POTENTIAL EFFECTS OF AN OIL PIPELINE RUPTURE ON REACH 2 OF MORICE RIVER

A SUBMISSION TO THE JOINT REVIEW PANEL ENBRIDGE NORTHERN GATEWAY PROJECT

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Frontispiece: Photo of a multithread section of Morice River located near the downstream end of Reach 2.

Photo 199 by Brian Huntington, Northwest Institute on October 4, 2009.

EXECUTIVE SUMMARY

The Enbridge Northern Gateway Project proposes to build a 91 cm (36 inch) oil export pipeline and a 51 cm (20 inch) condensate import pipeline from Bruderheim Alberta to Kitimat BC. The oil pipeline would transport conventional and synthetic oil, and over time an increasing amount of bitumen. The bitumen would be diluted with a thinner hydrocarbon or condensate and the combined product is referred to as diluted bitumen. These products are toxic to fish at low concentrations. The 1,176 km pipeline would cross over 600 fish-bearing streams in British Columbia, including some of the most important salmon habitats in the upper Fraser, Skeena and Kitimat watersheds.

This submission focuses on a portion of the pipeline route that is located adjacent to Morice River, 70 km south of Smithers. This 34 km long section of channel is referred to as 'Reach 2'. Within this area, Morice River has formed a wide floodplain that contains numerous active secondary channels, log jams and wetlands that comprise the core spawning and rearing habitat for Morice River fish populations. Schwab (2011) indicates that slope instability in this area has the potential to rupture the proposed pipelines. This report examines the implications of a pipeline rupture and subsequent clean-up efforts to river processes, fish and fish habitat.

The submission relies on data presented in the Enbridge 2010 application including impact pathways and spill volumes associated with a pipeline rupture in the Morice Watershed. As well, it relies on a rich background of fish and geomorphology information collected in the Morice Watershed during the past 40 years, observations from recent oil spill events in North America, and years of personal field experience in this watershed. On this basis, the potential consequences of a diluted bitumen spill into Morice River have been evaluated.

Current fish escapements to the Morice River are strong, the watershed is productive and habitats are intact. The Morice River supports the largest chinook salmon run in the Skeena River comprising more than 30% of the total Skeena escapement. The Skeena River is the second largest chinook river in BC. The Morice summer steelhead run is also the largest in the Skeena River supporting more than 20% of the total Skeena escapement. Morice River, particularly Reach 2, also supports a large recovering population of coho salmon, pink salmon, and blue-listed bull trout, and is a corridor for sockeye salmon adults and smolts moving to and from upstream spawning areas. Reach 2 in the Morice River provides critical spawning habitat and is the most productive rearing area for millions of juvenile salmon and steelhead that are present year-round. This river is the principal salmon spawning area within the Wet'suwet'en First Nations territory, and these runs have been fished for at least six thousand years.

An oil pipeline rupture would spread hydrocarbons throughout Reach 2 and would contaminate the log jams, side channels and shoreline areas that comprise key fish habitats. The more volatile fractions of the oil would be immediately toxic to fish and developing eggs located in this reach. The heavier bitumen components would slowly release polycyclic aromatic hydrocarbons (PAHs) that would have chronic effects on salmon egg development and juveniles rearing in these habitats for many years.

The volume of oil in the pipeline is sufficiently large that, even if the valves were closed immediately at the time of rupture, a large volume of oil could drain into the environment. Water velocities in Morice River exceed Enbridges's criteria for using conventional containment booms, absorbents and skimmers to collect hydrocarbons for much of the year, and ice conditions would curtail clean-up activities during periods of lower streamflow that occur in the winter.

The ability to promptly respond to a pipeline rupture would be hindered by the remoteness of the area, poor access along much of the river floodplain, and the complex network of debris and side channels in the river. The Morice River is covered in ice and snow during the winter and carries high sediment loads during spring run-off. These factors, along with the tendency for bitumen to sink and move into sediments on the river bed or banks, would make it impractical to effectively contain or recover spilled oil once it has entered the river.

Remedial actions that might be taken following a spill, such as collecting oil-covered debris and sediments and removal to decontamination sites, or burning oiled debris on gravel bars, could cause long-term habitat impacts. Observations on Pine River in north central BC indicate that log jam removal and re-construction following an oil spill in 2000 resulted in dramatic increases in channel instability. Log jam removal in Reach 2 of Morice River could lead to similar mainstem channel destabilization, with a subsequent loss of critical habitats for fish.

It is our opinion that diluted bitumen attached to debris and accumulated in the spawning gravels and shoreline sediments would persist and affect salmon and steelhead survival in Morice River for an extended period. Habitat impacts could similarly persist for decades. There do not appear to be any proven techniques for effectively mitigating these impacts.

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ABOUT THE REPORT

This document is an independent report requested by the Northwest Institute for Bioregional Research. The conclusions and opinions expressed in this report are entirely those of the two report authors and do not reflect the policies of Northwest Institute for Bioregional Research.

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A SUBMISSION TO THE JOINT REVIEW PANEL: ENBRIDGE NORTHERN GATEWAY PROJECT

1: INTRODUCTION AND OBJECTIVES

The Enbridge Northern Gateway Project (Enbridge) proposes to build a 91 cm (36 inch) oil export pipeline and a 51 cm (20 inch) condensate import pipeline from Bruderheim, Alberta to Kitimat, BC. The export pipeline will be designed to transport conventional light and heavy oil, synthetic oil, bitumen blended with condensate and bitumen blended with synthetic oil. Bitumen, derived from oil sands extraction is a thick sticky form of crude oil that needs heat, pressure, and dilution with lighter hydrocarbons to flow. The proposed pipeline will transport an increased amount of diluted bitumen as the total supply of bitumen increases relative to synthetic oil in Alberta. Condensate, diluted bitumen and synthetic oil can all be acutely toxic to fish upon exposure (Enbridge Volume 7B, Section 7).

The pipeline is designed for an average throughput capacity of 83,400 m^3 (525,000 barrels) per day of oil products. The condensate pipeline has a daily throughput capacity of 30,700 m^3 (193,000) barrels and would run parallel to the oil pipeline. The imported condensate would be used to dilute the bitumen shipped from the oil sands (Enbridge, 2010 Volume 1). *[1]

The proposed pipeline right-of-way is 1,176 km in length and crosses over 1,500 watercourses including at least 600 fish-bearing streams in British Columbia (Enbridge Volume 6a Section 11). The project would cross through some of BC's most important salmon habitats in the upper Fraser, Skeena and Kitimat watersheds.

This submission examines the implications of a pipeline rupture and subsequent clean-up efforts along a section of Morice River located approximately 70 km south of Smithers (Figure 1.1). Schwab (2011) indicates that a pipeline failure could occur within the Morice Watershed as a result of slope instability. Large slump earthflows in glaciolacustrine sediments and unstable fluvial fans are identified as risks to the section of pipeline located along the Morice River and Gosnell Creek. Schwab's report outlines a history of ruptured gas pipelines and road failures from landslides in this region. Swift et al. (2011) discuss added risks with diluted bitumen pipelines due to rapid corrosion and difficulties of leak detection. Within this context, our report examines the consequences of a diluted bitumen spill on river processes, fish and fish habitat.

Approximately 71 km of the proposed pipeline is located in the Morice Watershed, entering at pipeline KP 999 *[2] into the Owen Creek watershed and exiting at KP 1070 in the upper Gosnell Creek watershed (Figure 1.1). This area was selected for examination to illustrate the diverse fish populations and habitats that occur in this section of Morice River. The pipeline follows along the mainstem Morice River from KP 1006 to a mainstem crossing location near KP 1042. Morice River consists of a single thread channel at the crossing location. However, the channel abruptly changes its character 2 km downstream at the confluence with Gosnell Creek and Thautil River. Below this point, Morice River has a wide valley flat that contains numerous active secondary channels, log jams, wetlands and other features that comprise the core spawning and rearing habitat for Morice River fish populations. This section of channel is referred to as 'Reach 2'.

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[1] References to Enbridge documents in this report refer to its Northern Gateway Project application submitted to the National Energy Board for review. These documents can be found at http://www.northerngateway.ca/public-review/application.

[2] Pipeline distance points are based on maps and profiles submitted on March 11, 2011. These are different from the linear distance project maps submitted in November 2009 and presented in Figures 1.2 to 1.4.

The importance of the Morice River floodplain and riparian habitat was identified in the Morice Land and Resource Management Plan (LRMP) (ILMB 2007). Key goals established included maintaining the riparian and floodplain ecosystems, conserving the high value fish and wildlife habitat, and continuing to provide opportunities for river-based recreation (Plate 1.1).

This submission focuses on the potential effects of a rupture in the 36 km section of the pipeline located adjacent to or immediately upstream of Reach 2. Our analysis relies on information presented by Enbridge in their application submissions, including spill toxicity, impact pathways and potential volumes for a significant rupture along the pipeline route, including information provided in response to the Joint Review Panel (JRP) request made in January 2011. It also relies on a rich background of fisheries and geomorphology information collected during the past 40 years in the Morice Watershed. The inability to mitigate fisheries impacts to this very important section of Morice River was an important factor in the termination of the Morice-Nanika component of the Kemano Completion Project proposed by Alcan (now Rio Tinto Alcan) in the 1980's.

This submission also draws on information from other recent spills including the Pine River spill and clean-up in northeast BC in 2000, the Enbridge pipeline rupture on the Kalamazoo River in 2010, and some of the science documenting the longer-term effects of hydrocarbons on fish populations which became available following the Exxon Valdez spill in 1989.

Spill routing maps prepared by Enbridge [*1] indicate that a major spill in the 29 km of pipeline located in the Gosnell Creek watershed and along the Morice corridor between Owen Creek and the Morice River crossing upstream from the Gosnell confluence could move downstream into Reach 2 of Morice River. The location maps indicate shut-off valves would be spaced on average 8 km apart within this section of the pipeline route. A pumping station is planned near the crossing of Owen Creek (Km 1006). Potential control points for an oil spill response are all located downstream from Reach 2 (Polaris 2010). Control points are pre-planned locations where responders can safely and effectively deploy oil spill response equipment to limit downstream movement of oil on a river.

A spill volume of 2,000 m^3 has been used by Enbridge in their assessment of two hypothetical spills along the pipeline route (Enbridge Volume 7B, Section 9.4.1). This is less than the 3,100 m^3 spilled from Enbridge's 76 cm (30 inch) pipeline rupture on the Kalamazoo River in 2001 [*2] and more than the estimated 950 m^3 spilled at the Pine River 30 cm (12 inch) pipeline failure in 2000.

Given the large diameter of the proposed pipeline, and the significant volume that will be present in each kilometer of pipe between the valves, a complete rupture could result in a larger spill than the 2000 m^3 volume assessed by Enbridge if the pipeline is at maximum throughput. [*3] Projected maximum volume releases of oil by kilometer section along the route suggest that, in many sections, volumes ranging from 1,000 to 2,000 m^3 of oil could drain by gravity from a single one kilometer long section of the pipeline. [*4]

It should be emphasized that a large pipeline rupture releasing diluted bitumen in this section of Morice River could very quickly reach downstream habitats in lower Morice and Bulkley rivers, and potentially the Skeena River. These rivers comprise some of the richest fish habitats in North America where salmon

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[1] Maps submitted by Enbridge in response to Additional Information Request from Joint Review Panel dated January 19, 2011.

[2] This is based on a spill of 819,00 US gal (EPA estimate), 42 US gal/barrel and 6.29 barrels/m^3.

[3] For assumptions see Northern Gateway Response to Request for Additional Information, March 2011, Page 6.

[4] Volumes by section provided in GOSRP 11-032 Maps 113 to 117.

and steelhead from hundreds of upstream tributaries move through the lower river and estuary to the Pacific Ocean (Gottesfeld and Rabnett 2008). Our submission does not address the potential spill impacts on the lower river, or in other systems along the pipeline route in northwest BC that have slope stability risks and high salmon and steelhead values including the Zymoetz and Kitimat rivers.

The submission begins with a description of the study area including watershed attributes and fish resources relevant to assessing the potential consequence of a diluted bitumen spill on Morice River. Information from past major spill events including the 1989 Exxon Valdez oil spill, 2000 Pembina Pipeline oil spill on Pine River in northeastern BC, and the 2010 Enbridge spill in the Kalamazoo River is presented in Section 4. Reports from these events, combined with information presented in the Enbridge Northern Gateway submission, and years of personal field experience in the Morice Watershed form the background for an assessment of the potential consequences of an 'oil' spill in Morice River (Section 5). The study conclusions are presented in Section 6.

2: THE STUDY AREA

2.1 PHYSIOGRAPHY

The Morice River drains the east side of the Coast and Hazelton Mountains, and is the largest tributary to Bulkley River. Watershed elevations range from 1,800 to 2100 m in the basin headwaters to 576 m at the confluence with Bulkley River. Nanika and Morice lakes (approximate areas 56 and 112 km^2, respectively) are located near the western end of the watershed and, to some extent, naturally buffer the river flow in the downstream mainstem channel. Gosnell Creek and Thautil River join Morice River 2.5 km below the proposed KP 1042 crossing. These two watersheds have a combined basin area of 897 km^2 and elevations range up to 2,100 m asl. Other sizeable tributaries crossed by the pipeline include Owen, Lamprey, Cedric, Fenton and 24.5 Mile Creeks. Additional biophysical information of the study area is contained in reports by Fuhr et al. (1986) and in the Morice LRMP (ILMB, 2007).

2.2 HYDROLOGY

The Water Survey of Canada (WSC) has operated three stream gauging stations within the Morice River watershed. One year of record (1976) is available from the station Morice River at the Mouth (basin area 4,270 km^2) and 61 years of data are available from the station Nanika River at Outlet of Kidprice Lake (basin area 735 km^2). The most relevant station from the perspective of the present study is Morice River near Houston (basin area 1,900 km^2). This stream gauge, which has been in operation since 1961, is located near the outlet of Morice Lake, 13 km upstream from the proposed KP 1042 crossing (Figure 1.1).

The seasonal variation in discharge at the Morice River near Houston gauging station is illustrated on Figure 2.2.1. These data indicate that two periods of elevated flows occur annually. The snowmelt freshet begins in April or May and is typically the largest event in the year. However, rain or rain-on-snow events can also result in sizeable discharges in the period between September and November. The comparative size of the snowmelt freshet and fall floods on Morice River at the station Morice River near Houston reflects the buffering effect of Morice and Nanika lakes. For example, stream gauge data from the WSC stream gauging station on Telkwa River below Tsai Creek (basin area 368 km^2) is illustrated on Figure 2.2.2. This site is located 50 km north of Morice River in a comparable physiographic setting, but the watershed lacks any sizeable lakes. The comparatively short duration fall floods are therefore the largest events on record. A similar situation is expected to occur on the principal headwater tributary streams to Morice River below Morice Lake. Reach 2 of Morice River downstream from the Gosnell confluence is therefore expected to have a hydrograph that reflects both snowmelt and fall flood events.

The historical variation in annual maximum daily and instantaneous discharge observed on Morice River is illustrated on Figure 2.2.3. Flood frequency analyses have been undertaken using the BC Government computer program FFAME *[1] and the results are compiled in Tables 2.2.1 & 2.2.2. This analysis indicates that the chronology of ≥10 year return period instantaneous flood flows is as follows:

YEAR	APPROX. RETURN PERIOD (years)
1964	20
1969	50
1992	25
1997	20 (est.)
1998	10
1999	10
2002	30

Annual hydrographs, which include the 1969, 1992 and 1999 flood events, are illustrated on Figure 2.2.4. This analysis indicates that, during the 1969 flood of record, freshet flows decreased from 391 m^3/s to 100 m^3/s in 45 days. In contrast, during the 1999 freshet it took 80 days for flows to decrease from 322 m^3/s to 100 m^3/s. The 1992 fall flood of record took 34 days to decrease from 355 m^3/s to 100 m^3/s. This variability in recession rates indicates that the amount of time over which oil could be carried downstream by flood waters, or stranded on elevated sections of gravel bar, can vary significantly depending on flood characteristics.

A combination of glacier melt, lake and wetland storage, and autumn rains maintain high summer and fall flows in the mainstem Morice River until freeze-up which typically occurs in late-November. As a consequence, extreme summer low-flows do not occur in the main stem river.

2.3 WATER TEMPERATURES AND ICE

Mean daily water temperatures in the Morice River are above 5ºC from approximately the beginning of May to early November.*[2] Maximum water temperatures approach 15ºC in August. Morice Lake has a significant moderating effect on water temperatures in the upper river, with the section of river upstream from Gosnell Creek remaining ice-free year-round. The channels downstream from Gosnell Creek are typically covered in ice and snow from December through April. However, some open water leads can persist depending upon the severity of the winter (Plate 2.3.1).

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[1] Annual data have been analyzed using the Log Pearson Type III Distribution fitted by the Method of Moments. Presented results are an initial approximation as the spring freshet and fall floods have not been analyzed separately as recommended in Watt (1990). This analysis is therefore for discussion purposes only, and is not suitable as a basis for design.

[2] Juvenile salmon and steelhead become less active and seek overwinter cover such as log jams, banks with debris cover and clean interstitial spaces in cobble and boulder habitats when water temperatures are less than 5ºC (Bustard and Narver, 1974).

2.4 WATER QUALITY

A systematic water quality sampling program was conducted on the lower Morice River for a five-year period from 1983 to 1987 with a sampling frequency of approximately once per month. The results of this survey are summarized in Remington (1996), who concluded that Morice River water quality is excellent relative to criteria for protection of aquatic life. The review indicated that nutrient levels in the watershed are very low.

Significant natural sediment sources occur in tributary streams to Morice River, such as the Thautil River, and Gosnell and Houston Tommy creeks (Plates 2.4.1 & 2.4.2). Suspended sediment levels reduce water clarity in Reach 2 of Morice River during the May through early July snowmelt period, and during heavy rainfall events at other times of the year.

2.5 CHANNEL MORPHOLOGY

The channel characteristics of Morice River in the vicinity of the study area have been previously investigated by Envirocon (1984a & 1984b), Gottesfeld and Johnson Gottesfeld (1990), and Weiland and Schwab (1992). These reports have divided Morice River into a number of comparatively homogeneous reaches. As indicated on Figure 1.1, Reach 1 extends for a distance of 17 km between the outlet of Morice Lake and the Gosnell Creek/Thautil River confluence. Reach 2 consists of the area between Gosnell Creek/Thautil River and the confluence with Owen Creek, a distance of 34 km. Reach 3 extends between the confluence of Owen Creek and the Bulkley River, a distance of 37 km.

Reach 1 generally consists of a single thread channel with an average unvegetated width of approximately 60 m. The proposed KP 1042 crossing is located approximately 2.5 km from the downstream end of this reach.

Reach 2 has been described as:

> *"a wandering gravel bed river with one to several channels, frequent channel changes, gravel bars, forested islands, eroding banks, log jams and a network of seasonally flooded channel remnants over the floodplain. The floodplain occupies all the valley flat and varies in width between 300 and 1,400 meters."* *Weiland and Schwab, 1992, page 3.*

Weiland and Schwab (1992) concluded that most of the gravel accumulations in Reach 2 originate from the Thautil River basin. Extensive bank erosion along Thautil Creek contributes a large portion of the suspended sediment component and the Starr Creek basin is the source of much of the bedload.

Studies by Gottesfeld and Johnson Gottesfeld (1990) indicate that 97% of the river bed material is coarser than 2 mm. Historical air photo analysis indicates that the channel configuration in Reach 2 is:

> *"regularly re-organized by channel shifting or progressive meander cutting, abandonment of main channel segments, formation of new channels and the re-excavation of old channel segments which capture the main channel flow."* *Gottesfeld and Johnson Gottesfeld, 1990, pages 174 & 175.*

Dendrochronology studies suggest that:

> *"channel changes and floods extending from the present time back to the 1870's and 1880's are similar to those observed in the last few years."* *Gottesfeld and Johnson Gottesfeld, 1990, p. 177.*

Figure 2.5.1 illustrates conditions at the upstream end of Reach 2 and Figure 2.5.2 documents how this site has changed over the period since 1955. The imagery illustrates the numerous channels in this area and how their location and relative importance varies with discharge and has changed over time. Similar channel processes occur in the downstream section of the study area. Weiland and Schwab (1992) further investigated rates of channel change and documented the mobile character of the multithread channels that occur within Reach 2. They compared river conditions based on air photos flown in 1949 and 1988. The results are presented on Figure 2.5.3 and indicate the extent of erosion and deposition over this 39-year period. They found that rapid changes may occur within a narrow corridor along the main channel but the rate of channel migration into the inactive floodplain occurred at a much slower rate of 1 to 1.5 m per year.

Log jams play an important role in channel stability on Reach 2. As discussed in Gottesfeld and Johnson Gottesfeld (1990), log jams are *"typically assembled by a single flood and then have periodic additions (resulting) in volumes as large as 3,000 to 8,000 m^3" (page 174)*. Log jams are frequently situated at the head of a bar or island, along an eroding section of bank, at a channel junction or spanning the entrance to a secondary channel (Plate 2.5.1). The formation of these structures can initiate channel reorganization, their presence can stabilize an eroding bank or secondary channel inlet, and the loss of a structure (by erosion, fire, etc.) can destabilize a section of channel or allow the enlargement of a previously stable secondary channel.

The effect of log jams on channel processes in Reach 2 is particularly important due to the number of structures which have naturally formed. Studies based on an aerial photo mosaic prepared in June 1975 indicate that there were approximately 40 log jams per km of mainstem channel between the Gosnell/Thautil confluence and Lamprey Creek, and approximately 20 log jams per km of mainstem channel between Lamprey Creek and Owen Creek (Shepherd, 1979). These mainstem channel segments are approximately 17 km long, leading to an estimate of approximately 1,000 log jams in Reach 2 of Morice River (Table 2.5.1). Shepherd (1979) also estimated there were between 9 and 12.5 km of wetted shoreline for every km of river in these two sections, leading to an estimate of close to 370 km of shoreline in Reach 2 during the high flow period (Table 2.5.1). In addition to the log jams, individual log sweepers and debris are present throughout Reach 2 along the stream edge, and aquatic vegetation is common in the slower backwater areas located out of the main current.

2.6 HYDRAULIC GEOMETRY

The feasibility of responding to an oil spill on Morice River will be affected by wetted channel widths, water depths, cross-sectional area and current velocity. The WSC stream gauging notes for the station Morice River near Houston have therefore been compiled on Figures 2.6.1 to 2.6.4 to illustrate the relationship between these variables and discharge. Best-fit relationships have been established and the seasonal variation in these parameters is shown on Figures 2.6.5 to 2.6.8, based on the discharge data shown on Figure 2.2.1.

Hydraulic geometry data similar to that collected at the WSC gauge is not available for Reach 2 of Morice River. However, as indicated on Figure 2.6.9, the average river slope in Reach 1 (0.0024 m/m) is similar to that in Reach 2 (0.0017 m/m). *[1] River widths and upstream basin areas increase downstream of the Gosnell Creek/Thautil River confluence and consequently hydraulic geometry values will not necessarily be the same as those observed at the WSC gauge. Nevertheless, these data provide an initial (and

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[1] See Weiland and Schwab (1992) and Bustard and Schell (2002) for a more detailed discussion of river gradients within Reach 2.

potentially conservative) estimate of conditions within Reach 2 in areas where there is a well-defined mainstem channel.

The oil spill management implications of this analysis will be discussed in Section 5.

2.7 LAND USE AND FOREST COVER

Clear-cut logging has been undertaken over extensive areas of the Morice Watershed (Figure 2.7.1). Mountain pine beetle has also infected the watershed and sizeable areas are now composed of beetle-attacked or dead trees (Plate 2.7.1). Both these factors will tend to increase the size of potential flood flows. For example, an analysis by the BC Forest Practices Board (2007) indicates that mountain pine beetle damage has the potential to increase the size of peak flows by 60% in the Baker Creek watershed located west of Quesnel. Salvage logging was similarly predicted to increase the size of peak flows by up to 90% and flood events that used to occur once every twenty years could now take place every three to five years. These results imply that the pine beetle infestation has the potential to destabilize sensitive areas such as Reach 2 of Morice River. The probability of destabilization would be increased if riparian vegetation or log jams were disturbed or destroyed by anthropogenic activities such as attempting to clean-up an oil spill.

3: FISH RESOURCES OF MORICE RIVER

3.1 BACKGROUND

The mainstem Morice River adjacent to the pipeline provides critical spawning and rearing habitat for coho, chinook and pink salmon, and summer-run steelhead trout. It is the migration corridor for sockeye spawners moving up to Morice Lake and the Nanika River, and for smolts of sockeye and other anadromous species moving downstream to the lower Skeena. The mainstem Morice in this section also provides important rearing and staging areas for the blue-listed bull trout, mountain whitefish, rainbow trout and a several other fish species including prickly sculpins, largescale suckers, and Pacific lamprey.

Morice River fish stocks are especially important for the Wet'suwet'en First Nations, whose territory overlies the Morice Watershed and who have fished the Bulkley-Morice stocks (Plate 3.1.1) for at least six thousand years based on archaeological data collected at fishing sites including Moricetown on the Bulkley River (Rabnett, 2006). The Morice fish stocks are the main salmon resource within their territory. These stocks, especially the sockeye, provide for important food, ceremonial and social needs, and protection and restoration of Morice salmon stocks are considered vital to the Wet'suwet'en First Nations.

The salmon and steelhead runs in the Morice Watershed are wild stocks managed to safeguard the genetic diversity of populations, maintain habitat and ecosystem integrity and a sustainable fisheries as outlined in DFO's Wild Salmon Policy (FOC 2005) and BC's Steelhead Stream Classification Policy (Province of BC 2005). There is currently no hatchery augmentation of these runs.

Important sport fisheries for wild summer steelhead, chinook and coho along the Bulkley and Morice are dependant upon the spawning and rearing areas in this section of Morice River. These rivers, with their clear waters and impressive scenery, have an international reputation drawing anglers from around the world and are an important economic driver to the local economy (Plates 3.1.2 & 3.1.3). The wild salmon economy of the Skeena River watershed was valued at $110 million in 2004 (Business Consulting Services, 2006). *[1]

There is no month of the year when salmon or steelhead eggs, or their alevins, are not present in the gravels of Reach 2 of Morice River. There is also no time when juvenile salmon and steelhead are not present in this section of the river. In fact, species such as steelhead may spend up to four years rearing in the mainstem habitats prior to smolting. An oil pipeline rupture would therefore have direct consequences to multiple age classes of regionally significant fish species that spawn and rear along the pipeline route.

The fish species utilizing this section of Morice River are described in the following section. This includes a current summary of their abundance, life history timing and habitat utilization. Most of the life history and habitat information in this section is derived from detailed studies conducted during the Kemano Completion Project (Shepherd, 1979; Envirocon Ltd., 1984c) and from information compiled in Bustard and Schell (2002).

It is important to emphasize that the abundance estimates presented in this submission are the estimates for fish that actually escape the downstream capture fisheries to reach their spawning destinations. Morice River salmon contribute to the Alaska commercial fishery, BC troll and net fishery, tidal and freshwater sport fishery, and to the inland native fishery en route to their spawning areas.

3.2 CHINOOK SALMON

3.2.1 Abundance

Morice River is the most important chinook salmon river in the Skeena Watershed accounting for more than 30% of the Skeena escapements (Winther and Candy 2011). Skeena River has the second highest chinook salmon escapements of any river in British Columbia. Over 60 years of spawning escapement estimates are available for Morice River chinook, dating back to 1949 (SEDS 2010 data from Fisheries and Oceans, 2011). The spawners and redds (spawning sites) are large, and generally quite visible making enumeration of Morice populations from the air more reliable than for species like coho and steelhead. Estimated spawning populations have averaged just under 10,000 chinook for the period of record, and just over 10,000 fish for the past decade (Table 3.2.1.1; Figure 3.2.1.1).

3.2.2 Chinook Spawning Timing and Distribution

Morice River chinook salmon migrate into Morice River from July through late September. Spawning occurs throughout September and into early October. Nearly all chinook salmon spawn in the main channel of Morice River between Lamprey Creek and Morice Lake. Heaviest spawning occurs in the 4 km of Morice River immediately downstream from the lake. However, between 15 and 20% of the chinook spawning occurs in the mainstem Morice downstream from the pipeline crossing (Bustard and Schell 2002).

Chinook eggs and developing alevins remain in the bed material from the September spawning period until April or early May. Millions of chinook fry emerge with rising river levels and immediately distribute downstream along the river margin (Smith and Berezay 1983).

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1 This valuation did not include indirect and non-use values including species preservation, biodiversity, cultural heritage, and importance to wildlife.

3.2.3 Juvenile Chinook Rearing Habitat

Extensive studies of Morice River chinook fry rearing habitat by season were conducted during the Kemano Completion studies and detailed descriptions of depth, velocity and cover characteristics of habitats used by chinook fry are available (Envirocon Ltd., 1984c; Shepherd, 1979).

