Table of Contents

List of Tables

List of Figures

Acknowledgements

Cover Map

Copied in part from 'Sketch of the upper part of the Fraser River from Langley to Yale', 1859. Reproduced from an original print in the Provincial Archives of British Columbia by the Historical Map Society of British Columbia, Facsimile No. 2, 1984.

Source of displayed Photos

Airphotos in this report are from Provincial and Federal archives. Copies are filed at the Geographic Information Centre, Department of Geography, The University of British Columbia.

Support

Much of the data compilation for this atlas was achieved as part of contracts for the City of Chilliwack on sediment transport and flood hazard mitigation along the gravel-bed reach of the river. Funding ultimately derived from the British Columbia Emergency Flood Management Fund, supervised by the Water Management Branch of the former British Columbia Ministry of Environment, Lands and Parks (now British Columbia Ministry of Water, Land and Air Protection). Contributions have also been received from the Canada Department of Fisheries and Oceans via the Fraser Basin Council, and from the Natural Sciences and Engineering Research Council of Canada through research grants.Dr. V.J. Galay made many helpful suggestions for effective presentation.

Atlas of the alluvial gravel-bed reach of Fraser River in the Lower Mainland

showing channel changes in the period 1912-1999

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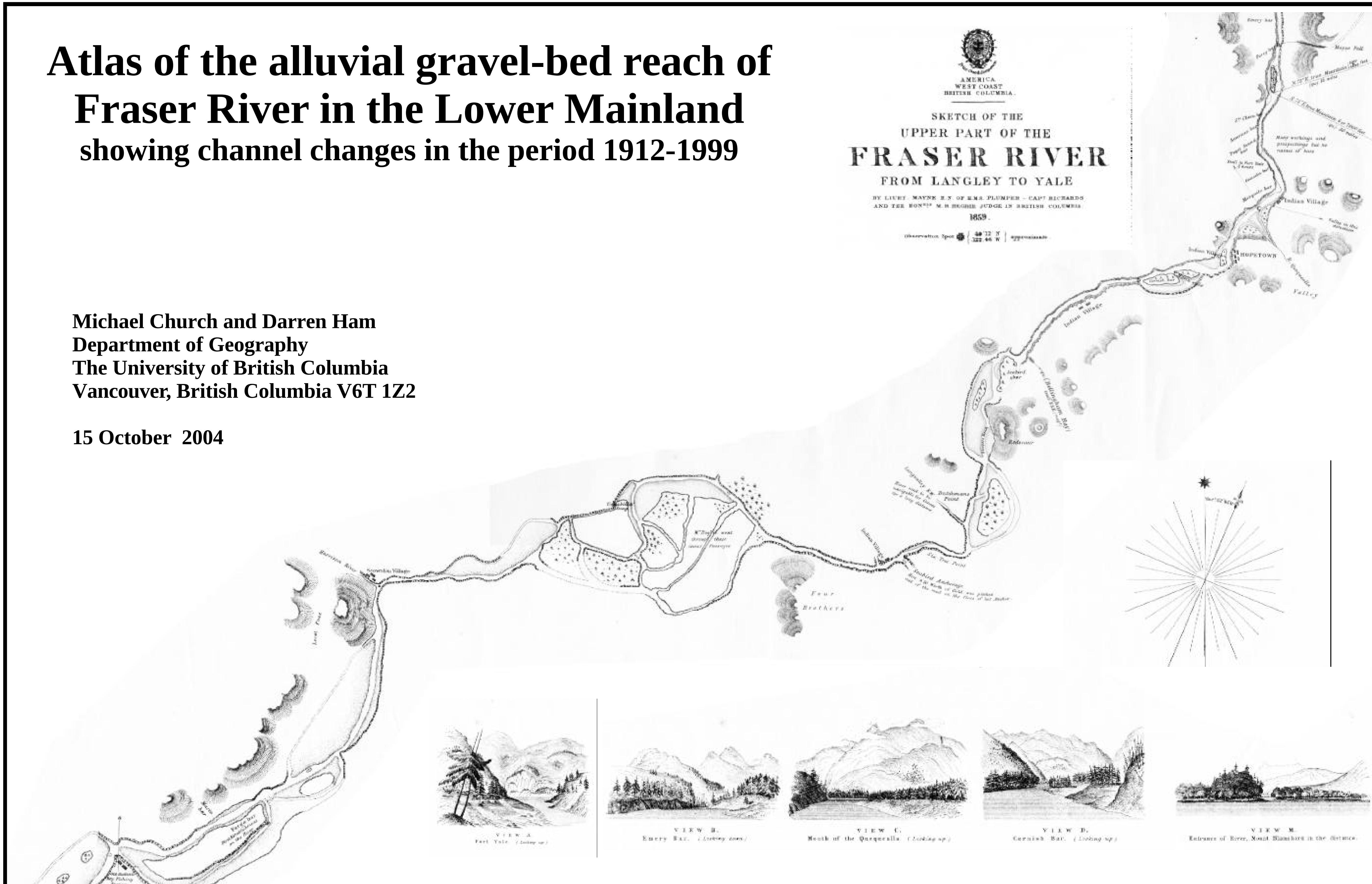
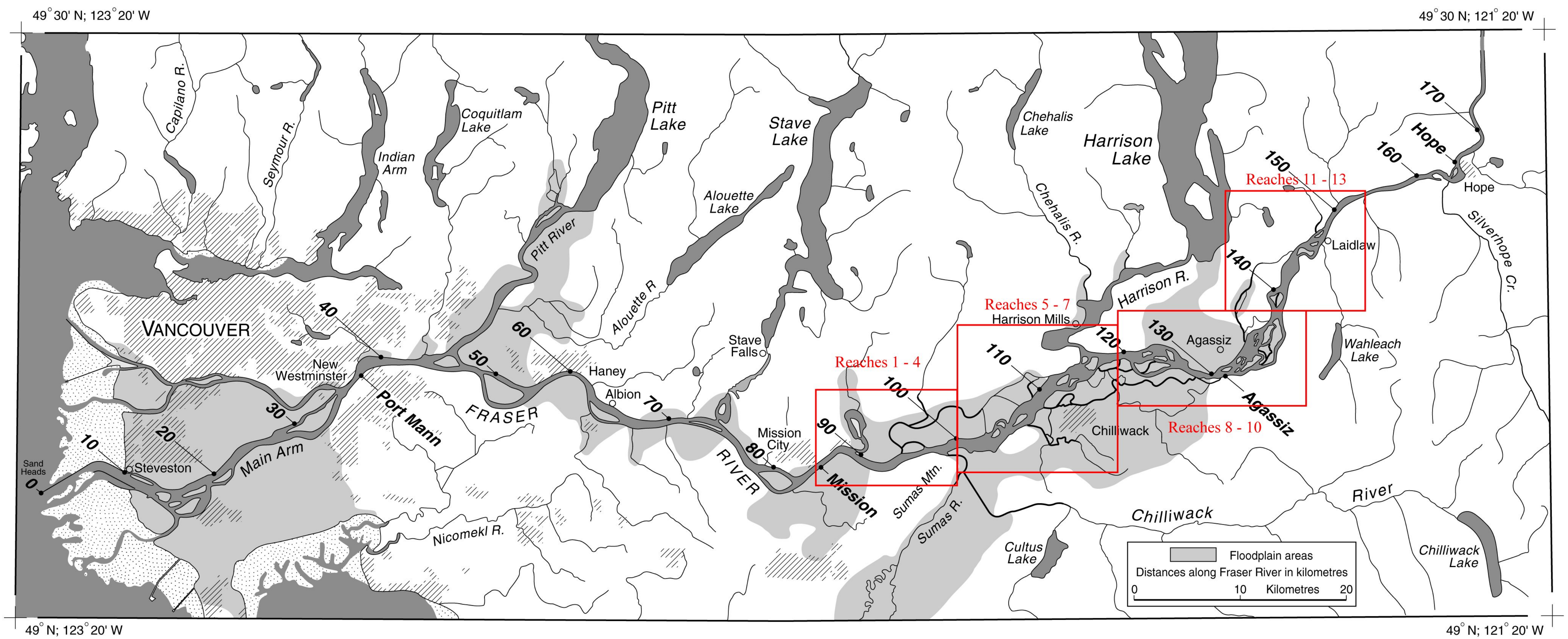
15 October 2004





Location map showing major sub-reaches used throughout manuscript and km markers showing the cumulative distance upstream from Sandheads.

Introduction

This atlas documents morphological changes along the alluvial gravel-bed reach of Fraser River in the Lower Mainland during the period 1912-1999 - essentially, for the duration of the 20th century. The reach extends fromHunter Creek (River km 153) to the Mission gauge (River km 86), a distance of 67 km. Within this reach the river deposits the gravel portion of the sediment load that it carries out of the upstream canyons. Deposition of the gravel is caused by the reduction in river gradient when it enters the Lower Mainland and approaches marine base level at the Strait of Georgia. The reduction in gradient reduces the power of the river to transport sediments onward.

Gravel is the first part of the river's sediment load (consisting also of sand and finer sediments) to be deposited because it is the largest material and requires the greatest power to maintain its onward transport. Because it is heavy material, it is transported along the bottom of the channel and deposited in bars within the channel, in contrast to most sand, silt and clay, which are borne in suspension by the river currents and may be deposited wherever the water flows. The river subsequently is forced to flow around the gravel bars, thereby creating an irregularly sinuous and divided (braided) channel pattern and islands. This habit is called a *wandering channel* (Desloges and Church, 1989) because of the irregular pattern of lateral channel shifting that occurs. The resulting network of perennial, seasonal and abandoned channels represents aquatic habitat of exceptionally high quality. Hence, this reach is of special ecological value.

The alluvial gravel-bed reach can be divided into five major subreaches with somewhat distinctive morphology (Table 1; Figure 1). Gradient declines by 10x between the upstream and downstream limits of the reach. This atlas further subdivides the reach into 13 subreaches for more detailed discussion.

The period of study is determined by the availability of reliable documentation of river morphology. The primary materials chiefly are air photographs taken between 1928 and 1999 by federal and provincial survey agencies. The 1912 map of the river (*1913 Map of New Westminster District*) is also used as a primary reference. Reference is made to earlier information, but the quality of early surveys is not sufficient for mapped comparisons to be made. The time between mappings is approximately 10 years from 1949, but it is variable in the earlier period according to the availability of photos. In addition, the "1940" coverage is assembled from several photographic projects executed between 1938 and 1943. In the later period, actual inter-map periods also vary according to the availability of the best photos, which should be obtained at low flow in order to reveal the greatest detail of the channel morphology.

Distances quoted in the atlas are river kilometres above Sand Heads, the mouth of the river. The distances are based on the main channel position in 1971 and may not be exact for other dates because of changes in channel position. Furthermore, the distances may not correspond exactly with independently reckoned distances since different lines might be adopted for measurements along the channel or channel zone. The adopted distances are standard in work reported from the UBC Department of Geography.

In the atlas, descriptions are facilitated by the adoption of recognized names for river localities. These are mainly the names of the principal bar/island groups. Such features attract local names, but persistent islands and side channels also carry official names and the two may not coincide. Hence, some names used in the atlas may vary from local usage, although attempts have been made to prefer the latter. Names are given on the 1999 base map presented for each reach. In the atlas, the terms "left bank" and "right bank" are used. These terms conventionally refer to the banks of the river when the observer is facing downstream. Hence, the "right bank" is, in general, the bank on the north side of the river or of an individual channel.

The atlas is organized into 4 sections, each depicting two or three subreaches. Each section consists of a sequence of maps, each of which is a georeferenced air photo mosaic at 1:50 000 scale depicting the river morphology at the photo date. The channel margin from the preceding map is superimposed on each display so that channel changes in the intervening period can be observed. The earliest mosaic/map is based on the 1928 air photography (the first on the river), and the channel margins depicted on the map of the 1912 survey are superimposed on that display. In addition, at the end of each section there is a mapped comparison of the 1949 and 1999 channels, showing the net change over the 50-year period of more reliable record.

The maps locate cross-sections at 1 km spacing for which section surveys are variously shown for 1952, 1984 and 1999. These sections are based on channel surveys from those dates. Each section of the atlas is accompanied by a brief text summarizing the main changes observed in each

Table 1. Level One channel sub-reaches of the gravel-bed reach of lower Fraser River (after Church et al., 2000).

Sub-Reach Name	Downstream Boundary	River km Limits	Mean Gradient	Mean Grain Size (mm)	Discharge at MAF (m^3s^{-1})*	Mean Gravel Transport (m^3a^{-1})+	Gradation Tendency	Major Morphological Features
Hope	Wahleach Creek	149-165	0.00055		8766	214 000	stable	single-thread cobble and gravel channel with stable lateral bars
Cheam	Agassiz Bridge	130-149	0.00052	50	8766	210 000	mildly degrading	large, mature islands with surrounding bars; single dominant channel and major secondary channels
Rosedale	Harrison River	118-130	0.00047	40	8766	90 000	strongly aggrading	multi-thread gravel channel with large island-bar complexes; laterally unstable
Chilliwack	Vedder River	100-118	0.00018	26	9790	small	mildly aggrading	multi-thread gravel channel with diagonally extending bars and subordinate islands
Sumas	Mission	86-100	0.000085	16 - sand	9790	0	degrading	single-thread, gravel-sand transition; submerged bars

* Based on gauges at Hope (first three reaches) and Mission (last two reaches). MAF = mean annual flood.
+ Transport is averaged for the period 1952-1999, estimated at the downstream end of the reach. Reported values represent bulk volumes.

