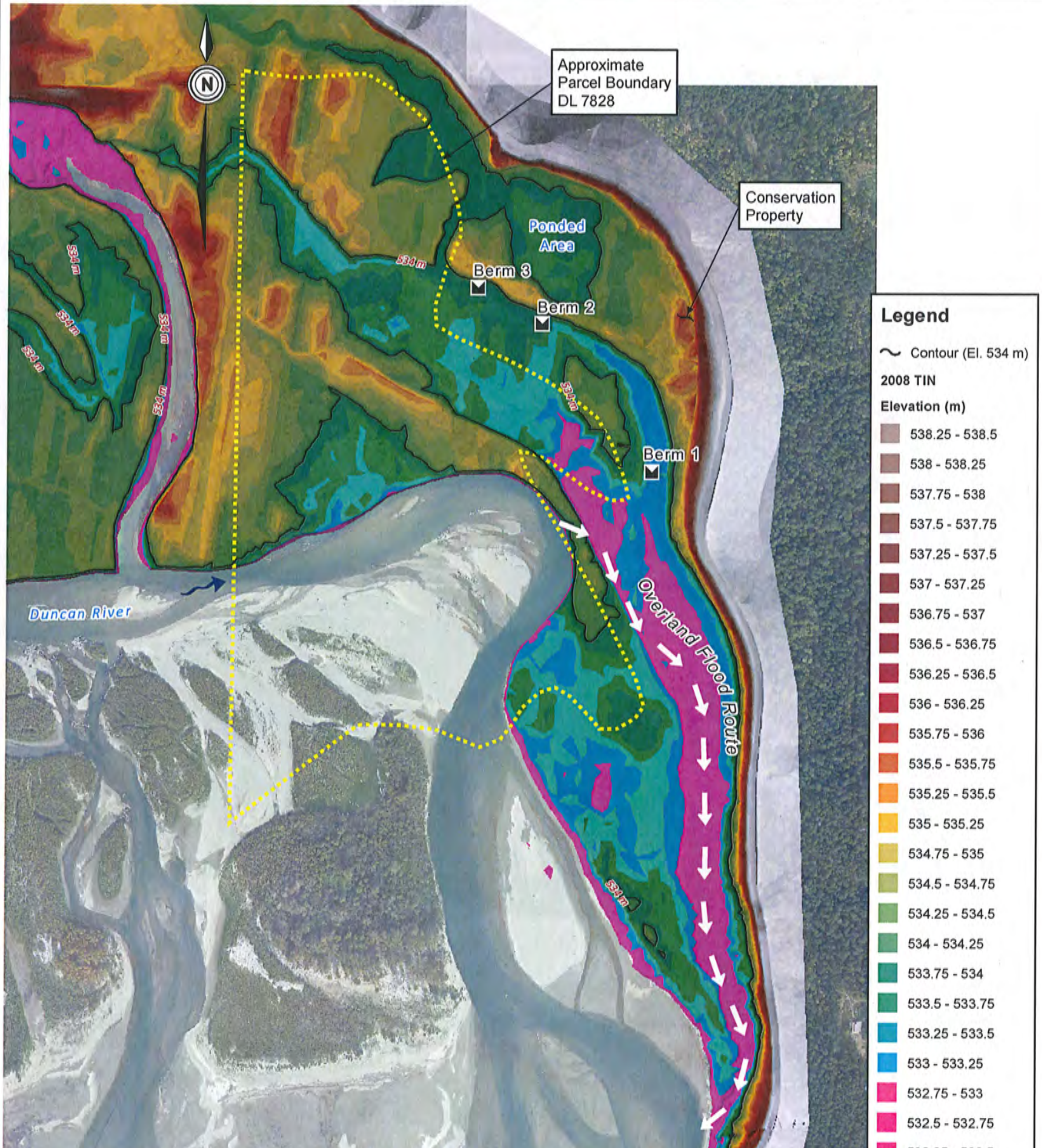

Reference: 2012 Orthophoto from BC Hydro.

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Project No.	Date
478-162	November 2013

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Potential Overland Flooding Routes

Figure 4-1

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Author: JLau

Addenda

Matsubara, D. and Ellis, E. (Nov 29, 2013). Physical Works No. DDMWORKS-01. Technical Memorandum: 2013 Argenta Slough Assessment. Technical Memorandum Prepared for BC Hydro, Burnaby, British Columbia 16pp. Prepared by Kerr Wood Leidal Consulting Engineers.

In order to preserve historical accuracy, the following addenda apply to this report and were supplied by B. Herbison (personal communication, December 16, 2013).

1) The "Berms" referred to in this report are abandoned beaver dams. The culvert discovered by KWL in "Berm 3" was placed in that beaver dam by local residents during the 1980s when the dam was actively being maintained by beavers. The culvert was part of an effort to manage upstream water levels.
2) Speculation about agricultural water management efforts on Argenta Slough downstream from that dam ('Berm 3') is the authors' opinion and should not be considered historical fact.