These studies indicated that chinook fry occupied shallow marginal areas along the mainstem shortly after emergence, shifted primarily to side channels during high flows, and were distributed throughout the mainstem and side channels by the fall and winter. Chinook fry preferred low velocity habitats along the stream margin and used cobbles and debris associated with root wads and log jams for cover (Plates 3.2.3.1 & 3.2.3.2). They tend to move into faster and deeper water as they grow, but their habitat is still along the river margins.

Estimates conducted over three years indicated that approximately 35-45% of the total chinook fry rearing between Morice Lake and Smithers occurred in Reach 2 of Morice River (Envirocon Ltd., 1984c).

Some out-migration of larger chinook juveniles occurs during the fall, but many chinook fry remain in-river for their first winter. During the winter, Morice chinook fry move into spaces in bed material, typically into clean cobbles along the stream edge. Fry have dispersed along Morice River and into the Bulkley and presumably along the Skeena River by the early winter and remain essentially inactive in the spaces in cobbles along the river edge from late October until the spring of the following year when they move downstream to the Skeena River estuary with rising river levels.

3.3 COHO SALMON

3.3.1 Abundance

Morice River coho stocks have accounted for an average of near 5% of the Skeena River runs since the 1950's with a downward trend until the past decade (Gottesfeld and Rabnett, 2008). Extremely low escapements during the 1990's led to a "coho crisis" including curtailments of the Skeena River commercial and sport fisheries. Coho escapements have been increasing through this past decade.

Historically, coho spawners have been difficult to enumerate effectively due to the long duration of spawning, widespread distribution in the watershed, the potential for high flows during the spawning period and the tendency for spawners to associate with cover. These factors typically led to inaccurate estimates of the actual number of spawners present. Since 1997, estimates of coho spawning escapements to the Bulkley and Morice rivers have been collected by conducting mark-and-recapture estimates at Moricetown Canyon. These estimates, in conjunction with frequent aerial counts during the spawning season, have been used to derive AUC *[1] estimates of coho abundance (Unpublished file data, DFO, Smithers). Based on these more reliable enumeration methods, the mean escapement estimate for the period 1997 to 2010 is 35,000 coho spawners above Moricetown (Table 3.3.1.1).

Annual aerial escapement counts indicate approximately 30-40% of the coho spawning above Moricetown use Reach 2 of the mainstem Morice River (pers. comm., Barry Finnegan, DFO, Smithers). The mean coho escapement estimates derived at Moricetown combined with the aerial counts, indicate between 10,000 and 15,000 coho spawners utilize the section of Morice River adjacent to the proposed pipeline

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[1] Area under the curve estimates based on the counts through the spawning season and numbers of fish corrected for residence time on redds.

(Table 3.3.1.1). Another approximately 2,500 coho use Gosnell Creek, a major tributary to Morice River on the proposed pipeline route (Unpublished file data, DFO Smithers).

3.3.2 Coho Spawning Timing and Distribution

The first coho spawners enter Morice River in August with spawning extending from October into December. The peak of spawning in the side channel sections of Morice River occurs in November, with large numbers of spawners still present well into December in some years. For example, on December 9, 2009, close to 10,000 coho spawners were present in Morice River (Barry Finnegan, unpublished file data DFO, Smithers).

Historical observations suggest that the mainstem reach of Morice River from Gosnell to Lamprey Creek and sections of the mainstem Gosnell Creek are the core spawning habitats for coho in Morice River (Bustard and Schell, 2002). Side channel areas, in particular, are heavily used by spawners. Smaller numbers of coho spawners occur in Nanika River, lower Owen, McBride, Lamprey, and Houston Tommy creeks and Thautil River. More spawning occurs in smaller tributaries when fall freshets enable coho spawners better access to smaller systems.

In a typical year millions of coho fry *[1] emerge between mid-May and early July from the section of Morice River adjacent to the proposed pipeline route.

3.3.3 Juvenile Coho Rearing Habitat

Shortly after emergence, coho fry re-distribute downstream along the main stem river and some move into the lower ends of accessible tributaries and pond habitats adjacent to the main stem river. Coho rear in Morice River habitats for one or two years prior to leaving the systems as smolts from April through July (Shepherd, 1979; Plate 3.3.3.1).

Detailed studies describing habitat preferences of juvenile coho have been undertaken on Morice River (Envirocon Ltd. 1984c; Shepherd, 1979). The studies indicate high use of side channel areas throughout the summer and fall periods, with estimates of over 80% of the coho utilizing side channels compared to mainstem habitats.

During the active rearing period from May through October, coho utilize areas such as side pools, off-channel ponds on the floodplain, log jams and pool habitat along the channel margin. Coho fry are usually associated with some form of cover such as debris, root wads and shoreline vegetation. Yearling coho make greater use of deeper areas in log jams.

As temperatures decline in the winter, coho move deep into debris cover such as log jams and undercut banks with root wad cover (Plate 3.3.3.2; Bustard and Narver, 1974). They remain inactive through the winter period. The availability of suitable winter cover is probably a limiting factor for coho production in Morice River. Hartman (1965) noted a pronounced reduction in coho density in sections of the Chilliwack River where log jam cover was absent.

Estimates of coho production in the mainstem Morice and Bulkley rivers suggest that the section of Morice River Reach 2 that is adjacent to the pipeline corridor accounted for more than 50% of the mainstem river coho rearing between Morice Lake and Smithers (Envirocon Ltd., 1984c).

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1 This assumes an average of 3000 eggs per female and 30% survival from egg to fry (from Groot and Margolis, 1991).

Tributaries account for a significant amount of juvenile coho production in Morice River. Estimates for all tributaries combined suggested that Gosnell Creek accounted for nearly one-half of the total tributary coho production in the Morice Watershed (Envirocon Ltd., 1984c).

3.4 SOCKEYE SALMON

The Morice-Nanika sockeye stock is the largest sockeye run in the Bulkley Watershed. Sockeye escapements for Morice-Nanika have fluctuated substantially in the past 60 years. High escapements in the early 1950's gave way to 40 years of declining stock numbers. Escapements increased in the 1990s and have averaged near 8,000 fish in the past decade compared to approximately 10,000 sockeye for the period of record (Figure 3.2.1.1). Exploitation rates in the commercial and inland fisheries in the range of 50% combined with the low productivity of Morice Lake have been important factors influencing sockeye escapements. Lake fertilization studies have been undertaken on Morice Lake in an effort to increase sockeye production closer to its potential rearing capability. Rabnett (2006) provides a detailed update on the Morice sockeye issues.

Sockeye salmon adult spawners move through Morice River mainly during August en route to the main spawning areas in the Nanika River and shoreline spawning locations mainly in Morice Lake. Sockeye smolts move downstream from rearing areas in Morice Lake through Morice River mainly during the month of May (Smith and Berezay, 1983). The majority of sockeye smolts from Morice Lake are two-year olds, presumably reflecting the lake's low productivity (Shepherd, 1979).

Although Morice River serves mainly as a migration corridor for sockeye spawners and smolts, some historical spawning in the main stem river has been reported prior to 1975. There have also been recent observations of sockeye spawning in Morice River adjacent to the proposed pipeline route (Barry Finnegan, unpublished data, DFO, Smithers).

3.5 PINK SALMON

3.5.1 Abundance

Pink salmon were first observed in Morice River in 1953, following the installation of the fishways at Moricetown several years earlier. While escapements exceeding 800,000 fish have been recorded, the mean pink escapement for the past decade has been near 50,000 fish (Table 3.2.1.1; Figure 3.2.1.1). Morice pinks have comprised about 7% of the total Skeena pink escapement during the past decade. Some pink salmon are taken in the native fishery and pink salmon are now part of the sport fishery on the Bulkley and lower Morice rivers.

3.5.2 Pink Spawning Timing and Distribution

Pink salmon migrate into Morice River mainly in August, with a peak of spawning in early September. Studies conducted as part of Kemano Completion Project indicated that approximately 75% of the pink spawners were using side channel locations. These studies indicated that approximately 90% of the Morice River pinks salmon spawners were observed in the river section between Gosnell and Owen Creek (Bustard and Schell, 2002) along the immediate pipeline route.

Pink salmon spawner densities were approximately 30 times higher in suitable spawning areas in the side channel locations compared to mainstem habitats (Plates 3.5.2.1 & 3.5.2.2). Those pink salmon that spawn in the main stem river tend to use edge areas, since flows are too fast and bed material is too large in areas away from the edges in much of the mainstem.

In a typical year millions *[1] of pink salmon fry congregate just below the gravel surface in side channels of Morice River during April in preparation for emergence and downstream migration that occurs mainly during May. In many of these channels fry emerge at night, and may have to congregate in high densities in confined pools waiting for water levels to rise enough to allow access into the mainstem river to continue their downstream migration. Large numbers of migrating birds congregate in these areas to feed on pink fry 'trapped' in the isolated channels.

3.6 SUMMER STEELEHAD

3.6.1 Abundance

Morice and Bulkley rivers are world-class rivers renowned for their wild summer-run steelhead populations (Plates 3.1.2 & 3.1.3). Anglers require special licenses to fish these classified waters, and only catch-and-release fishing is allowed on steelhead to protect the stocks and the quality of the fishery. Steelhead mark-and-recapture estimates indicate an average of close to 19,000 steelhead spawners have been present in the Bulkley and Morice rivers upstream from Moricetown in the past decade (Table 3.6.1.1). *[2]

Genetic sampling conducted in 2007 and 2008 at the Tyhee Test Fishery to determine stock composition of Skeena steelhead entering the lower Skeena River, suggests that approximately 60% of the steelhead upstream from Moricetown are bound for the Morice River (Beacham and Beere, 2009). These studies indicate that the Morice River supports the largest steelhead run in the Skeena Watershed, comprising more than 20% of the total Skeena population.

3.6.2 Steelhead Spawning Timing and Distribution

The first steelhead appear in Morice River in early to mid-August and continue to move into the river through the autumn. Adults are distributed throughout the mainstem Morice during the fall. Lough (1995) estimates approximately 80% of Morice steelhead overwinter in the section from the upper Morice River bridge (near pipeline crossing at KP 1042) to Owen Creek confluence. Most of the remaining 20% of Morice steelhead winter in the river section downstream from Owen Creek.

Most Morice steelhead spawning occurs at the end of May and early June, with the rising water temperatures and streamflow conditions (Envirocon Ltd. 1984c). Spawning occurs during the spring freshet so exact spawning locations are difficult to delineate, and available information relies largely on radio-telemetry studies. Steelhead spawning in Morice River is widely dispersed between key tributary streams including Owen, Gosnell and Lamprey creeks, and the main stem river including documented

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[1] Assumes 1,500 eggs per female and 5% survival from egg to fry stage based on data presented in Groot and Margolis (1991).

[2] Data from SKR Consultants (2011). Steelhead mark-recapture estimates are influenced by a fallback factor of marked steelhead at the tagging site (Welch et al., 2009). The fallback correction is based on sonic tagging that indicates a portion of the steelhead that are tagged at Moricetown do not move past the canyon to the recapture location, leading to an overestimate of steelhead numbers. We have used a fallback of approximately 20%, an intermediate estimate used by SKR Consultants (2011).

sites between the pipeline crossing and Gosnell Creek and side channels in Morice River adjacent to the pipeline route. *[1]

Steelhead fry emergence occurs from late July in some tributary locations through to mid-August in sites in Morice River just downstream from the proposed pipeline crossing (Envirocon Ltd., 1984c).

3.6.3 Juvenile Steelhead Rearing Habitat

Most Morice River steelhead remain in freshwater for three or four winters prior to smolting (Plate 3.6.1.1). Steelhead that leave the river after four winters have spent approximately 45 months in the river, 19 of these months in an active growing period from May until the end of October, and 26 months in a relatively inactive period from November through mid-May (Bustard and Schell, 2002).

Specific juvenile steelhead habitat studies have been conducted in Morice River, particularly during the Kemano Completion Project (Envirocon Ltd., 1984c). Steelhead fry use shallow areas in riffles and marginal flats along the river edge and close to cover for the first summer. By November, most steelhead fry are found in the interstices of cobble and boulder habitats.

As steelhead juveniles grow, they move into deeper and faster waters, still typically within a few meters of the stream margin and cover. Boat electrofishing surveys indicated steelhead parr tend to drop downstream and were abundant along the Bulkley mainstem (Envirocon Ltd., 1984c - Section F). Shepard and Algard (1977) indicated that larger steelhead parr in the mainstem Morice were most abundant in log jam habitat during the summer. Steelhead parr overwinter in low velocity sites with debris, log and boulder cover. Observations elsewhere indicate log jams provide important overwintering habitat for steelhead parr (Hartman, 1965). We assume steelhead use of the log jams for overwinter cover in the Morice River is consistent with these other observations (Plate 3.6.1.2).

Estimates based on sampling throughout the Morice Watershed suggest that nearly one-half of the steelhead fry and younger steelhead parr rearing in the Morice Watershed occurred in Morice River tributaries with the balance in the main stem river (Envirocon Ltd., 1984c). The side and main channel habitats of the Morice River reach adjacent to the pipeline corridor accounted for 50% of the mainstem river steelhead fry and 35% of the steelhead parr rearing between Morice Lake and Smithers.

3.7 OTHER FISH SPECIES

Bull trout adult and sub-adults are present in the mainstem Morice throughout the year. Bull trout in British Columbia are now designated as a blue-listed species with populations considered vulnerable and at risk. Morice bull trout typically spawn and spend their early rearing periods in tributaries before returning to the main stem river (Bustard and Schell, 2002). Extensive radio-telemetry studies conducted in the Morice Watershed (Bahr, 2002) identified Gosnell Creek as a key spawning stream. An important bull trout staging area is located at the Gosnell confluence and several staging areas in Gosnell Creek are in the vicinity of the proposed pipeline route (Bustard and Schell, 2002).

Mountain whitefish are the most common resident fish species in the mainstem Morice River. Adults occupy a wider range of fast water habitats in the mainstem compared to other species and are not as reliant on nearby cover as juvenile salmon and steelhead. Whitefish fry and yearlings were mainly found

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[1] See Bustard and Schell (2002) for a summary of existing spawning information.

in shallow sections of the mainstem Morice, but spawning areas in the system are not known (Envirocon Ltd., 1984c). Whitefish appear to be vulnerable to hydrocarbons, as demonstrated by the many whitefish found dead in sections of the Pine River following the spill in 2000 (Baccante, 2000).

Prickly sculpins are also present in Reach 2 of Morice River. These bottom-dwelling fish are vulnerable to a hydrocarbon spill as large numbers of dead sculpins were found immediately downstream from the Pine River spill in 2000 (Baccante, 2000).

Pacific lamprey up to 70 cm in length have historically been abundant and widely distributed in the Morice River. Anecdotal observations at Moricetown Canyon suggest lamprey have been in decline in recent years. Lamprey adults are a food source for the Wet'suwet'en people. Adult lamprey spend an entire year in the river prior to spawning in June and July. Lamprey spawning has been observed in side channels in Reach 2 of Morice River. Lamprey ammocoetes remain buried in fine sediments for up to six years prior to transforming from a blind suckerless form to an eyed parasitic form that leaves freshwater. Lamprey ammocoetes captured in the Morice River were nearly always in areas of slow water and silt bottom (Envirocon Ltd., 1984c). These habitats would be vulnerable to hydrocarbon deposition in shoreline areas.

4: PAST OIL SPILL AND CLEAN-UP EXPERIENCE

4.1 INTRODUCTION

Previous oil spills in North America provide a basis for identifying important issues and evaluating potential short and long-term impacts of a ruptured pipeline spilling 'oil' into Morice River. We have selected three past spills that provide information relevant to the effects of an oil spill in Morice River.

The three spill cases include the March 24, 1989 Exxon Valdez crude oil spill in Prince William Sound,*[1] the August 1, 2000 Pembina Pipeline conventional crude oil spill on Pine River in northeastern BC and the 2010 Enbridge Kalamazoo diluted bitumen spill in Michigan. The Exxon Valdez spill was accompanied by significant scientific research that led to advances in understanding hydrocarbon effects on fish, especially the effects of polycyclic aromatic hydrocarbons (PAHs). The Pine River spill occurred 300 km east of Morice River, and provides insights into the direct impacts of a crude oil spill on fish in this region and subsequent habitat issues following clean-up operations. The Kalamazoo River spill provides information on the behaviour of diluted bitumen in water and the resulting clean-up difficulties. A description of each of these events is presented below.

4.2 EXXON VALDEZ OIL SPILL

The Exxon Valdez went aground on the Alaska coast in March 1989. Approximately 110,000 m^3 of crude oil was released into Prince William Sound and eventually 1750 km of Alaska's shorelines were contaminated. The spilled oil killed millions of salmon and herring, marine birds and mammals. Booms, absorbents, skimmers and burning of oil slicks on the water were rendered ineffective following fierce storms shortly after the spill. The subsequent shoreline clean-up continued to impact plant and animal

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[1] Mr. Miles, one of the report authors, was retained as an 'oil spill geologist' working with the Shore Clean-up Assessment Team on this spill.

life. Pressurized hot water and a range of chemical dispersants and manual methods were used in the clean-up operations. A detailed description of the spill and the subsequent clean-up operation is described in Ott (2005).

The effects of the Exxon Valdez oil spill (EVOS) and clean-up on fish species were well studied, and work conducted by scientists led to a clearer understanding of the processes that can affect fish survival once oil is spilled into the aquatic environment. Some of the most interesting work was conducted on pink salmon spawning in the lower ends of streams along the Alaska coast. Up to 70% of the wild pink salmon in Prince William Sound spawn in intertidal stream areas, and many of these areas were contaminated by the spill (Murphy, et al., 1999). The pink salmon studies have relevance to potential effects of a major oil spill on salmon populations in Morice River.

Studies focused on pink salmon egg development, the most sensitive life history stage for salmon. Polycyclic aromatic hydrocarbons (PAHs) are a component of crude that has high potential toxicity. PAHs can persist for long periods in the stream or coastal sediments and eventually leach back into the water column following a disturbance, such as a sizeable storm. PAHs act within the cell disrupting basic functions leading to embryo deformities and stunted growth.

Studies following the Exxon Valdez spill showed that pink salmon eggs would pick up PAHs from water flowing through the gravels, and concentrate them in the fat tissues. Scientists detected higher mortality, metabolic problems and deformities in embryos exposed to initial PAH levels as low as 1 part per billion, and that greater mortality occurred in eggs exposed to more weathered oil (Heintz, et al., 1999 and 2000). That was because the toxic components become more concentrated in the residual oil as the water-soluble fraction (WSF) dissolves out. Carls et al., (1999) reported herring eggs could concentrate up to two orders of magnitude greater PAH levels than the surrounding water.

The oil did not have to be in the redds to harm developing embryos. Instead oil initially deposited on banks and upstream areas became mobilized, and subsequently flowed through the gravels. Repeated cycles of weathering and releasing PAHs at levels that affected pink salmon embryos persisted for up to four years after the spill in the Alaskan streams (Murphy, et al., 1999).

These studies illustrate the persistent effects of oil deposited in stream sediments that release low levels of PAH molecules that can have a damaging effect on multiple generations of fish species such as pink salmon. Levy (2009) indicates that chronic toxicity to fish increases with higher concentrations of alkyl PAHs. These compounds are found at highest concentrations in heavier oils where they may comprise up to 6% of the product compared to <2% in lighter refined oils and condensate (Levy, 2009).

We assume the process of concentrating PAHs in the developing eggs would also occur in coho and chinook salmon and developing steelhead that spawn in the section of Morice River along the pipeline corridor. Instead of being exposed to weathering from repeated tidal changes and wave action, PAH accumulation in Morice sediments would be subject to freshet flows in the spring and fall, but would be buried within stream sediments or under snow and ice from November through April. As a consequence, PAHs would be gradually released by weathering over a long time period.

Oil from the Exxon Valdez spill was pulled down into the deeper sediments of Prince William Sound beaches and continues to persist today. Studies have demonstrated that the PAH component of the remaining oil is intact and therefore toxic. At the present rate of decline, the remaining oil may take decades or possibly centuries to disappear entirely. *[1]

4.3 PINE RIVER OIL SPILL

Pembina Pipeline Corporation (Pembina) operates a 30 cm (12 inch) oil pipeline through the Pine River valley in northeastern BC. As discussed in northwest hydraulic consultants ltd. (nhc) (2001) and Summers (2004), the line ruptured on August 1, 2000 releasing approximately 1,000 m^3 of crude oil with approximately 450 m^3 entering Pine River. The location of this pipeline failure is indicated on Figure 4.3.1.

The WSC has operated a stream gauging station on Pine River at East Pine since 1961. This site has a basin area of 12,100 km^2 and is located 160 km downstream from the pipeline failure. *[2] The daily discharges observed in 2000 are plotted on Figure 4.3.2 in comparison to historically observed flows. This analysis indicates that the August 1, 2000 failure occurred during a river discharge of only 161 m^3/s. Peak flows earlier in the season reached values of 939 and 932 m^3/s on May 27 and July 4, 2000 respectively. The historical variation in annual maximum daily and instantaneous discharge is illustrated on Figure 4.3.3 and the flood frequency calculations are compiled on Tables 4.3.1 & 4.3.2. *[3] These analyses indicate that the annual maximum discharge (on Pine River at East Pine) in 2000 was approximately 70% of the predicted 2-year return period flood.

The August 2000 pipeline rupture site is illustrated on Figure 4.3.4. An analysis of historical air photos for this site (Figure 4.3.5 a&b from EDI and MMA, 2002) indicates that the pipeline was installed sometime between 1960 and 1967. A meander bend cutoff occurred downstream of the pipeline crossing sometime between 1969 and 1989 and this could have locally increased the river gradient. Between 1989 and 1997 the deepest part of the river (or thalweg) shifted to the edge of the right bank *[4] and the channel bank appears to have shifted to the right in comparison to 'as-constructed' conditions. The pipeline rupture occurred on the left bank point bar. This event indicates that pipeline failure can occur out of the mainstem channel and during modest flow conditions.

Post-failure clean-up and repair activities are described in reports by Alpine Environmental Consulting Ltd. (2001), northwest hydraulic consultants ltd. (2001 & 2002) and Summers (2004). Five days after the spill, observers examined five short sections of the Pine River downstream from the spill and enumerated dead fish (Baccante, 2000). Over 1600 fish were collected in a combined distance of just under 4 km along a 30 km long section of river. The highest mortalities were located 14 km downstream from the spill site. Residents noted dead fish in the Pine River as far as 50 km below the spill location (Alpine, 2001). Species collected included mountain whitefish, sculpins, arctic grayling, rainbow trout, bull trout and burbot. Baccante (2000) concludes that observers would significantly underestimate the actual number of dead fish since many would sink into deep pools, be hidden under log jams or drift farther downstream, and concludes that the kill involved many thousands of fish.

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1 http://www.evostc.state.ak.us/recovery/lingeringoil.cfm

2 Streamflow values in the basin headwaters may not be accurately represented by this downstream gauge.

3 Annual data have been fitted using the Log Pearson Type III Distribution fitted by the Method of Moments. This analysis is an initial approximation as snow melt and rain or rain on snow derived floods have not been analyzed separately as recommended in *Watt (1990)*. This analysis is therefore for discussion purposes only and is not suitable as a basis for design.

4 While looking downstream

Alpine (2001) reviewed Baccante's (2000) fish data and assembled background data collected prior to the spill along with snorkel counts post-spill to assess the spill effects on fisheries. Their assessment suggests 50 to 70% of the fish in the first 30 kms downstream from the spill site were killed. Both studies had to make some broad assumptions in deriving the estimated mortalities, but conclude that significant portions of the fish populations in the 30 km section below the spill zone were directly killed from the toxic effects of the oil spill.

Alpine (2001) notes that a tanker truck had previously overturned near the 2000 Pembina oil spill site on August 18, 1994 and released 5 m^3 of gasoline and diesel into the river. This section of the Pine River was subject to fish abundance surveys associated with fish enhancement work, and data from before and after the tanker spill was collected. The study concluded that there was a 30-fold decline in fish numbers after the tanker spill, suggesting a significant impact from this earlier spill on the fish populations in this section of the Pine River. Observations conducted by swimmers using snorkels in the Pine River in 2005 indicated fish populations have recovered in the Pine River (Triton Environmental Consultants Ltd., 2006), but direct comparisons in the river sections most affected to historical information are inconclusive. Surveys conducted 5 years after the spill event suggest that residual oil continued to persist in some bottom substrates of the Pine River (Goldberg, 2006).

The Pine River downstream from the spill location is primarily functioning as a rearing section for fish. Most spawning and juvenile rearing occurs in the tributary streams to the Pine River (Baccante, Fish and Wildlife section head, Ft. St. John, personal comm.), so the most sensitive life history stages for most fish to potential chronic impacts from residual hydrocarbons were avoided. The apparent recovery of rearing fish in the mainstem Pine River may be supported by fish populations that spawn in areas not affected by the spill.

Pennart, et al. (2004) showed that the relative abundance of benthic invertebrates in the Pine River was depleted up to 120 km downstream from the spill site in 2000. Although invertebrates had partially recovered one year later, hydrocarbons were still detectable in Pine River sediments two years after the spill. The ecosystem exhibited on-going impacts from hydrocarbons despite the fact that most indicators were found to meet federal and/or provincial guidelines shortly after the spill.

Summers (2004) *[1], made four visits to the Pine River in 2003, three years after the spill, to examine the physical changes and effects the clean-up of the oil had on Pine River fish habitat. He concluded that the initial spill response led to fish habitat impacts in the immediate spill area and downstream from back channel infilling and rock armouring.

However the most significant habitat effects were associated with the oil spill clean-up activities that altered or removed and burned up to 40 log jams or woody debris structures that were contaminated with oil (Summers, 2004). The importance of these features for maintaining channel stability and fish habitat was recognized and approximately a dozen replacement structures were constructed. Plates 4.3.1 to 4.3.6 illustrate instream activities during the cleaning, removal and construction of new log jams in the Pine River. Nhc revisited the constructed log jams in 2002 and reported that Pine River had shifted through a former secondary channel (the 'White Rock Channel') in an area that had previously been protected by a naturally occurring log jam. More specifically nhc reported that:

> *"The White Rock cut-off channel was formed when a massive log jam was removed from the upstream end of an overflow channel during the 2000 clean-up work on Pine River. This allowed Pine River to switch to the left, into the now unobstructed overflow channel, and cut off the*

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[1] DFO habitat biologist based in Prince George.

> *Lemoray Creek meander loop, forming the Lemoray cut-off channel … When Pine River switched, the cut-off channel was about 30 m wide and much steeper than the abandoned meander loop, an unstable state. This changed during the freshets of 2001 and 2002 when the channel widened up to 180 m in places … While we expected large channel changes in the cut-off channel, the dramatic changes in channel dimension exceeded our expectations and resulted in damage to some of the reconstructed log jams and failure to others. We do not recommend any additional work at this site in particular, or the White Rock cut-off in general. It is our opinion that the magnitude of the changes occurring within the White Rock cut-off channel prohibits the effectiveness of constructing log jams to train the river." nhc. December 2002, page 6.*

The pre-failure 1996 air photos of this site and the area of removed and reconstructed log jams is indicated in Figure 4.3.6. Subsequent changes to the river channel are illustrated on Figure 4.3.7, based on 'recent' Google Earth imagery. The mainstem river can be seen to have occupied secondary channels which were formerly located in the vicinity of log jams LJ 42 and LJ 47 (see Figure 4.3.6). Bank erosion has allowed the river to generally become wider and straighter; the extent of instream gravel accumulations have also increased dramatically. The magnitude of these changes is impressive, particularly considering that the annual maximum floods in the post-2000 period have had return periods of ≤ approximately 10 years at the Pine River at East Pine gauging station.

Summers (2004) concluded that the massive erosion associated with the river shifting course in this section was probably related to the log jam removal on the Pine River, and that many kms of downstream fish habitat would have been impacted.

The debris and log jam removal on the Pine River was an emergency response and involved extensive use of heavy equipment in the river (Plates 4.3.3 to 4.3.5). These activities led to habitat disturbance and impacts to riparian areas and instream habitats. Some debris from within the channel including existing log jams was used to help re-build some of the log structures.

The Pine River example indicates that substantial fish kills occurred with the initial oil spill. Efforts to clean the oiled habitats such as removing oiled log jams in the river can be damaging over both the short and longer term leading to a straighter, wider and less complex river channel. Assessments in the Pine River also demonstrate that hydrocarbons can persist in river sediments for at least five years after the spill.