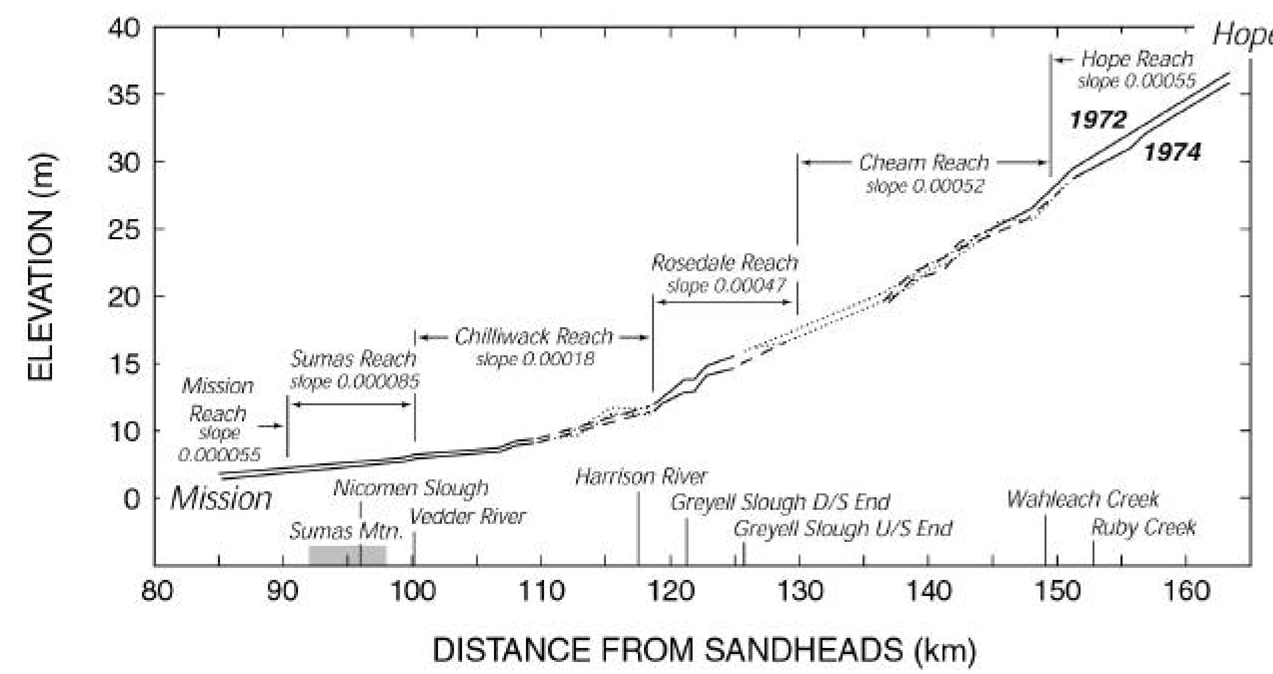


Figure 1. Water surface profile with major reach breaks. The dates 1972 and 1974 indicate the years in which the profiles were made. Both dates were years with above average floods.

reach. In those descriptions, references to specific sites are annotated by (xxA), (xxB), etc., where xx is the date of the base airphoto map (e.g., 19**28**), and the letter corresponds with a letter on the airphoto map.

A peculiarity of the presentation is that reaches, subreaches and river cross-sections are presented and discussed in reverse enumerated order (from subreach 13 to subreach 1, for example). That is because our survey numbering systems proceeds upstream from Mission gauge, but the logical order for interpretive discussion proceeds downstream, with the flow.

Additional information presented in the atlas includes talweg (deep channel) position on each of the survey dates, the long profile along the talweg line at each date, and information of gravel texture through the gravel reach, collected between 1982 and 2001.

It must be recognized that each of the photomaps depicts the river at a different flow, so that part of the apparent change in bar deposits observed from map to map may be due to water level changes. The superimposed channel margins, however, represent vegetation edges, so that they are consistently comparable with vegetated channel margins seen on the later map. Comparisons before 1949 are probably less accurate than later ones because the 1912 map may not be entirely reliable for features within the channel zone (in a few places distinctly unusual island features are shown). Furthermore, georeferencing of the 1928 photos may have been less successful than of later sets both because of extreme distortion in those photos and because of a relative lack of identifiable reference points at that early date . Finally, the "1940" map is a collage from several dates.

In interpreting the maps further, the flood history of the river (Figure 2) should be kept in view. Major floods transport much more sediment than the smaller ones and so are capable of effecting major changes on the river. The primary gauging record along the river is from the Hope gauge (Water Survey of Canada station 08MF005; drainage area 217 000 km^2) and is continuous from 1912. The largest floods within the period of study occurred (in rank order) in 1948, 1972, 1950, 1964, 1955, 1997, 1921, 1999, 1920, 1967 and 1974. However, the highest known flow on the river occurred in 1894, before the first reliable surveys but near enough the early record to possibly have had special influence over it. Analysis of the flood records demonstrates that above average and below average floods tend to be clumped into recognizable periods. Hence, the period before 1925 was one of dominantly above-average floods while the following period to 1947 had mainly below average ones. From 1948 to 1976 floods tended to be very high (7 of the 11 highest flows occurring in this period), and then low to near the end of the record (see Figure 3).

Finally, some circumstances of the sedimentation history of the river may have a significant bearing on observed river channel changes. During the 18th and early 19th centuries, the period of relatively cool climate known as the "Little Ice Age" may have created conditions of increased sediment supply from certain mountain tributaries of Fraser River. Perhaps more significantly, the latter half of the 19th century witnessed major sediment disturbances along the Fraser itself and certain of its principal tributaries, including extensive placer gold digging on the river bars and terraces and the major railway building projects along the Fraser and Thompson rivers. Engineering disturbances continued until after the mid-20th century with railway and highway construction. Gravel and cobbles introduced into the river and its tributaries by these activities would require many decades to pass downstream into the Lower Mainland. River channel changes in the 20th century may in part reflect the movement and deposition of these materials.

Disclaimer

The interpretive notes accompanying the maps are designed to identify major channel changes on a reach-length basis. Whilst they might form the starting point for more detailed study to determine the history of channel changes at individual sites, they are by no means exhaustive and should not be substituted for detailed site studies where practical problems warrant such investigations.

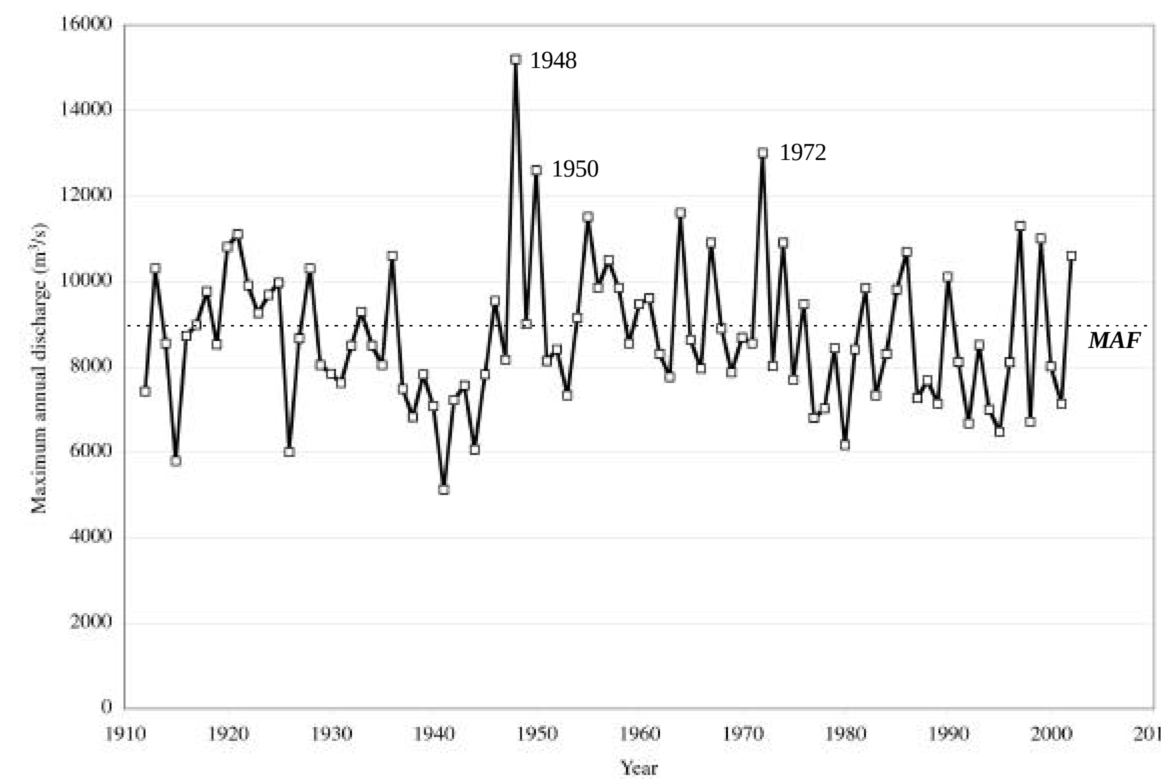


Figure 2: Historic annual maximum daily flow sequence. ***MAF*** = mean annual flood.

Figure 3. Cumulative flood flow departures showing principal trends in flows compared to long-term mean discharge. A rising graph indicates a period of persistently ***above*** average annual floods, whilst a falling graph indicates persistently ***below*** average floods.

Reaches 11 - 13 (HunterCreek to Spring Bar)

At Hunter Creek, Fraser River escapes confinement by mountain slopes, landslide deposits and terraces and becomes fully alluvial (that is, a river flowing entirely in its own deposits). In fact, the reach downstream to Wahleach Bar (Laidlaw: km 146) has remained stable in recent decades, but changes occurred here in the late 19th and early 20th centuries. In 1912, right bank side channels at Vasasus Island, at Wahleach Island, and at Seabird Island were much more active than today. The latter, Maria Slough, was a major channel of 200 to 300 m width within which several islands occurred. Peters Island was larger than today and the main channel downstream was confined to the left side of the contemporary channel between Peters Island and Spring Bar. A complex set of minor islands existed at Spring Bar.

a) 1912 - 1928

The right bank side channel entrances were severely restricted or cut off by railway construction late in the 19th century so that, by 1928, they were already substantially reduced. Between 1912 and 1928 up to 350 m of erosion occurred on the upstream side of Peters Island (28A), with a total loss of 40 ha. At Seabird Island, two huge scallops were eroded from the island front, one with up to 1000 m of bank retreat at the point of maximum change (28B), the other with over 500 m at the maximum (28C). In all 200 ha of land were converted from floodplain to channel in front of Seabird Island. Mean retreat rates at these three sites (250 m at 28A, 470 m at 28B and 230 m at 28C) are among the largest recorded erosion values within the entire gravel reach. There was only minor compensating floodplain creation along the left bank, but the islands at Spring Bar coalesced into several larger units (28D). These events, which greatly increased the channel area in the reach, probably reflect substantial deposition of gravel in the channel, but details of deposition are not clearly depicted on the 1928 photos. In all, the expansion of channel area amounts to 305 ha in reaches 11-13 between 1913 and 1928.

b) 1928 - 1940

From 1928 to 1940 the Vasasus and Wahleach Island back-channels stabilized but elsewhere riverbank erosion continued, with about 150 m retreat at Peters Island (40A) and major erosion (up to 350 m) at Seabird Island (40B). This erosion altered the main channel alignment and began to modify the downstream morphology. Flow was increasingly directed toward erosion resistant materials along the left bank (40E), then towards the islands at the head of Spring Bar (40D) which were trimmed several hundred metres. The left-hand channel at Spring Bar was opened considerably, affecting the head of Herrling Island (reach 10). Although significant erosion (up to 150 m) was also observed along lower Seabird Island (40C), an emerging mid-channel gravel bar indicates that this area was becoming a significant depositional environment. The material likely originated at Seabird Island (40B).

c) 1940 - 1949

Between 1940 and 1949 the channel remained stable above Peters Island, while modifications continued downstream. The 1949 photos, the first series that shows channel morphology at low water levels, clearly depicts large sediment bodies upstream (49C) and downstream (49D) of Peters Island, The emplacement of these bars drove the major erosion at Peters and upper Seabird Islands over the preceding few decades. The former has become Wahleach Bar and we refer to the latter as Peters Bar. Sediment congestion was notable here in 1949. An additional 75 m of retreat occurred along the downstream margin of Peters Island (49A), while an additional 400 metres was eroded along Seabird Island (40B) as the main channel was forced along the right bank of the island. Here, an emergent bar had formed by 1949 and now protects the site from further significant retreat. A large deposit at Spring Bar (49E) is the evident reason for the erosion on mid Seabird Island. These deposits forced the main flow of the river into the left channel branch about the Spring islands (49F), trimming an additional 175 m off them. The establishment of vegetation on some of the new surfaces indicates incipient stabilization of these recent deposits.

