KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS
200 - 4185A Still Creek Drv.
Burnaby, B.C.
V5C 6G9
604-294-2088 P
604-294-2090 F
www.kwl.ca

Technical Memorandum

DATE: July 20, 2009

TO: Jeff Westlake, Operations and Maintenance Manager, Pemberton Valley Dyking District

FROM: Jennifer Young, EIT
Sarah Lawrie, M.A.Sc. EIT
David Zabil, P.Eng
Stefan Joyce, P.Eng

RE: **ARN CANAL DRAINAGE IMPROVEMENT PROJECT**
Field Investigations and Hydraulic Analysis of Arn Canal (DRAFT)
Our File: 0713.040

1. INTRODUCTION

The Pemberton Valley Dyking District (PVDD) retained Kerr Wood Leidal Associates Ltd. (KWL) to perform a field review and hydraulic analysis of Arn Canal. The Arn Canal is a manmade drainage channel that drains agricultural and developed lands behind the Pemberton Creek and Lillooet River dykes. The channel drains a mountainside area, agricultural lands and an urban development before it discharges to Pemberton Creek via floodboxes. See the location Figure 1.

The overall objective of this study is to characterize the existing hydraulic capacity of Arn Canal and offer recommendations to steer future analysis and improvement works to address flooding issues. The project scope includes reviewing existing data and reports, carry out a comprehensive field inspection of pertinent areas and drainage facilities, perform a hydraulic analysis of the Arn Canal and characterize the existing conditions. Improvements to the canal hydraulics will be investigated in the next phase of this study.

2. FIELD INFORMATION GATHERING

Field visits were performed by David Zabil, Jennifer Young and Sarah Lawrie on November 5 and 6, 2008. Jeff Westlake from PVDD also participated in the field visits. The purpose of the field visits was to perform an inventory of drainage features and assess the existing conditions of the Arn Canal. A summary photo record of the field investigations is attached as Appendix 1. Figure 2 shows the location of drainage features identified during field visits.

A detailed survey was conducted to collect cross-section information along Arn Canal for the purposes of performing the hydraulic analysis. Survey work was done between November 18 and December 11, 2008. The survey was timed such that the deciduous vegetation was bare but prior to the commencement of heavy winter snow. In addition to the cross-sections surveyed along the Arn Canal, additional cross-sections were collected along Pemberton Creek to increase the resolution for the hydraulic model at the confluence with Arn Canal. The locations of cross-sections surveyed are shown in Figure 2. Table 1 shows the surveyed bridges and culverts along the Arn Canal.

Table 1: Surveyed Bridges and Culverts on Arn Canal

Chainage*	ID	Description	Upstream Invert	Dowstream Invert	Length	Geometry	Size	Material
m			m	m	m		mm	
0+502	Wooden Farm Bridge 1	Log bridge	205.97	205.95	4.02	Irregular		Log bridge, natural bottom
1+353	Wooden Farm Bridge 2	Log bridge	205.04	204.96	4.88	Irregular		Log bridge, natural bottom
1+797	Wooden Farm Bridge 3	Wood bridge	204.06	204.04	3.17	Irregular		Log bridge, natural bottom
2+047	Collin's Road Culvert	Collins Road Crossing	205.44	205.23	24.50	Elliptical	2200x3800	CMP
2+186	Wooden Farm Bridge 4	Log bridge	204.47	204.43	3.96	Irregular		Log bridge, natural bottom
2+841	Railway Culverts	Left culvert at railway	204.91	204.52	28.20	Circular	1800	CMP
		Mid culvert at railway	204.97	205.18	24.90	Circular	2100	CMP
		Right culvert at railway	204.31	203.96	24.70	Circular	1800	CMP
3+196	High School bridge	Bridge at High School	204.14	204.07	9.95	Irregular		Concrete bridge, natural bottom
3+462	Poplar Road Bridge	Pedestrian bridge at Poplar Rd	203.98	203.95	2.29	Irregular		Concrete bridge, natural bottom
4+016	Pedestrian Bridge	Pedestrian bridge over canal	204.01	203.99	2.48	Irregular		Wood bridge, natural bottom
4+159	Highway 99 Bridge	Highway 99 Crossing	204.23	204.08	12.97	Irregular		Concrete bridge, natural bottom
4+667	Floodboxes	Left culvert at Pemberton Creek dyke	203.90	203.56	32.10	Circular	1200	CMP
		Mid culvert at Pemberton Creek dyke	203.47	202.90	35.10	Circular	1200	CMP
		Right culvert at Pemberton Creek dyke	203.95	203.59	32.20	Circular	1200	CMP

3. HYDROLOGIC AND HYDRAULIC MODELLING

Two models were developed for Arn Canal and Pemberton Creek, XP-SWMM RUNOFF for the hydrology of the watersheds and MIKE11 for the hydraulics of the channels. XP-SWMM RUNOFF uses inputs such as rainfall and catchment characteristics (area, slope, soil type, etc.) to generate flow estimates. MIKE11 requires flow, channel and crossing characteristics for water level and velocity estimates.

3.1 XP-SWMM Hydrologic Model Catchments

3.1.1 Catchments

The Arn Canal and Pemberton Creek watersheds were discretized into subcatchments using contours, field watercourse information, and existing drainage information. The major model catchments are shown in Figure 1.

In total, 19 catchments were created and imported into the XP-SWMM model. Catchments were assigned the following attributes:

- slopes, using available contour information;
- existing impervious area, using 2006 aerial photographs to determine land use
- typical land use impervious percentage information; and
- groundwater parameters based on typical values for soils.

3.1.2 Impervious Percentage

Existing land use impervious percentages were estimated based on the land use type visible in the aerial photography and typical land use impervious percentages shown in the table below.

Table 2: Impervious Percentages by Land Use

Land Use Zone	Description	Total Impervious Percentage
Farm	Agricultural Lands	5
Forest	Undeveloped Areas	0
HD Res	High Density Residential	65
LD Res	Low Density Residential	50

3.1.3 Soil Parameters

The groundwater portion of XP-SWMM – RUNOFF was used to better estimate the groundwater and interflow portions of the runoff hydrograph. The watersheds were assumed to be till soils, and typical groundwater parameters for this type of soil were assumed.

The infiltration and groundwater parameters used in the models were based on KWL's database of calibrated saturated winter condition model parameters for similar soil conditions. The infiltration rate in the lowland catchments was set to zero to represent flooded field and/or high water table conditions.

3.1.4 Design Storms

The Pemberton Valley Dyking District requested that design storms be created for the 2, 5, 10, 25, 50, 100 and 200-year 24-hour design events. A Chicago-style distribution design event with a 2-hour averaged peak was selected. The design storm distribution is a synthetic hyetograph that has the same average intensity as the intensity-duration frequency (IDF) curve indicates for all storm durations from the 2-hour to 24-hours. The design storms were generated using the AES Pemberton A rain gauge station IDF curve and are shown in Figure 3.

3.1.5 Design Flow Hydrographs

The XP-SWMM model was run to produce the design flow hydrographs for input into the MIKE 11 hydraulic model.

3.2 MIKE 11 HYDRAULIC MODEL

A MIKE11 model has previously been developed for the Lillooet River, including several tributaries such as the Ryan River, Green River, Miller Creek, and the Birkenhead River. The Pemberton Creek and Arn Canal reaches were added to this model. The model includes channels, bridges and culverts within the study reaches. Figure 2 shows the culvert and bridge locations and the extent of the modelled channel reaches. Channel cross-sections (maximum of 300 m apart) and culvert/bridge sizes were obtained from the 2008 field survey.

3.2.1 Full Lillooet River Model

To confirm that the addition of the Arn Canal and Pemberton Creek detail did not result in significant changes in the full Lillooet River Model, the 200-year flood was simulated. The updated model was run using the existing 200-year boundary conditions on the Lillooet River and all tributaries. The results were compared to previous work confirming that the updated model produced similar flows and water levels. Adding the Arn Canal and Pemberton Creek detail resulted in a maximum 1 cm decrease in the water levels in the Lillooet model.