4.4 KALAMAZOO RIVER SPILL

On July 26, 2010 a 76 cm (30 inch) pipeline operated by Enbridge Energy Partners ruptured and released 3100 m^3 of diluted bitumen into Talmadge Creek which flows into Kalamazoo River. The spill was eventually contained in a reservoir located 56 km downstream. One year later, the clean-up of oil is still in progress with more than 500 workers attempting to recover submerged oils and contaminated sediments along the Kalamazoo River downstream to Morrow Lake. *[1]

EPA officials do not know how much oil sank to the river bottom and indicate it poses a unique challenge for evaluating long-term effects. Most of the clean-up has focused on extracting oil submerged in the bottom of the river and mixed with the river sediments. *[2] At the time of this report, the submerged oil was still being collected at certain points along the river bed and in the delta at Morrow Lake.

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1 http://www.epa.gov/enbridge spill/

2 EPA incident commander Ralph Dolloph interview, Kalamazoo Gazette July 24, 2011.

The Kalamazoo River spill indicates that the pipeline industry is still in the process of developing techniques to clean up unconventional oil such as diluted bitumen that can sink into the river bed. The previously referenced comments from the EPA incident commander indicate that the behavior of diluted bitumen once it gets into a river and the long-term effects of such a spill and associated clean-up activities are presently unknown.

Photo records presented by EPA *[1] show that clean-up activities have resulted in streambanks that are cleared of riparian vegetation, with matting laid along the riparian zone to reduce equipment damage. Extensive areas of sediments have been dredged and, along with shoreline debris, have been taken to decontamination sites.

5: POTENTIAL OIL SPILL IMPACTS ON MORICE RIVER

5.1 IMMEDIATE FISH AND HABITAT IMPACTS

5.1.1 Spill Toxicity and Dispersal in Reach 2 Morice River

The Enbridge submission presents two historical examples of what might be expected in Reach 2 of Morice River if a significant rupture and release of hydrocarbons were to occur (Enbridge Volume 7B, Section 7.1). The information indicates that depending upon the site factors and volumes, immediate mortality to fish populations would occur in the areas downstream from the spill area due to the condensate portion of the diluted bitumen. The first example is the Pine River spill near Prince George that resulted in up to 70% fish mortalities in the first 30 km section of river. The second example is a small diesel spill (26 m^3) resulting in a 90% mortality of resident fish in a 16 km downstream section within 24 hours of the spill (Lytle and Peckarsky, 2001). Enbridge indicates that diesel would behave somewhat similarly to the condensate used to dilute the bitumen. Both are toxic to fish at low concentrations. Some of the material would disperse into the water column and some would evaporate from the water surface within hours.

Transient exposure to condensate as it passes through the river section downstream from the spill site would be deadly to fish and benthic invertebrates. However, the Enbridge submission indicates the diluted bitumen component would be expected to have a greater effect than condensate, given its greater persistence (Enbridge Volume 7B, Section 7.8).

The average water velocity on Morice River in the period between May and November is estimated to be at least 1 m/s (see Figure 2.4.9). On this basis, it would take approximately 10 hours for the condensate portion of an oil spill in the upper section of Morice River or the lower portion of Gosnell Creek to travel the 34 kms throughout Reach 2 of Morice River. In another day the plume could have travelled as far downstream as Smithers. *[2] Depending upon wind speed and temperature, most of the lighter components may persist for one to three days before breaking down or evaporating (Levy, 2009).

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[1] http://www.epa.gov/enbridgespill/pdfs/enbridge_slideshow_20101014.pdf

[2] The assumption of time and distance used in this scenario are conservative. Enbridge, in response to IR No.3 to Northwest Institute for Bioregional Research in Round 2 of questions (November 2011), estimated oil from a spill event could travel up to 76 kms in 12 hours from near Owen Creek on Morice River to near Round Lake on Bulkley River. This is an average speed of 1.7 m/second. Enbridge's spill projections did not extend beyond the 12-hour modeling exercise.

However, approximately 2% of the condensate consists of PAH that would typically end up in sediments and biodegrade over time (Enbridge Volume 7B, Section 4.3.3).

The spill trajectory mapping provided by Enbridge in response to the JRP request shows this entire section of Morice River Reach 2 would be affected by a pipeline rupture that occurred along Morice River or Gosnell Creek. *[1]

As outlined by Enbridge (Volume 7B, Section 5.2)

> *"A fast-flowing watercourse quickly transports hydrocarbons downstream, although stranded hydrocarbons may remain in backwaters and along shorelines and log jams, and some contaminants may infiltrate into the sediments."*

Based on the above evidence, it is our opinion that within 10 hours of an upper Morice or lower Gosnell Creek pipeline rupture, the 34 km section of Morice River comprising more than 300 km of shoreline edge during high flow periods, would have been exposed to the volatile portion of the oil.

The bitumen portion would be moving through the water column and settling along slow-flowing sections of the river bottom and along the stream margin, back eddies and extensive side channels of the river and attaching itself to instream debris. The bitumen will be very difficult to locate in this reach, especially during the higher run-off period when turbidity from natural sediments will limit visibility. During flood conditions, the oil could be incorporated into the sediments along the shoreline, on to gravel bars and stream banks and into the streambed materials. Depending upon the time of year, a multitude of log jams and extensive areas of bed materials including spawning gravels would be contaminated with hydrocarbons.

The configuration of salmon spawning sites (redds) promotes the interchange of surface waters into the subsurface (hyporheic zone) where the eggs are deposited (Tonina and Buffington, 2009). The elevated deposit or tailspill of the redd faces into the current and promotes intragravel exchange with the surface waters. Normally this facilitates the exchange of well-oxygenated water. It also would facilitate the transfer of hydrocarbons into the hyporheic zone where contact with eggs and developing embryos would occur.

The effects described above would occur upstream from the first potential in-river oil spill control point identified by Enbridge consultants (Polaris 2010).

5.1.2 Spill Containment in Reach 2 Morice River

There is typically a time lag between when a spill occurs and when the valves are closed and the spill is reported. It took just under one hour for Pembina's pipeline to be shut down during the Pine River spill (Levy, 2009). The Kalamazoo River spill continued for over 12 hours before the line was finally closed. Investigations suggest that operators initially treated the loss of pressure in the line as an internal issue known as column separation *[2] rather than a leak (Swift et al., 2011)

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1 GOSRP – 11-031 map sheets 109 to 116

2 Column separation occurs when condensate under pressure moves from liquid to gas forming a bubble that impedes oil flow. Symptoms are similar to a leak, but the proper operator response is to pump more oil through the pipeline.

Given the 40 km distance from the nearest community (Houston) to the mid section of Reach 2 of Morice River, there appears to be little possibility of rapidly mobilizing the materials required to capture or contain the leaking hydrocarbons in this section of Morice River. There is poor road access to many sections of the river, especially in the upper portion of Reach 2 where the logging roads have been intentionally kept off the floodplain. There are only a few boat launches to access the river in this reach and there are no permanent residences.

The complex channel configuration in Reach 2, and the fact that the river is covered in ice and snow from mid-December until rising waters melt and dislodge the ice in late April would further restrict response efforts. These conditions would make an immediate response to a spill in this area extremely difficult to undertake. At the same time, the potential for toxic effects from the volatile portion of the oil to adversely affect responders could further delay early response from crews due to safety concerns.

Spill response options will be constrained by water depths, channel width and velocities in the river. For example Table 5.1.2.1, based on data presented in Enbridge (Volume 7B, Section 7.4), summarizes the range of water velocities over which various containment options can be employed. The criteria for three commonly employed techniques are as follows:

Diversion Boom	< 2.0 m/s
Containment Boom	<1.0 m/s
Sorbent Boom or Sweep	<0.5 m/s

These criteria are indicated on Figure 5.1.2.1 in relationship to the seasonal variation in water velocities at the WSC Morice River near Houston stream gauging station. This initial analysis indicates that sorbent booms or sweeps could only be deployed in the mainstem channel during unusually low flow conditions in the late winter (when deployment would likely be made impossible by ice conditions). Containment booms could not be utilized throughout the snowmelt freshet or during average flow conditions between April and November. Diversion booms are the only technique that meet the deployment criteria (except for periods of high flood flows) and this procedure can only be used to divert surface water into a pre-existing or constructed area of low water velocity. However, Morice River is too large and deep to readily construct earth dikes and containment weirs during periods of high flow. Options to use pumping and re-circulating devices to release submerged bitumen would be limited by poor site access and high sensitivity of spawning habitats located throughout the reach.

The above analysis, which is based on data from the WSC gauging station in Reach 1, suggests that most commonly employed techniques for containing or collecting oil spills cannot be employed due to excessive water velocity. Additional field information (or hydraulic analyses) would be required to undertake comparable analyses for Reach 2 on Morice River. However, given the larger watershed area, similar channel gradient and comparable mainstem widths, similar constraints on deploying sorbent or containment booms are expected. Added to this are the EPA observations on the Kalamazoo River that diluted bitumen behaves differently than conventional crude oils. More of the bitumen sinks below the water surface where it attaches to debris and vegetation or deposits along the channel edge.

The difficulties of utilizing conventional containment methodologies on a large fast-flowing river are highlighted in a July 2011 rupture of a 30 cm (12 inch) oil pipeline on the Yellowstone River, Montana that released approximately 160 m^3 of conventional oil into the river. There are no impoundments on this river and the oil had flowed more than 40 km downstream by the following day.

The chief of disaster services stated that *[1]

> *"With the Yellowstone running at flood stage and all of the debris, it makes it dang tough to get out there to do anything."*

The report goes on to describe crews putting out absorbent material along stretches of the river near Billings and near Laurel, but there were no attempts at capturing oil farther out in the river. In some areas oil flowed underneath booms and continued downstream.

Water depths, channel cross sectional area and wetted channel width on Morice River at the WSC gauge undergo significant seasonal variations (see Figures 2.6.5 to 2.6.8). These values can also change quickly as discharges rise and fall over the course of a storm event (see Figure 2.2.4). As a consequence, oil that is released during high flow conditions can become stranded on wetted sections of river bank or gravel bars which subsequently dewater as the flow diminishes. Similar water level variations occurred during the Exxon Valdez oil spill due to tidal and storm effects and this resulted in oil seeping into the subsurface sediments. These materials were therefore partially protected from weathering and resulted in a chronic long-term source of oil and other related contaminants.

It is our opinion that, given the size and water velocities in the Morice River and the extent of channels and debris accumulations in Reach 2, that containment once the oil is in the river is unlikely to be successful, and that the deposition of hydrocarbons throughout Reach 2 would occur.

Morice River salmon and steelhead populations would be seriously compromised since these are the critical habitats for spawning and rearing fish during all seasons in Reach 2. If the spill occurred between September and June, millions of developing salmon eggs would be exposed to the hydrocarbons. From June through August developing steelhead eggs would be impacted. Any time of the year would expose the juvenile chinook, coho and steelhead rearing in the log jams, side channels and along the mainstem shorelines in this section to toxic hydrocarbons. Adult salmon, including sockeye, as well as steelhead, bull trout, and other species could be present. In our opinion, the evidence from past spills combined with information presented in the Enbridge submission, and our understanding of fish distributions in this system suggests that the immediate impacts to Morice River fish populations could be severe.

5.2 LONG-TERM FISH AND HABITAT IMPACTS

There are two options to consider when evaluating the long-term impacts to fish and fish habitat of a significant spill of diluted bitumen along Reach 2 of the Morice River.

1. Responders could attempt to undertake remedial action in this section of river similar to clean-up operations on Pine River or Kalamazoo River.

2. Alternatively, assessments could indicate that this type of clean-up would actually cause additional damage beyond the spill effects alone in terms of long-term loss of habitat, and this section of the river could be left mostly unremediated.

Both options, discussed in more detail in the following section, will lead to chronic toxicity to embryos and degraded rearing habitat that will reduce the number of fish that survive in the Morice River.

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[1] Comments from the chief of disaster services for Yellowstone County as cited from http://www.cbc.ca/news/world/story/2011/07/03/montana-oil-spill-yellowstone-river.html.

5.2.1 Option 1 – Undertake Remedial Clean-Up Action

Remedial activities in Pine River focused on clean-up in the vicinity of the immediate spill site that included removing vegetation and soils contaminated with oils and replacing clean soils at the site. The site was rip-rapped to protect the newly exposed banks. Heavy equipment was allowed to move into the river and remove debris and log jams downstream from the spill areas that were coated with oil. This material was burned on the gravel bars, and efforts were made to replace some of the log jams considered critical to the river hydraulics.

The Kalamazoo River clean-up has also involved removing contaminated soils and vegetation in the spill zone (Talmadge Creek). Over a year has been spent cleaning up pockets of oil visible along the shoreline of the river and removing contaminated sediments. Much of Kalamazoo River is a single thread channel with little channel complexity and few log jams, debris accumulations or side channels. Oil recovery in Kalamazoo River has benefited from the presence of a downstream lake allowing oil to be collected from the surface and bottom sediments. The submerged oil has taken the greatest recovery effort. Clean-up includes using equipment to agitate the stream bottom in an attempt to get the bitumen to float for recovery.

As outlined in Section 2.5, it is estimated that there are approximately 1000 log jams on Reach 2 of Morice River (Table 2.5.1). Experience on Pine River (discussed in Section 4.3) indicates that log jam removal on a wandering gravel bed river can cause substantial mainstem channel destabilization. This includes increased rates of bank erosion, decreased river sinuosity, increased channel widths, generally increased water velocities, increased rates of sediment transport, increased instability in secondary channels and potential shifts in channel morphology if a wandering channel is forced into a 'braided' configuration. Similar processes can also occur on smaller channels such as the secondary channels in Reach 2. For example, the experimental removal of woody debris in a small forested stream in Alaska is reported to have:

> *"resulted in dramatic redistribution of bed sediment and changes in bed topography. Removal of debris changed the primary flow path, thereby altering the size and location of bars and pools and causing local bank erosion and channel widening. Marked bed adjustments occurred almost immediately following experimental treatment in May 1987 and continued through to the end of the study period in 1991. Increased bed material mobility was attributable to destabilization of sediment storage sites by removal of debris buttresses, elimination of low-energy, backwater environments related to debris, and an inferred increase in boundary shear stress resulting from the removal of debris-related flow resistance. In contrast to these changes, which favored sediment mobilization, deposition was favored by the elimination of debris-related scouring turbulence and by increased flow resistance from a developing sequence of alternate bars."* *Smith, et al., 1993*

As a consequence, the removal of oiled woody debris is expected to have long-term and serious effects on river processes and habitat characteristics in Reach 2 of Morice River. Experience on coastal watersheds which have been destabilized by riparian logging (e.g. Hartman, Scrivener and Miles, 1996) indicate that these effects can persist for many decades or possibly centuries. The removal of large woody debris in a section of a small coastal BC stream resulted in a 5-fold reduction in juvenile salmonid standing crop compared to a section where debris was left undisturbed (Fausch and Northcote, 1992).

These activities combined with efforts to flush submerged oil from the shorelines, back eddies and bed materials in the river and remove contaminated sediments would continue to impact the fish habitat including the benthic invertebrate communities that are a key component of the food chain for fish.

If efforts were made to remove oiled-debris and sediments, the operations would also have direct impacts to riparian areas and streambed sections where remediation activities would be conducted. Operating heavy equipment in-channel as conducted on Pine River (Plates 4.3.3 to 4.3.5) would lead to direct damage to developing eggs/alevins and those juveniles that survived immediate toxicity from the condensate. For example, young steelhead and chinook salmon move into the gravel and cobble bed material seeking cover and can be crushed by instream equipment operation.

Loss of woody debris would result in reduced summer and winter habitat for all species of juvenile fish, especially coho juveniles and steelhead parr that are most strongly associated with debris complexes in the Morice (Section 3). Extensive programs of stream rehabilitation have occurred throughout North America in an effort to restore woody debris to fish habitats that have been compromised by its historical removal (e.g. Slaney and Zaldokas, 1997; Gregory, et al., 2003; Abbe, et al., 2003). However, replacing woody debris that has been removed as a result of hydrocarbon contamination would be a challenging task due to limited riparian access, naturally occurring channel instability, complex river hydraulics and the erosive effects of spring break-up. Recent surveys in the Pacific Northwest (Southerland, et al., 2011) indicate that 21% of engineered log jams had failed, an additional 51% had impaired function and that only 21% of the inventoried structures provided low water pools suitable as refugia for adult fish.

Debris jams located at the top of side channels tend to buffer downstream high flows, helping to protect developing eggs and alevins from scour. Post-oil spill removal of the structures would reduce the stability of spawning sites in side channels leading to more scouring and poorer survival of incubating eggs and alevins.

The riparian disturbance and road access to the river needed to conduct remedial activities throughout Reach 2 would degrade the river features that make it attractive to recreation and sport fishery activities. As well, the riparian areas provide important sources of nutrients and insect inputs, shading for the stream channels and bank stability.

Despite clean-up efforts, it is expected that PAHs would continue to be released from oil accumulated in the sediments in the river over time. Much of Reach 2 is comprised of gravel bed materials that can be mobilized during high flow conditions leading to a repeated sequence of scour and deposition exposing and burying PAH sources.

Evidence from the pink salmon studies conducted in Alaska suggests very low concentrations of PAHs would affect the development of embryos in the spawning sections of Morice River. The time frame that these effects will persist is unknown for this system due to its cold temperature regime, long-winters and low nutrient levels, factors that all contribute to a slower weathering and breakdown of hydrocarbons.

The Enbridge submission estimates that

> *"with mitigation and emergency response measures, soil contamination may last two to ten years in portions of the riverbanks and shorelines."* *(Enbridge Volume 7B, Section 7.3.2)*

Enbridge also states that

> *"in fast-flowing waters, some of the condensate evaporates and some moves from the surface into the water column and could subsequently migrate into groundwater....Hydrocarbons can travel with groundwater and be exchanged with soil material for years; residual contamination may persist for an extended time."* *(Enbridge Volume 7B Section 7.4.2)*

5.2.2 Option 2 – Do not undertake remedial clean-up action

If oiled debris and contaminated sediments are left in place, oil contaminated sites would remain as long-term sources of PAHs in the sediment and debris. Enbridge indicates the following:

> *"Diluted bitumen or synthetic oil adsorbed into riparian vegetation and coarse debris can be remobilized into the waterbody. Bacterial degradation is relatively slow for stranded oil because of its relatively small surface area and viscosity. In slow-flow systems, relatively insoluble PAHs may settle in sediment, and can persist, leading to chronic toxicity for aquatic organisms and uptake into the food web. Based on literature and experience, PAH levels may remain above sediment quality guidelines, unless remediated". (Enbridge Volume 7B, Section 7.5.2)*

Such a scenario suggests that without remediation, PAHs would continue to be released from contaminated areas and could continue to be harmful to developing eggs and alevins throughout the Morice system for an undetermined time period.

Deposition of bitumen on shoreline bed materials and debris would contaminate the surfaces that provide the food and cover required by rearing fish. Periphyton and benthic invertebrates would be impacted, and the interstitial areas typically utilized by steelhead and chinook salmon fry (especially for winter cover) would be degraded, leading to reduced productivity over the long-term.

Enbridge (Volume 7B, Section 7.8) states:

> *"a hydrocarbon spill into a waterbody has a high potential to affect fish and fish habitat productive capacity. By identifying important habitat along the pipeline route and developing mitigation measures to protect these resources, the overall ecological function of ecosystems can be protected."*

Long-term measures to mitigate impacts and compensate for impacted stream sections proposed by Enbridge (Volume 7B, Section 7.8.3) include the following:

- *angling closures to limit pressure on remaining stocks;*
- *stocking of species of concern to aid population recovery; and*
- *habitat compensation.*

The concept of mitigating for oil spill impacts to the wild salmon and summer steelhead stocks in Morice River by angling closures on this world-class fishery, stocking with hatchery fish and attempting some form of compensation are not appropriate in the complex and extensive habitats of Reach 2 of Morice River.

Angling restrictions for Skeena steelhead include a catch-and-release regulation that has been in place for more than a decade. Similarly, there is no recreational harvest of sockeye in the Morice, or of pink salmon in most of the Morice River. Only coho and chinook salmon could benefit from angling closures that would be placed on downstream anglers on the Bulkley and Skeena rivers where more of the sport fishery occurs. The non-retention fishery placed on Pine River following the 2000 spill is still in place a decade later.

Steelhead biologists have concluded that the relative risk of employing hatchery fish augmentation as a mitigation tool is high compared to natural recovery, assuming the habitat remains intact and productive (Ward, 2006). The Steelhead Stream Classification Policy (Province of BC 2005) clearly states that "In no case will hatchery-augmentation be considered as a substitute for habitat protection and restoration". Similarly, the goals of the Wild Salmon Policy (FOC, 2005) promote maintaining habitat and ecosystem integrity and minimizing risks to vulnerable salmon habitats.

Efforts to effectively use habitat compensation as a measure to respond to impacts from a bitumen spill in the habitats of Reach 2 on Morice River would, in our opinion, be extremely difficult. The complex and extensive channel structure and spawning habitats could not be replicated in a habitat compensation program. The example on Pine River that involved removing, burning and attempting to replace log jam structures is indicative of the difficulties of this kind of program on Reach 2 of Morice River.

6: CONCLUSIONS

Approximately 71 km of the two proposed Enbridge pipelines are located adjacent to Morice River and its major tributary Gosnell Creek. The oil and condensate pipelines would transport large volumes of toxic materials through this watershed. In some instances, the pipelines would be located within a few hundred meters of the mainstem Morice River with crossings in both the upper Morice River and Gosnell Creek. Schwab (2011) indicates that there are geotechnical risks to the long-term integrity of the pipeline. A pipeline failure could lead to a release of bitumen and condensate into the mainstem Morice River. Enbridge has provided maps indicating that spilled material could enter Morice River at multiple locations and flow downstream.

Reach 2 of Morice River has a wide valley flat that contains numerous active secondary channels, log jams, wetlands, and other features that provide the productive spawning and rearing habitat for Morice River fish populations. Estimates derived from previous studies conducted by DFO indicate there are approximately 1,000 log jams and over 300 km of shoreline in the multiple channels that occur in this 34 km section of river.

Substantial populations of salmon and steelhead utilize Reach 2 of Morice River. Fish habitat in the watershed is productive and intact despite the recent pine beetle infestation and associated forest harvesting. There are no impoundments, industrial effluents and channelized or degraded river sections. Despite considerable variability in abundance, escapements of salmon and steelhead in the past decade are strong compared to historical estimates.

Eggs or alevins are present in the gravels in Reach 2 of Morice River in every month of the year and juvenile fish rearing occurs year-round throughout the side channels and mainstem edge areas. The extensive channels and associated log jams and shoreline areas provide habitat for a substantial proportion of the coho, chinook and steelhead that rear in Morice River. Most of the pink salmon spawning occurs in the side channels of Reach 2. Millions of salmonid fry utilize these habitats annually. These fish would be at risk of direct toxic effects of spilled hydrocarbons if a pipeline rupture were to occur.

The volume of oil within the pipeline is sufficiently large that even if the valves (which are located on average approximately 8 km apart) were closed immediately at the time of rupture, a significant volume of diluted bitumen would drain into the environment from the section of pipe located between the valves. Hydrocarbons entering Gosnell Creek or Morice River would spread widely through Reach 2 and diluted bitumen would be spread through the log jams, side channels and along the shoreline sediments and into the spawning gravels. Condensate or the more volatile fractions of the diluted bitumen would be directly toxic to rearing fish and developing eggs located throughout this section of the river. Longer-term habitat degradation would also occur due to subsequent efforts to remediate the effects of a spill, and the retention of PAHs in the sediments, debris and groundwater habitats.

There are many factors that will make it difficult to effectively capture and clean-up spilled oils in Reach 2 of Morice River. Our assessment indicates that Morice River is too large, the water velocities are too fast for much of the year and the channels are too complex to use conventional containment booms, absorbents and skimmers to effectively collect oil as proposed in the Enbridge submission. There are no downstream lakes or reservoirs to collect hydrocarbons between Reach 2 of Morice River and Skeena River.

Morice River and Gosnell Creek are sufficiently remote that an immediate response could not be undertaken following an oil spill. The limited road access to the river will hinder response efforts. The complexity of multiple river channels and the enormous volume of natural debris in the river would limit effective access by boat to many locations. If the spill occurs in the winter, ice and snow cover would make hydrocarbon capture and clean-up impractical. The tendency for bitumen to sink and move along the river bottom would make it extremely difficult to contain spills with surface equipment such as a boom. Poor visibility due to natural turbidity in this section of the river during parts of the year would also constrain efforts to locate submerged hydrocarbons.

Subsequent actions that might be undertaken following a spill, such as collecting oil-covered debris and sediments, taking oiled materials to decontamination sites, or burning the debris on gravel bars, are not practical solutions given the limited riparian access and the complexity of debris and shoreline habitats in this reach. Based on the documented difficulties following the 2000 oil spill on Pine River, efforts to replace oiled log jams in Reach 2 are unlikely to be successful and could cause long-term channel instability and habitat impacts.

The retention of PAHs in the river sediments including spawning gravels, on wood debris and along shorelines has been shown to be damaging to salmon egg development at very low concentrations. Scientists have demonstrated that PAHs can adversely affect pink salmon embryo survival, and that the risks persist for extended periods. Based on this background science, diluted bitumen attached to debris and accumulated in the bottom and shoreline sediments in Reach 2 of Morice River would persist and affect salmonid survival in the Morice for an extended but unknown period.

Given the potential for a pipeline failure along Morice River (as outlined in Schwab, 2011 and Swift et al., 2011), there are serious risks of large-scale impacts to the exceptional fisheries values that occur in this area. The remote location, challenging physical environment, diversity of fish species and complex habitat characteristics will severely constrain Enbridge's ability to undertake both an effective response or successful long-term remediation should a spill occur. In our opinion the proponent has not provided the information needed to demonstrate that an oil spill from a pipeline rupture adjacent to Reach 2 of Morice River could be effectively controlled or remediated.

We conclude that transporting large volumes of condensate and diluted bitumen through this watershed poses a significant and long-term risk to the substantial wild fish populations in the Morice River.