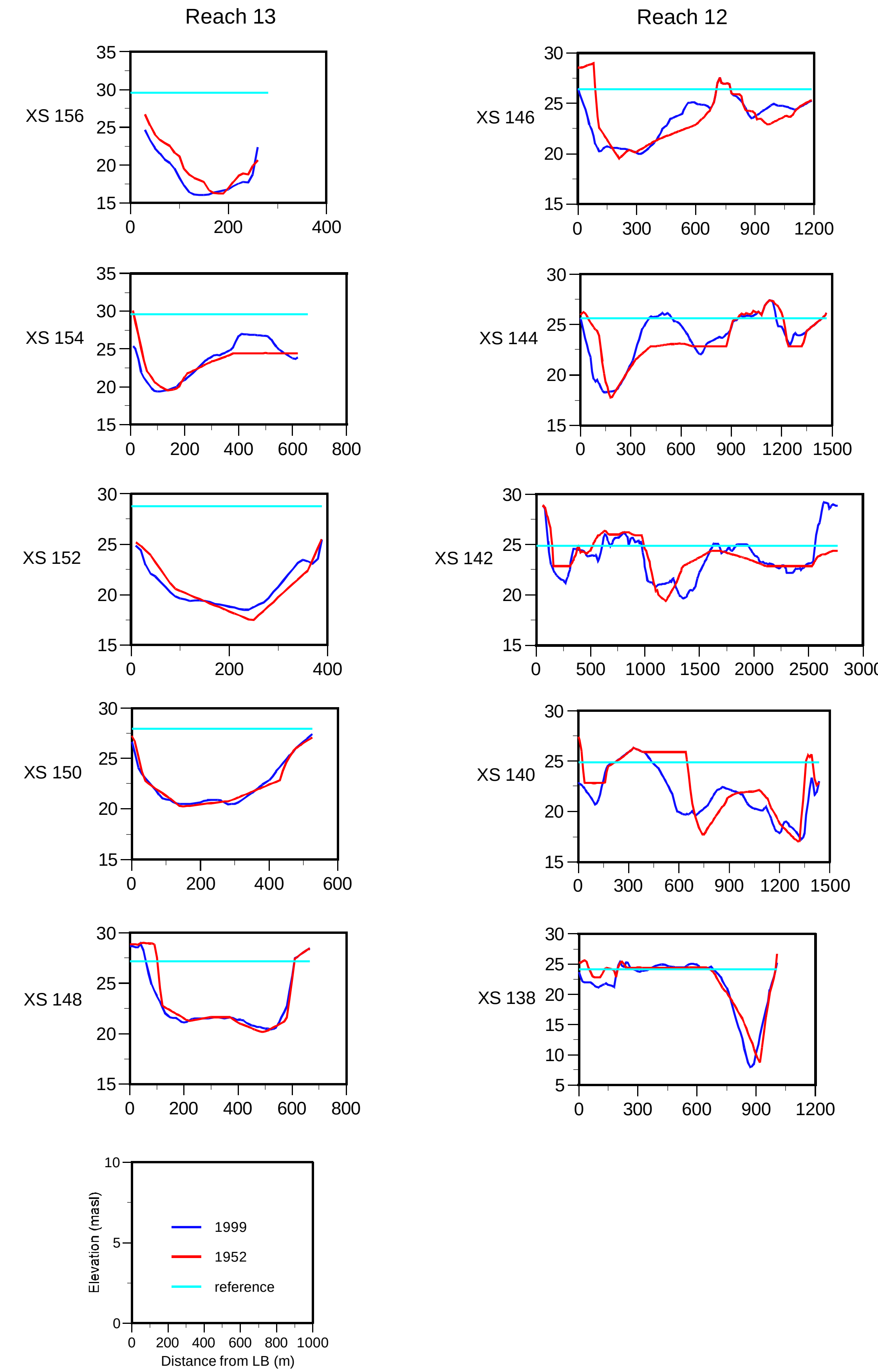
The juxtaposition of erosion and deposition is not accidental. Material eroded from upstream is transferred into the next downstream sediment deposit, hence material from Peters Island has formed Peters Bar, the erosion thereby induced on upper Seabird Island leading to the sedimentation at Spring Bar and erosion at middle Seabird Island. At the upstream end of the reach, the 206 ha growth of Wahleach Bar represents the sediment influx into the reach, estimated as 10.3 million m^3 of sand and gravel over the 9 years, while at the downstream end, material eroded from middle Seabird Island has passed into the next downstream reach along Herrling Island.

d) 1949 - 1962

In the latter half of the 20th century, changes in this reach have become much more restricted. The most significant continuing erosion has been at Peters Island, where the long convex bend of the channel about Wahleach Bar continued to move into the island between 1949 and 1962 (62A) as the consequence of continued sedimentation and channel division at the western end of the bar. However, at the west end of the island, vegetation stabilized earlier bar deposits there (62B) so that the total vegetated area did not change much. There continued to be erosion at upper Seabird Island (62C) but by 1962 sediment deposition into the channel between Seabird Bar and the island (62D) reduced flows along the island margin. Vegetation expanded substantially on several bars, especially on Spring Bar (62E). Vegetation signifies the buildup of bar gravels to a relatively high level. After vegetation becomes established, sand is trapped and builds the surface even higher to establish new islands.

e) 1962 - 1971

Between 1962 and 1971 there was limited new erosion of established channel banks except at Peters Island (71A), where erosion continued



at a lower rate than previously experienced. The channel between Wahleach Bar and Peters Island (71A) was choked with sediment by 1971, with substantial sediment accumulation near the eroding shore of the island which probably reduced the force of flood flows impinging on the island. Elsewhere, there was limited erosion at the head of Spring Bar (71B) and only limited extension of vegetation cover, mainly on channel bars.

f) 1971 - 1983

Between 1971 and 1983, two major floods (1972; 1974) were experienced, but they appear to have had relatively limited effect in these subreaches. By 1983, persistent erosion at the waist of Peters Island threatened to cut the island in two (83A). Downstream, there was visible erosion at the Spring Islands (83B) while at Peters and Seabird bars, extension of established vegetation is evident (83C).

g) 1983 - 1991

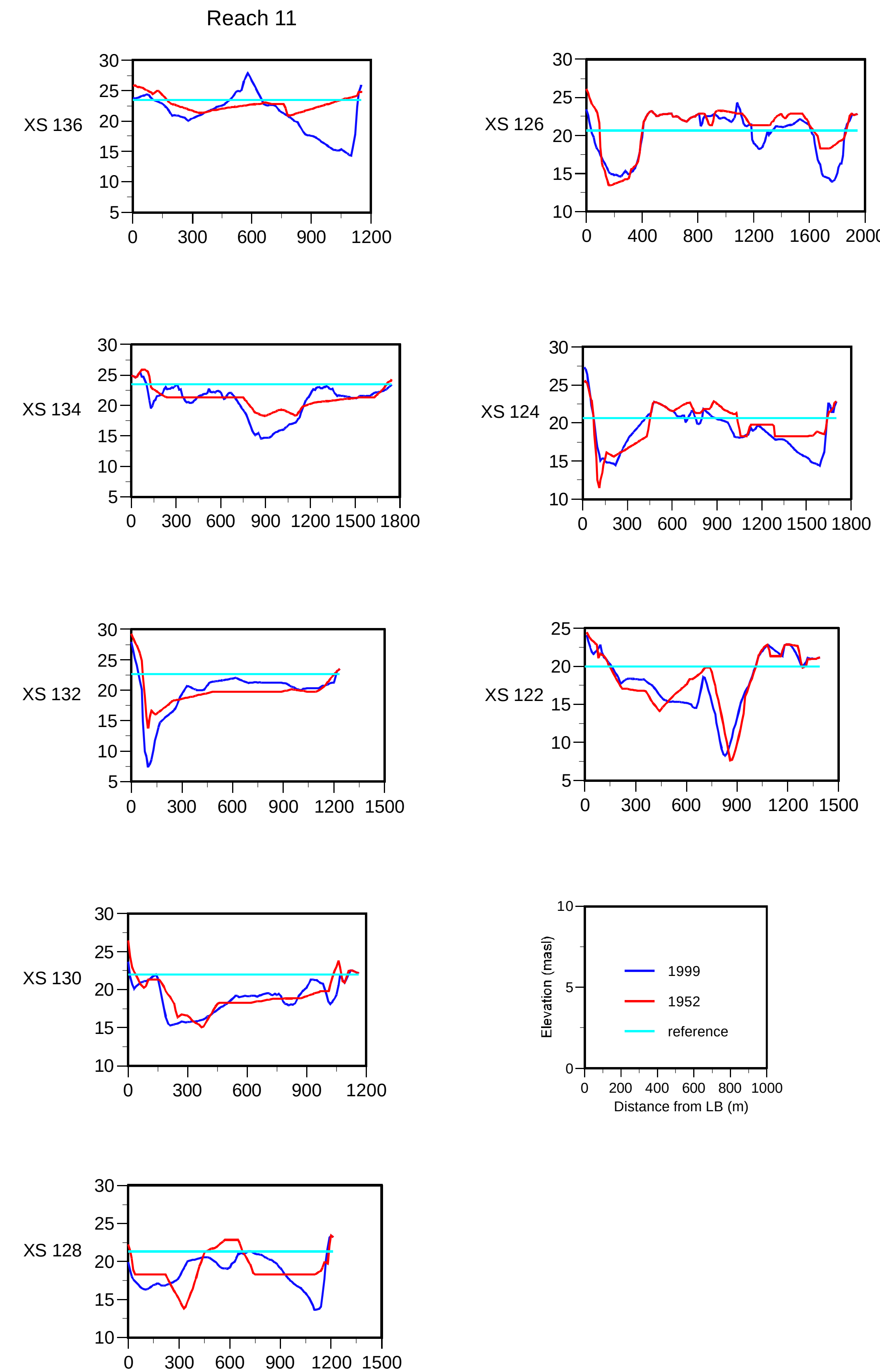
After 1983 there was very limited erosion in the reach. Peters Island has not, in fact, been severed and is currently protected by a rock wall constructed in the early 1990s. There was, however, considerable extension of vegetation on the channel bars. There were few high flows in this period, which partly accounts for this trend. But it is also known (Church et al., 2001) that the reach has been degrading in the latter half of the 20th century so that, nearing the end of the century, some of the bars established before 1950 were probably elevated above normal water levels as the result of this process, further facilitating island production. General lowering of the channel bottom is evident from the cross-sections, especially in subreach 11 where a distinct deepwater channel of some 500 - 700 m width is increasingly evident. At Spring Bar (91A) the right-bank channel again becomes fully active in this period (XS 128 - 124). It is noteworthy that, whilst there has been considerable extension of island surface within the channel zone, the outer limits of the channel zone have remained largely the same throughout the latter 20th century.

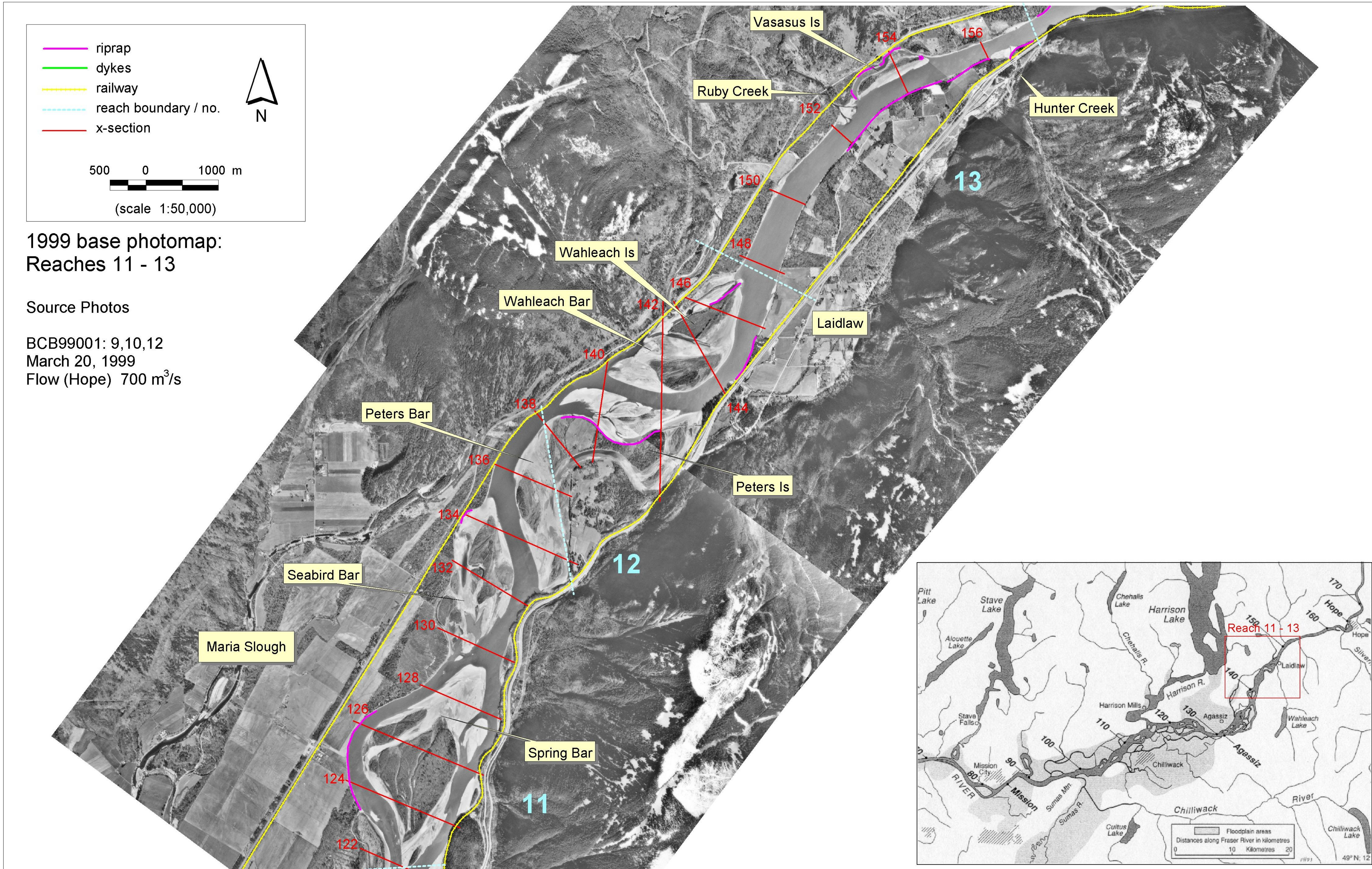
h) 1991 - 1999

A significant development evident in the middle part of the reach (Peters - Upper Seabird) by 1971, and throughout the reach by 1991 (but most evident on the 1999 low water photos) is the establishment of a regular meandering pattern. The meander wavelength is 5 km so, for a principal undivided channel width of about 500 m, the ratio of meander wavelength to width is about 10:1. The value is set by the prior position of the major riffles (channel crossover points) between the successive major bars, of which there are four in the reach (two per meander). This ratio falls within the range observed for alluvial channels, so that it might be expected to be stable. The major channel change created by meander development is the renewal of the right bank branch about Spring Bar. The bar is, today, an island / medial bar complex (i.e., with major channels on both sides; 99A) but in the future the right bank channel is likely to become dominant.