3.2.2 Arn Canal Model

After a successful full model run, Arn Canal portions were extracted into a smaller, stand-alone submodel. This model was run with a 2-year Pemberton Creek water level boundary (203.5 m) at the mouth of the Arn Canal to determine the capacity of the Arn Canal under free outlet conditions. The design flow hydrographs were run through the Arn Canal model. This allowed computation of the Arn Canal hydraulic capacity independent of influence from high Pemberton Creek water levels.

3.2.3 Pemberton–Arn Model

A third model was created of Pemberton Creek and Arn Canal portions. This was done to speed up run times for the analyses required for this study. The model was modified to reflect the expected future development in the Pemberton core area. The cross-sections for the Arn Canal were modified from the CN Rail culvert to the floodboxes. It was assumed that future developments would be built along the canal cutting off the overbank portions of the cross sections. The limits of encroachment of development on the canal are shown on Figure 4. The downstream boundary condition on Pemberton Creek was set to 202.5 meters (approximately a 2-year return Lillooet River water level) to simulate free outlet conditions. This model was used to assess of how Pemberton Creek water levels affected the floodboxes on Arn Canal independent of influences from high Lillooet River water levels. The model was validated. See Section 3.3 for validation methods. The validated model was used for subsequent design storm analysis.

3.3 Model Validation

The Pemberton – Arn model was validated using photos of flooding during the March 11-12, 2007 rainfall event. Comparing this rainfall event to the IDF curve shows that it was a 2-year event at the 12-hour and 24-hour durations. This event caused flooding in the upper catchments (above the CN Rail) on the Arn Canal. Photos of this event complete with date and time information were provided by the PVDD. Flood water levels at three key locations (see Table 3) were estimated from the photos using surveyed cross sections and the 1990 Floodplain Map produced by the BC Ministry of Environment.

The XP-SWMM model was run using the March 2007 rain data and the resulting hydrographs were input into the Pemberton-Arn MIKE11 model. The model was run and the water levels were checked at the three key location. The modelled water levels upstream of the Collins Road Culvert were a good match, but the levels downstream appeared to be higher then those estimated from the photos. The bed roughness was reduced from 0.1 to 0.065 for the Arn Canal channel downstream of the Collins Road Culvert. The model was re-run and the water levels were checked again. The modelled and observed water levels upstream of the Collins Road matched very well. The modelled levels upstream of the CN Rail culverts were approximately 0.3 m higher than the levels estimated from photos (see Table 3). Given the approximate nature of the validation data, further changes to the model were not pursued. The slight overestimation of water levels by the model will result in conservative design event flood levels.

Of note, the model indicates that the Arn Canal stayed high for approximately a day during the validation event, meaning that the exact time stamps on the photos were not critical to the validation process.

Table 3: Flood Levels at Validation Locations

Chainage	Description	Estimated Water Level (from Photo)	Modelled Water Level
1+791	Farm bridge upstream of Collins Road (March 12 at 2:51 pm)	207.0	207.0
2+169	Downstream side of Collins Road Culvert (March 12 at 10:48 am)	206.4	206.6
2+815	Upstream side of CN Rail Culverts (March 12 at 10:54 am)	206.0	206.3

4. MODEL RESULTS

4.1 EXISTING HYDRAULIC CONDITIONS

4.1.1 Arn Canal Peak Flow Estimates

To estimate design peak flows and existing channel capacities, the Arn Canal model was run with a 2-year Pemberton Creek water level boundary. The instantaneous peak flow estimates for the Arn Canal at critical locations are summarized in Table 4. The channel flow capacity in Table 4 represents bank full canal capacity at each location. Flows in excess of these values will cause overbank flooding at the corresponding critical location. The shaded sections of the table indicate the return period flows that exceed the canal capacity at the section assuming a free outlet to Pemberton Creek.

Table 4: Arn Canal Instantaneous Peak Flow Estimates with Free Outlet to Pemberton Creek

Location	Cross Section Chainage (m)	Simulated Peak Flows (m^3/s)							
		Channel Flow Capacity	2-year	5-year	10-year	25-year	50-year	100-year	200-Year
Arn upstream of floodboxes	4+637	7.5	3.8	4.7	5.5	6.2	6.7	7.0	7.8
Arn upstream of Hwy 99 bridge	4+141	>7.6	3.6	4.4	5.3	5.9	6.3	6.6	7.6
Arn downstream of high school bridge	3+185	5.8	3.5	4.3	5.2	5.8	6.2	6.5	7.5
Arn upstream of CN Rail	2+815	1.8	3.6	5.1	5.7	7.3	8.4	9.5	10.6
Arn upstream of Collins Road	1+791	2.2	3.3	4.7	5.5	7.3	8.9	10.4	12.9
Arn upper agricultural area	0+854	1.4	2.5	3.7	3.9	4.2	4.5	5.5	6.8

The flow capacities in Table 4 indicate that the portion of the canal upstream of the Collins Road crossing currently does not have the capacity to pass a 2-year return period flow regardless of downstream water levels in Pemberton Creek. The portion of the canal downstream of the CN Rail culverts has several critical locations that can pass flows in the range of 10 to 100-year return period. The area downstream of the high school bridge is the critical section in this reach, and can pass approximately a 25-year return period flow. The section upstream of the Highway 99 bridge can pass greater than a 200-year return period flow and the section upstream of the floodboxes can pass a 100-year flow.

4.1.2 Arn Canal Water Level Profiles

Water level profiles were generated for the Arn Canal with free outflow to Pemberton Creek (see Figure 5). The profiles also show the bridge deck or embankment elevation and bottom chord or culvert crown elevations for the major canal crossings, and the Lillooet River 200-year and 20-year Floodplain Mapping elevations which include freeboard. The Arn Canal flood levels are much lower than the Floodplain Mapping elevations based on the Lillooet River floods, even if freeboard is taken into account.

The water level profiles also show locations where head-loss (drop in water level) occurs at bridges, culverts and changes in channel section. Several large head-losses occur in the Arn Canal. Table 5 shows the location of head-losses in the water level profile and the reasons that these occur.

Table 5: Location and Cause of Head-Loss in the Water Level Profile

Location	Approximate Chainage (m)	Estimated 2-year Water Level Drop (m)	Estimated 200-year Water Level Drop (m)	Reason for Drop in Water Level
Upstream of first wooden farm bridge	0+300	0.08 (evident in >5-year)	0.29	Channel bottom irregularity. Channel bottom elevation is approximately 0.7 m higher than upstream elevation.
Downstream of second wooden farm bridge	1+400	0.05 (evident in >5-year)	0.26	Channel bottom irregularity. Channel bottom elevation is approximately 1.0 m higher than upstream elevation.
Collins Road Culvert and immediately downstream	2+047	0.02 (evident in >10-year)	0.25	Steep drop in channel bed level downstream of culverts. In higher return period flows the culvert becomes full causing a change in flow conditions.
Downstream of fourth wooden farm bridge	2+480	0.14	0.0 (backwatered)	Channel widens in this area and may overflow into the adjacent slough.
CN Rail Culverts	2+840	0.03	0.09	In higher return period flows the culvert becomes full causing a change in flow conditions.
Floodboxes	4+667	0.21	0.85	In higher return period flows the culverts become full causing a change in flow conditions. Free outlet conditions.

4.2 Hydraulic Conditions With Development Fill

Based on discussions with the PVDD, the MIKE11 model was updated to reflect the expected future development encroachment on to the Arn Canal floodplain in the Pemberton core area. It was assumed that future developments would be built along the canal cutting off the overbank portions of the cross sections. The limits of encroachment of development on the canal are shown on Figure 4. The cross-sections for the Arn Canal were modified from the CN Rail culvert to the floodboxes and the design event models were run to assess the potential effects of the development encroachment on the water levels in the canal. The model results showed that the fill increases the 200-year peak water level by up to 0.2 m.

4.2.1 Pemberton–Arn Canal Water Level Profiles

Water level profiles were generated using the validated Pemberton-Arn model (see Figure 6). The profiles show the bridge deck and bottom chord elevations for the major canal crossings and the Lillooet River 200-year and 20-year Floodplain Mapping elevations. Figure 6 shows that even with backwater effects from Pemberton Creek, the Arn Canal flood levels are still much lower than the Floodplain Mapping elevations based on the Lillooet River floods.