7: CERTIFICATION

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FIGURES

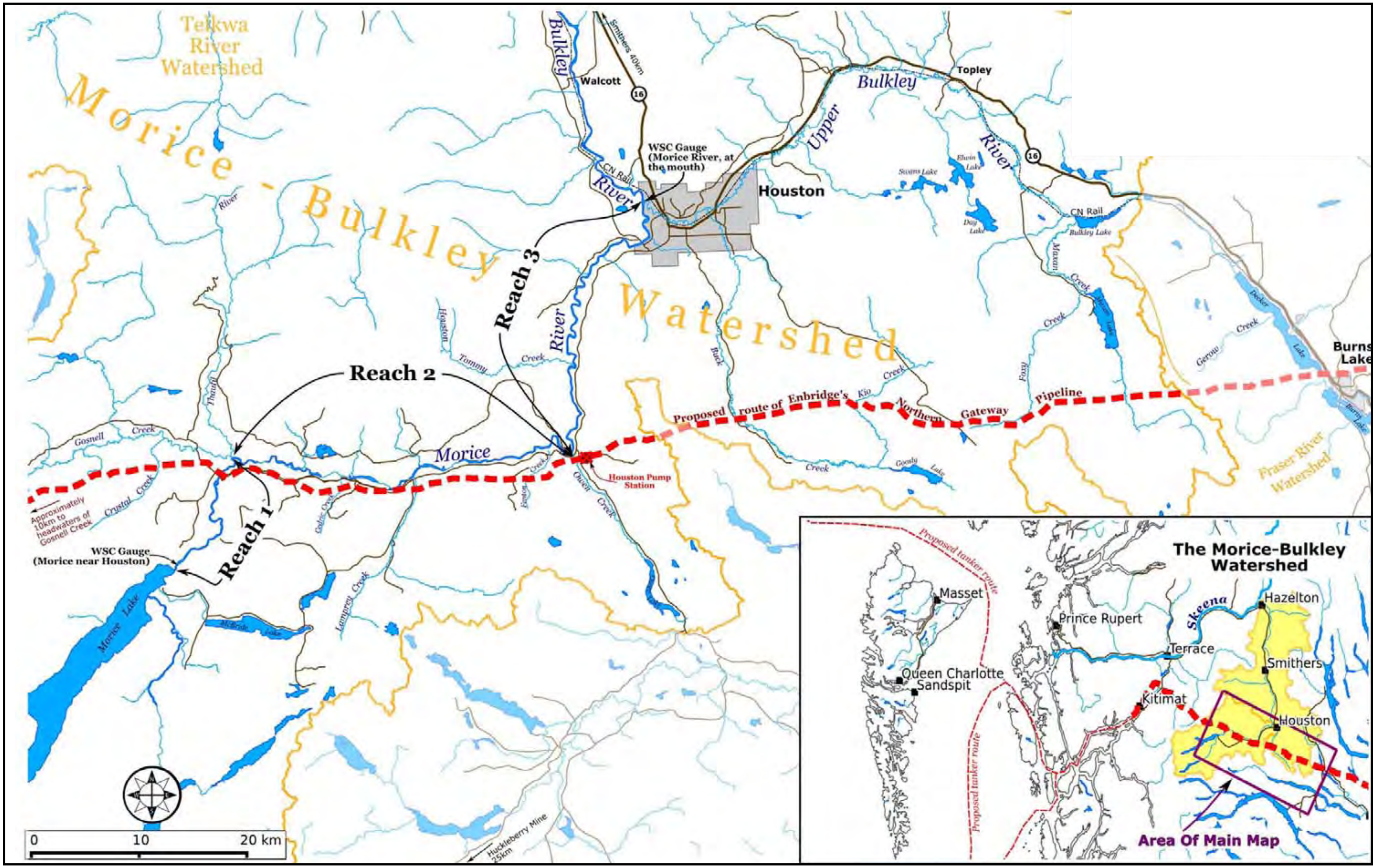
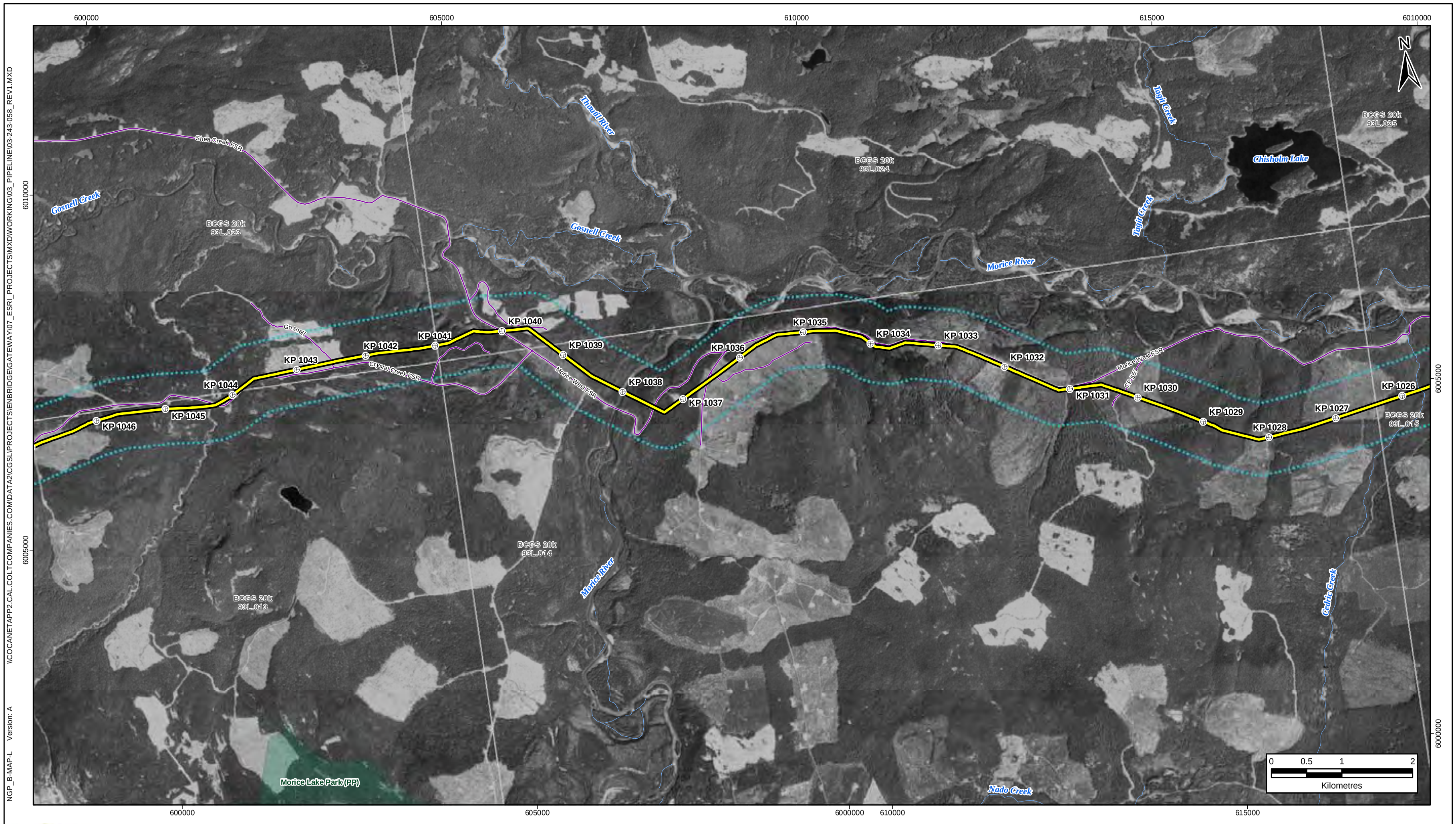


Figure 1.1: Proposed route of Enbridge crude oil and condesate pipelines in the Morice - Bulkley Watershed. [Map by Morgan Hite, Hesperus Arts - www.hesperus-wild.org. Map date: June 2011.]



ENBRIDGE
NORTHERN
GATEWAY PIPELINES

LEGEND

⊕	Northern Gateway Pipeline KP	▨	PEAA Corridor
▬	Northern Gateway Pipeline Route	🟥	Indian Reserve
●-●	Proposed Facility Powerline	🟦	National Park (NP) / Provincial Park (PP)
---	Proposed Facility Road	🟩	Other Protected Area*
—	Potential Access	▨	AB Crown Reservation (CR) / BC Forest Recreation (FR)
☐	Proposed Pump Station	☐	Land Title Parcel

NORTHERN GATEWAY

NOTES:
- B&W Orthophoto imagery displayed acquired from BC Imagery Warehouse as 1m pixel size, from 1996-2003.
- Centreline updated July 29, 2009 (REV R). Kilometre posts correspond to July 29, 2009 (REV R) slack alignment.
- Project Effects Assessment Area (PEAA) corresponds to the July 29, 2009 (REV R) Route and is current as of Aug. 2009.
- Indian Reserves obtained from GeoBase®, current as of Oct. 2009.
- National Parks: NRCan CLAB Lv1 (May 2009); AB Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Protected Areas & Forest Recreation: ILMB, BC Government (Oct. 2009).
- BCGS grid shown is the BC Geographic System 1:20,000 grid; Land Title Parcels current to Aug. 2009.

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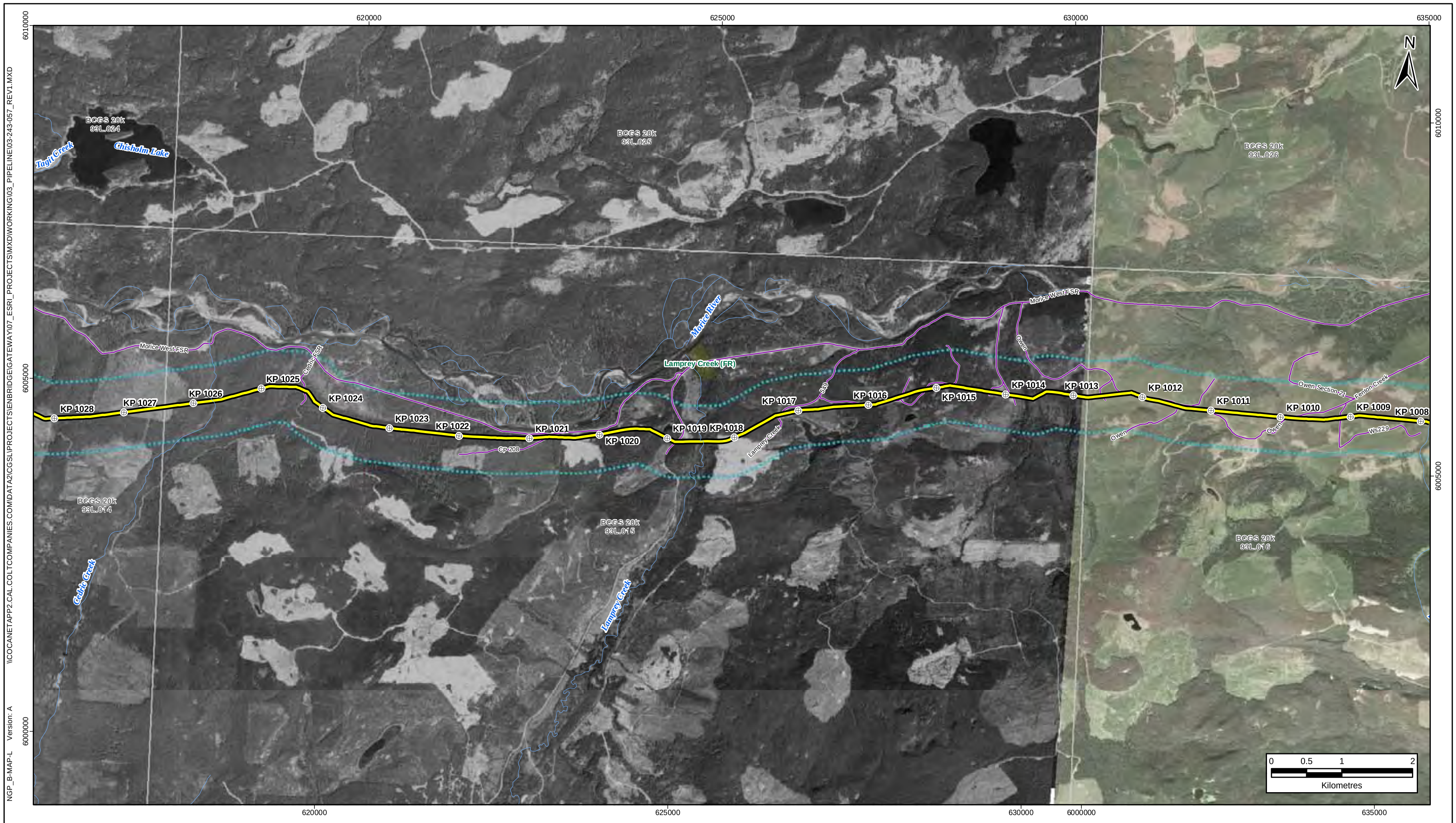
DRAWN JK	ENBRIDGE NORTHERN GATEWAY PROJECT PROPOSED ROUTE ROUTE ATLAS IMAGERY MAP 58				
CHECK CW	PROJECTION UTM 9N	DATUM NAD83	CONTRACTOR NAME WORLEYPARSONS CALGARY	MAP NUMBER 03-243-058	REV. 1
DESIGN JK	SCALE 1:50,000	DATE 4 Nov 2009	PROJECT NUMBER 08C7138	ORIG.PAGE SIZE 11X17	WorleyParsons
APPR. LP					

www.worleyparsons.com

Figure 1.2: Alignment mosaic KP 1046 to 1026.



ENBRIDGE
NORTHERN
GATEWAY PIPELINES

LEGEND

⊕ Northern Gateway Pipeline KP	PEAA Corridor
Northern Gateway Pipeline Route	Indian Reserve
Proposed Facility Powerline	National Park (NP) / Provincial Park (PP)
Proposed Facility Road	Other Protected Area*
Potential Access	AB Crown Reservation (CR) / BC Forest Recreation (FR)
Proposed Pump Station	Land Title Parcel

NORTHERN GATEWAY

NOTES:
- Imagery displayed acquired from BC Imagery Warehouse as 0.5-1m pixel size, from 1996-2007, and from SPOT 5 satellite, 2.5m resolution.
- Centreline updated July 29, 2009 (REV R). Kilometre posts correspond to July 29, 2009 (REV R) slack alignment.
- Project Effects Assessment Area (PEAA) corresponds to the July 29, 2009 (REV R) Route and is current as of Aug. 2009.
- Indian Reserves obtained from GeoBase®, current as of Oct. 2009.
- National Parks: NRCan CLAB Lv1 (May 2009); AB Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Protected Areas & Forest Recreation: ILMB, BC Government (Oct. 2009).
- BCGS grid shown is the BC Geographic System 1:20,000 grid; Land Title Parcels current to Aug. 2009.

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DRAWN JK
CHECK CW
DESIGN JK
APPR. LP

ENBRIDGE NORTHERN GATEWAY PROJECT
PROPOSED ROUTE
ROUTE ATLAS IMAGERY MAP 57

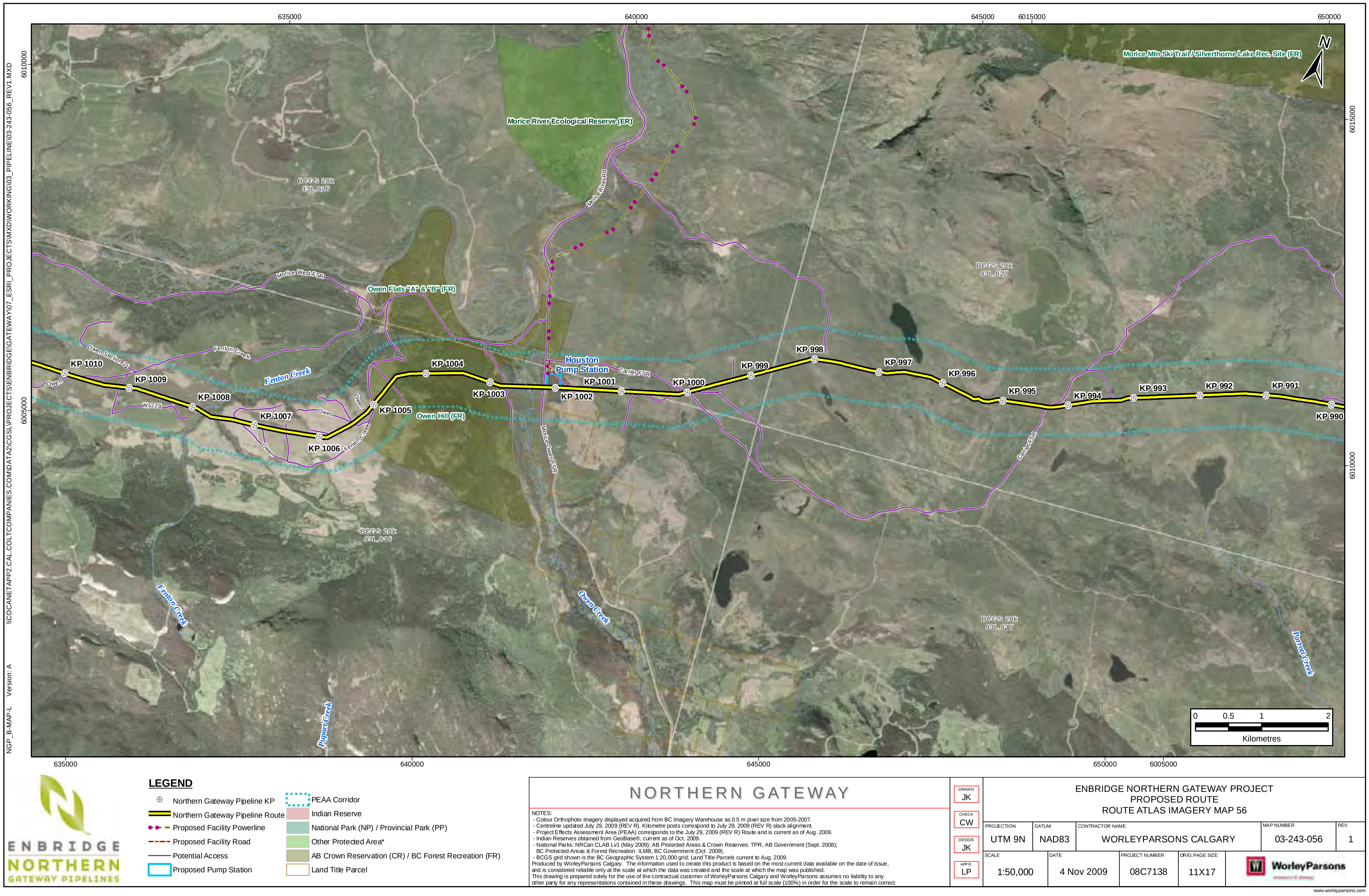
PROJECTION	DATUM	CONTRACTOR NAME	MAP NUMBER	REV.
UTM 9N	NAD83	WORLEYPARSONS CALGARY	03-243-057	1

SCALE	DATE	PROJECT NUMBER	ORIG.PAGE SIZE
1:50,000	4 Nov 2009	08C7138	11X17

WorleyParsons

www.worleyparsons.com

Figure 1.3: Alignment mosaic KP 1028 to 1008.



NOTES:
- Colour Orthophoto imagery displayed acquired from BC Imagery Warehouse as 0.5 m pixel size from 2005-2007.
- Centreline updated July 29, 2009 (REV R). Kilometre posts correspond to July 29, 2009 (REV R) slack alignment.
- Project Effects Assessment Area (PEAA) corresponds to the July 29, 2009 (REV R) Route and is current as of Aug. 2009.
- Indian Reserves obtained from GeoBase®, current as of Oct. 2009.
- National Parks: NRCan CLAB Lv1 (May 2009); AB Protected Areas & Crown Reserves: TPR, AB Government (Sept. 2008); BC Protected Areas & Forest Recreation: ILMB, BC Government (Oct. 2009).
- BCGS grid shown is the BC Geographic System 1:20,000 grid; Land Title Parcels current to Aug. 2009.

Produced by WorleyParsons Calgary. The information used to create this product is based on the most current data available on the date of issue, and is considered reliable only at the scale at which the data was created and the scale at which the map was published.
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Figure 1.4: Alignment mosaic KP 1010 to 990.

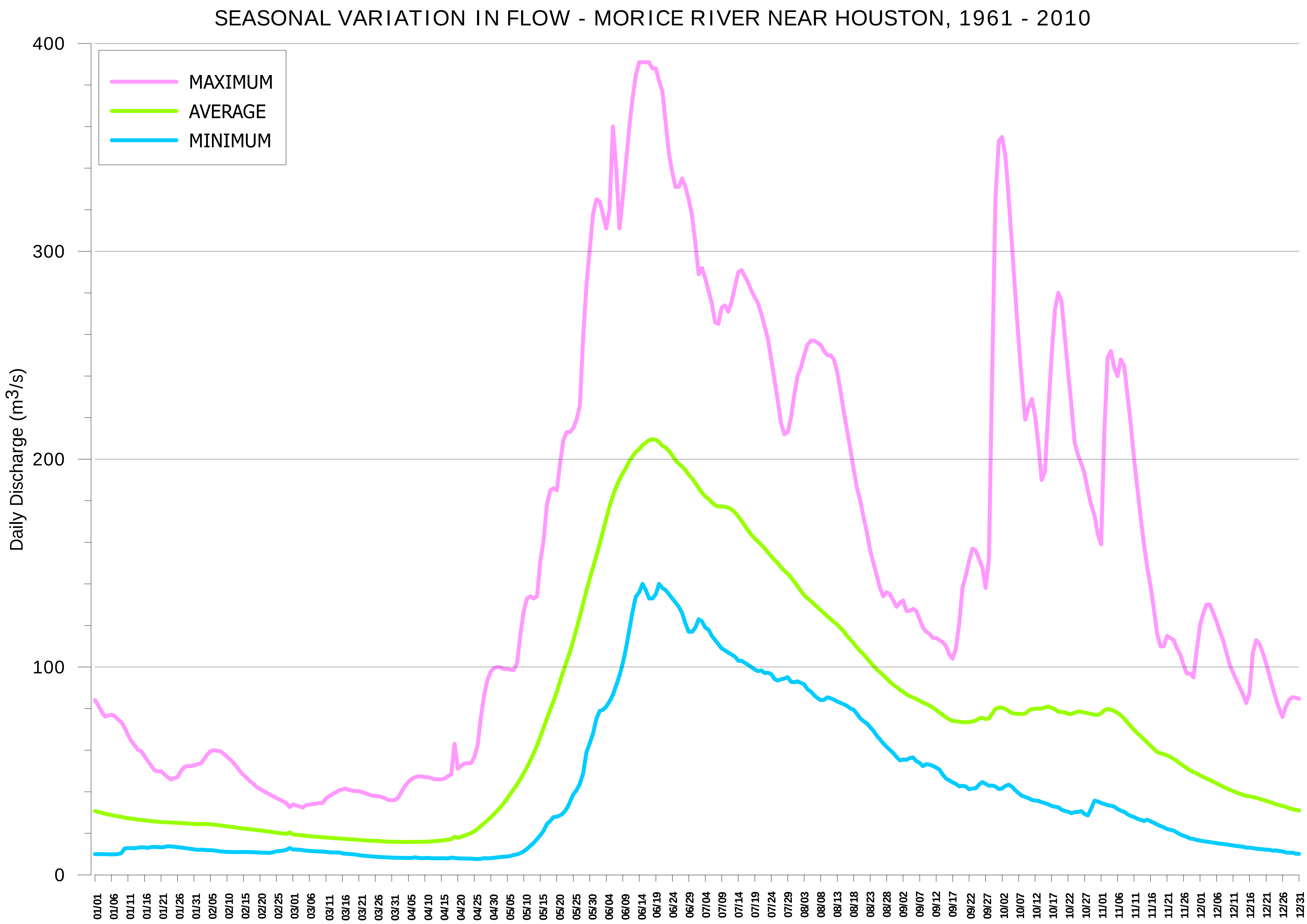


Figure 2.2.1: Seasonal variation in discharge, Morice River near Houston.

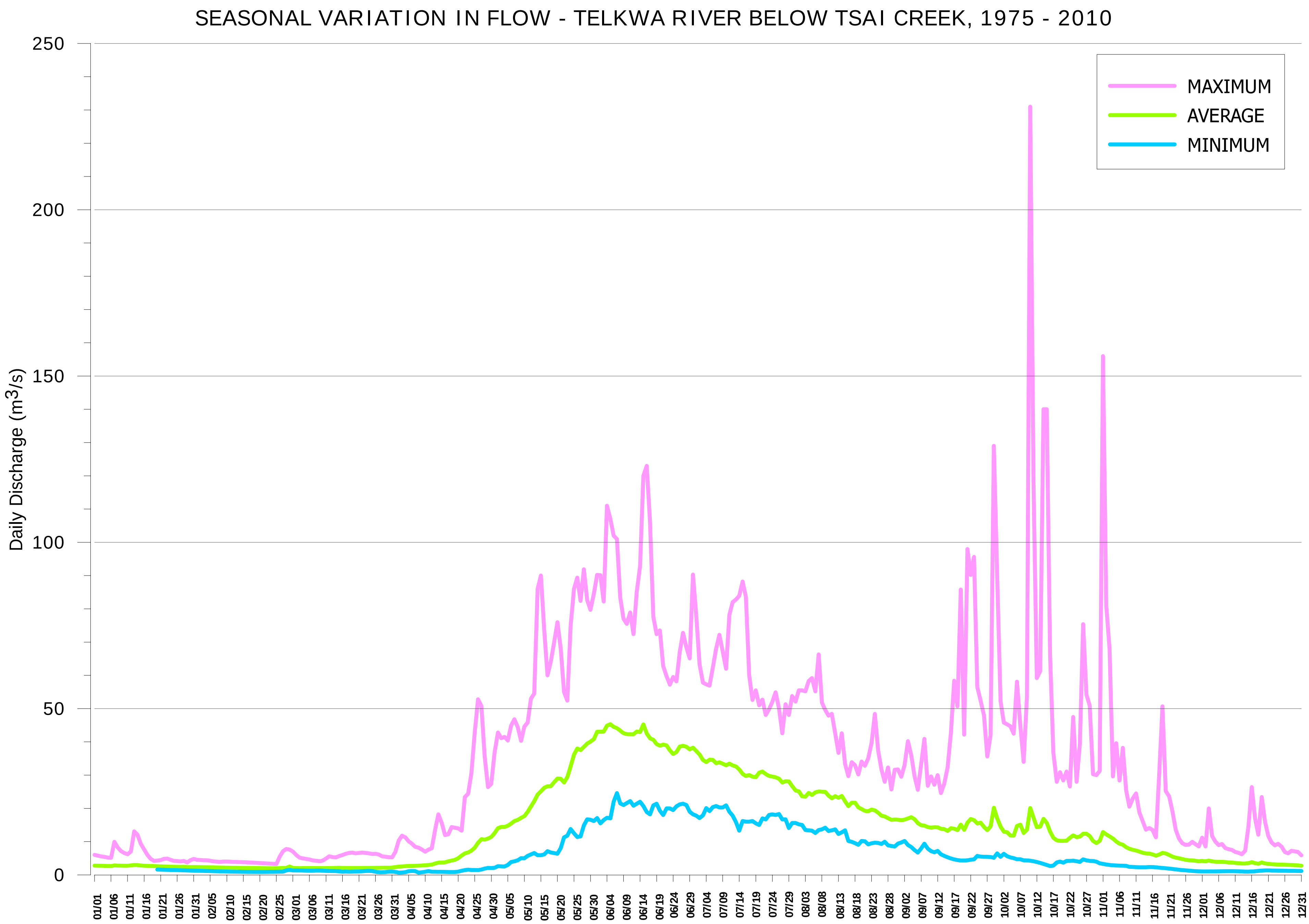
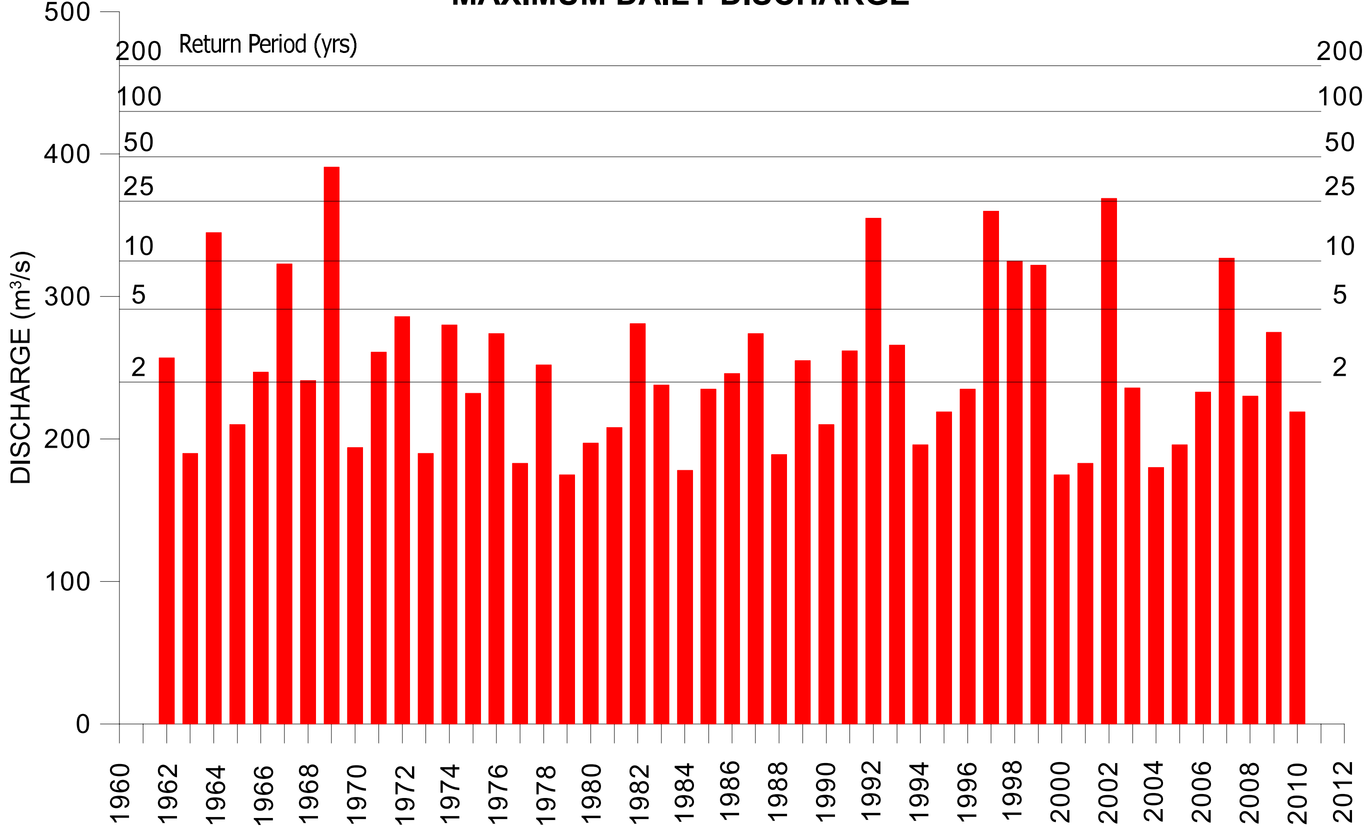
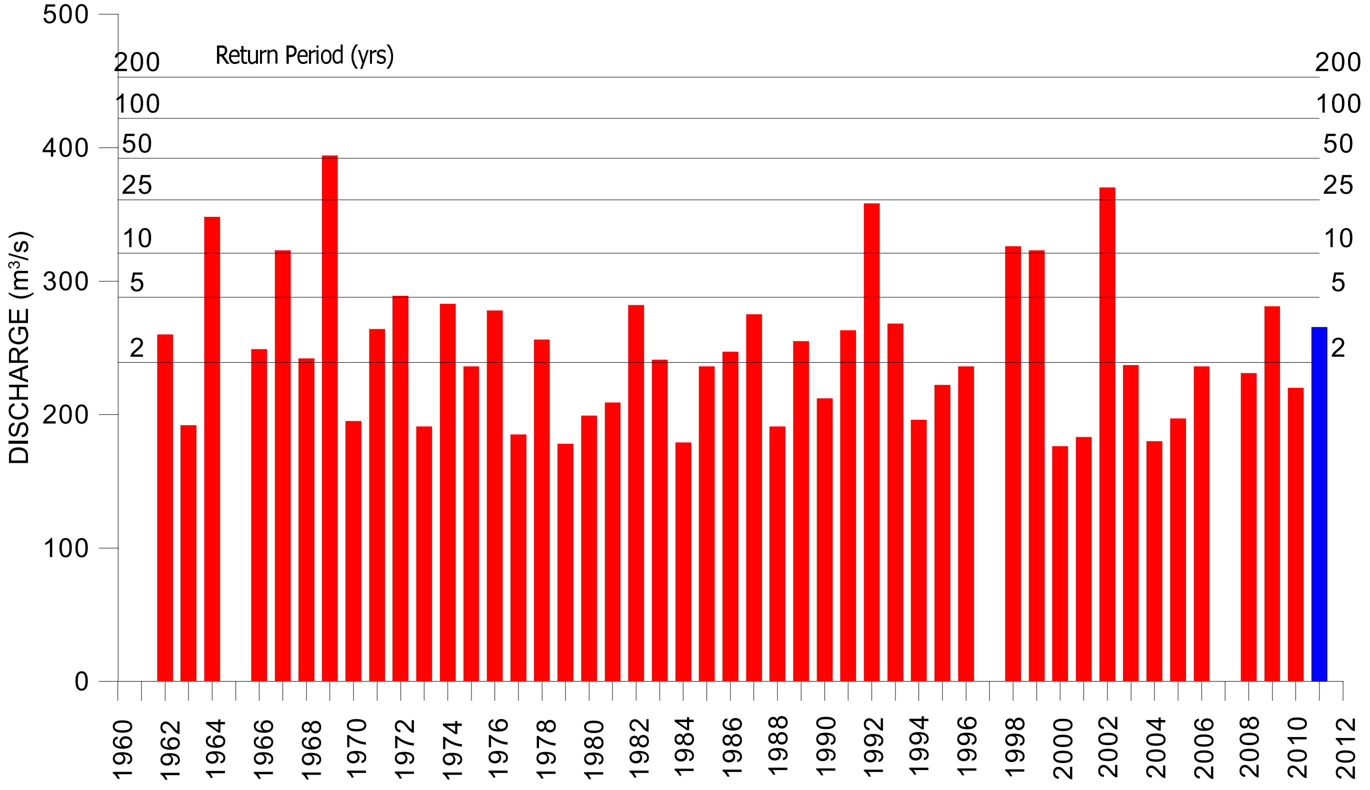


Figure 2.2.2: Seasonal variation in discharge, Telkwa River Below Tsai Creek.