Summary

This history, with the emplacement of a major volume of channel sediment early in the 20th century, and island growth and channel simplification in the latter half, suggests the influx of high volumes of bed material between the late 19th century and the early 20th century, and a substantial reduction of incoming bed sediment since. Such a history is consistent with the known degradation in these reaches in the latter half of the century. In this later period, substantial volumes of sediment have been passed downstream into reaches 8 - 10, creating significant instability there.

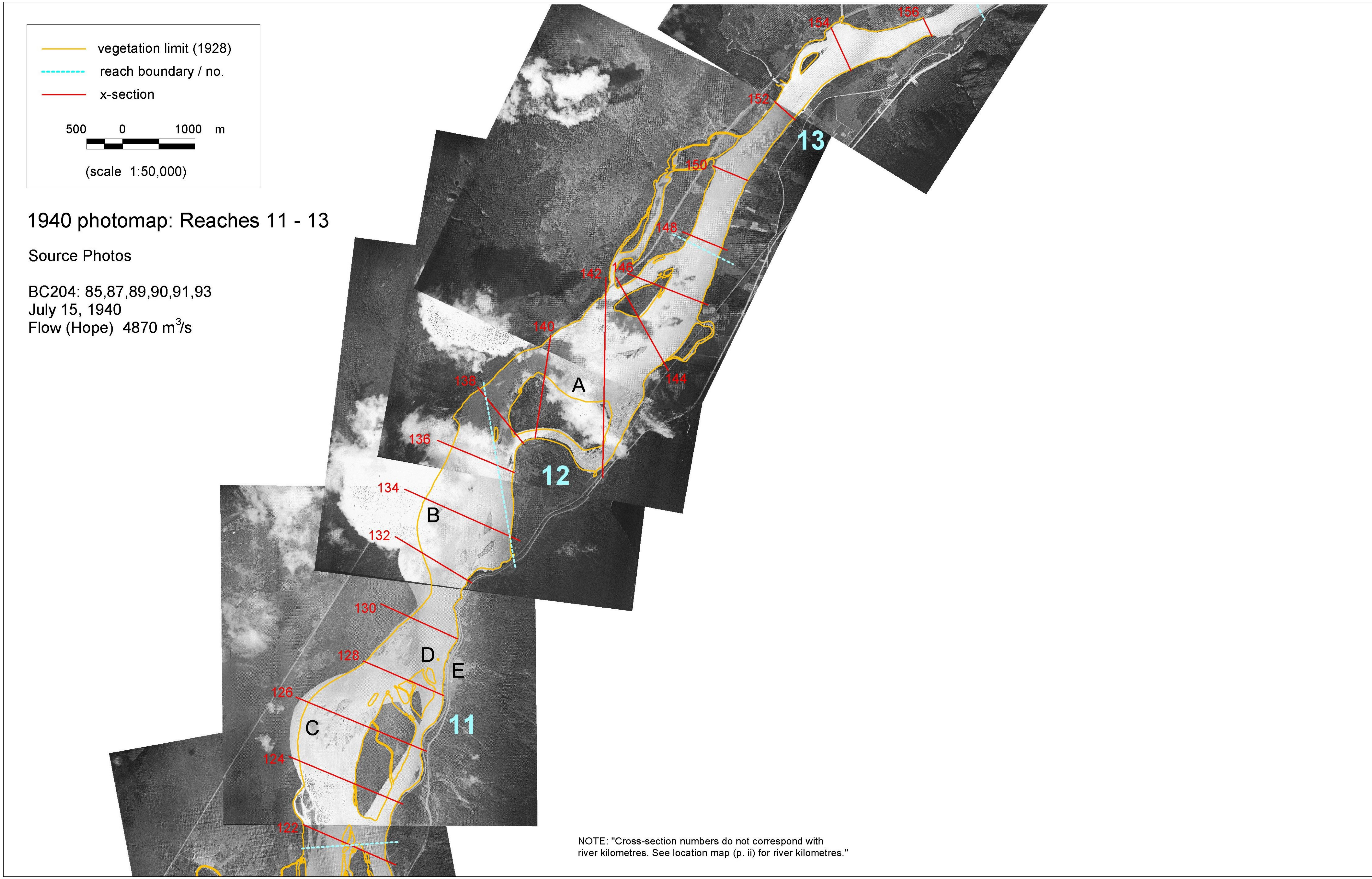



riprap
dykes
railway
reach boundary / no.
x-section
N
500 0 1000 m
(scale 1:50,000)
1999 base photomap:
Reaches 11 - 13
Source Photos
BCB99001: 9,10,12
March 20, 1999
Flow (Hope) 700 m³/s
Vasasus Is
Ruby Creek
Hunter Creek
Wahleach Is
Wahleach Bar
Laidlaw
Peters Bar
Peters Is
Seabird Bar
Maria Slough
Spring Bar
11
12
13
122
124
126
128
130
132
134
136
138
140
142
144
146
148
150
152
154
156
Pitt Lake
Stave Lake
Alouette Lake
Chehalis Lake
Harrison Lake
Chehalis R.
Harrison R.
Harrison Mills
Stave Falls
Mission City
Mission
RIVER
Sumas Mtn
Sumas R.
Chilliwack
Agassiz
Reach 11 - 13
Laidlaw
Hope
Wahleach Lake
Cultus Lake
Chilliwack River
Chilliwack Lake
Floodplain areas
Distances along Fraser River in kilometres
0 10 Kilometres 20

1928 photomap: Reaches 11 - 13

Source Photos

A288: 87,89,91,93,95,96,98,99,101,102,104
A289:2
A296: 82,84,86,87,88,89,91
July 15, 1928
Flow (Hope) 5780 m^3/s



1940 photomap: Reaches 11 - 13

Source Photos

BC204: 85,87,89,90,91,93
July 15, 1940
Flow (Hope) 4870 m^3/s

NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

vegetation limit (1940)
reach boundary / no.
x-section

500 0 1000 m

(scale 1:50,000)

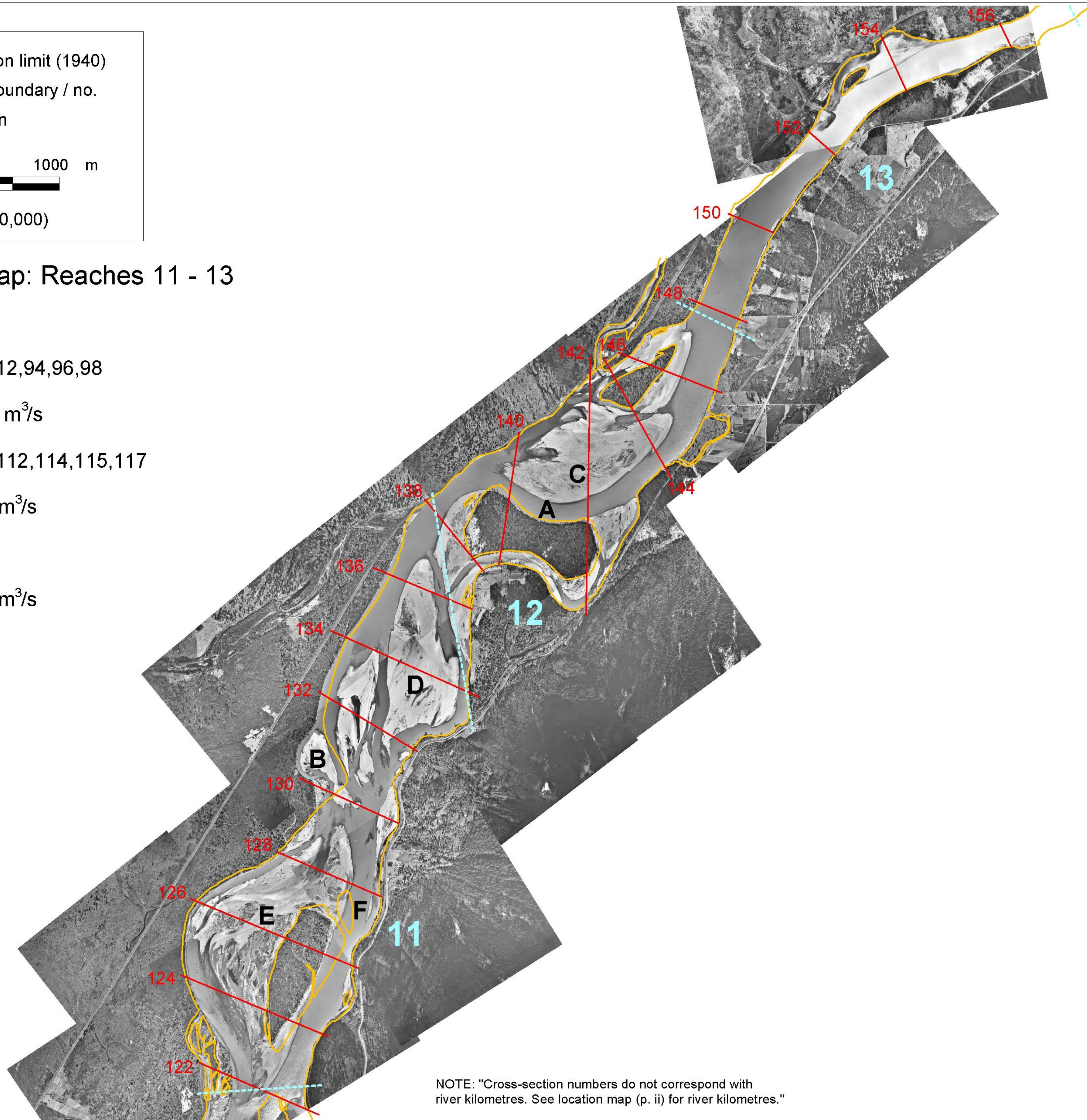
1949 photomap: Reaches 11 - 13

Source Photos

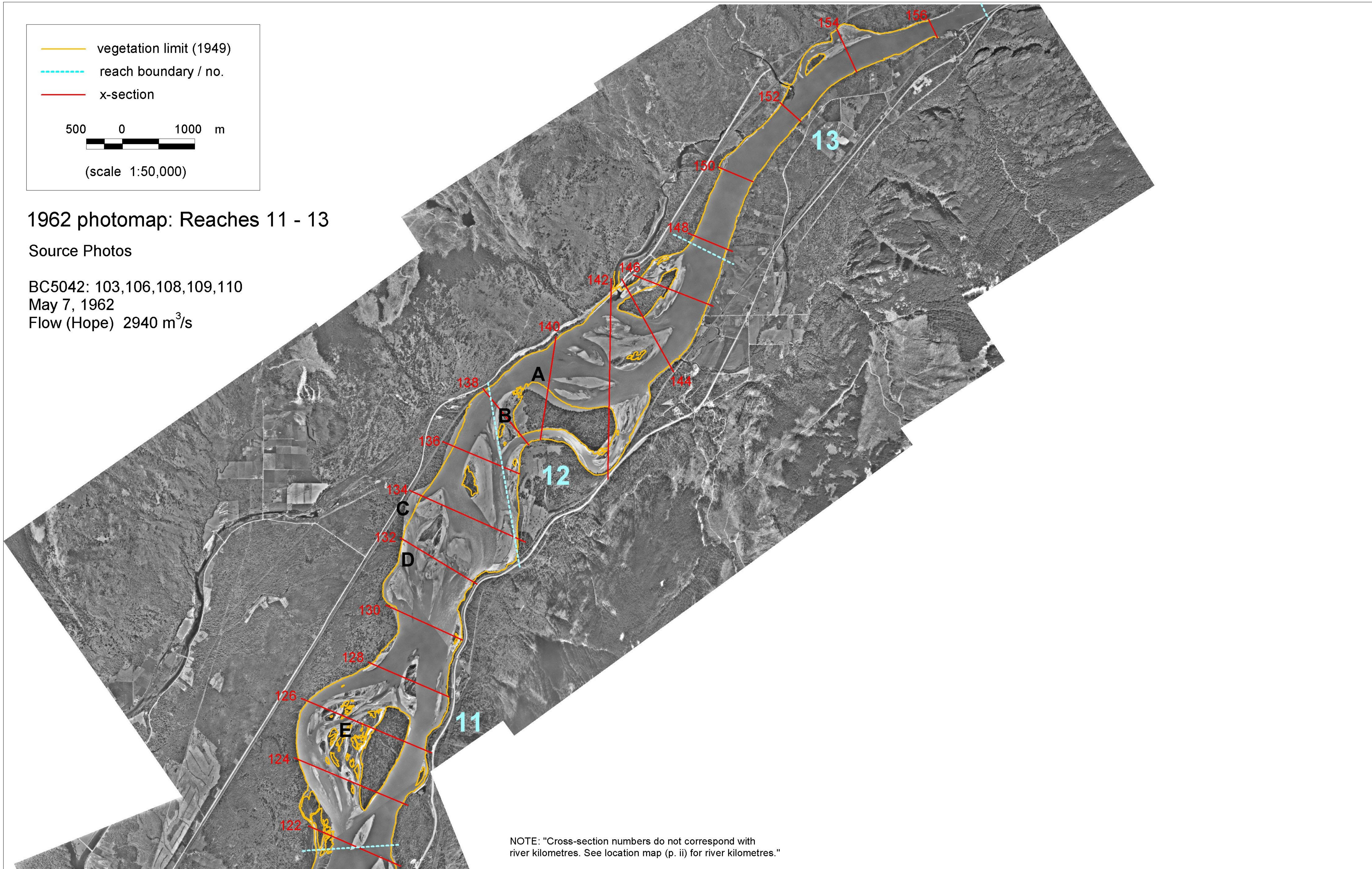
BC719: 3,6,8,10,12,94,96,98
March 23, 1949
Flow (Hope) 730 m^3/s