The water level profiles in Figure 6 show the effects of the Pemberton Creek water levels on the downstream end of Arn Canal. The model results indicate that the Arn Canal floodboxes close briefly during the 25-year event before the water levels reach their maximum. This is not visible on the 25-year peak water level profiles. In the 50-year event, the peak water level profiles clearly show the floodboxes closed at the time of the peak (water level is higher on the downstream side of the floodboxes than on the upstream).

The Arn Canal water levels during the 2-year event are affected by the Pemberton Creek levels up to the Poplar Road bridge. In the 200-year event, the backwater influence extends up to the CN Rail crossing. There is no back water influence from the Pemberton Creek levels upstream of the CN Rail crossing.

It should be noted that Lillooet River water levels may also affect the Arn Canal peak water levels. It is estimated that the Lillooet River levels in excess of approximately the 10-year return period will start to affect the Arn Canal levels.

Table 6 summarizes the return period of the water level that can just pass under the bottom chord of the existing bridges or through existing culverts without surcharging based on the Pemberton-Arn model. It also summarizes which return period flow overtops the bridge deck of culvert embankment.

Table 6: Bridge and Culvert Capacities

Bridge or Culvert Location On Arn Canal	Return Period Exceeding Culvert Crown or Bridge Chord Elevation	Return Period Exceeding Bridge Deck or Embankment Elevation
Wooden Farm Bridge (0+504)	100 year	> 200 year
Wooden Farm Bridge (1+356)	2 year	50 year
Wooden Farm Bridge (1+798)	< 2 year	5 year
Collins Road Culvert (2+047)	100 year	> 200 year
Wooden Farm Bridge (2+188)	< 2 year	10 year
CN Rail Culverts (2+841)	50 year	> 200 year
High School Bridge (3+200)	50 year	> 200 year
Poplar Road Bridge (3+463)	25 year	100 year
Pedestrian Bridge (4+014)	>200 year	> 200 year
Highway 99 Bridge (4+153)	100 year	> 200 year
Floodboxes (4+667)	< 2 year	> 200 year

Please note that Table 6 should not be used to identify which bridges require upgrading or replacement. Many of the bridges and culverts are simply backwatered and are not the cause of large head losses or the overtopping water levels. Required upgrades will be identified in the next phase of this study.

4.2.2 Arn Canal 2-Year Flooding Extents

The results from the Pemberton-Arn model were used to generate a 2-year return period flood level for the area upstream of the CN Rail culverts. The 2-year return period flood extents are shown in Figure 7. The water levels from the model were extended into the floodplain based on the contours from the 1990 Floodplain Map produced by the BC Ministry of Environment to determine the extents of the flooding in this area. The floodplain extents show significant flooding in the area between the CN Rail crossing and the Collins Road crossing, as well as in the fields near the upper end of the modelled Arn Canal reach. This extent of flooding seems to correlate well with the flooding observed during the March 11, 2007 flood which was approximately a 2-year event.

4.3 PEMBERTON CREEK WATER LEVEL PROFILES

Figure 8 shows the Pemberton Creek water level profiles with a free outlet to the Lillooet River. For comparison, the Lillooet River 200-year and 20-year return 1990 Floodplain Mapping elevations (including freeboard) are shown. The estimated flood levels in Pemberton Creek are lower than the Floodplain Mapping elevations below the Arn Canal confluence, however, farther upstream, the current model predicts higher water levels. This is likely due to the addition of more detailed information than existed in the Floodplain Mapping analysis. Backwater effects from the Lillooet River would raise the downstream portion of the Pemberton Creek peak water level profiles and therefore these profiles should not be used to assess adequacy of the dykes along Pemberton Creek.

5. DESIGN CRITERIA FOR CANAL IMPROVEMENTS

As stated in Section 4.2.1, the Pemberton Creek backwater does not influence Arn Canal peak water levels upstream of Collins Road. This means that the canal's capacity in the upstream agricultural areas is not reduced by Pemberton Creek water levels. The limited Arn Canal capacity is largely due to the flat longitudinal slope of the channel, the channel size, and the low portions of the floodplain in the areas shown on Figure 7. Improvements to the Arn Canal can be made to reduce flooding in this area.

Based on discussions with the PVDD, the canal improvements will be based on two design criteria. The upper agricultural area upstream of the CN Rail culverts would be upgraded to pass the 2-year return period flow. Due to ongoing development in the areas downstream of the CN Rail culverts, this portion of the Arn Canal would be upgraded to pass the 200-year return period flow to prevent flooding and damage to property in the developed areas.

Figure 9 shows the existing Arn Canal water level profiles (2-year above and 200-year below CN Rail). it is expected that because the 2-year water level profile downstream of the CN Rail crossing is very flat (0.04%), minimal water level reduction could be achieved through conveyance improvements downstream of the CN Rail. Eliminating the flooding between Collins road and the CN Rail may not be possible with downstream channel improvements alone. Filling of the low portions of floodplain, adding a pump station, dyking, or a combination of these may be necessary to meet the criteria in this area. Flooding in the Arn Canal upstream of Collins Road may be eliminated with channel conveyance improvements and possibly some minor filling. The 2-year peak water level profile could be lowered above the CN Rail as shown by the dashed blue line in Figure 9. Downstream of the CN Rail, filling and dyking are the likely solutions to contain the 200-year flow in the channel.

The next phase of this study will investigate the upgrades required to meet the 2-year and 200-year conveyance criteria.

6. SUMMARY

Hydrologic and hydraulic models were developed for the Arn Canal and Pemberton Creek. The hydraulic model was validated using the March 11-12, 2007 flood event. Adjustments to channel roughness values were made during the validation to better match the observed levels. Once the changes were made, the modelled and observed water levels were within 0.3 m of one another. The model produced the higher levels and therefore also produces conservative design event flood levels.

The hydraulic model was run with the design event flows and the following observations were made. The portion of the canal upstream of the CN Rail culverts currently does not have enough capacity to pass a 2-year return period flow without flooding the adjacent fields. This portion of the canal is very overgrown with vegetation, which increases the roughness of the channel and reduces the flow capacity. This section also has several locations where channel bottom irregularities cause head-losses in the channel. Low pockets of farmland adjacent to the channel further reduce the bank full capacity of the canal.

The portion of the canal downstream of the CN Rail culverts has several critical sections that can pass flows in the range of 25 to >200-year return period. The area downstream of the high school bridge is the critical section and can pass a 25-year return period flow. The section upstream of the Highway 99 bridge can pass greater than a 200-year return period flow and the section upstream of the floodboxes can pass a 100-year flow.

It was found that fill due to potential future development will reduce the overbank capacity and cause the water levels downstream of Collins Road to be higher by up to 0.2 m.

The Floodplain Mapping 20-year and 200-year elevations based on the Lillooet River flood are significantly higher than the corresponding return period water levels in the Arn Canal based on localized rainfall events and a low Lillooet River water level. The model indicated that the addition of channel detail in the portion of Pemberton Creek between the Highway 99 bridge and the Arn Canal confluence caused the peak water levels to exceed those shown in the Floodplain Mapping and therefore the current model detail should be added to the overall Lillooet model before assessing or designing flood protection works along Pemberton Creek.

Based on discussions with the PVDD, the design criterion for the upper agricultural area upstream of the CN Rail culverts will be to pass the 2-year return period flow. Downstream of the CN Rail culverts, the Arn Canal will need to pass the 200-year return period flow.

In the portion of the channel upstream of the CN Rail culverts, vegetation management may increase the flow capacity of Arn Canal by reducing the channel roughness. Other possible improvements to the canal in this section include dredging the channel to increase depth in the areas where bottom irregularities cause head-losses in the channel, widening the left bank to increase the flow area, lowering the Collins Road culvert, and filling the low spots in the farmland. A pump station and/or extensive filling may be required to drain the area between Collins Road and the CN Rail crossings.

In the reach near the Highway 99 bridge there is the potential to slightly increase capacity by pulling back the banks of the canal to create extra storage and flow area. However due to the low slope of the water level profiles in this reach, the water level reduction would likely be in the order of centimetres at the CN Rail crossing. To contain the 200-year flow in the lower section of the canal, fill adjacent to the channel and dyking will be required.