MORICE RIVER NEAR HOUSTON, 1962 TO 2010, plus 2011 (prelim.)
MAXIMUM DAILY DISCHARGE



MORICE RIVER NEAR HOUSTON, 1962 TO 2010, plus 2011 (prelim.)
MAXIMUM INSTANTANEOUS DISCHARGE

Figure 2.2.3: Historical variation in annual maximum daily and instantaneous discharge, Morice River Near Houston, 1962-2010. [WSC 2011 preliminary real time data to July 8.]

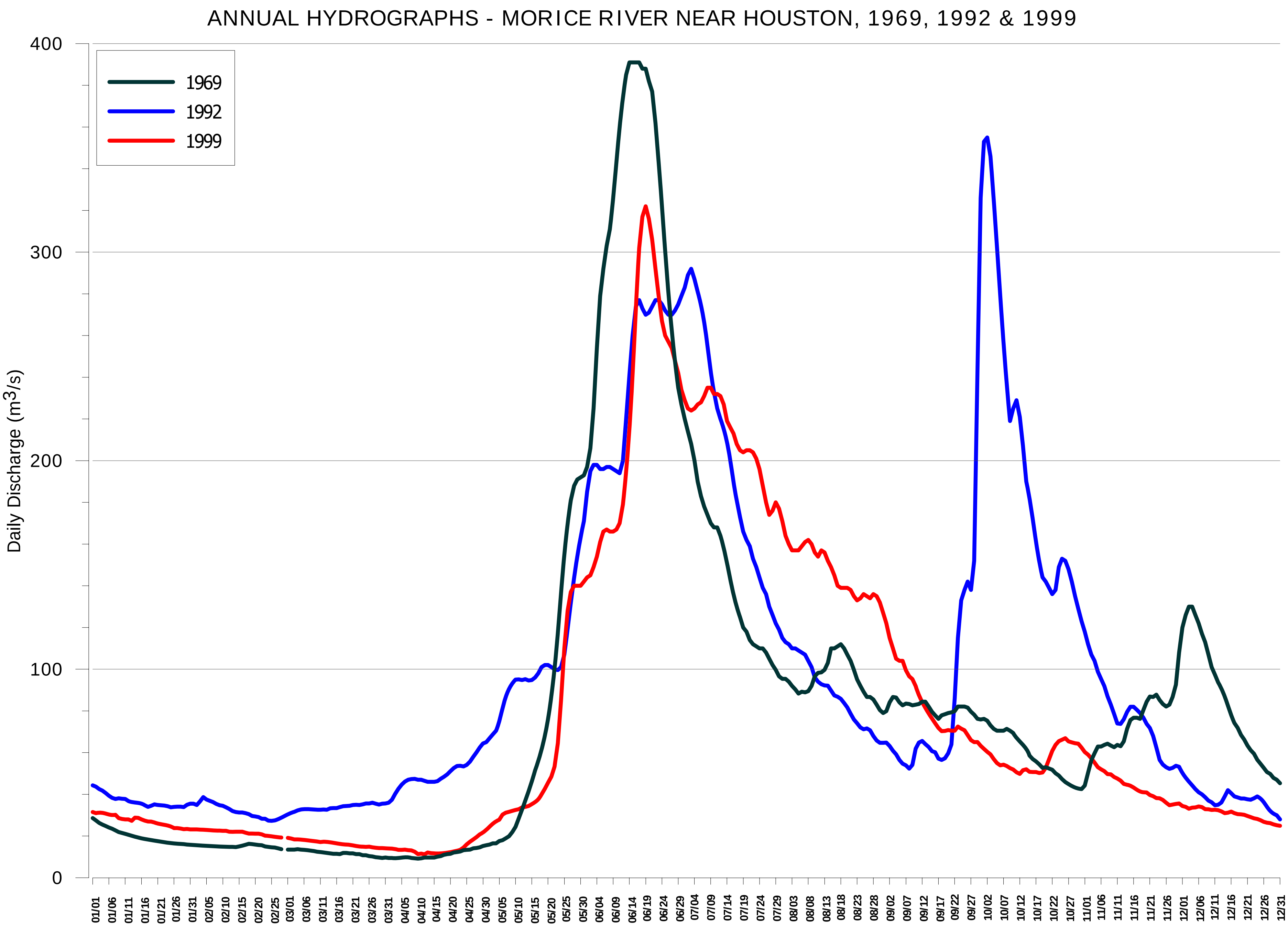
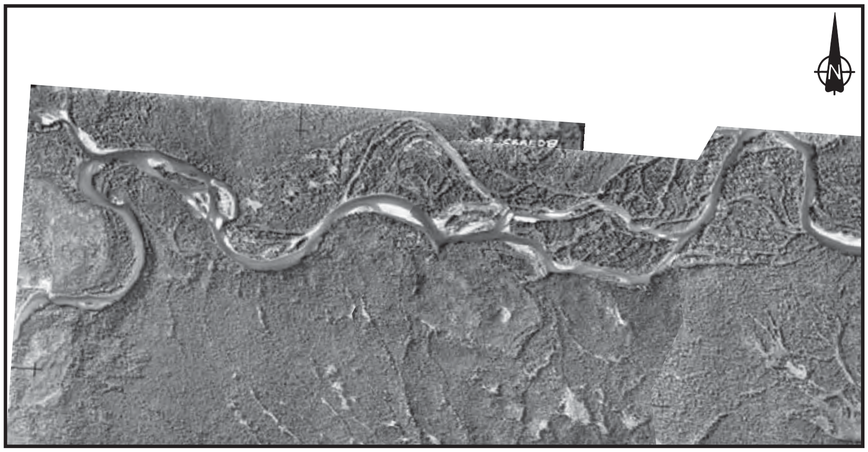


Figure 2.2.4: Annual hydrographs, Morice River near Houston 1969, 1992 and 1999.

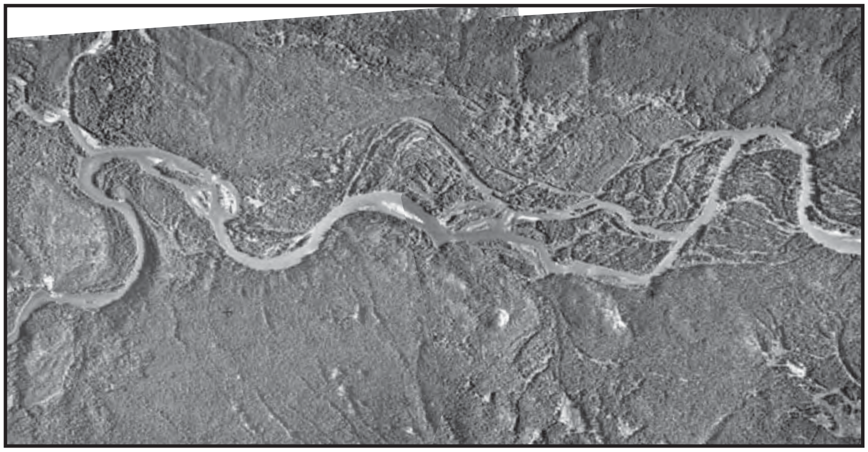
Figure 2.5.1: Recent Google Earth image showing channel conditions at the confluence of Reach 1 and Reach 2 on Morice River.



(i)

Date: August 20, 1955
BC1993 #61, 63 & 64

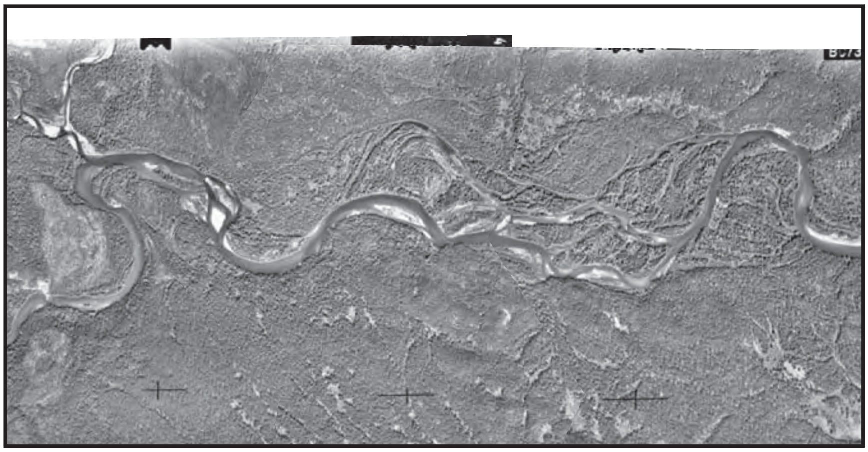
Discharge:	
Morice River near Houston	na



(ii)

Date: July 19, 1960
BC2777 #9 & 13

Discharge:	
Morice River near Houston	na



(iii)

Date: July 27, 1971
BC7362 #144-146

Discharge:	
Morice River near Houston	168 m^3/s

(iv)

Date: 2011?
Google Earth Imagery

Discharge:	
Morice River near Houston	m^3/s

Figure 2.5.2: Historical changes in channel morphology, upstream end of reach 2, Morice River.

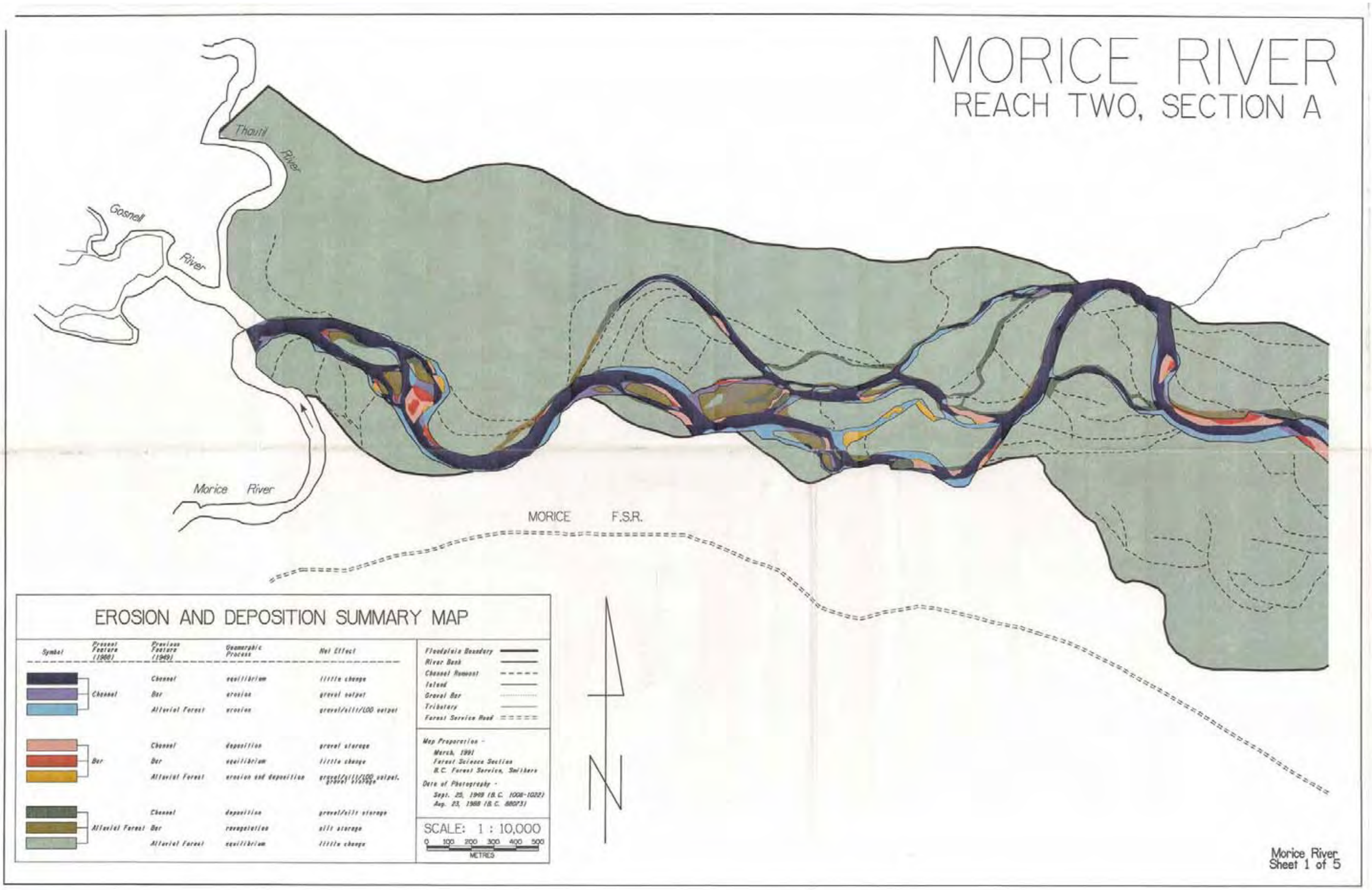


Figure 2.5.3: Net erosion and deposition between 1949 and 1988 at the upstream end of Morice River Reach 2 (from Weiland and Schwab, 1992).

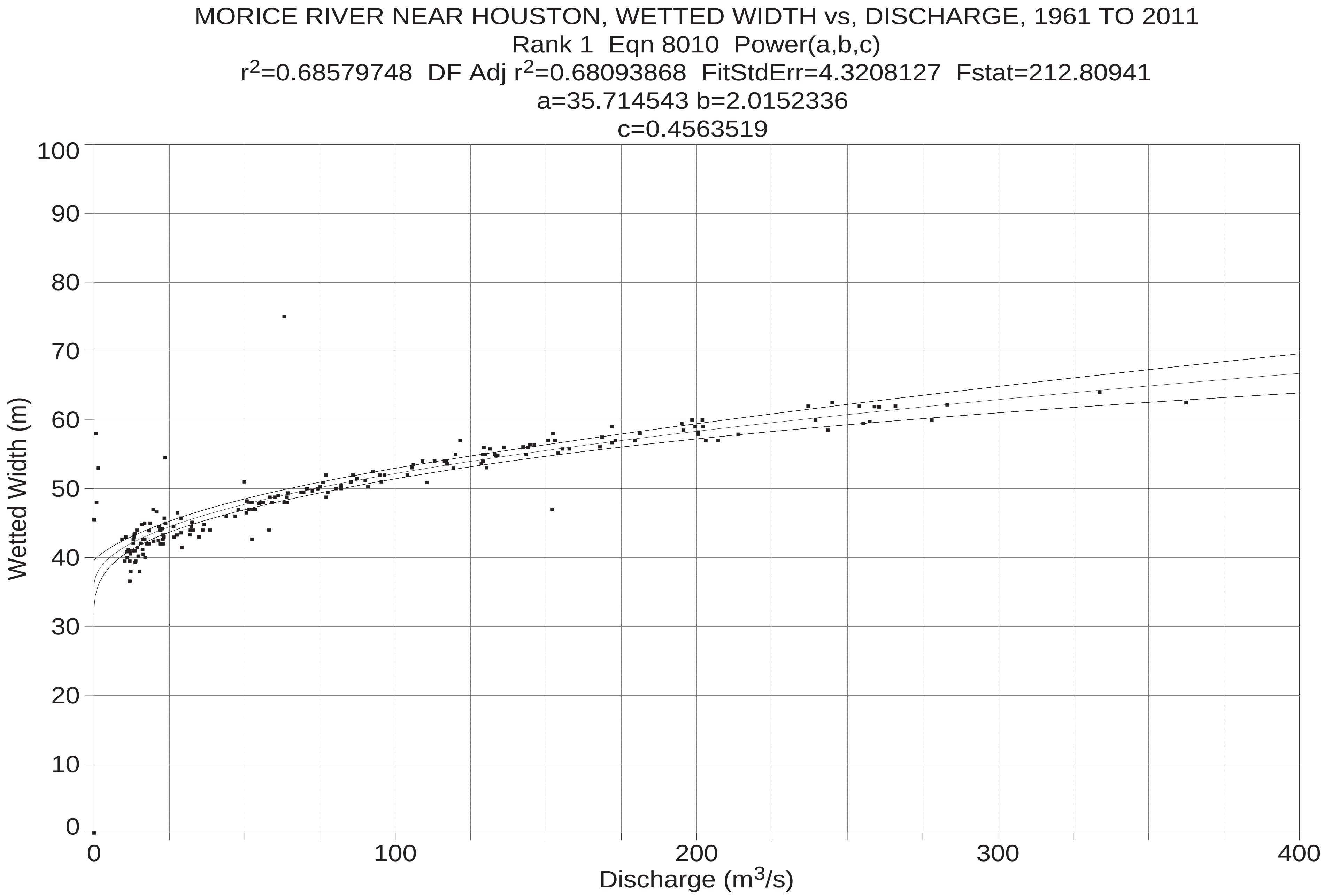


Figure 2.6.1: Relationship between wetted width and discharge at the WSC gauge Morice River near Houston, 1961 to 2011, showing the best fit line and 95% confidence limits.

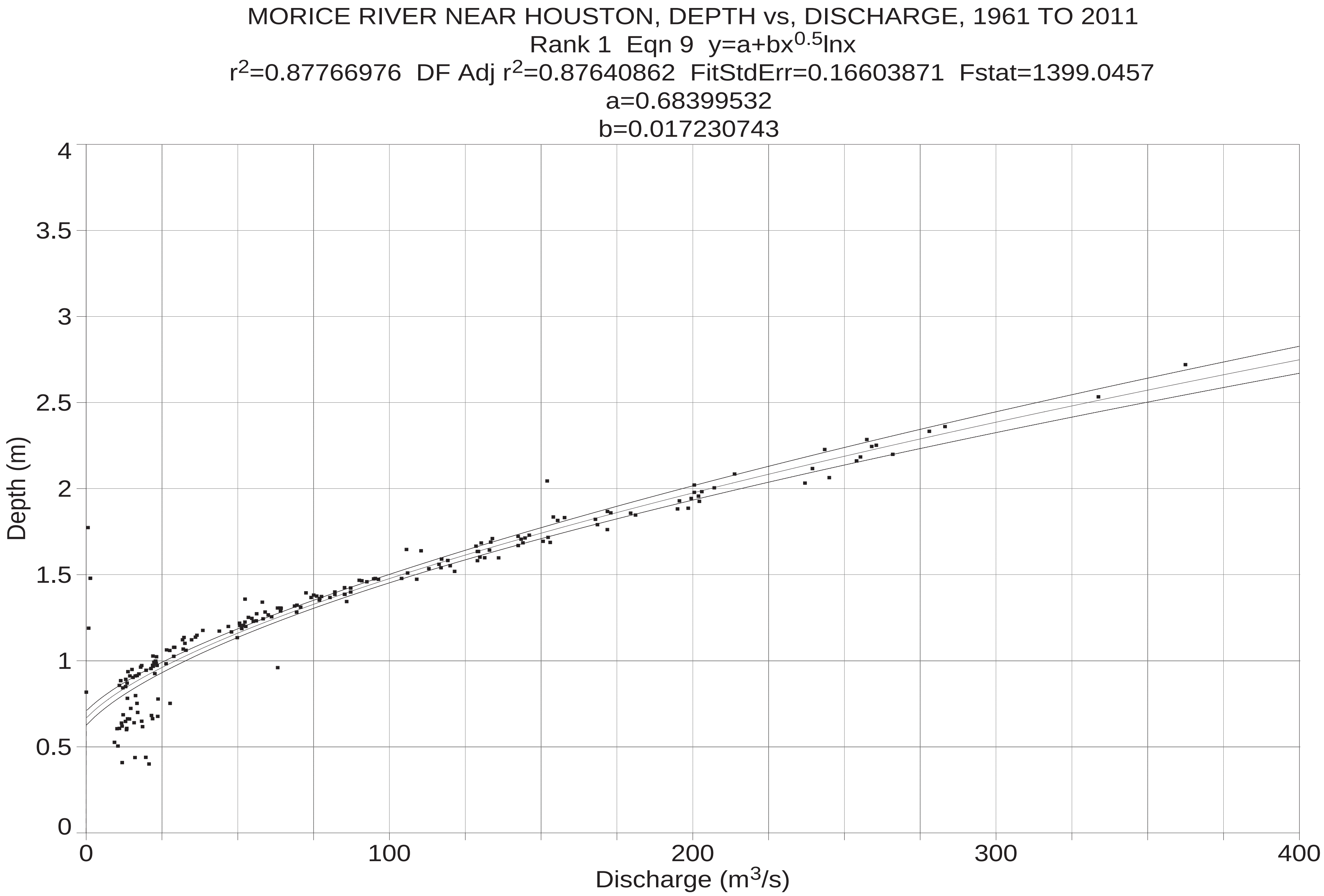


Figure 2.6.2: Relationship between depth and discharge at the WSC gauge Morice River near Houston, 1961 to 2011, showing the best fit line and 95% confidence limits.

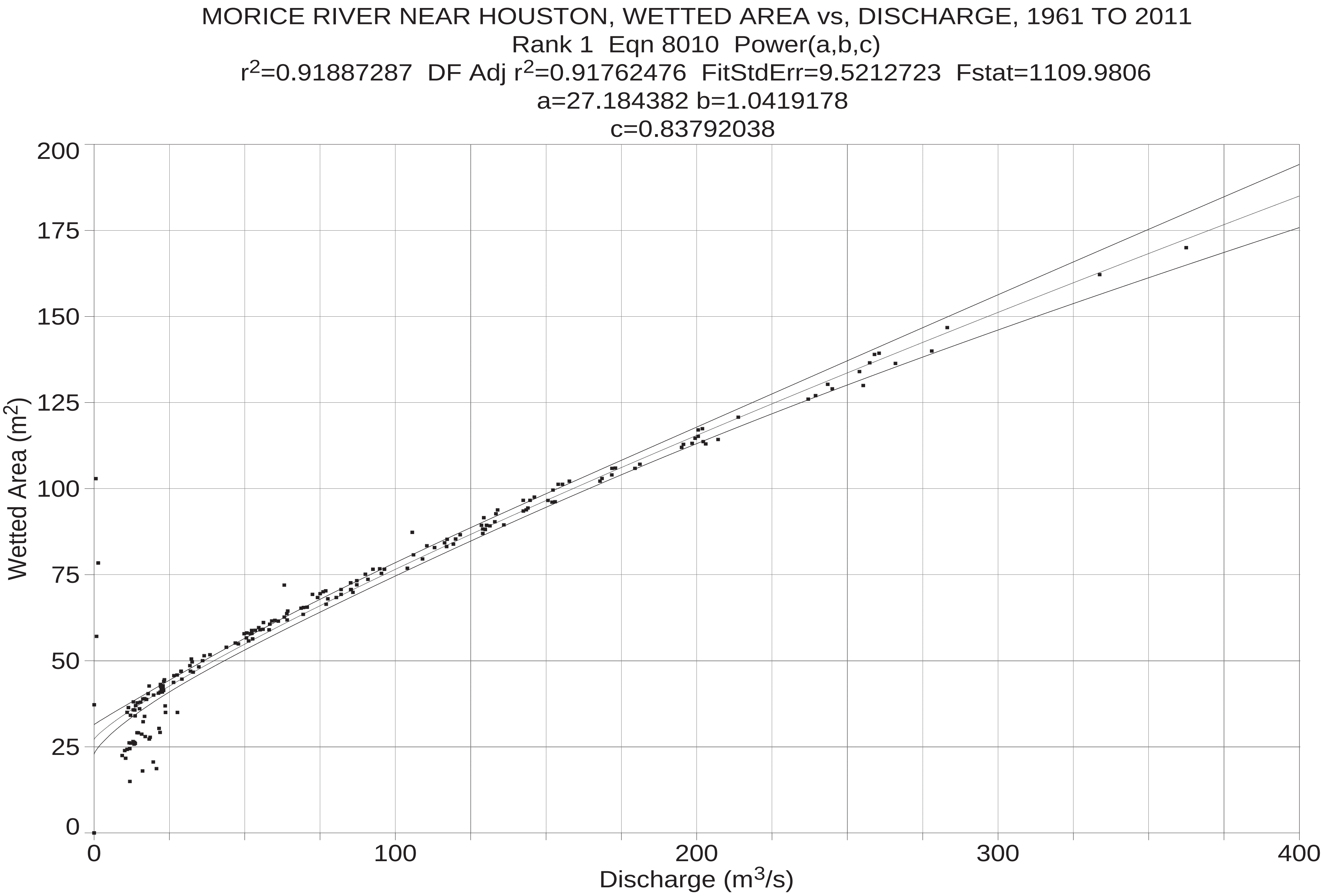


Figure 2.6.3: Relationship between wetted area and discharge at the WSC gauge Morice River near Houston, 1961 to 2011, showing the best fit line and 95% confidence limits.