BC721: 108,110,112,114,115,117
March 31, 1949
Flow (Hope) 730 m^3/s

BC731: 93,94,96
April 6, 1949
Flow (Hope) 980 m^3/s



NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

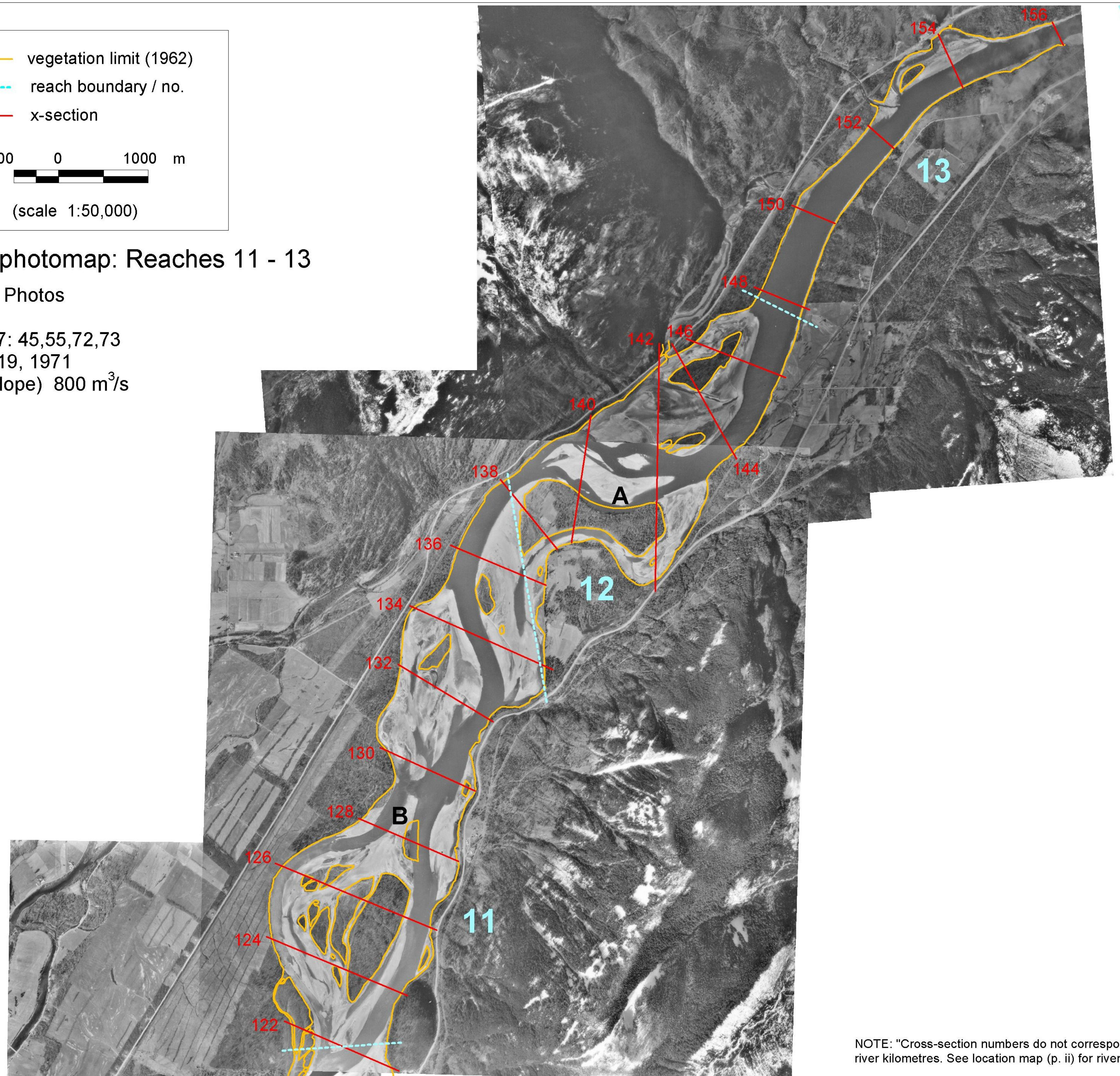


vegetation limit (1949)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1962 photomap: Reaches 11 - 13
Source Photos
BC5042: 103,106,108,109,110
May 7, 1962
Flow (Hope) 2940 m³/s
156
154
152
13
150
148
146
142
140
144
A
138
B
136
12
134
C
132
D
130
128
126
E
11
124
122
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

1971 photomap: Reaches 11 - 13

Source Photos

BC5407: 45,55,72,73
March 19, 1971
Flow (Hope) 800 m^3/s



NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

vegetation limit (1971)
reach boundary / no.
x-section

500 0 1000 m

(scale 1:50,000)