7. NEXT STEPS

Further investigation is required to determine which improvements would provide the most benefit. This may include modelling the improvements to the channel and reducing the roughness factor (due to vegetation removal) in the upstream reaches. The channel improvements will aim to contain the 2-year flows in the channel in the upper agricultural and contain the 200-year flows in the area downstream of the CN Rail culverts.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Jennifer Young, EIT
Project Engineer

Prepared by:

Sarah Lawrie, M.A.Sc., EIT
Project Engineer

Reviewed by:

David Zabil, P.Eng
Stormwater Engineer

Encl.

STATEMENT OF LIMITATIONS

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of the Pemberton Valley Dyking District. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

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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Photo 1
Arn Canal downstream of the floodbox

Photo 2
Arn Canal floodbox

Photo 3
Arn Canal downstream of the Hyw 99 bridge

Photo 4
Arn Canal from the Hwy 99 bridge

Photo 5
Arn Canal from the pedestrian bridge upstream of Hwy 99

Photo 6
Arn Canal from the highschool bridge

Photo 7
Arn Canal upstream of the highschool bridge

Photo 8
Arn Canal downstream of the CN Rail embankment

Photo 9
Wetland upstream of CN Rail embankment

Photo 10
Arn Canal from the CN Rail embankment (upstream)

Photo 11
Arn Canal downstream of Collins Rd.

Photo 12
Arn Canal upstream of Collins Rd.

Photo 13
1st Inlet channel upstream of Collins Rd.

Photo 14
Channel at the base of the hillslope (1)

Photo 15
Channel at the base of the hillslope (2)

Photo 16
Channel at the base of the hillslope (3)

Photo 17
3rd Inlet channel upstream of Collins Rd.

Photo 18
Arn Canal upstream of Collins Rd. – low freeboard (example 1)

Photo 19
Arn Canal upstream of Collins Rd. – low freeboard (example 2)

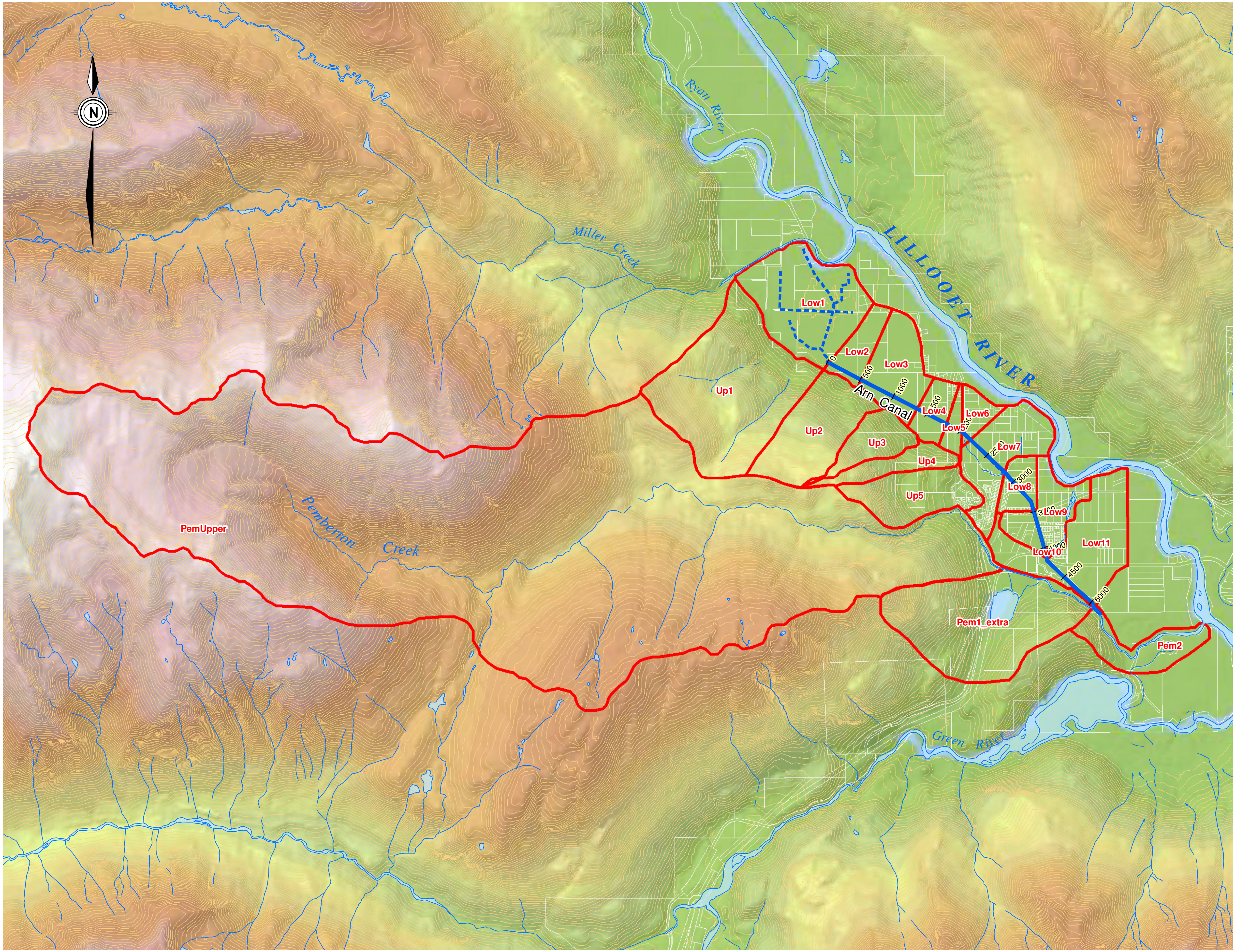
Photo 20
Arn Canal upstream extent of the model (view from last cross-section downstream)

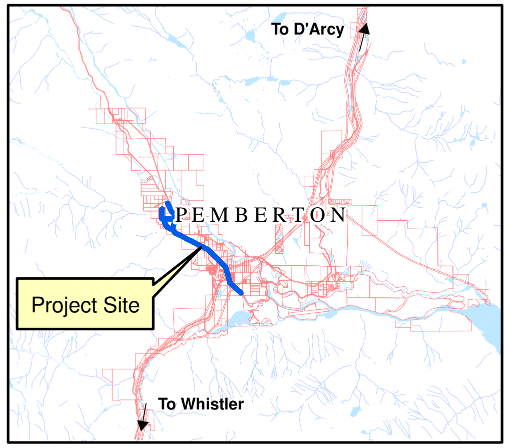
Photo 21
Arn Canal - upstream extent of the model (view upstream)