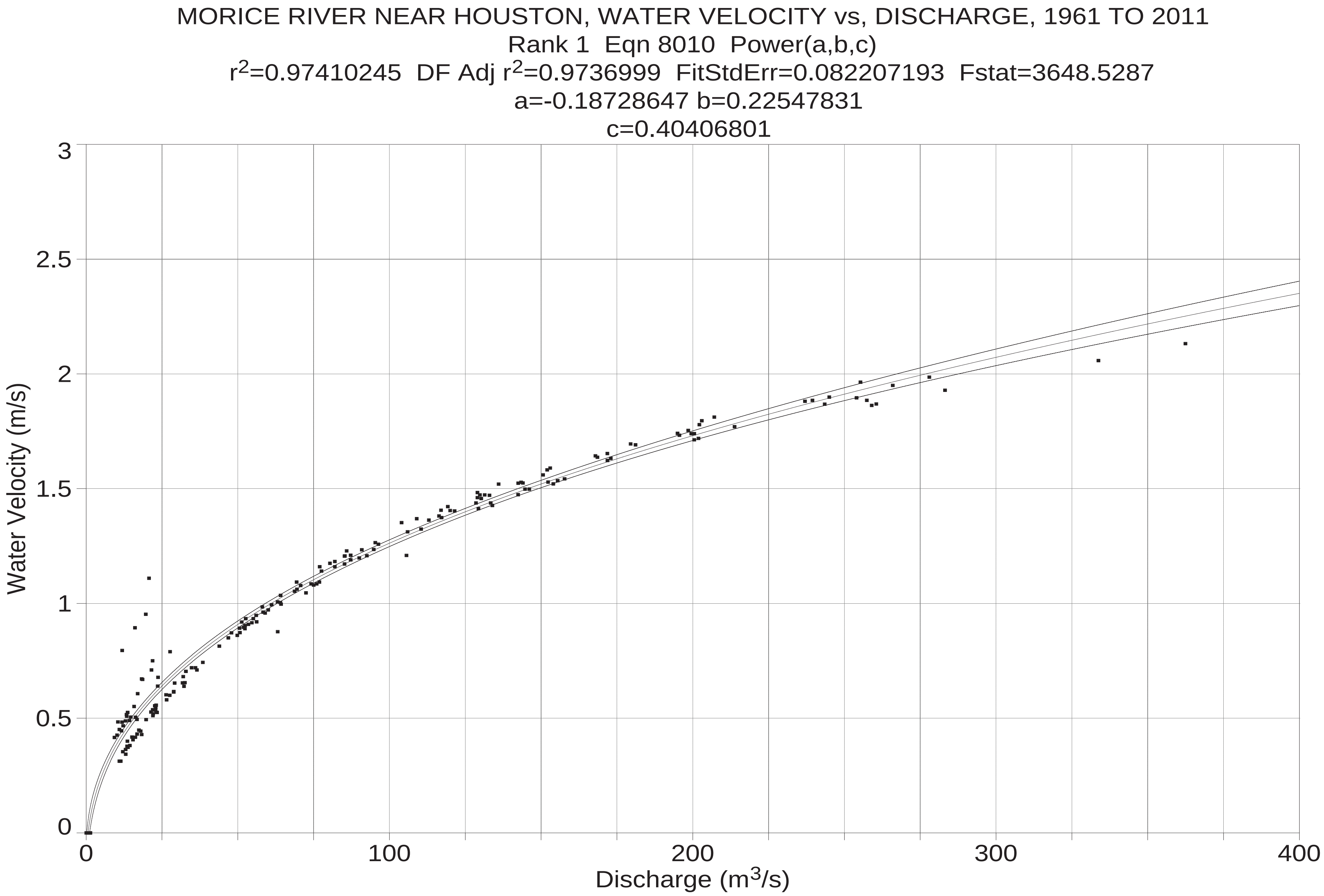
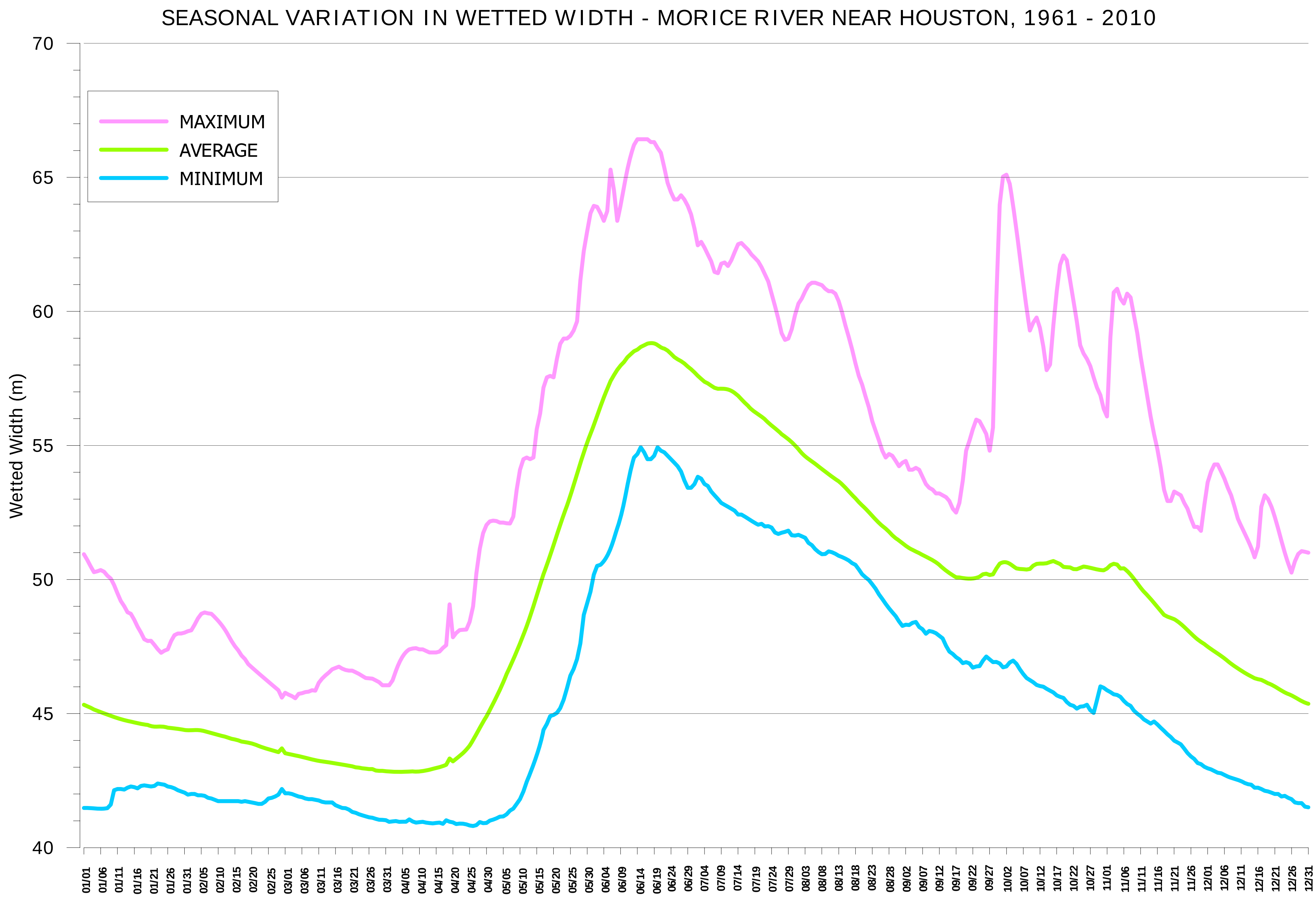


Figure 2.6.4: Relationship between water velocity and discharge at the WSC gauge Morice River near Houston, 1961 to 2011, showing the best fit line and 95% confidence limits.



SEASONAL VARIATION IN WETTED WIDTH - MORICE RIVER NEAR HOUSTON, 1961 - 2010

Figure 2.6.5: Seasonal variation in wetted width, Morice River near Houston.

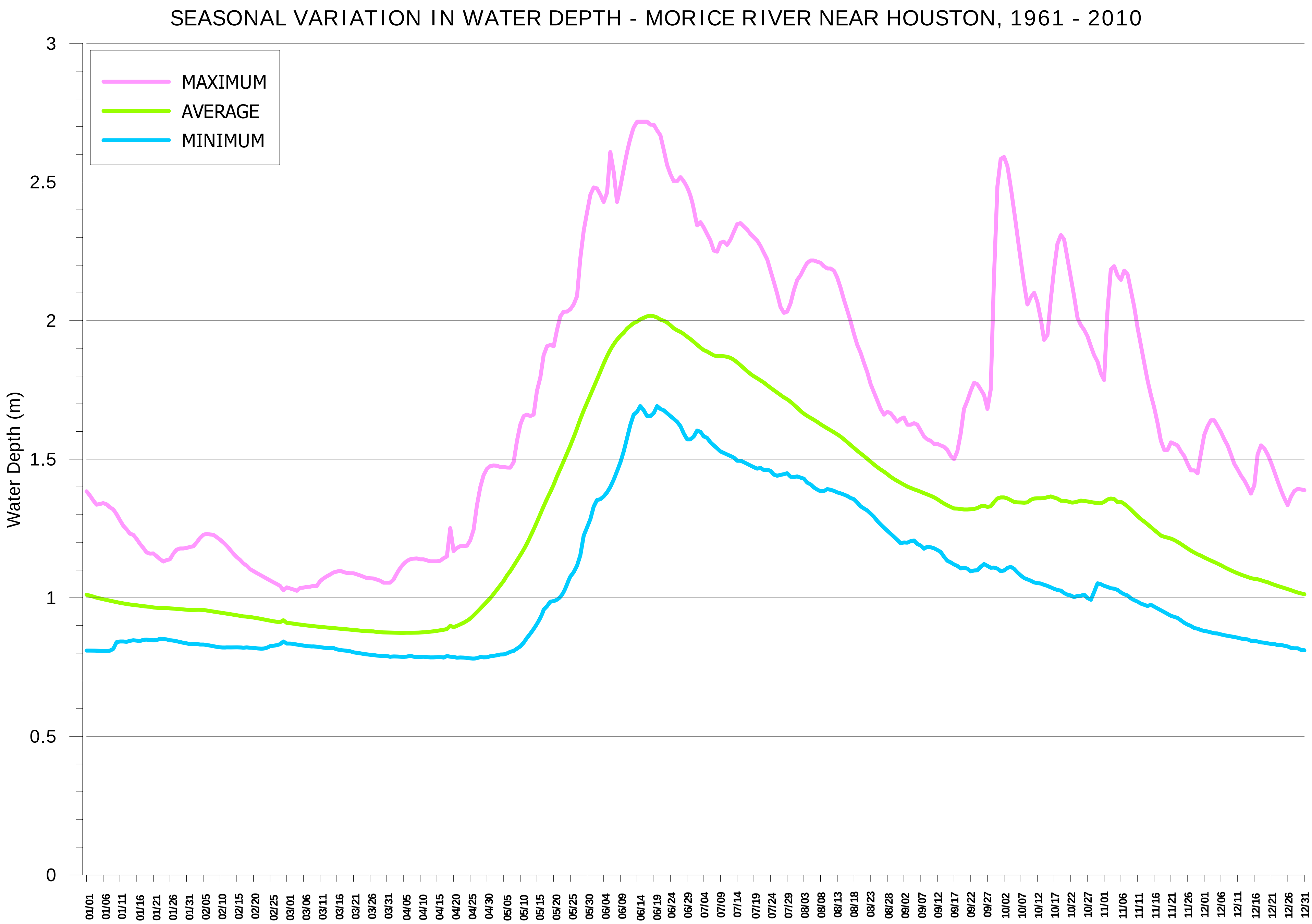


Figure 2.6.6: Seasonal variation in water depth, Morice River near Houston.

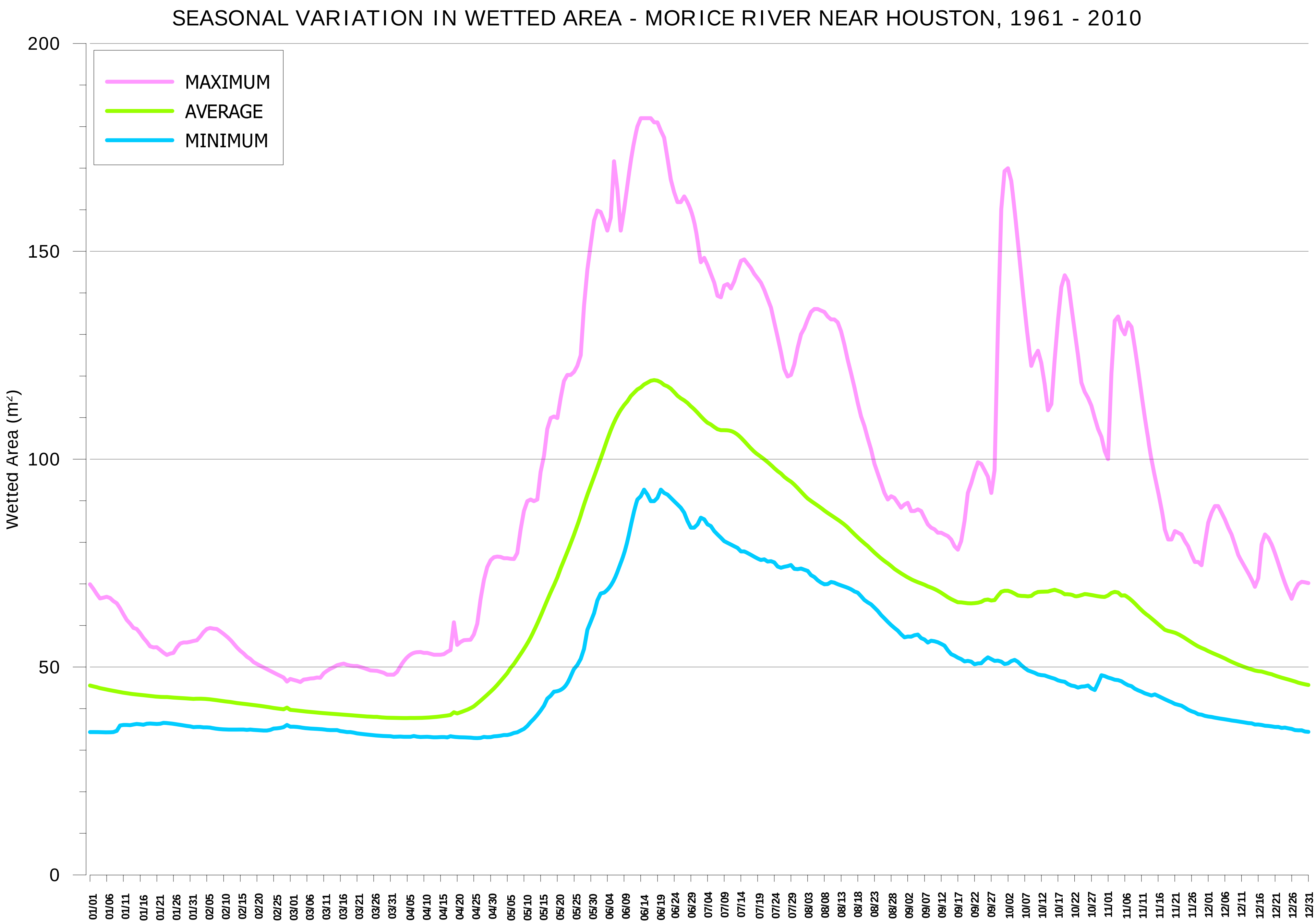


Figure 2.6.7: Seasonal variation in wetted area, Morice River near Houston.

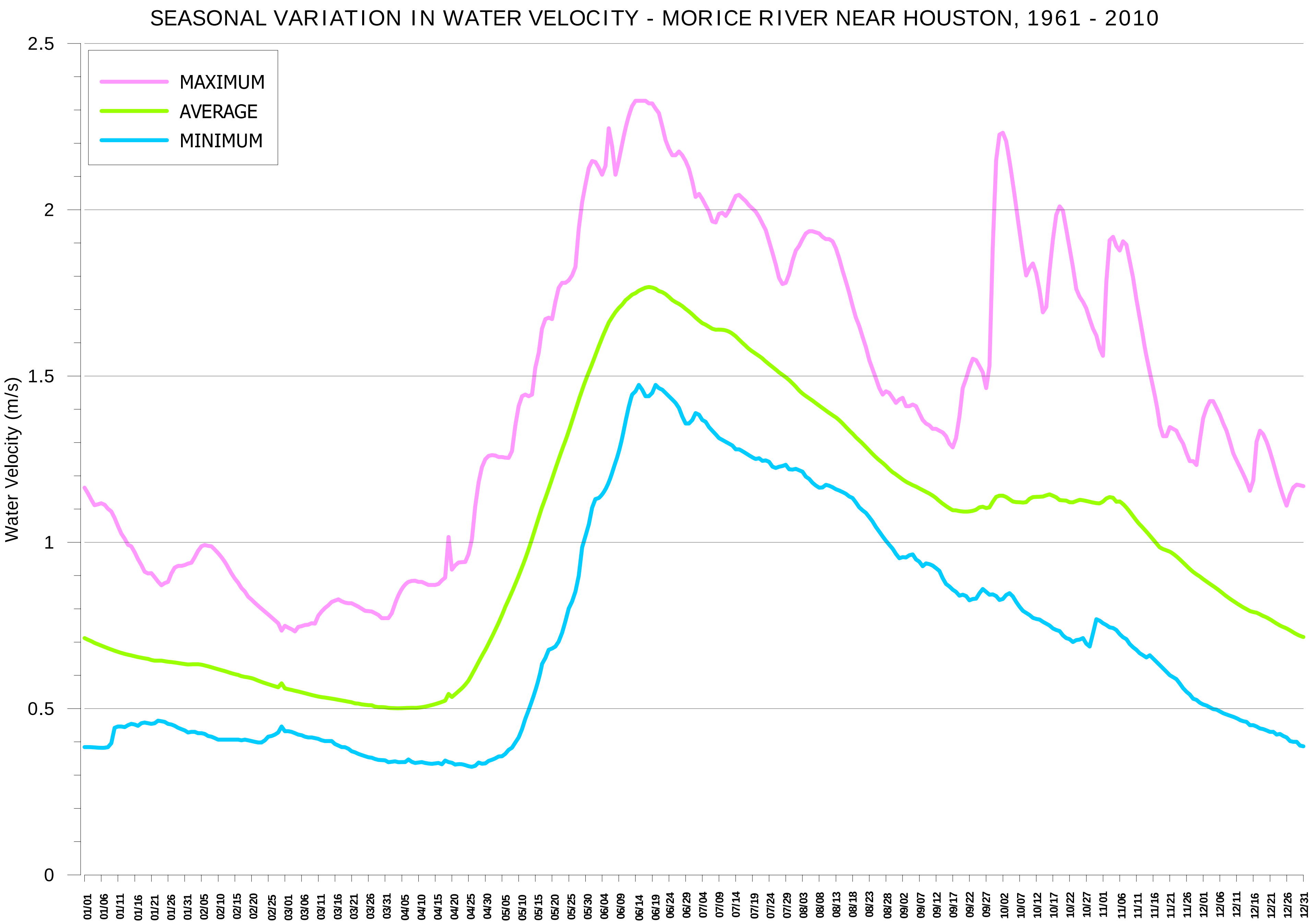


Figure 2.6.8: Seasonal variation in water velocity, Morice River near Houston.

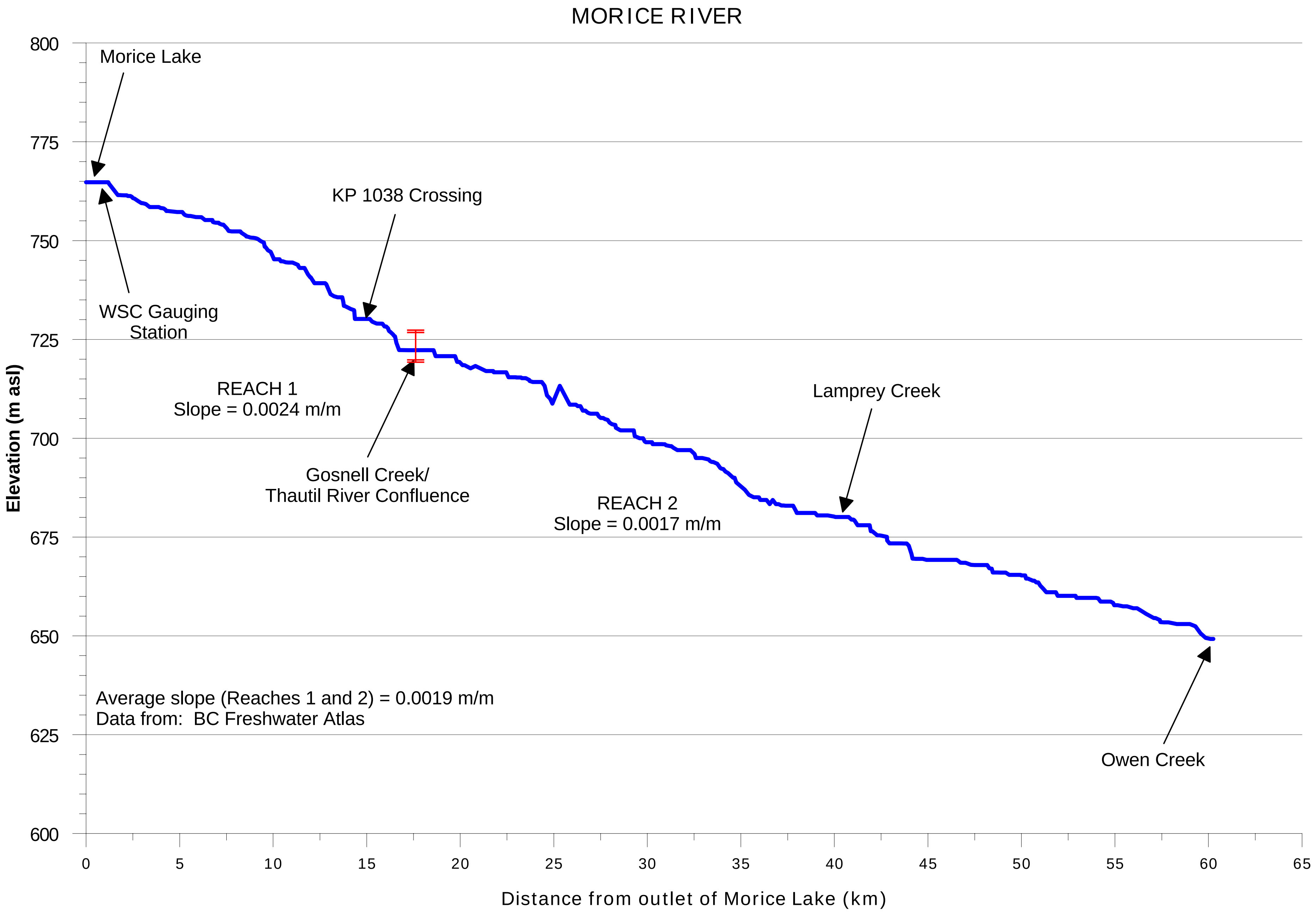


Figure 2.6.9: Long profile of Morice River from Morice Lake to Owen Creek.

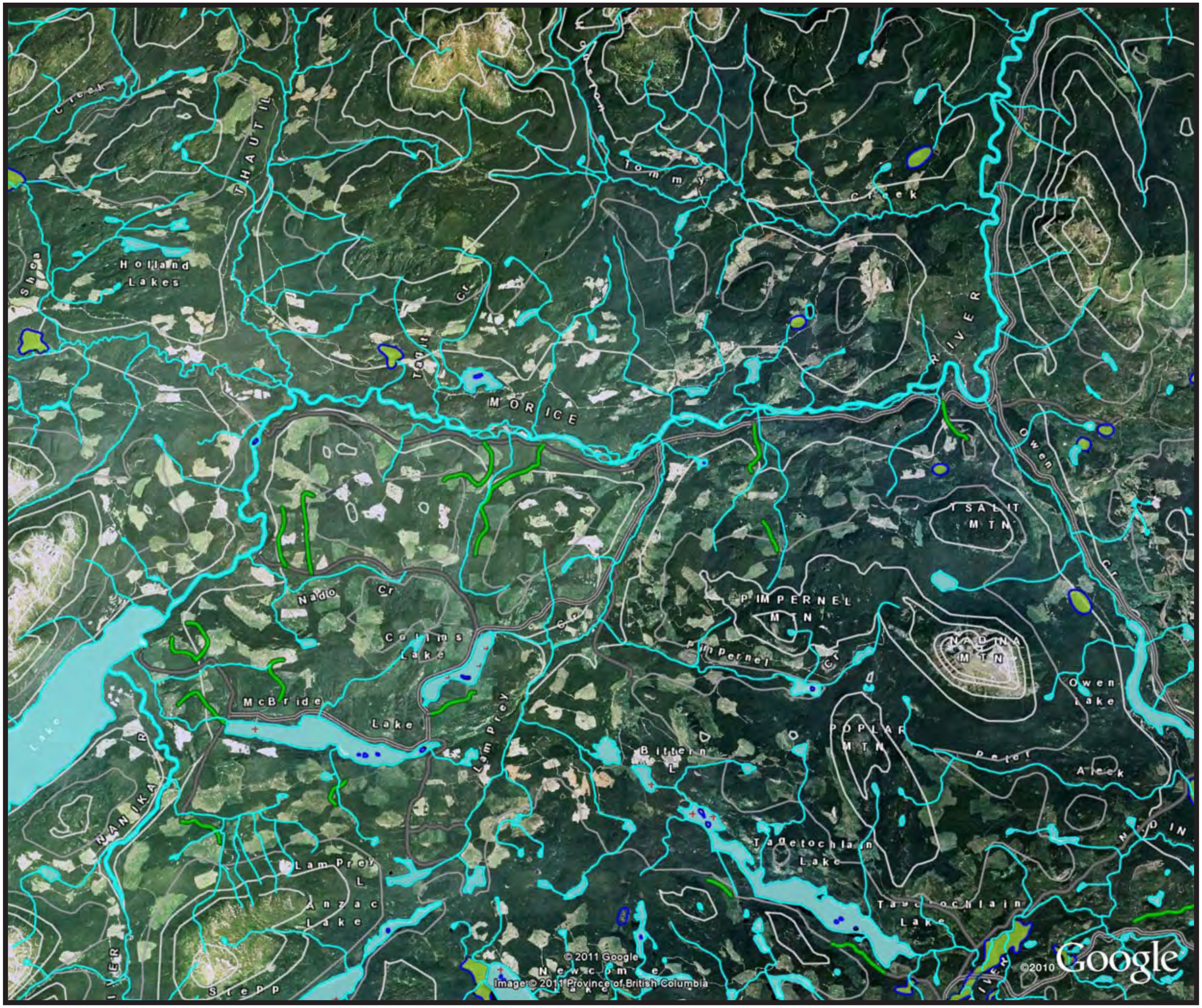


Figure 2.7.1: Google Earth image illustraing the extent of forest harvesting.