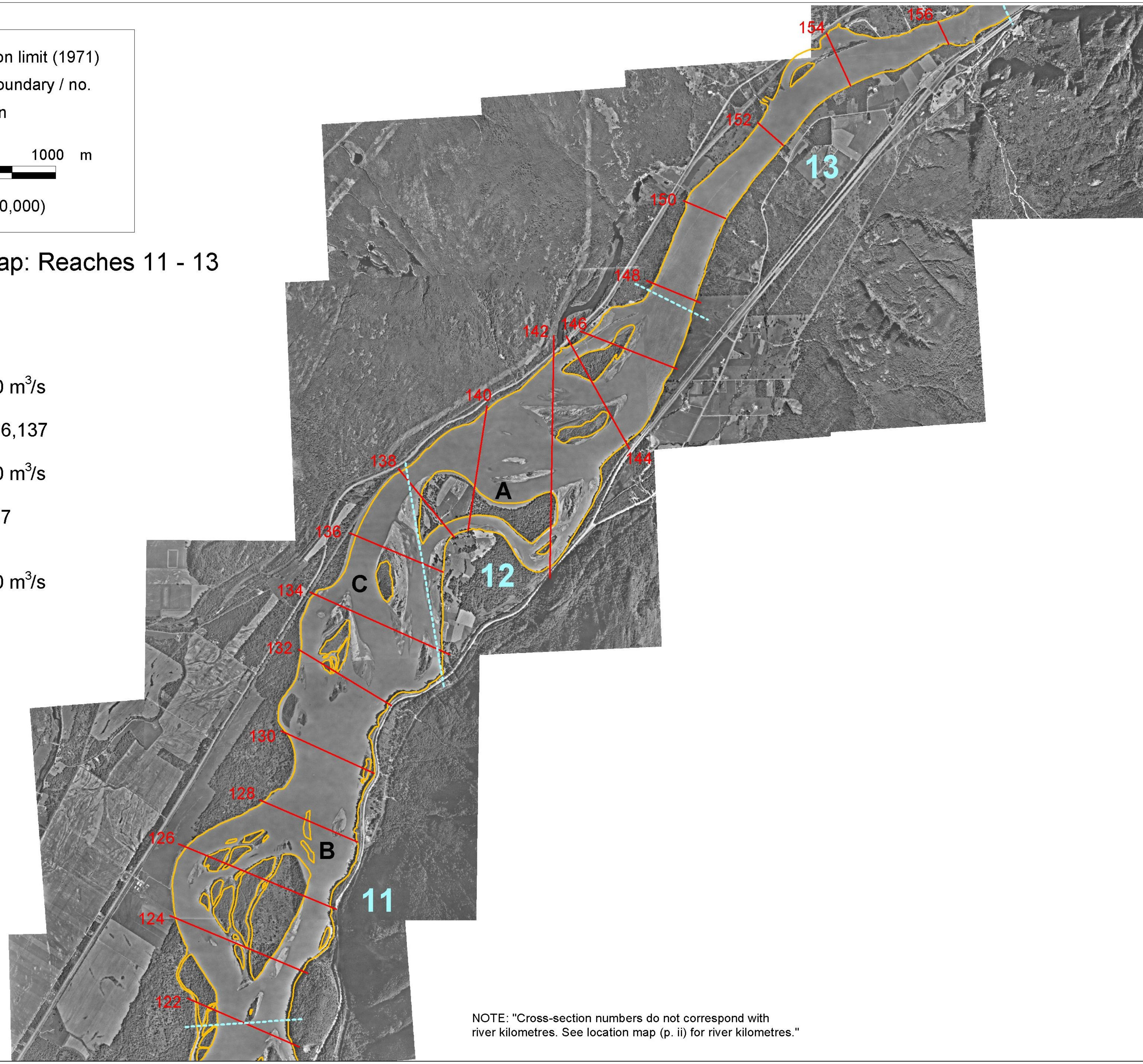
1983 photomap: Reaches 11 - 13

Source Photos

BC83007: 17
July 19, 1983
Flow (Hope) 6110 m^3/s

BC83012: 135,136,137
July 22,1983
Flow (Hope) 5380 m^3/s

BC83017: 154,187
BC83018: 77,117
July 30, 1983
Flow (Hope) 4820 m^3/s

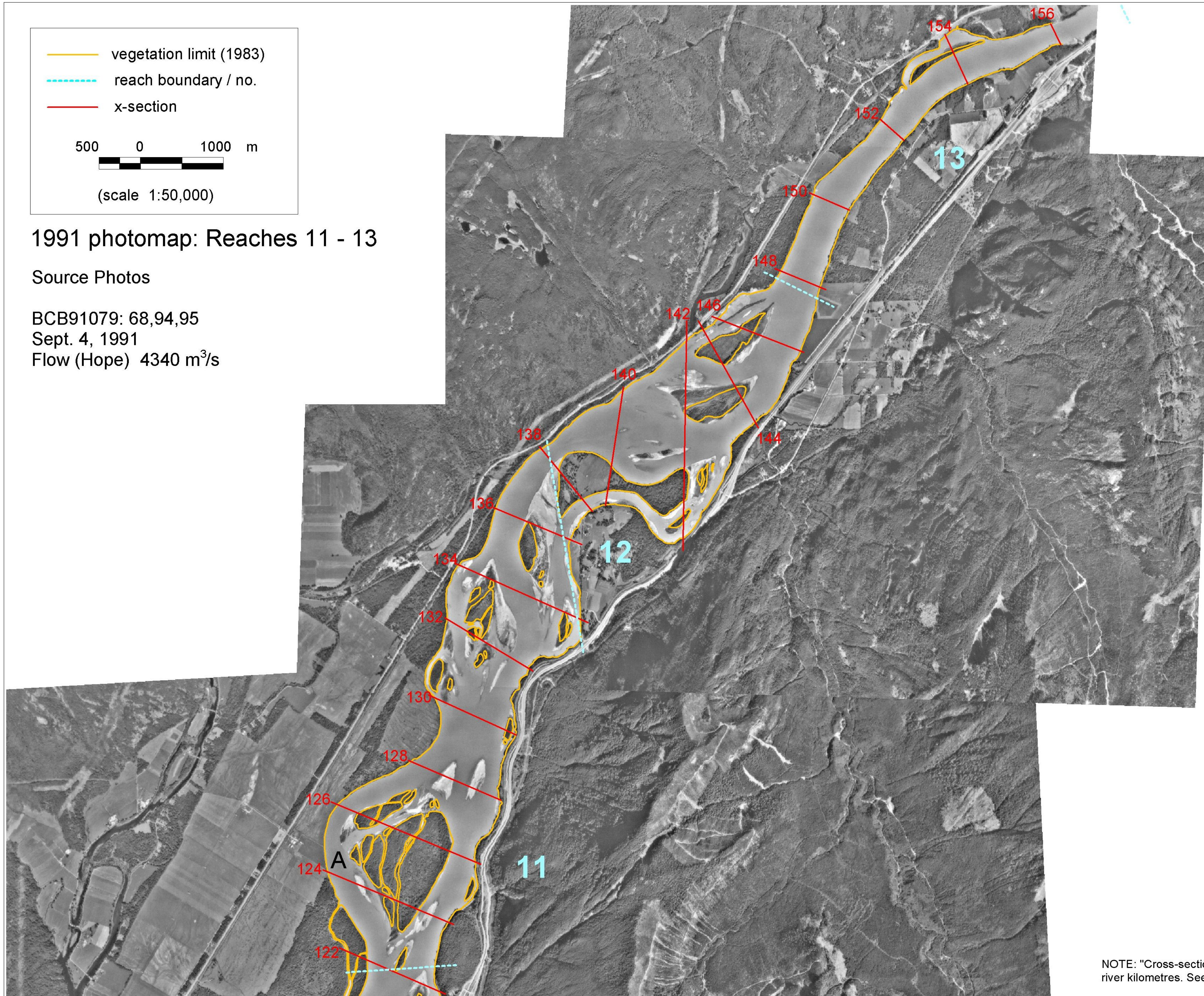


NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

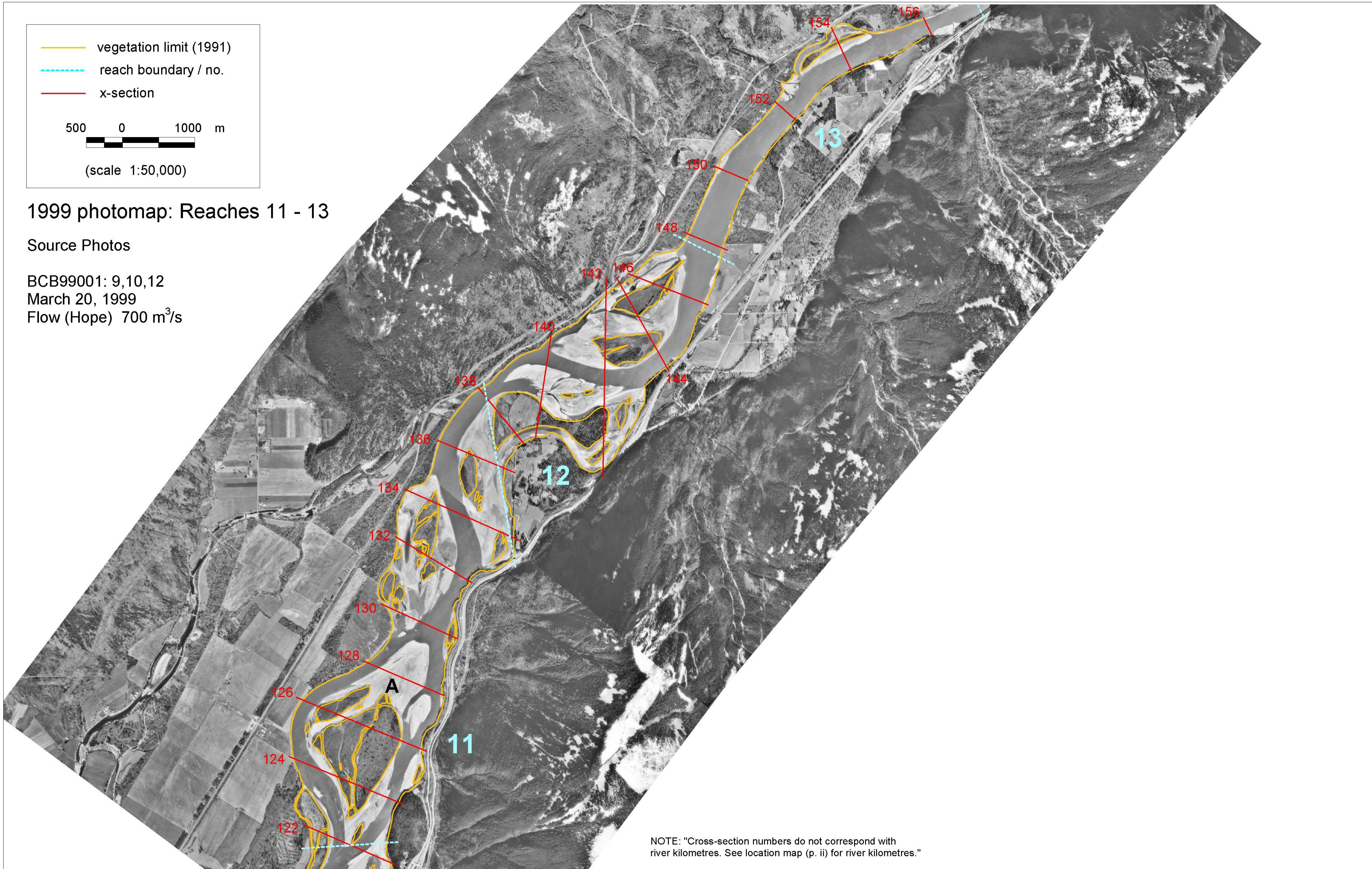
1991 photomap: Reaches 11 - 13

Source Photos

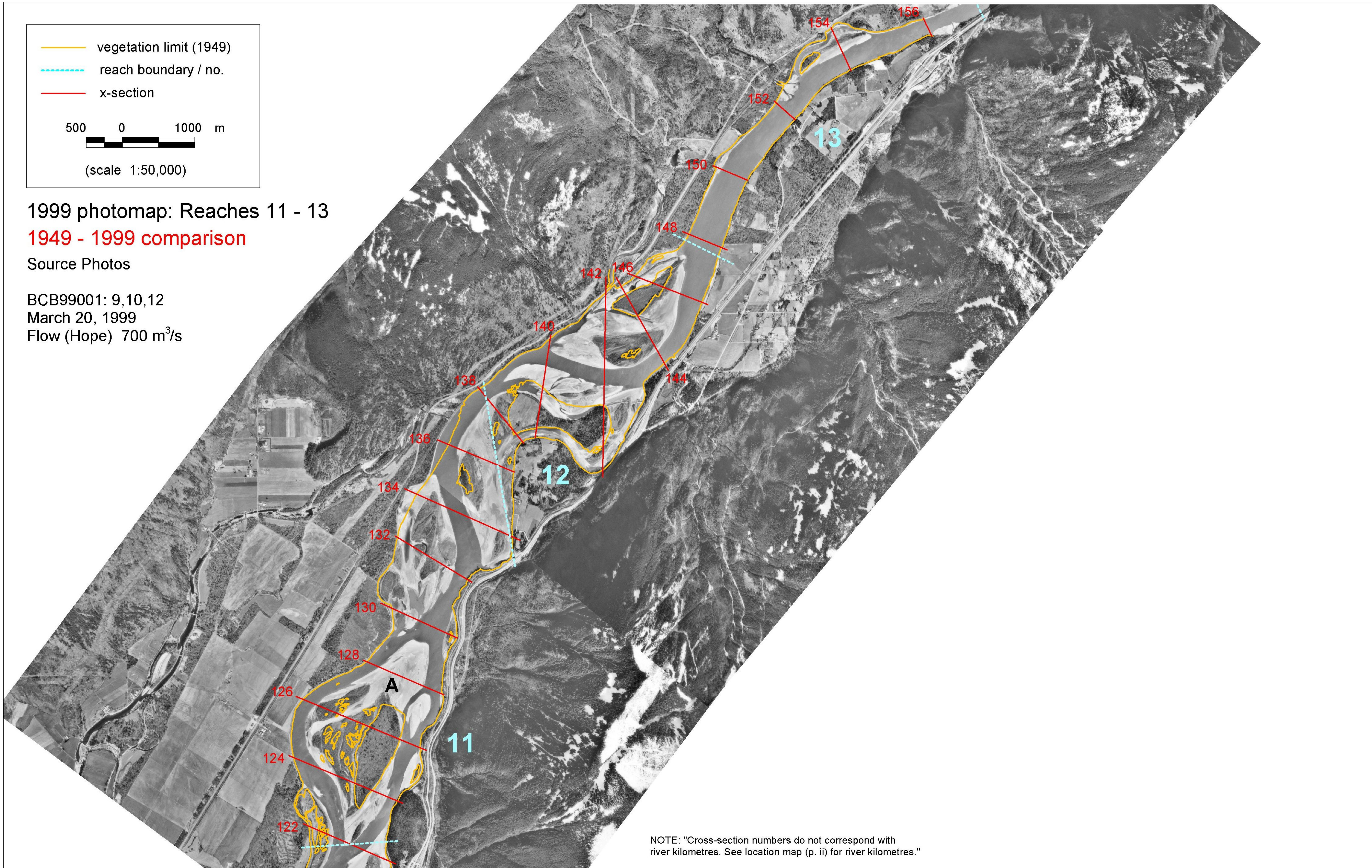
BCB91079: 68,94,95
Sept. 4, 1991
Flow (Hope) 4340 m^3/s



NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."



vegetation limit (1991)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1999 photomap: Reaches 11 - 13
Source Photos
BCB99001: 9,10,12
March 20, 1999
Flow (Hope) 700 m³/s
156
154
152
13
150
148
146
142
140
144
138
136
12
134
132
130
128
A
126
11
124
122
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."


vegetation limit (1949)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1999 photomap: Reaches 11 - 13
1949 - 1999 comparison
Source Photos
BCB99001: 9,10,12
March 20, 1999
Flow (Hope) 700 m³/s
156
154
152
13
150
148
146
142
140
144
138
136
12
134
132
130
128
A
126
11
124
122
NOTE: "Cross-section numbers do not correspond with
river kilometres. See location map (p. ii) for river kilometres."

Reaches 8 - 10 (Herrling Island to Carey Point)

There is a persistent history of channel instability in these reaches. Two major zones of sediment deposition and channel shifting, one along middle and lower Herrling Island (subreach 10) and the second in the vicinity of Greyell Island (subreach 8), are separated by subreach 9 in the vicinity of Ferry and Powerline Islands. The latter reach has remained much more nearly stable. It includes the Agassiz-Rosedale bridge point and was the site of a WSC gauge (08MF035; drainage area 218 000 km^2) that operated between 1966 and 1986.

The 1912 survey shows that there already were complex island groups at Herrling and Greyell Islands. At the bridge site there were active secondary channels behind Ferry Island and the island that is today known as Powerline Island. Sloughs (floodplain channels) on both banks were still active (cf. Maria Slough) or had only relatively recently been cut off, so they were mapped as substantial channels.

a) 1912 - 1928

Between 1912 and 1928 the right bank complex of secondary channels opposite middle Herrling Island (28A) appears to have changed considerably, with both erosion and deposition, and vegetation development, occurring. (It must be borne in mind that the 1912 survey might not be entirely accurate in its depiction of within-channel features; some of the changes in this area appear to be rather unlikely.) At upper Herrling Island it appears that island extension and consolidation occurred (28B), whilst at middle Herrling Island, major erosion occurred along the main channel left bank (28C) due to the incursion of a river bend around a developing mid-channel bar/island. Bank retreat of up to 350 m occurred. Similarly, on the right bank opposite lower Herrling Island (28D) up to 500 m of bank retreat occurred and an area of 75 ha was lost. At the same time there was erosion along the lower part of what was then Herrling Island proper (28E). The dramatic channel widening was the consequence of a rapidly developing bar/island complex in an area of major sedimentation at the lower end of Herrling Island. The entire area lies on and upstream of a major diagonal riffle that crosses the channel from the Powerline Island corner to the lower end of Herrling Island (28F). Sedimentation is apt to be persistent at this site, as well, because the river immediately downstream makes a right bend into a reach of restricted width where the channel is fixed against high ground upstream from Ferry Island. Hence, backwater and slackening currents would occur in the sedimentation area. In this period significant erosion occurred on the left bank opposite the riffle, upstream of the high ground (28G).

The secondary channel behind Herrling Island was also active in this period. The configuration of the channels about Spring Island (farther upstream) would have fed a substantial amount of water into this channel. Between 1912 and 1928 it appears that sedimentation substantially exceeded erosion in the upstream portion of the channel. The downstream sequence sedimentation-erosion is common in secondary channels with limited sediment transporting capability.

Bars that grew into Powerline and Ferry Islands were established near the end of the 19th century and, during the period 1912-1928, developed into significant islands. The secondary channel behind Ferry Island moved left while, on the right bank, Cheam Slough also was active. Around the downstream right bend, a significant bar/island developed in the channel near Hopyard Hill (28H) whilst compensating erosion occurred on both banks of the river. Farther downstream major erosion occurred on the right bank (28I) opposite the growing bar/island complex of Gill Islands off Greyell Island. Up to 350 m of bank retreat occurred on the Kent side of the river, providing sediment for significant deposition and the disappearance of a major secondary channel in the corner immediately upstream of Mt.Woodside (28J).

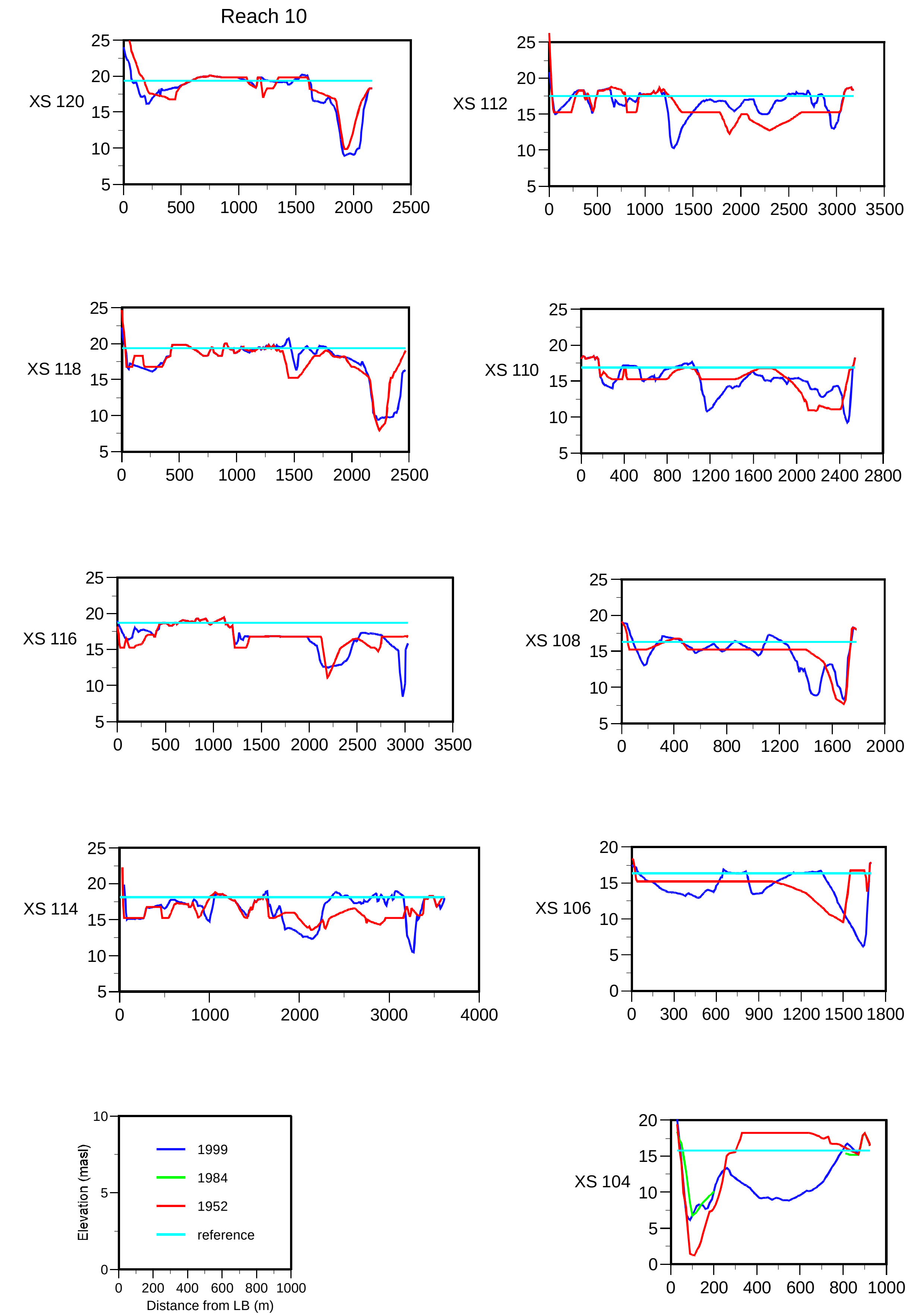
There was a substantial reduction in secondary channel capacity through Greyell Island itself during this period, in effect creating the single large island by the coalescence of several earlier ones. Yet at the downstream limit of the island (and of reach 8) and the downstream end of Jesperson (Greyell) Slough (28K), major erosion occurred. Bank retreat of 400 m was experienced. This was the consequence of the river being forced to the left by sediment deposition in front of Mt.Woodside (28L: the sediments are not obvious on the photomap see 40I).