Pemberton Valley Dyking District
Arn Canal
Drainage Improvement Project

Legend

Major Catchment Boundary





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Scale in Metres 1:50,000

Project No.	Date
713-040	May 2009

Location and Catchment Map

Figure 1

Map Document: (O:\0700-0799\713-040\430-Gis\MXD-Rp\713040Fig1.mxd)
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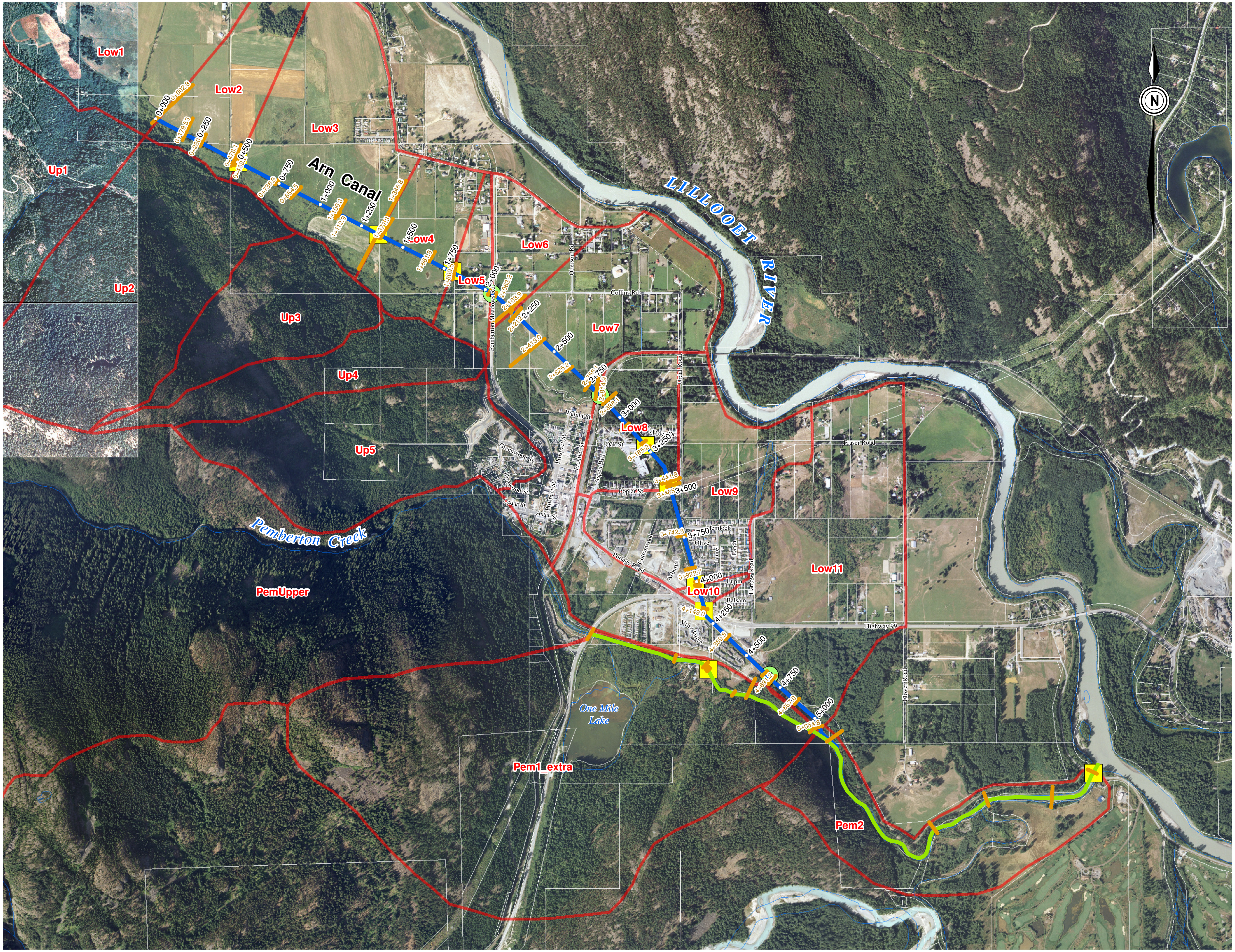
Pemberton Valley Dyking District
Arn Canal
Drainage Improvement Project



Legend

- Major Catchment Boundary
- Watercourse
- Culvert
- Bridge
- Cross Section Location
- Arn Canal Modelled Reach
- Pemberton Creek Modelled Reach

Reference: 2006 Orthophoto.

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500 0 500
Scale in Metres 1:20,000

Project No.	Date
713-040	July 2009

Drainage Inventory

Figure 2

Map Document: (O:\0700-0799\713-040\430-Gis\MXD-Rp\713040Fig2.mxd)
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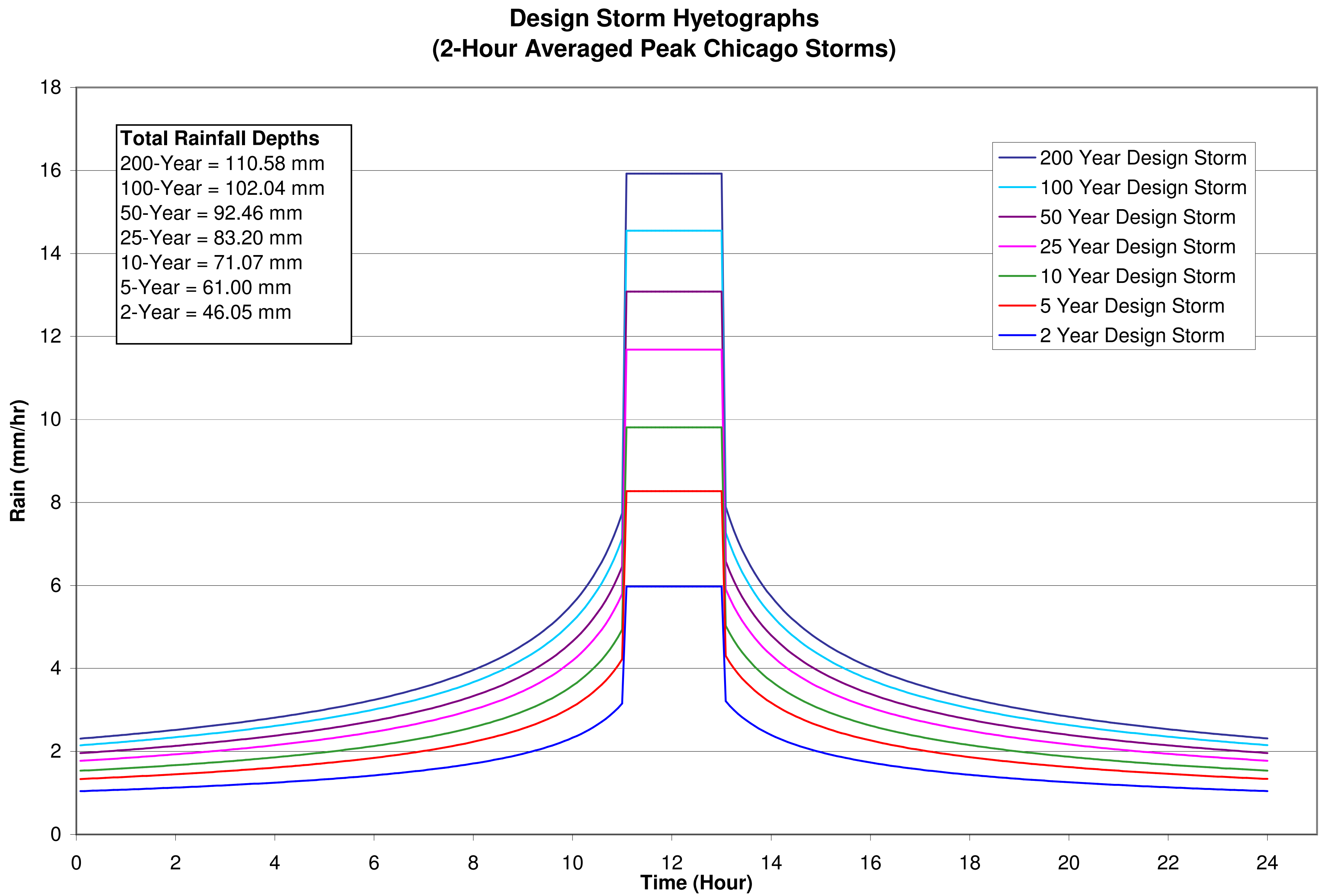
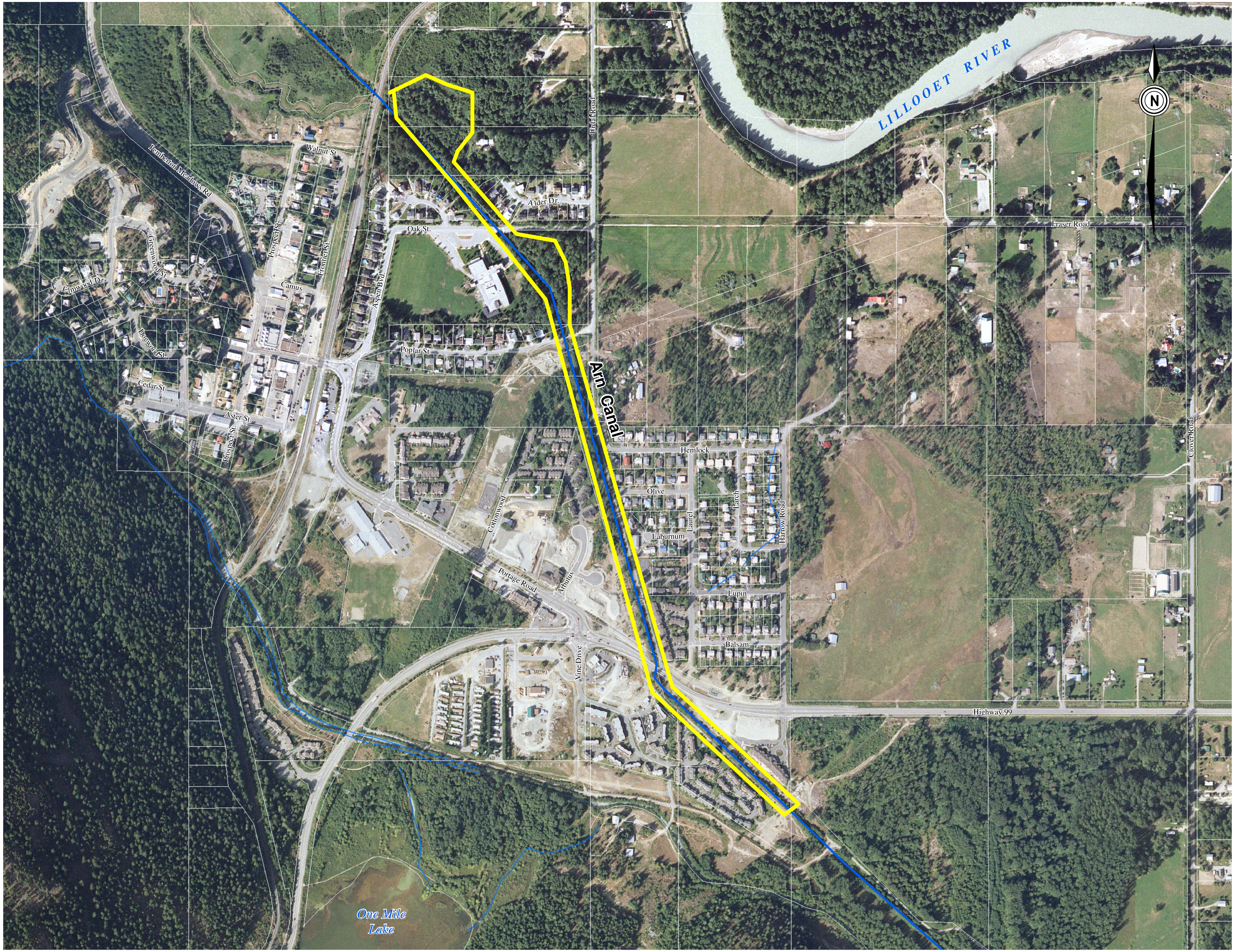