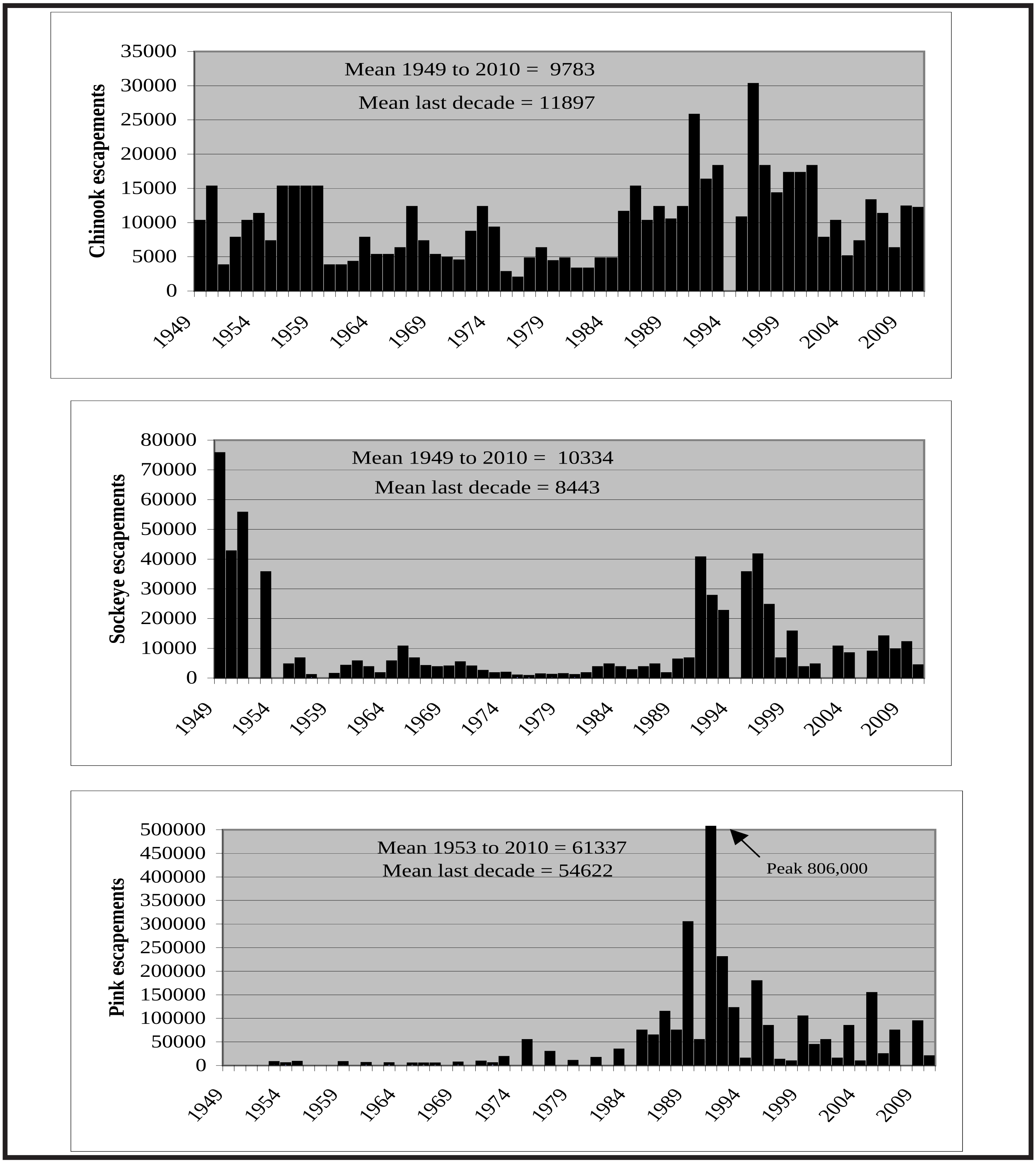
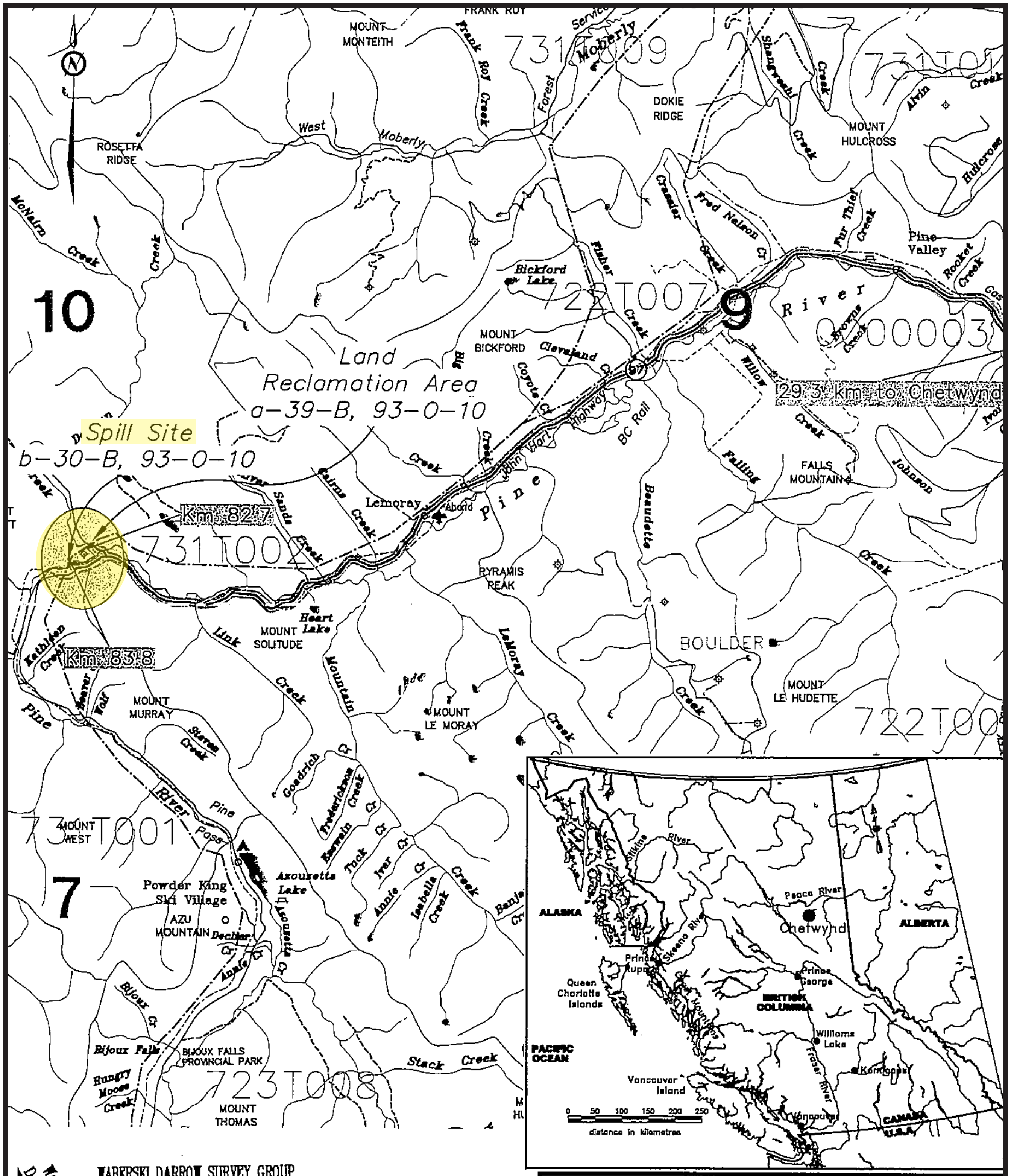


Figure 3.2.1.1: Escapement summaries for Morice chinook, sockeye and pink salmon.



WABERSKI DARROW SURVEY GROUP
10720 – 100th Avenue,
Fort St. John, B.C., V1J 1Z3
Ph. (250)787–0300 Fax (250)787–1611

SCALE:	1: 250,000
DATE:	September 14, 2000
DWG No.	000404e25

PINE RIVER PROJECT 2000

Project Location

northwest hydraulic consultants

Figure 4.3.1: Location of August 1, 2000 pipeline rupture on Pine River (from nhc, 2001).

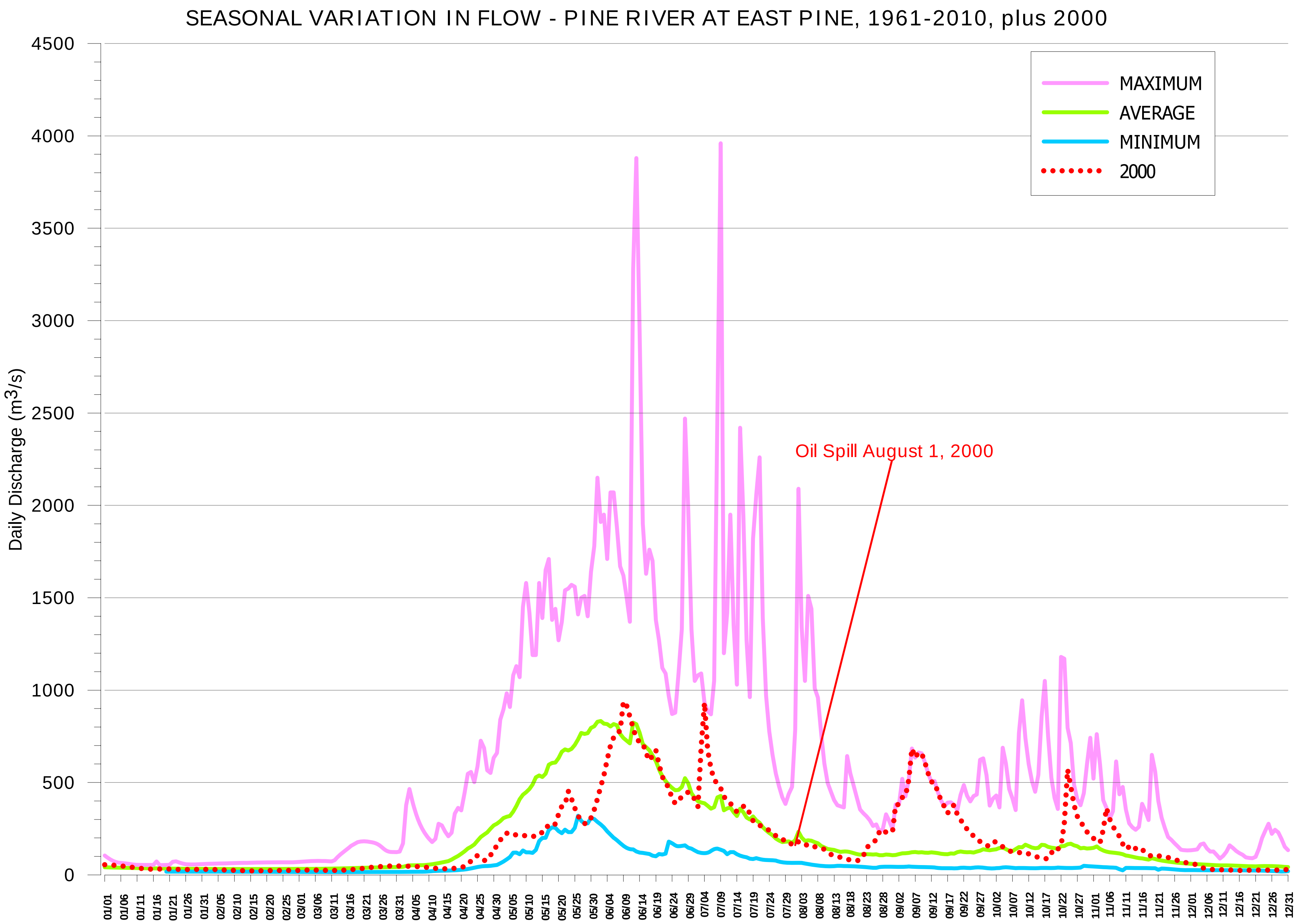
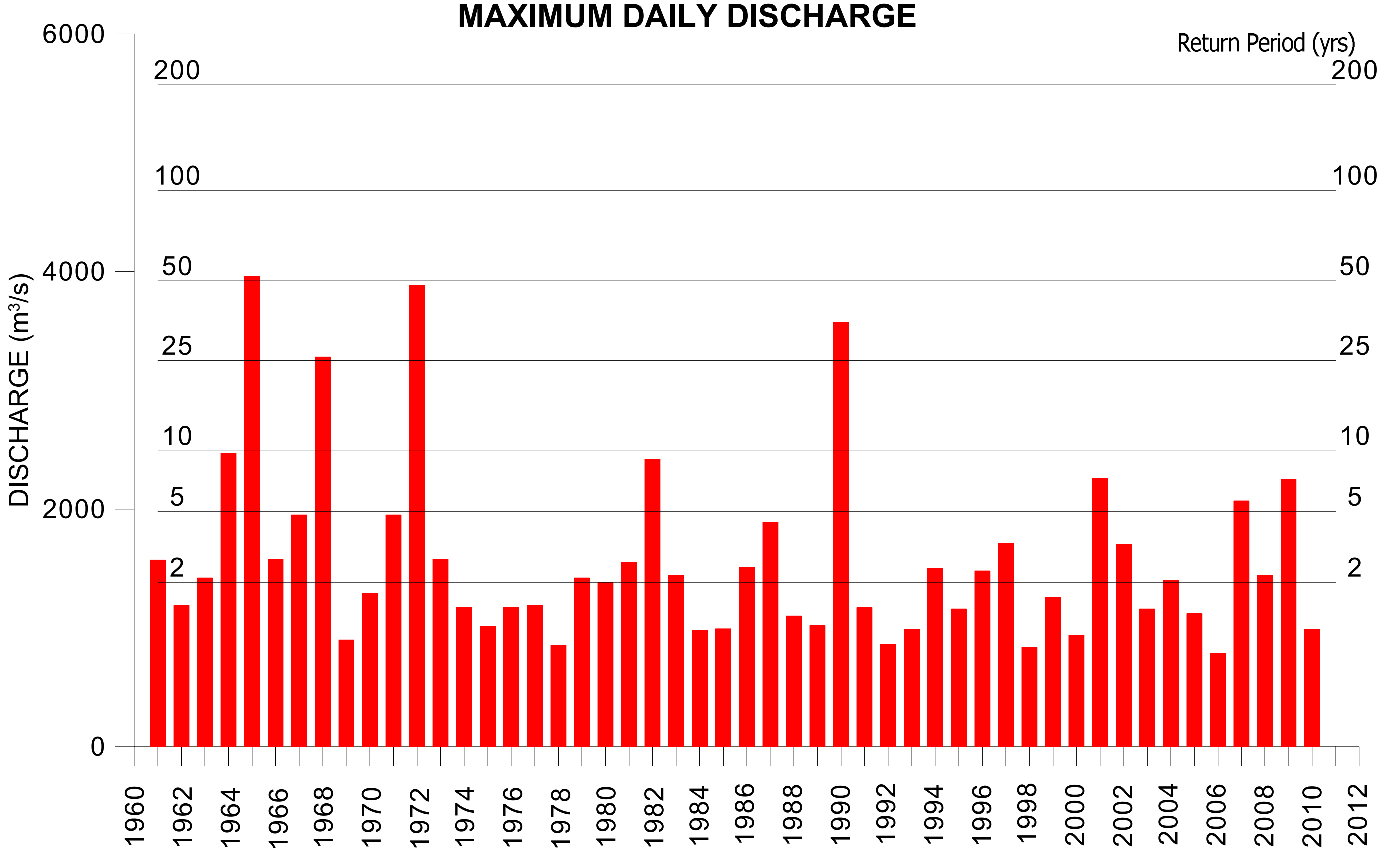


Figure 4.3.2: Seasonal variation in discharge, Pine River at East Pine, 1961 to 2010, plus 2000.

PINE RIVER AT EAST PINE, 1961 TO 2010, plus 2011 (prelim.)
MAXIMUM DAILY DISCHARGE



PINE RIVER AT EAST PINE, 1978 to 2010, plus 2011 (prelim.)
MAXIMUM INSTANTANEOUS DISCHARGE

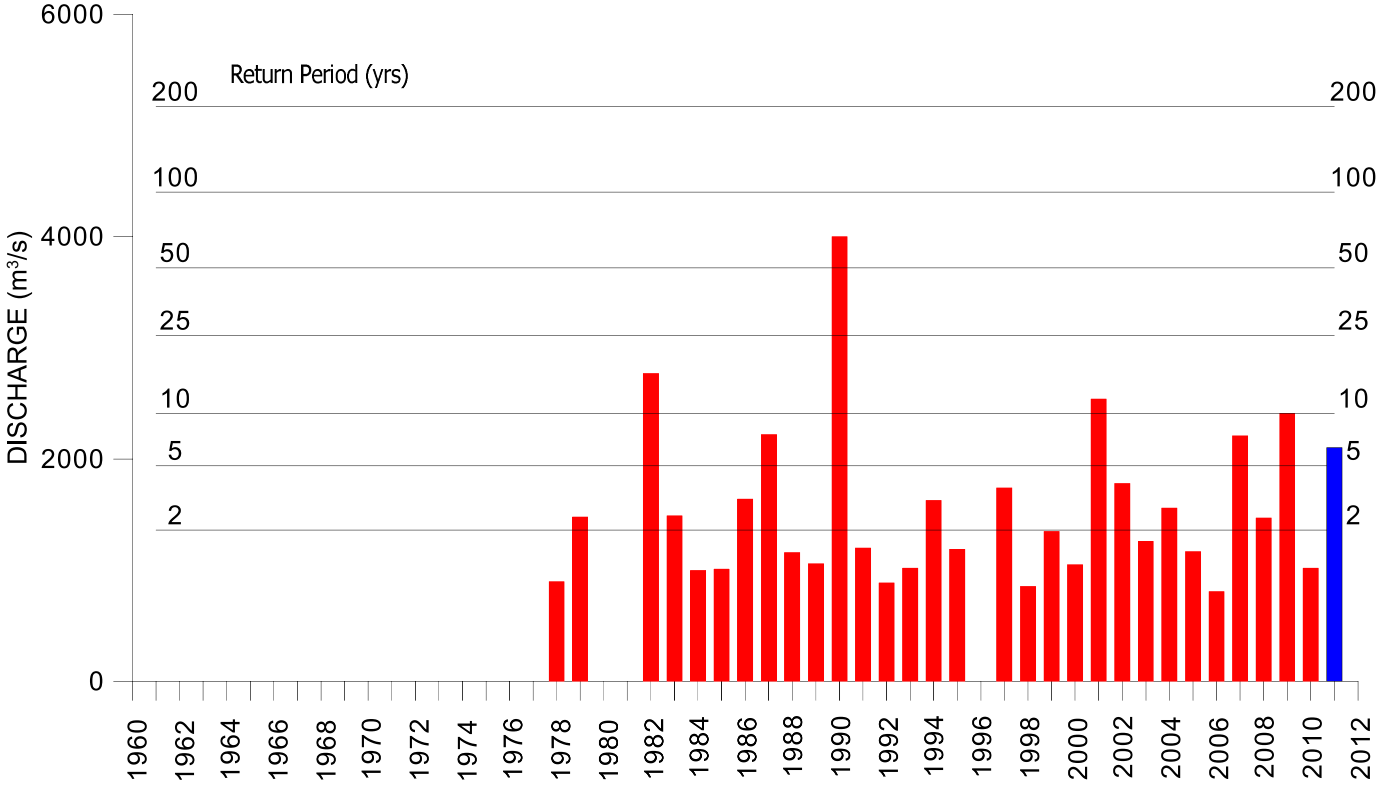


Figure 4.3.3: Historical variation in annual maximum daily and instantaneous discharge, Pine River at East Pine, 1961-2010, plus WSC 2011 (prelim.) real time data to July 8.

IAS (01) 54434 #32 & 33		August 9, 2001 Air Photos			
REFERENCED DRAWING NO.		REFERENCED DRAWING DESCRIPTION			
A	May 21, 2002	Issued For Discussion	SA	MM	
F - 26					

APPROXIMATE SCALE: 1:5,000
DATE: May 21, 2002
DRAWN: S. Allegretto
DESIGNED: S. Allegretto
CHECKED: M. Miles
APPROVED:

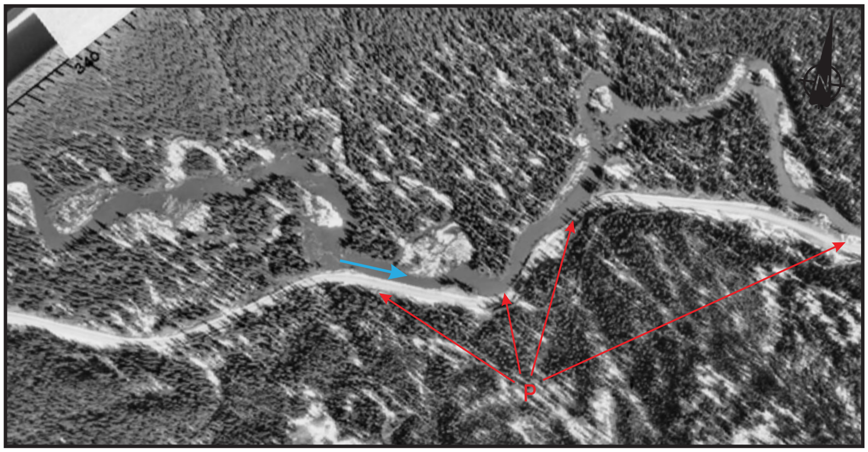
M. MILES AND ASSOCIATES LTD.
645 ISLAND ROAD, VICTORIA, BC, V8S 2T7
Phone: 250-595-0653 Fax: 250-595-7367 email: mmaa@coastnet.com

CLIENT:
NORTHWEST INSTITUTE FOR BIOREGIONAL RESEARCH

PROJECT:
EFFECTS OF AN OIL SPILL ON REACH 2 OF MORICE RIVER

TITLE:
LOCATION OF AUGUST 2000 OIL SPILL ON PINE RIVER

FIGURE 4.3.4
PROJECT NO.
DRAWING NO.
REV: A



(i)

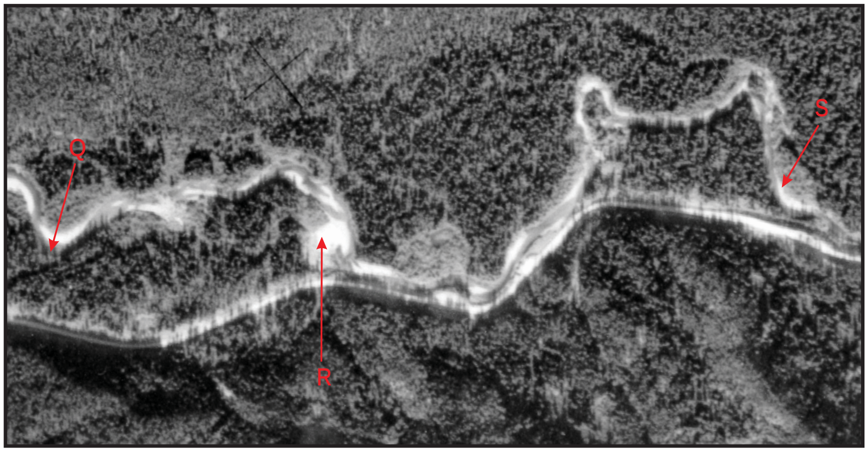
Date: May 17, 1953
BC1650 #59

NOTE**:**

- Extent of inundation during high water conditions.
- Location of John Hart Highway and apparent instream encroachments (P).

Discharge:

Pine River at East Pine	na



(ii)

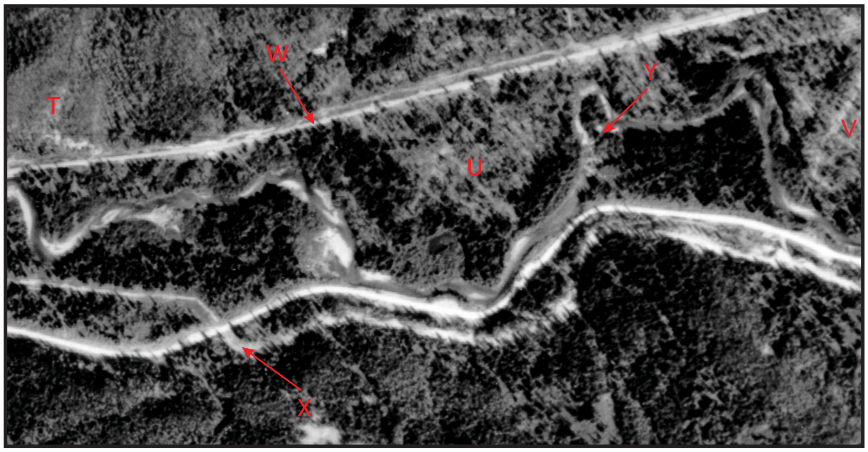
Date: September 11, 1955
BC2136 #65

NOTE**:**

- Low water channel conditions.
- Size and extent of unvegetated instream gravel accumulations (e.g. Q and R) and vegetation development on formerly unvegetated bars (e.g. S).

Discharge:

Pine River at East Pine	na



(iii)

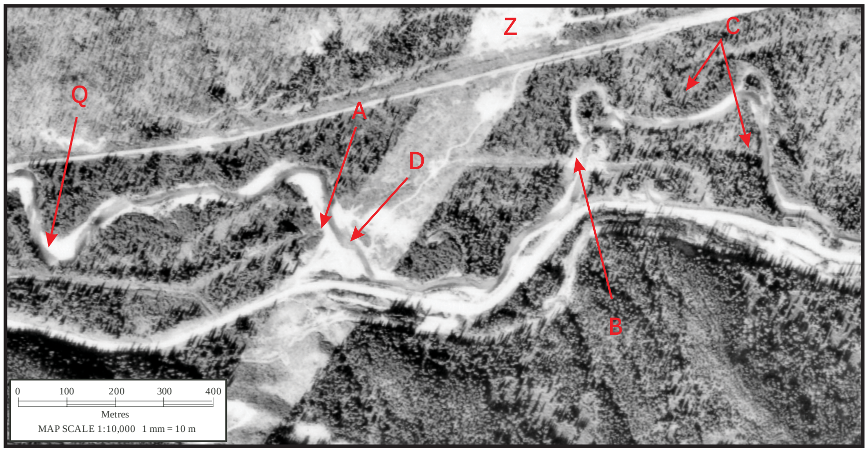
Date: July 20, 1960
BC2770 #10

NOTE**:**

- Clearing of left bank valley wall (T) and portions of the valley flat (e.g. U and V).
- Construction of the BC Railway (W) and pipeline ROW (X).
- Incipient cut-off channel (Y).

Discharge:

Pine River at East Pine	na



(iv)

Date: August 13, 1967
BC5264 #216

NOTE**:**

- Construction of BC Hydro transmission ROW (Z) and riparian clearing at Pine River crossing.
- Second pipeline ROW with stream crossings at A and B.
- Additional valley flat logging (e.g. C).

Discharge:

Pine River at East Pine	127 m^3/s

Figure 4.3.5A: Historical changes in channel morphology on Pine River in the vicinity of the August 1, 2000 oil spill (from EDI & MMA, 2002).

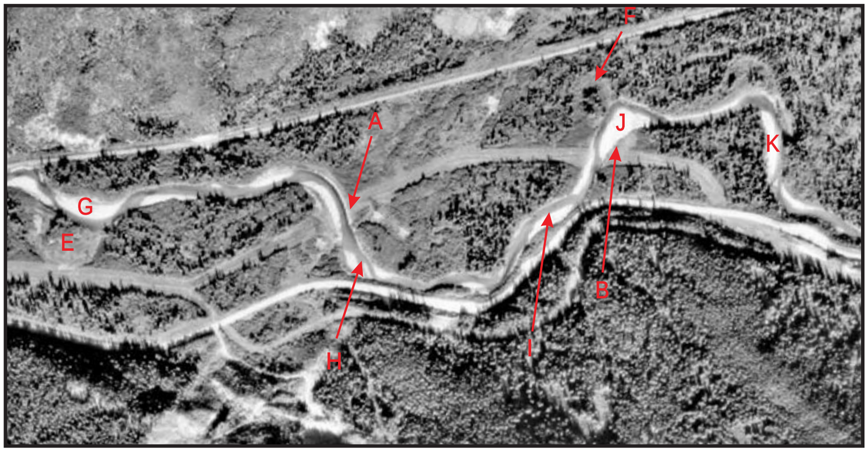
(v)

Date: June 15, 1969
BC7177 #175

NOTE:

- Channel cut-off at Y.

Discharge:
Pine River at East Pine 278 m³/s



(vi)

Date: August 31, 1989
30BC89064 #72

NOTE:

- Increased size of pipeline ROW (A and B).
- Channel cut-off at E and F.
- Extensive sediment accumulations (e.g. G, H, I, J and K) following upstream channel avulsion.

Discharge:
Pine River at East Pine 140 m³/s

(vii)

Date: September 1, 1997
30BCC97182 #131

NOTE:

- Further sediment accumulations (e.g. in the vicinity of G, H, J and K).
- Straightened channel at pipeline crossing B, likely resulting in channel downcutting and erosion of the right bank.

Discharge:
Pine River at East Pine 125 m³/s

(viii)

Date: August 9, 2001
IAS (01) 54434 #33

NOTE:

- Replacement pipeline crossing B following rupture in August 2000. The pipeline failure occurred on the left bank outside of the main river channel.
- Reworking of sediment accumulations (e.g. G and H) indicating the channel is still readjusting to the post-1960 influx of coarse sediment.

Discharge:
Pine River at East Pine 216 m³/s

Figure 4.3.5B: Historical changes in channel morphology on Pine River in the vicinity of the August 1, 2000 oil spill (from EDI & MMA, 2002).