Behind Jesperson Slough and Carey Point, a substantial network of sloughs appears to have shrunk dramatically in size between the two dates. These channels were cut off or controlled early in the century and it is likely that the apparent change represents mainly the difference between the 1912 cartographic conventions and the 1928 photo. Apparent shifts at several sites along these channels are also an artifact of imperfect registration of these two early records.

Overall, there is abundant evidence of lateral instability in these reaches during this period, with bank erosion and compensating bar deposition. Substantial sediment influx and outer banks still largely unprotected are the reasons for these phenomena.

b) 1928 - 1940

By 1940, erosion of the island head at Spring Bar (see 40D: reaches 11-13) had increased flow conveyance along the left channel and further caused 150 m of erosion along the downstream end of that island (40A), doubling left channel width. The establishment of this larger channel caused significant erosion at the head of Herrling Island and set the main flow firmly against the right bank at the head of reach 10. Immediately downstream, the channel experienced significant sedimentation with the growth of several islands at 40B and immediately left along the right bank (40C; see also 49B). A small island at the head of this group was eroded but did not appreciably alter flow alignment along the concave edge of Herrling Island, since very little erosion is observed. Meanwhile, deposition at 40C forced the channel directly south, eroding a significant island (40D), thence towards the right bank opposite lower Herrling Island (40E) where loss of another 375 m (36.5 ha) was observed. Material that was eroded



here was likely deposited along the downstream end of Herrling Island, possibly as far as Hopyard Island.

There was substantial erosion at the head of Powerline Island (40F), likely caused by the channel shift into the right bank immediately upstream, but high water levels preclude a more definitive statement. Minor erosion along the head and left bank of Ferry Island suggests this material was not deposited there, but further downstream near Hopyard Hill where a major bar had formed by 1943 around the existing island (43G). *From Hopyard Island downstream, 1943 photography has been substituted because of a large gap in the 1940 coverage. Since water levels were much lower in the 1943 photography, additional details of bar formation can be observed.* Island consolidation continued in the Greyell-Gill Islands area whilst the river swung wide to the right around continued sediment accumulation outside Gill Island (43H). This created continuing significant erosion on the Kent shore and the downstream end of Greyell-Gill Islands (both 150 m of retreat) as a more sinuous talweg was developing. The major area of developing bar and island in front of Mt.Woodside (Carey Bar: 43I) likely was already largely present in 1928, though material eroded from the Kent shore was added to it.

In this period, the most striking instability was in reach 10 (Herrling Island), with the corner upstream of Powerline Island appearing to act like a choke to onward movement of sediment (the appearance of deposits here is obscured by high water in 1940, but is very clear on the 1949 low-water photographs). The pattern of instability in reaches 8 and 9 was much more regular and modest. Bed material being fed into those reaches past Powerline Island probably was largely derived from the major erosion opposite lowerHerrling Island (40E, 49D).

c) 1940 - 1949

From 1940 to 1949, the head of Herrling Island was further eroded (49A) as the left bank channel previously established along Spring Bar was maintained. The channels immediately downstream along the outer side of upper and middle Herrling Island (49B) experienced additional sedimentation and there was dramatic development of bars and island surface in the area. (Some spectacular gravel sheets are visible on the photomap.) At the same time, there was 75 m of erosion on the right bank opposite and the network of minor channels there largely silted up. Immediately downstream, there was massive deposition, marking the establishment of Tranmer Bar (49C). This development drove bar and island erosion at mid-Herrling Island as the channel was forced to the left. Immediately downstream again, a huge area of bar deposits became consolidated at lower Herrling Island (49D), driving continued major erosion on the right bank. It is likely that much of the sediment here and in Tranmer Bar originated as far upstream as mid-Seabird Island (reach 11, upstream). Losses in this period opposite lower Herrling Island were again up to 300 m and totaled 23 ha. Deposition at lowerHerrling Island blocked the downstream end of Herrling secondary channel and extended into the "bay" eroded in the preceding decades (28G).Accordingly, theHerrling channel continued to shrink.

There was continued erosion at Powerline Island (49E), but also compensating bar deposition, apparently at least in part a response to downstream movement of the major riffle at this site due to the massive sedimentation at Herrling Island. A minor bar on the southwest corner of the island began to grow downstream. Ferry Island remained stable in this period, while gravel accumulations along the north side of the island produced minor compensating right bank erosion. There was also additional sedimentation around Hopyard Island (49F) (again, major gravel sheets are visible on the photo),with some compensating scour on the left bank.

Island consolidation continued in the Greyell-Gill Islands area whilst the river continued to swing wide towards the right around growing sediment accumulation at Gill Island (49G), causing an additional 100 m of compensating erosion along the Kent shore. This material continued to be deposited at the growing Carey Bar complex (49H), joining previously separated bar and island deposits into a single unit and significantly reducing the size of the secondary channel along Mt. Woodside. This bar growth further resulted in limited erosion on the left bank near Carey Point (49I).

d) 1949 - 1962

In 1962, the main channel still held to the right bank opposite upper Herrling Island. Accordingly, there was modest additional sedimentation against the island and erosion on the right bank (62A: up to 75 m of retreat). Tranmer Bar continued to grow outward into the main channel during this period, producing a shoal area in the main channel and causing continued significant erosion on middle Herrling Island (62B). There was also significant erosion at the back of Tranmer Bar. There is evidence of continuing sedimentation at the tail of lower Herrling Island, particularly at its northwesterly limit (62C), with significant erosion continuing on the opposite bank. The length of shore subject to erosion was, however, substantially reduced by 1962 (1 km versus 2.5 km in 1949). The outward growth of Tranmer Bar was a significant factor in this change.

Right bank erosion in the period continued onto the upstream end of Powerline Island, whilst the bar on the downstream side broadened and extended downstream toward the now extant Agassiz-Rosedale Bridge. The net effect of changes at the downstream limit of reach 10 was to significantly reduce the bend angle as the river entered reach 9 (62D), thus reducing flow resistance and sediment choking effects there. (A significant guidebank is evident in the downstream end ofHerrling secondary channel).

At Ferry Island, the back-channel was silting up in this period, but a significant, crescent-shaped mid-channel bar appeared (62E) off the downstream tip of Island 32 (the downstream part of the Ferry Island pair). It is reasonable to suppose that this represents an early indication of increasing bed material transfer through the erstwhile "choke point" upstream. With the growth of this bar there was corresponding erosion of Hopyard Island. That erosion was substantially greater than is indicated by themapped comparison of vegetation lines, since substantial unvegetated bar surface was also swept away. Part of the material was deposited on the diagonal riffle immediately downstream.

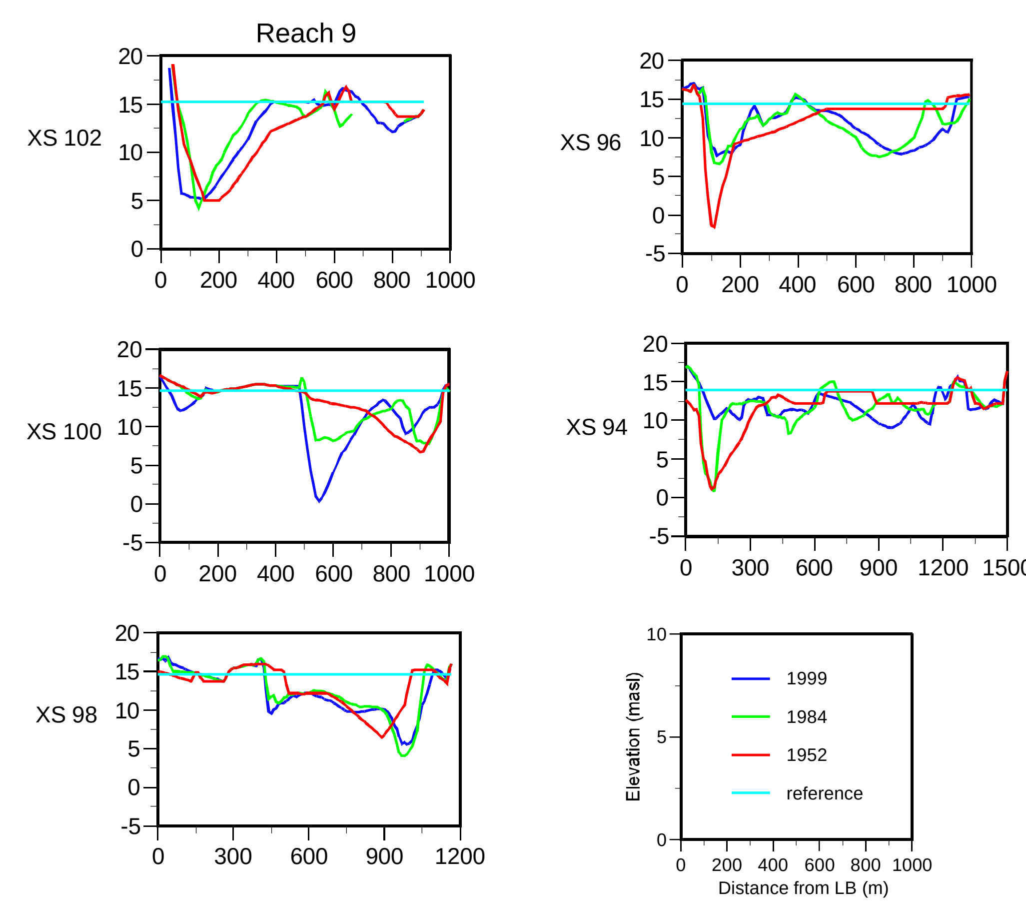
Farther downstream, a complex situation developed in the 1949-1962 period as continued sediment accretion on outer Gill Islands (62F) and at Carey Bar (62G) appears to have substantially reduced channel conveyance.Whilst this prompted continued erosion on theKentshore (100 to 150m),despiteitsnow being partially riprapped, and on outer Greyell Island, it also appears to have produced the diversion of substantial flow into the channel system through and behind the Gill Islands and Greyell Island, with significant erosion near the avulsion point (62H) near the upstream end of reach 8.Attheotherendof the reach, there was island development on Carey Bar and the Carey Point area remained stable for the first period in the record.

e) 1962 - 1971

Between 1962 and 1971 there were very limited changes along upper Herrling Island, giving the appearance that a stabilizing trend observed in the reaches upstream was propagating into subreach 10. Tranmer Bar continued to grow outward, causing significant compensatory erosion on the outer bank of middle Herrling Island (71A). The photomap illustrates some dramatic but probably transitory sediment deposition in the channel immediately downstream (71B). Lower Herrling Island appears to have largely stabilized and reduced erosion (up to 75 m maximum) was experienced during this period on the right bank opposite.

However, river action around Powerline Island eroded the head end of it, enlarging the side channel behind the island and extending the deposit on the downstream end so that a longitudinal bar now extended right under the main span of the relatively recently constructedAgassiz-Rosedale bridge (71C).At Ferry Island, the downstream bar expanded dramatically to establish the modern Big Bar (71D). Part of the sediment volume involved in these developments probably originated in the continued erosion at mid-Herrling Island.

The growth of Big Bar caused substantial erosion of Hopyard Island (71D). The eroded sediment was spread downstream over the erstwhile diagonal riffle (71E) to form a large right bank bar that would ultimately evolve partly into a new island on the riffle and partly into modern Hamilton Bar. Sedimentation here significantly reduced the conveyance in the old main



channel. This development, in turn, caused increased flow diversion and dramatic erosion at Gill Islands (71F), further opening the channels through the Gill Island area. These developments stabilized the formerly eroding part of Kent Shore (71G), although some erosion occurred farther downstream. While there were changes of detail at Carey Bar (71H), no major changes occurred there, nor at Carey Point, in this period.

f) 1971 - 1983

Between 1971 and 1983 two major floods passed through the river. In subreach 10, they did not change previously established trends. There were minor extenstions of vegetation on upper Herrling Island, but remarkably little change in the channels, implying little sedimentation there. Tranmer Bar continued its growth (83A), the deposited material having moved into the reach from subreach 11. The surface of Tranmer Bar continued to be very active, with both erosion and vegetation establishment occurring. As the result of Tranmer Bar growth, the outer edge of mid-Herrling Island continued to be eroded. Lower Herrling Island remained stable, with substantial extension of vegetation cover (83B), and the opposite right bank (83C) was stabilized as the result of riprap placement. These developments forced sediment eroded from mid-Herrling Island through into subreach 9.

In subreach 9, the bar extension of Powerline Island continued (83D) and the river established a smooth transition through the former abrupt bend. Big Bar (83E) continued its growth. (The relatively high stage of the 1983 photos prevents all details being visible.) Old Hopyard Island entirely disappeared and a new Hopyard Island began to develop (83F).

Major developments occurred in the upper part of subreach 8. In response to the growing sedimentary congestion in the area, a new main channel opened up through the back of Gill Bar (83G). The isolated area to the right developed into the core of modern Hamilton Bar. Flow through the Gill/Greyell Islands continued to effect erosion there (83H). The redirection of flow at Gill Bar led to the development of a deep channel behind the Carey Island/bar area on the front of Mt.Woodside (83I; see XS 84, 86), and to the development of a major channel through the Carey Island/Bar (83J) that directed flow squarely at Carey Point (83K). By 1983, major erosion had commenced at that site, with up to 125 m of bank retreat visible on the upstream corner.

g) 1983 - 1991

During 1983-1991 there were no major floods. At many sites, substantial vegetation extension occurred during the period. Nonetheless, river channel changes set in train during the preceding period continued. Upper Herrling Island remained stable, with vegetation extension. There was significant vegetation growth also on Tranmer Bar but sedimentation continued on the downstream side, leading to a wide shoal zone in the channel (91A) and continued erosion on mid-Herrling Island. The locus of the erosion shifted downstream, however, and began to remobilize the material deposited there early in the century.