Kerr Wood Leidal Associates Ltd.
O:\0700-0799\713-040\420-Model\ArnCanal\SWMM\Rain\ChicagoStorms.xlsDesign Storm Curves mmhr

Figure 3



Map Document: (O:\0700-0799\713-040\430-Gis\MXD-Rp\713040Fig8.mxd)
21/05/2009 -- 9:33:30 AM

Pemberton Valley Dyking District
Arn Canal
Drainage Improvement Project

Legend

Watercourse

Channel and Overbank Extents Assuming Fill from Potential Future Development

Reference: 2006 Orthophoto.

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

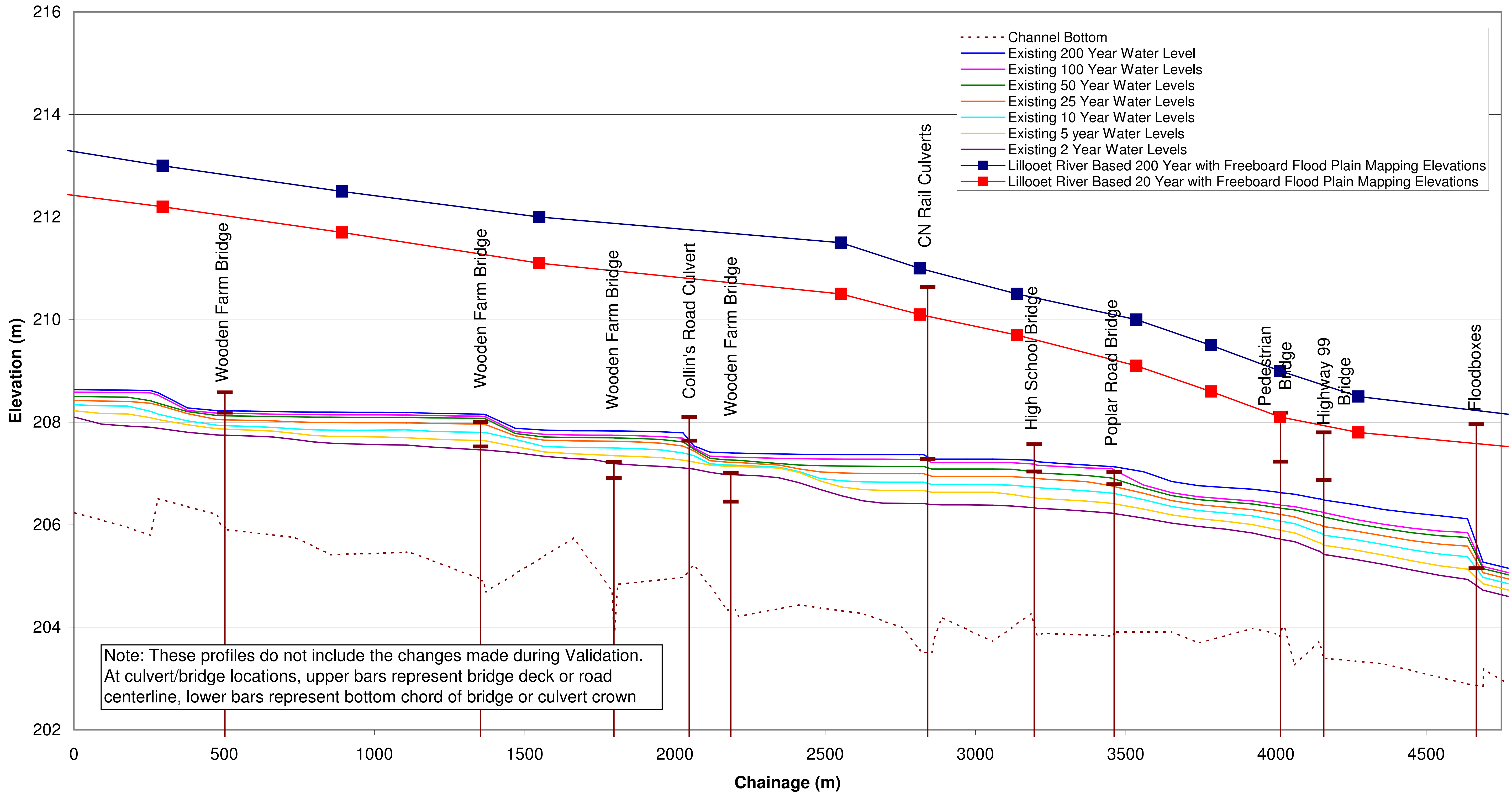
150 0 150
Scale in Metres 1:7,500

Project No.	Date
713-040	May 2009

Arn Canal Channel and Overbank Extents

Figure 4

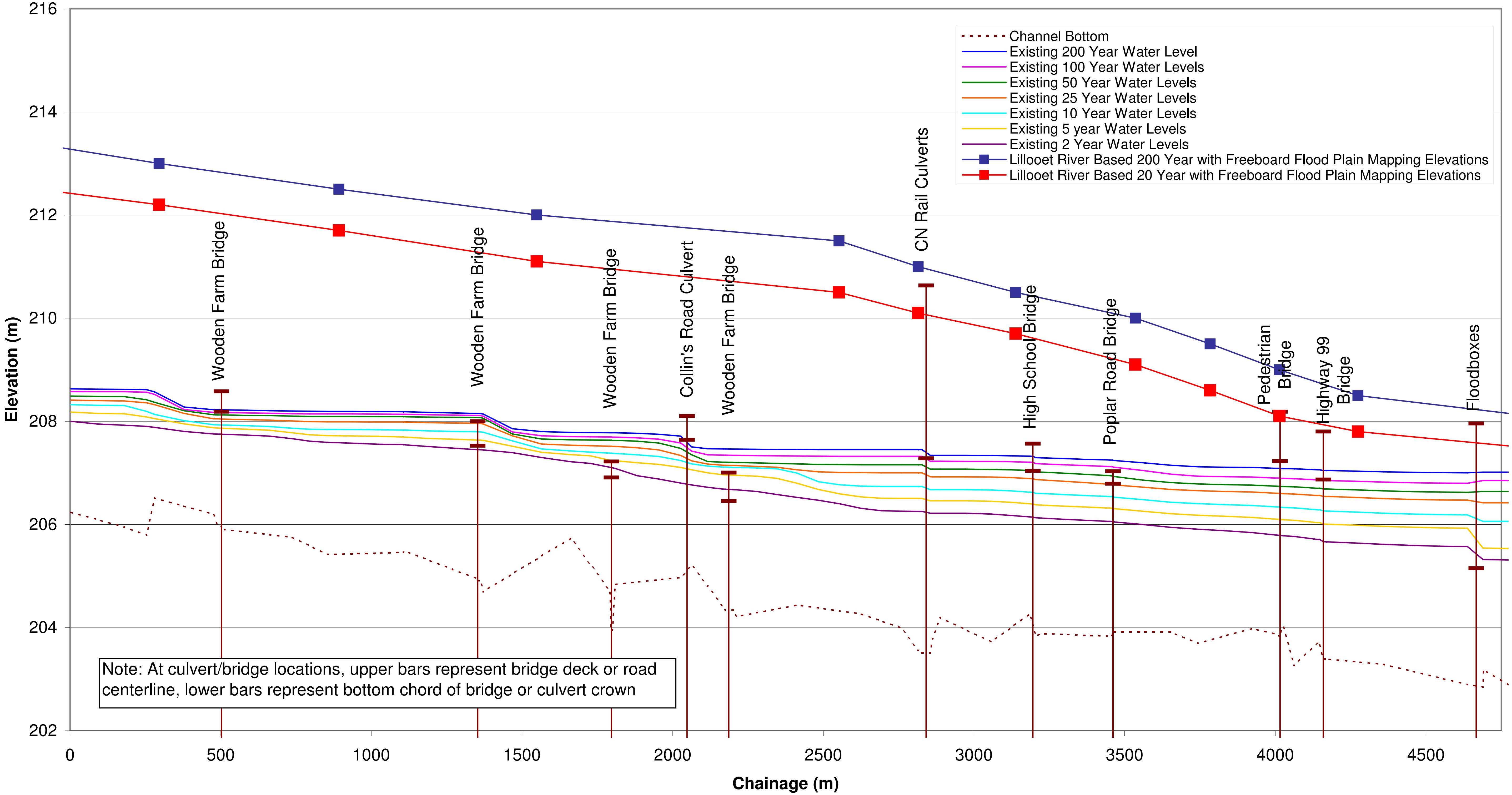