15BCB96074 #198	August 26, 1996				
Discharge: Pine River at East Pine 135 m³/s					
REFERENCED DRAWING NO.	REFERENCED DRAWING DESCRIPTION				
A	July 11, 2011	Issued for discussion			
F - 28					

APPROXIMATE SCALE:
DATE: July 11, 2011
DRAWN: S. Allegretto
DESIGNED: S. Allegretto
CHECKED: M. Miles
APPROVED:

M. MILES AND ASSOCIATES LTD.
645 ISLAND ROAD, VICTORIA, BC, V8S 2T7
Phone: 250-595-0653 Fax: 250-595-7367 email: mikemiles@shaw.ca

CLIENT:
NORTHWEST INSTITUTE FOR
BIOREGIONAL RESEARCH
PO BOX 2781, SMITHERS, BC
V0J 2N0

PRE-OIL SPILL CHANNEL MORPHOLOGY & LOCATION OF LOG JAMS

1996 AIR PHOTO MOSAIC
PINE RIVER NEAR LEMORAY

FIGURE 4.3.6

PROJECT #
Km #
REV: A

Google Earth Imagery | Date to be determined

Discharge: Pine River at East Pine ____ m³/s

REFERENCED DRAWING NO.	REFERENCED DRAWING DESCRIPTION				
A	July 11, 2011	Issued for discussion			
F - 29					

APPROXIMATE SCALE:
DATE: July 11, 2011
DRAWN: S. Allegretto
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V0J 2N0

POST-OIL SPILL CHANNEL MORPHOLOGY

RECENT GOOGLE EARTH IMAGERY
PINE RIVER NEAR LEMORAY

FIGURE 4.3.7

PROJECT #
Km #
REV: A

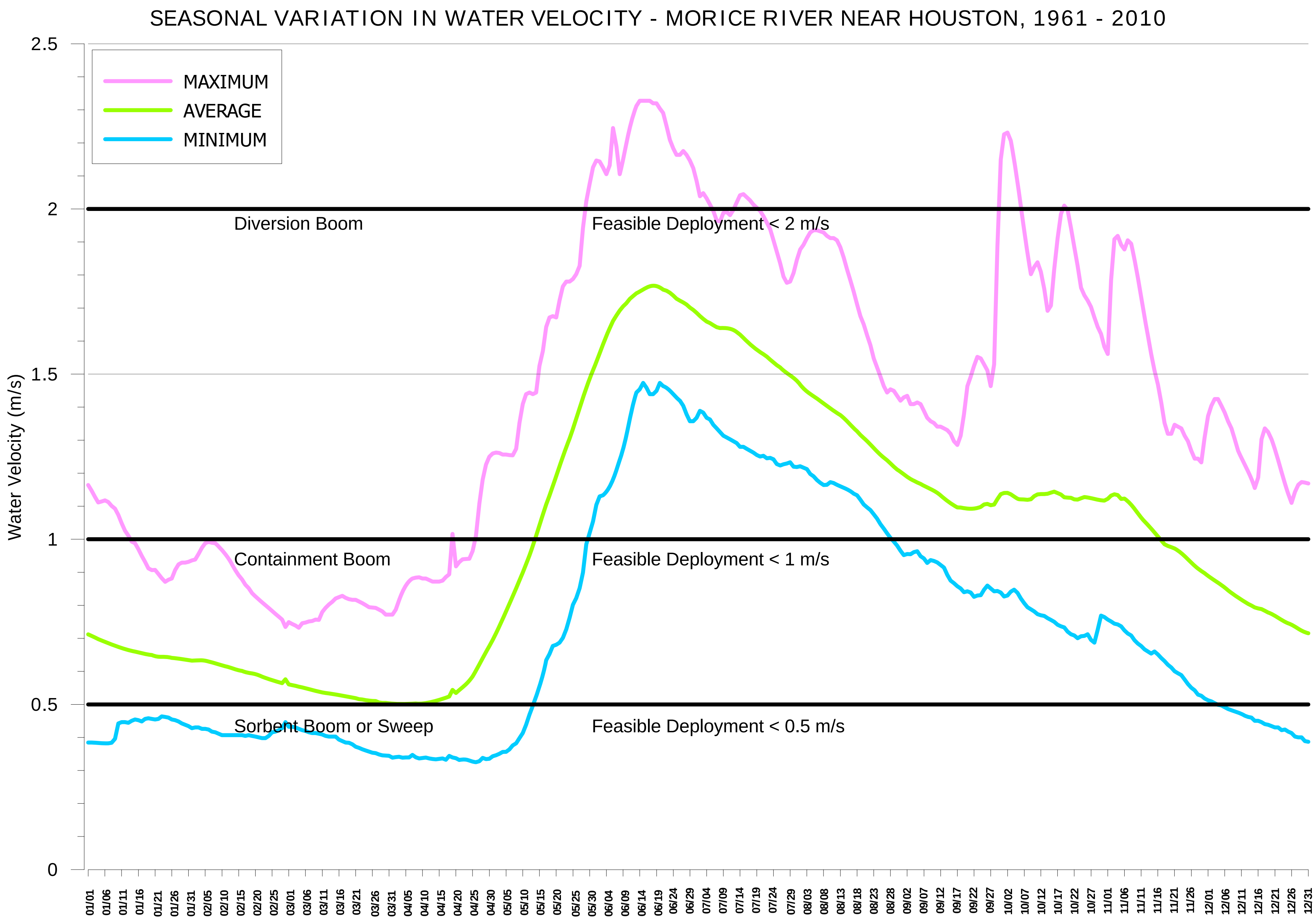

Figure 5.1.2.1: Feasibility of deploying various oil spill containment techniques as a fuction of seasonal water velocities on Morice River near Houston.

TABLES

TABLE 2.2.1: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE, MORICE RIVER NEAR HOUSTON, 1962 TO 2010

MORICE RIVER NEAR HOUSTON
Maximum Daily Discharge (m3/s) Skew: .742

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit See NOTES below	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	234	290	332	389	435	484	536	.0868	.0268
Gumbel (Maximum Likelihood)	239	289	321	363	393	424	454	.0937	.0371
Pearson Type III (By Moments)	242	294	325	362	387	411	435	.0767	.0583
Log Pearson Type III (By Moments)	240	291	325	367	398	430	462	.0864	.0436
Average	239	291	326	370	404	437	472		
Adopted Value	240	291	325	367	398	430	462		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	221	251	265	321	295	378	333	462	362	532	392	610	423	694
Gumbel (Maximum Likelihood)	224	254	266	311	292	350	325	400	349	437	373	474	397	511
Pearson Type III (By Moments)	226	258	271	317	296	355	324	399	344	430	363	460	381	489
Log Pearson Type III (By Moments)	225	255	268	316	294	358	325	413	348	456	370	499	392	544
Average	224	254	267	316	294	360	327	419	351	464	375	511	398	559
Adopted Value	221	258	265	321	292	378	324	462	344	532	363	610	381	694

[1] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

[2] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 2.2.2: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INST. DISCHARGE, MORICE RIVER NEAR HOUSTON, 1962 TO 2010

MORICE RIVER NEAR HOUSTON
Maximum Instantaneous Discharge (m3/s) Skew: .811

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit See NOTES below	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	234	287	327	382	425	471	520	.114	.0198
Gumbel (Maximum Likelihood)	238	286	318	358	387	417	446	.0987	.0361
Pearson Type III (By Moments)	240	291	321	358	383	407	431	.0826	.0539
Log Pearson Type III (By Moments)	239	288	321	361	392	422	453	.0917	.0422
Average	238	288	322	365	397	429	462		
Adopted Value	239	288	321	361	392	422	453		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	220	250	262	318	291	373	327	453	354	520	382	593	411	673
Gumbel (Maximum Likelihood)	223	253	263	309	289	347	320	395	343	431	366	467	389	503
Pearson Type III (By Moments)	225	256	267	314	291	352	319	396	338	428	357	458	374	487
Log Pearson Type III (By Moments)	224	254	266	313	290	354	320	408	341	449	363	491	383	535
Average	223	253	265	313	290	356	321	413	344	457	367	503	389	550
Adopted Value	220	256	262	318	289	373	319	453	338	520	357	593	374	673

[1] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

[2] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 2.5.1: SUMMARY OF REACH LENGTH, LOG JAM ABUNDANCE AND SHORELINE PERIMETER ALONG THE MAINSTEM MORICE RIVER ADJACENT TO THE PROPOSED PIPELINE

Location	Reach	Pipeline km	Distance (km)**	Log jams /km*	Number of log jams	Shoreline /km*	Km of shoreline
Owen to Lamprey Creek	2	1006-1023	17	40	680	9	153
Lamprey to Gosnell	2	1023-1040	17	20	340	12.5	212.5
Gosnell to Morice Crossing	1	1040-1042	2	7	14	5	10
Total			36		1034		375.5

* Based on DFO aerial mosaic taken during high flow conditions in June 1975 (Shepherd 1979).

** Pipeline km distance based on Enbridge spill routing maps, March 15, 2011

TABLE 3.2.1.1: SUMMARY OF CHINOOK, SOCKEYE AND PINK SALMON ESCAPEMENTS TO MORICE TO 2010

YEAR	CHINOOK	PINK	SOCKEYE
1949	10,000	N/R	75,000
1950	15,000	N/R	42,000
1951	3,500	N/R	55,000
1952	7,500	N/R	UNK
1953	10,000	3,500	35,000
1954	11,000	1,000	UNK
1955	7,000	4,000	4,000
1956	15,000	N/R	6,000
1957	15,000	N/R	400
1958	15,000	25	25
1959	15,000	3,500	750
1960	3,500	N/R	3,500
1961	3,500	1,500	5,000
1962	4,000	N/R	3,000
1963	7,500	1,000	1,000
1964	5,000	N/R	5,000
1965	5,000	500	10,000
1966	6,000	500	6,000
1967	12,000	400	3,400
1968	7,000	N/R	3,000
1969	5,000	2,500	3,300
1970	4,600	N/R	4,700
1971	4,200	4,500	3,300
1972	8,400	1,000	1,800
1973	12,000	14,000	1,000
1974	9,000	N/R	1,200
1975	2,500	50,000	225
1976	1,700	100	100
1977	4,500	25,000	600
1978	6,000	200	500
1979	4,100	5,800	700
1980	4,500	100	400
1981	3,000	12,500	1,000
1982	3,000	N/R	3,000
1983	4,500	30,000	4,000
1984	4,500	N/I	3,000
1985	11,300	70,000	2,000
1986	15,000	60,000	3,000
1987	10,000	110,000	4,000
1988	12,000	70,000	1,000
1989	10,200	300,000	5,600
1990	12,000	50,000	6,000
1991	25,500	806,400	40,000
1992	16,000	226,000	27,000
1993	18,000	118,000	22,000
1994	UNK	10,700	UNK
1995	10,500	175,000	35,000
1996	30,000	80,000	41,000
1997	18,000	8,500	24,000
1998	14,000	5,000	6,000
1999	17,000	100,000	15,000
2000	17,000	40,000	3,000
2001	18,000	50,000	4,000
2002	7,500	11,000	UNK
2003	10,000	80,000	10,000
2004	4,800	5,000	7,750
2005	7,000	150,000	A/P
2006	13,000	20,000	8,252
2007	11,000	70,000	13,400
2008	6,000	A/P	9,000
2009	12,082	90,000	11,455
2010	11,897	15,600	3,685
Mean - period of record	**9,783**	**61,337**	**10,334**
Mean - last decade	**10,128**	**54,622**	**8,443**

KEY: N/O - Stream inspected, no fish observed
N/R - No record
N/I - Stream was not inspected
A/P - Adult present
UNK -Inadequate information for estimate

TABLE 3.3.1.1: MORICETOWN COHO MARK-AND-RECAPTURE ESTIMATES, 1997 TO 2010

Year	Estimate	Upper 95% CI	Lower 95% CI		Morice Allotment *	
					30%	**40%**
1997	6,451	8,991	3,911		1,935	2,580
1998	25,104	40,371	15,611		7,531	10,042
1999	40,702	51,255	33,879		12,211	16,281
2000	19,907	25,535	14,279		5,972	7,963
2001	39,683	43,226	36,139		11,905	15,873
2002	33,695	38,014	29,377		10,109	13,478
2003	51,374	59,119	43,628		15,412	20,550
2004	30,719	33,902	27,536		9,216	12,288
2005	54,711	59,382	50,040		16,413	21,884
2006	23,624	26,228	21,020		7,087	9,450
2007	30,107	35,785	24,429		9,032	12,043
2008	36,522	45,517	27,527		10,957	14,609
2009	73,414	78,429	68,399		22,024	29,366
2010	28,489	30,571	26,107		8,547	11,396
Mean	**35,322**				**10,596**	**14,129**

Unpublished data from files of DFO, Smithers

CI - confidence intervals

* Morice allottment is based on percentage of total estimate at Moricetown tagging site allocated to mainstem Morice River.

TABLE 3.6.1.1. MORICETOWN STEELHEAD MARK-AND-RECAPTURE ESTIMATES OF POPULATIONS OF FISH IN THE BULKLEY AND MORICE RIVERS ABOVE MORICETOWN, 1999 TO 2010

Year	**Estimate**	**Upper 95% CI**	**Lower 95% CI**
*1999 **	*28,527*	*58,350*	*16,250*
*2000 **	*41,428*	*103,819*	*18,876*
2001	15,948	24,040	10,920
2002	25,398	33,481	20,890
2003	12,150	14,908	10,388
2004	15,670	23,126	11,425
2005	15,341	20,753	12,459
2006	15,138	19,767	12,511
2007	19,073	32,258	11,621
2008	27,484	37,856	22,097
2009	24,973	30,112	21,578
2010	41,140	44,934	38,058
Mean	23,523	36,950	17,256

* Estimates from 1999 and 2000 not used to calculate means due to low number of initial marks and recaptures

Data from SKR Consultants (2011)

Data uncorrected for potential fall back

TABLE 4.3.1: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM DAILY DISCHARGE, PINE RIVER AT EAST PINE, 1961 TO 2010

PINE RIVER AT EAST PINE
Maximum Daily Discharge (m3/s) Skew: 1.79

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit See NOTES below	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	1,350	1,990	2,540	3,380	4,110	4,930	5,860	.0604	.0291
Gumbel (Maximum Likelihood)	1,450	1,970	2,320	2,750	3,070	3,390	3,710	.111	.0603
Pearson Type III (By Moments)	1,370	2,080	2,590	3,250	3,750	4,240	4,730	.0881	.0348
Log Pearson Type III (By Moments)	1,380	1,980	2,490	3,250	3,920	4,680	5,570	.0700	.0346
Average	1,390	2,010	2,480	3,160	3,710	4,310	4,970		
Adopted Value	1,380	1,980	2,490	3,250	3,920	4,680	5,570		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years		
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	
Log Normal (Maximum Likelihood)	1220	1530	1690	2390	2050	3210	2560	4550	2970	5800	3420	7270	3910	9000	
Gumbel (Maximum Likelihood)	1300	1610	1730	2210	2010	2620	2360	3150	2610	3540	2860	3930	3110	4320	
Pearson Type III (By Moments)	1200	1550	1710	2450	2040	3140	2460	4040	2770	4720	3080	5390	3390	6060	
Log Pearson Type III (By Moments)	1230	1530	1680	2350	2000	3080	2460	4280	2840	5400	3260	6740	3710	8350	
Average	1240	1550	1700	2350	2030	3010	2460	4000	2800	4860	3160	5830	3530	6930	
Adopted Value	1200	1610	1680	2450	2000	3210	2360	4550	2610	5800	2860	7270	3110	9000	

[1] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

[2] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 4.3.2: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM INST. DISCHARGE, PINE RIVER AT EAST PINE, 1978 TO 2010

PINE RIVER AT EAST PINE
Maximum Instantaneous Discharge (m3/s) Skew: 1.77

Frequency Distribution	Estimate of Specified Recurrence Interval Discharge in m3/second							Goodness of fit See NOTES below	
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	1	2
Log Normal (Maximum Likelihood)	1,310	1,950	2,510	3,410	4,210	5,130	6,190	.0736	.0205
Gumbel (Maximum Likelihood)	1,420	1,920	2,260	2,680	2,990	3,300	3,610	.112	.0513
Pearson Type III (By Moments)	1,350	2,010	2,480	3,100	3,570	4,020	4,480	.0627	.0252
Log Pearson Type III (By Moments)	1,360	1,940	2,410	3,110	3,720	4,400	5,170	.0626	.0255
Average	1,360	1,960	2,420	3,080	3,620	4,210	4,860		
Adopted Value	1,360	1,940	2,410	3,110	3,720	4,400	5,170		

95% Confidence Limits for Specified Recurrence Interval in m3/second

Frequency Distribution	2 years		5 years		10 years		25 years		50 years		100 years		200 years	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Log Normal (Maximum Likelihood)	1150	1540	1560	2520	1870	3510	2310	5250	2680	6940	3070	9010	3490	11500
Gumbel (Maximum Likelihood)	1220	1620	1620	2230	1870	2650	2170	3180	2400	3590	2620	3980	2840	4380
Pearson Type III (By Moments)	1130	1560	1550	2460	1810	3160	2130	4080	2370	4760	2600	5440	2840	6120
Log Pearson Type III (By Moments)	1180	1570	1570	2410	1840	3170	2210	4390	2500	5530	2810	6890	3140	8520
Average	1170	1570	1570	2400	1850	3120	2210	4230	2490	5200	2770	6330	3080	7640
Adopted Value	1130	1620	1550	2520	1810	3510	2130	5250	2370	6940	2600	9010	2840	11500

[1] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for all points.

[2] Modified Kolmogorov-Smirnov goodness of fit test based on unbiased plotting positions for 5 largest points.

Analytical procedures used to prepare this summary were made available by the River Forecast Centre, Water Management Branch, B.C. Ministry of Environment. This assistance is gratefully acknowledged.

TABLE 5.1.2.1: CONTAINMENT TECHNIQUE OPTIONS FOR RELEASES TO WATERCOURSES (From Enbridge Volume 7b, Section 7.4)

Technique	Primary Use	Controlling Variables	Effects on Environment	Major Resources
Containment boom	• to contain the release where it enters water, or if released hydrocarbons are travelling downstream	• current speed[1] must be less than 1.0 m/s	• minor disturbance at anchor points	• work crew • booms • work boat and safety boat • storage site for recovered hydrocarbons and water or for the BoomVane
Diversion boom	• to divert the slick, in large or swift watercourses, to calmer water and/or to one bank for recovery	• current speed must be less than 2.0 m/s	• minor disturbance at anchor points	• work crew • boom for diversion • work boat and safety boat or BoomVane
Sorbent boom or sweep	• to absorb release across narrow watercourses • to absorb sheen behind containment boom	• current speed must be less than 0.5 m/s • degree of contamination must be minor	• minor disturbance at anchor points	• work crew • sorbent boom • work boat and safety boat • disposal containers or incinerator for used sorbents
Earth dike	• to contain the release across shallow streams and intermittent creeks	• availability of sufficient earth	• damage at excavation and construction sites	• work crew or operator • earth-moving or digging equipment • boom recovery device and storage area for recovered hydrocarbons • sandbags, liner material, sheets or metal or wood
Containment (inverted) weir	• to slow upstream velocity in shallow watercourses, and to allow water movement from site while containing released hydrocarbons • to maintain constant water level at release site	• availability of personnel – may require constant maintenance in fast-flowing streams • availability of construction materials	• surface disturbance	• work crew • earth-moving equipment or shovels • culvert material

PLATES

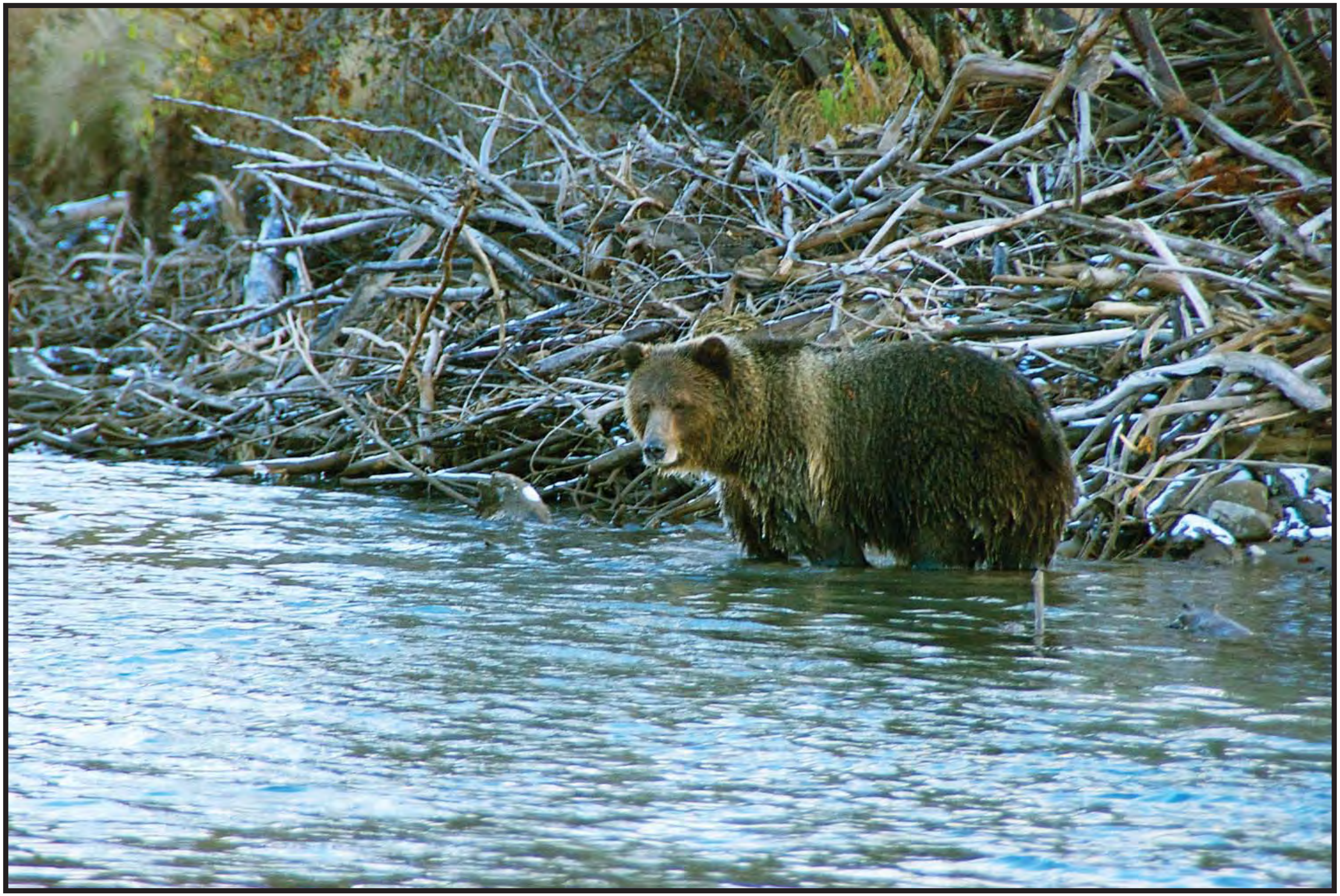

Photo by Tony Harris

Plate 1.1: Grizzly bear feeding on salmon in Reach 2 of Morice River.

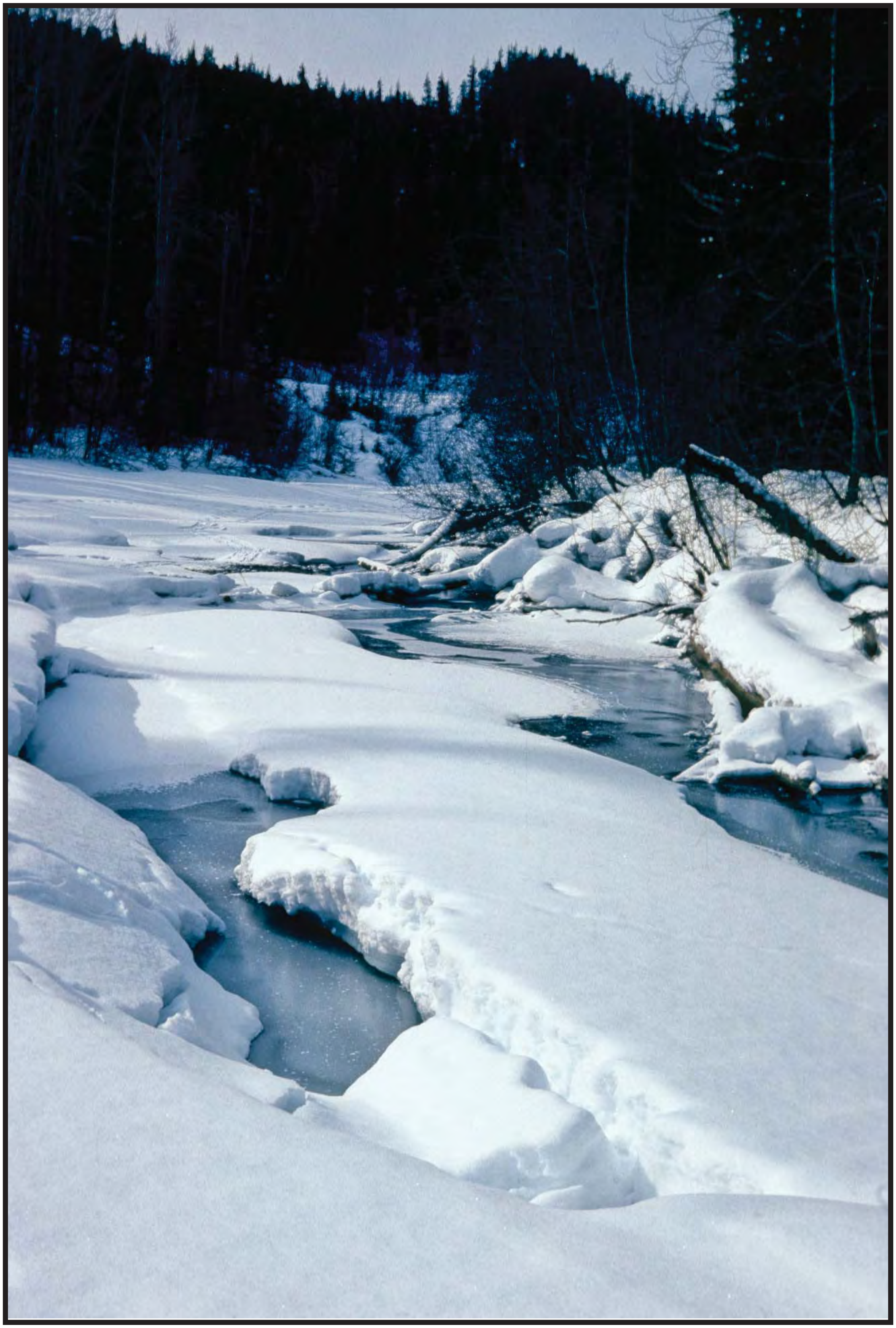

Photo by Dave Bustard

Plate 2.3.1: Snow and ice cover the mainstem and side channels of Morice River from December through early April.

Photo by Dave Bustard

Plate 2.4.1: Natural sediment sources enter Morice River at the Gosnell-Thautil confluence during the spring freshet.

Photo by Dave Bustard

Plate 2.4.2: Gosnell Creek during freshet period. High turbidity would make oil spill capture and clean-up in Reach 2 difficult.

October 4, 2009 Photo 211 by Brian Huntington

Photograph of log jams on the channel edge and at the inlet to a secondary channel.

October 4, 2009 Photo 210 by Brian Huntington

Photograph of a log jam at the head of an island.

Plate 2.5.1: Photographs of log jams on Reach 2 of Morice River.

October 4, 2009 Photo 184 by Brian Huntington

Looking upstream to the Morice River Thautil Creek/Gosnell River confluence.

October 4, 2009 Photo 196 by Brian Huntington

Looking downstream over Morice River to the Lamprey Creek confluence.

Plate 2.7.1: Examples of mountain pine beetle damaged forests along Morice River.

Photo by SKR Consultants Ltd.

Plate 3.1.1: Morice River fish stocks are especially important to Wet'suwet'en people, who have fished these stocks for thousands of years.

Photo by Tony Harris

Plate 3.1.2: The Morice River ecosystem is intact and spectacular, drawing anglers from around the world.

Photo by Tony Harris

Plate 3.1.3: Summer steelhead trout captured in Reach 2 Morice River, the main overwintering and spawning section of the river

Photo by Dave Bustard

Plate 3.2.3.1: Millions of juvenile chinook rear along the shoreline below the main spawning sections in Morice River.

Photo by Dave Bustard

Plate 3.2.3.2: Shallow cobble sections along the mainstem edge provide important summer and winter rearing habitats for chinook and steelhead juveniles.

Photo by Dave Bustard

Plate 3.3.3.1: Juvenile coho are present in the Morice River year-round. Many coho leave after one or two winters.

Photo by Dave Bustard

Plate 3.3.3.2: Juvenile coho are dependent upon debris such as this root wad for cover year-round.

Photo by Dave Bustard

Plate 3.5.2.1: Most of the Morice River pink and coho salmon spawning occurs in Reach 2. This photo shows pink salmon redds in a side channel.

Photo by Dave Bustard

Plate 3.5.2.2: Salmon alevins such as these pink salmon in Reach 2 of Morice are particularly sensitive to spilled hydrocarbons.

Photo by Dave Bustard

Plate 3.6.1.1: Juvenile steelhead spend up to four years rearing in habitats along Reach 2 of Morice River.

Photo by Tony Harris

Plate 3.6.1.2: Log jams such as this site in Reach 2 are critical habitats for steelhead parr during summer and winter periods.

Plate 4.3.1: Crew working to clean oil out from under a log jam on Pine River. [From nhc, 2001.]

Plate 4.3.2: Oil coated log jams on Pine River were removed and burned. [From nhc, 2001.]

Plate 4.3.3: Log jam removal and reconstruction on Pine River. [From nhc, 2001.]

Plate 4.3.4: Log jam construction on Pine River. [From nhc, 2001.]

Plate 4.3.5: Logs placed in log jam reconstruction on Pine River. [From nhc, 2001.]

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Plate 4.3.6: May 2002 photographs of log jams constructed in the White Rock cut-off channel on Pine River. [Photos by M. Miles.]