Arn Canal Water Level Profiles
With Free Outlet to Pemberton Creek



Kerr Wood Leidal Associates Ltd.
O:\0700-0799\713-040\420-Model\ArnCanal\MIKE11\Build3\Pemberton Profiles20090716.xlsARN

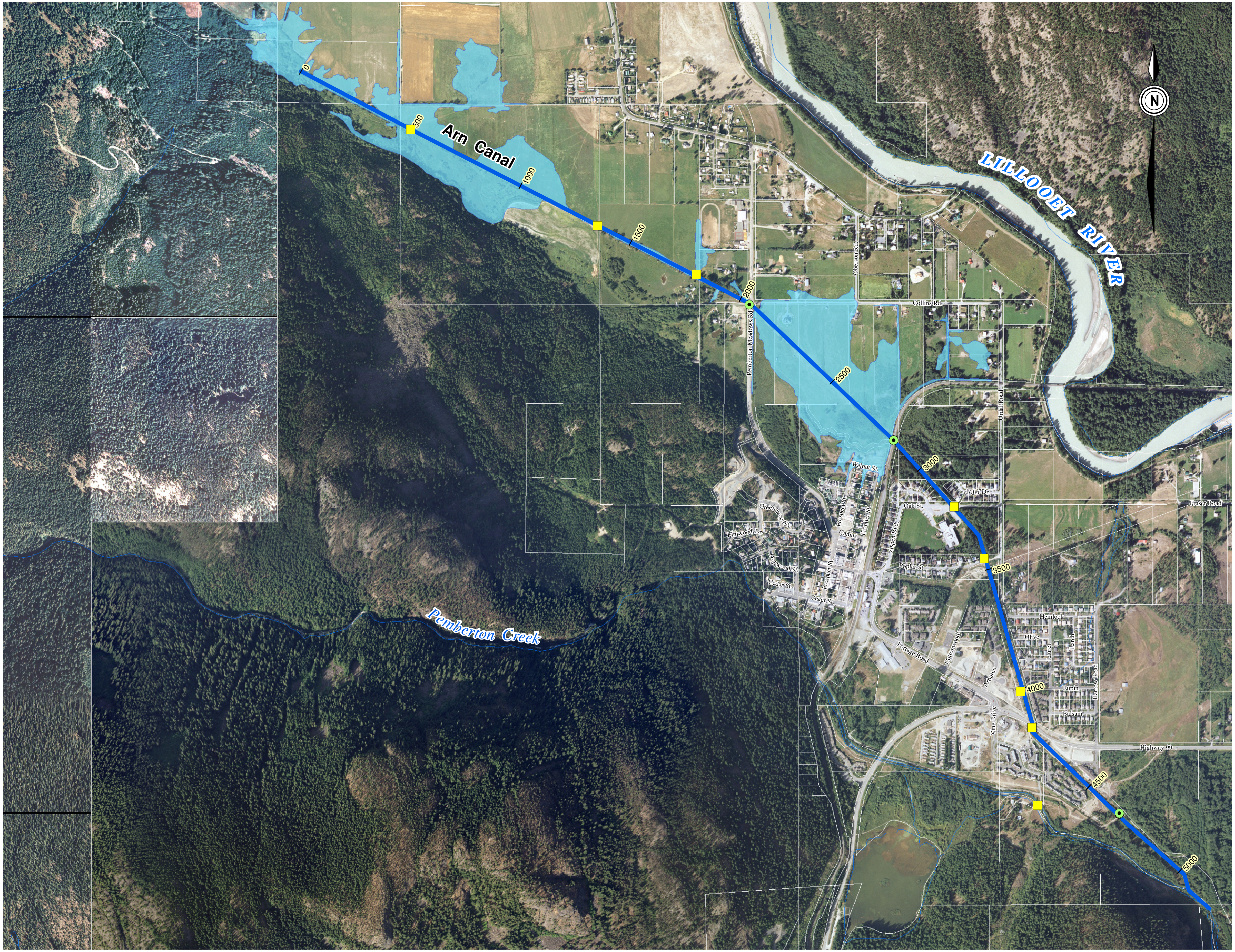
Figure 5

Arn Canal Water Level Profiles
(Pemberton-Arn Model with Free Outlet to Lillooet River)



Kerr Wood Leidal Associates Ltd.
O:\0700-0799\713-040\420-Model\ArnCanal\MIKE11\Build3\Pemberton Profiles20090716.xlsArn_Pem

Figure 6



Pemberton Valley Dyking District
Arn Canal
Drainage Improvement Project

N

Legend

- Watercourse
- Culvert
- Bridge
- Approximate 2-Year Flood Area Based on Topography from the 1990 Floodplain Mapping

Reference: 2006 Orthophoto.

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

300 0 300

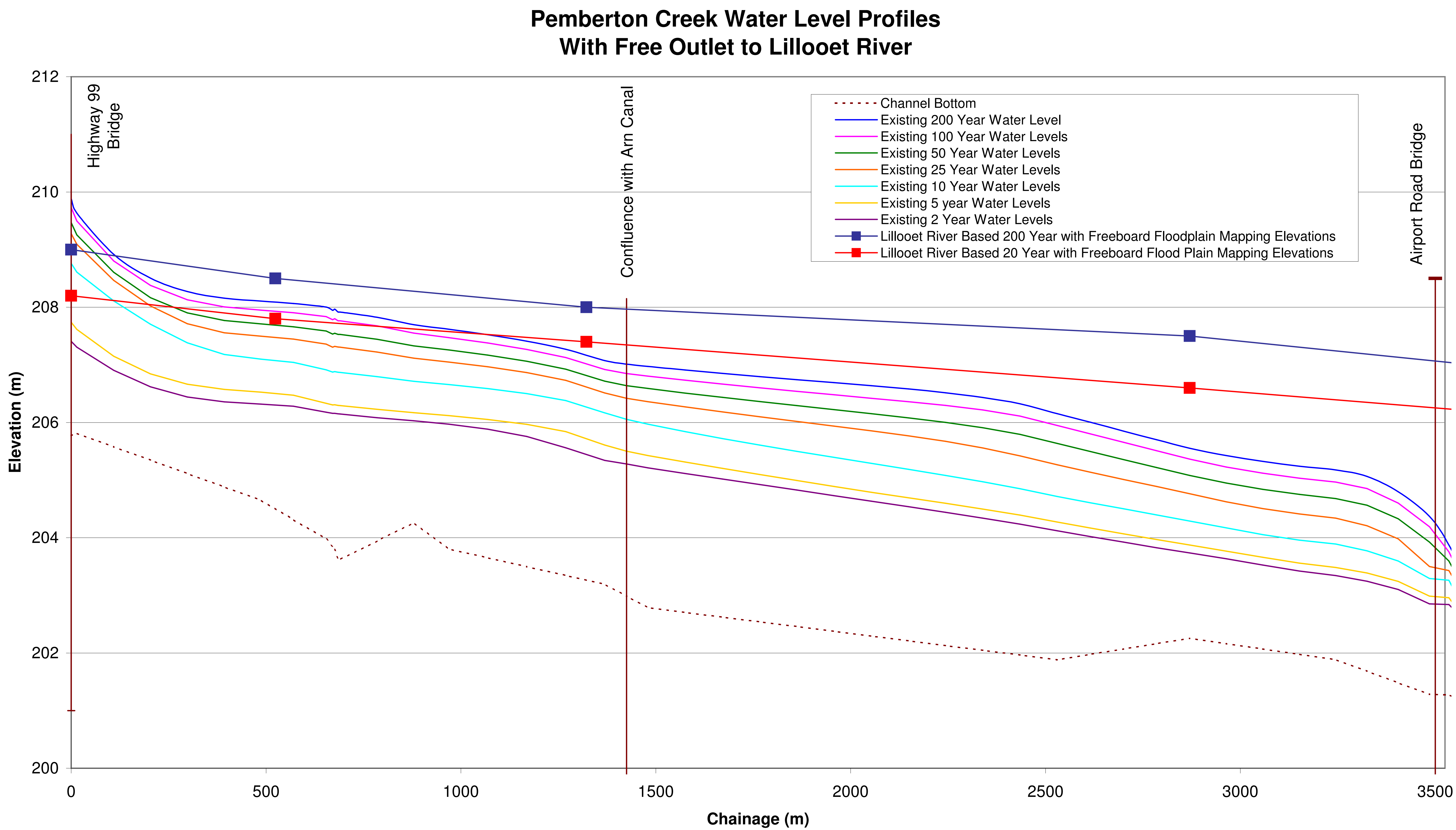
Scale in Metres 1:15,000

Project No.	Date
713-040	July 2009

2-Year Flood Area

Figure 7

Map Document: (O:\0700-0799\713-040\430-Gis\MXD-Rp\713040Fig7.mxd)
16/07/2009 -- 12:22:48 PM



Kerr Wood Leidal Associates Ltd.
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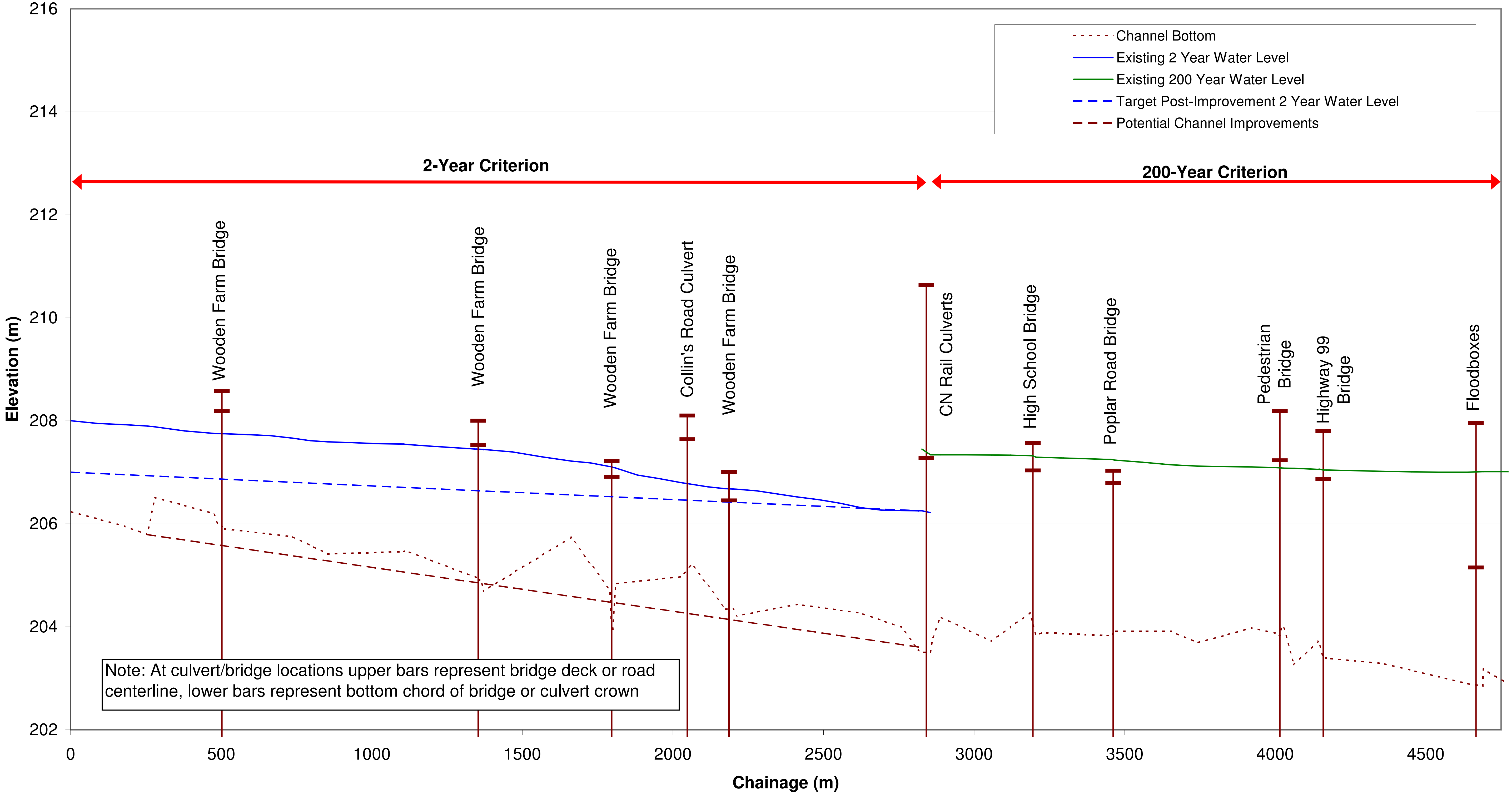
Figure 8

Proposed Arn Canal Conveyance Criteria



Kerr Wood Leidal Associates Ltd.
O:\0700-0799\713-040\420-Model\ArnCanal\MIKE11\Build3\Pemberton Profiles20090716.xlsArn_Pem_postimprove

Figure 9