At Powerline Island the downstream bar continued to grow (91B) and significant sedimentation occurred in the side channel. (A substantial patch of vegetation developed on an artificially constructed mound of sediment on the bar upstream of the bridge, the product of pipeline excavations.) Big Bar continued to build downstream, and vegetation was well established on the upper part, and also on the new Hopyard Island. Persistent sedimentation behind the established island at Hamilton Bar (91C) extended this feature and essentially attached it to the right bank where, years before, the main channel had passed. Most of the sediment involved in these developments probably derived from the erosion along lower Herrling Island, although the channel along the left bank at Ferry Island was being significantly deepened during the period (see XS 98 and 100).

Two significant channels were present about Gill Islands (91D,E). The left branch flowed along the front of Greyell Island, causing erosion there (91E), most of the material being deposited immediately downstream. The right branch flowed against a now extensively riprapped Kent shore, thence to Mt.Woodside and toward Carey Point. Meanwhile, the former wide, shallow summer channel (91F) between Gill Islands and the upstream part of Carey Island silted up so that Carey Island was annexed to Gill Islands. The spread of vegetation in the Gill Island area and on the downstream portion of the now truncated Carey Bar, the consequence of the generally low freshets in these years, undoubtedly helped to fix the new channel alignments. At Carey Point (91G), more than 100 m of erosion occurred, for a loss of 5 ha (XS 80). The erosion progressed west along the shore as the alignment of the main channel slowly rotated clockwise. Sedimentation at the downstream end of Greyell channel appears to have been at least partly the cause of this evolution, although erosion also occurred along outer Carey Bar.

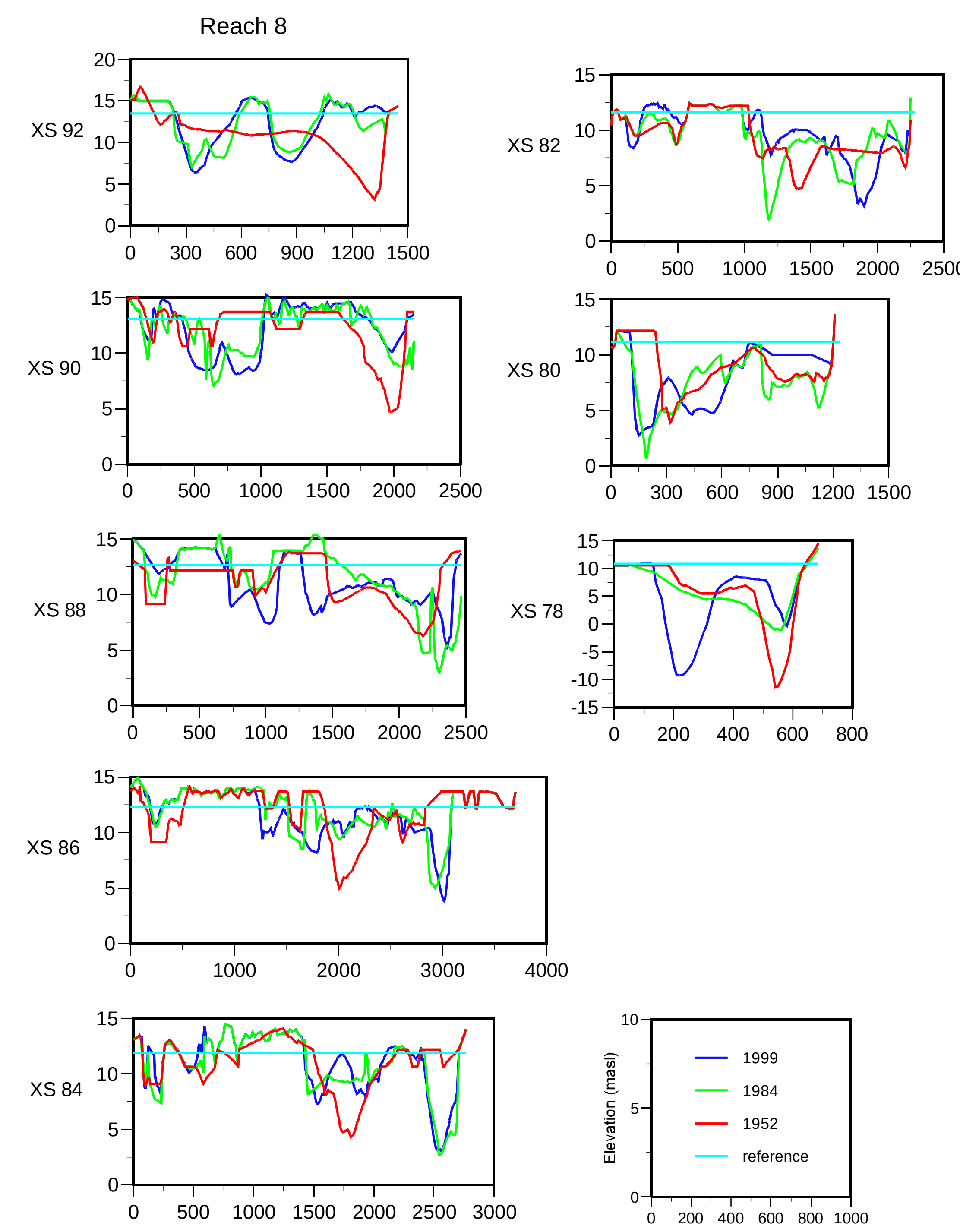
h) 1991 - 1999

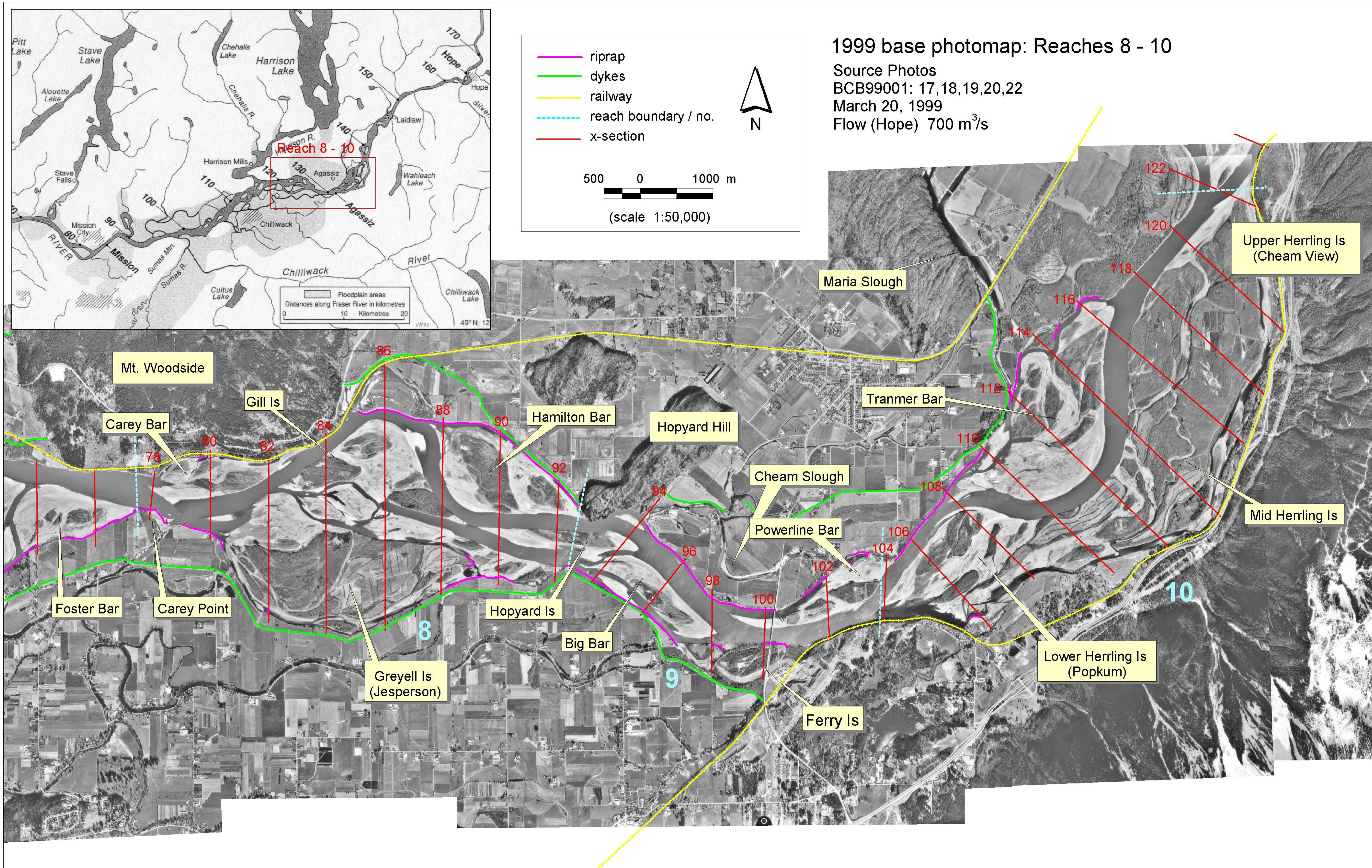
Between 1991 and 1999 no major changes occurred in subreach 10 but there were important adjustments of flow alignment, portending future changes. Continued but limited extension of Tranmer Bar sustained erosion at mid-Herrling Island (99A), but there was no further erosion on the downstream part of the bar. Established trends continued at Powerline Island, the downstream extension of the bar having now grown to project a smooth extension into the right bank (99B). This extension, and the deepening of the channel along the left bank led to increased spill of high water into the secondary channel behind Big Bar, leading to erosion at Island 32 (99C).

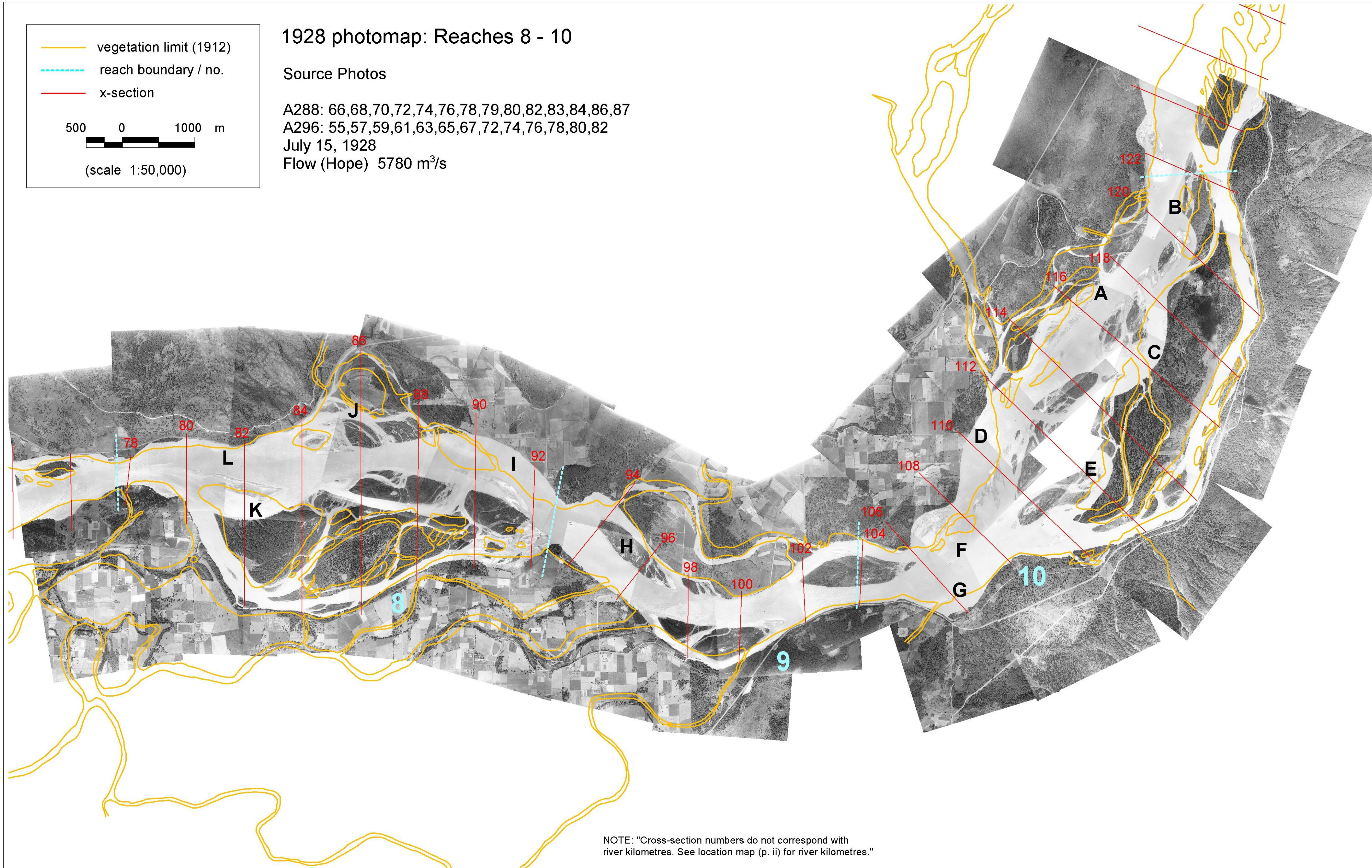
Big Bar continued to extend to the point that the channel between Big Bar and Hopyard Island (99D) became only a summer riffle. This forced nearly all of the main flow against the tip of Hopyard Hill, from where it turned west toward Gill Island. Erosion on upper Gill Island (99E) led to sedimentation downstream (99F), where the channel turns abruptly left. The abrupt turn reduced conveyance here and increased summer flow through the Gill/Greyell island group. Since 1999 this trend has continued and it appears that a new main channel is developing to the left of the main islands in the Gill Islands group (XS 90). At Carey Point (99G), erosion continued to move west as the main channel established a more rectilinear path past Carey Bar. Sediment deposition on outer Carey Bar and in front of the mouth of Jesperson Slough were part of this development (see XS 78 for the resulting leftward shift of the thalweg).

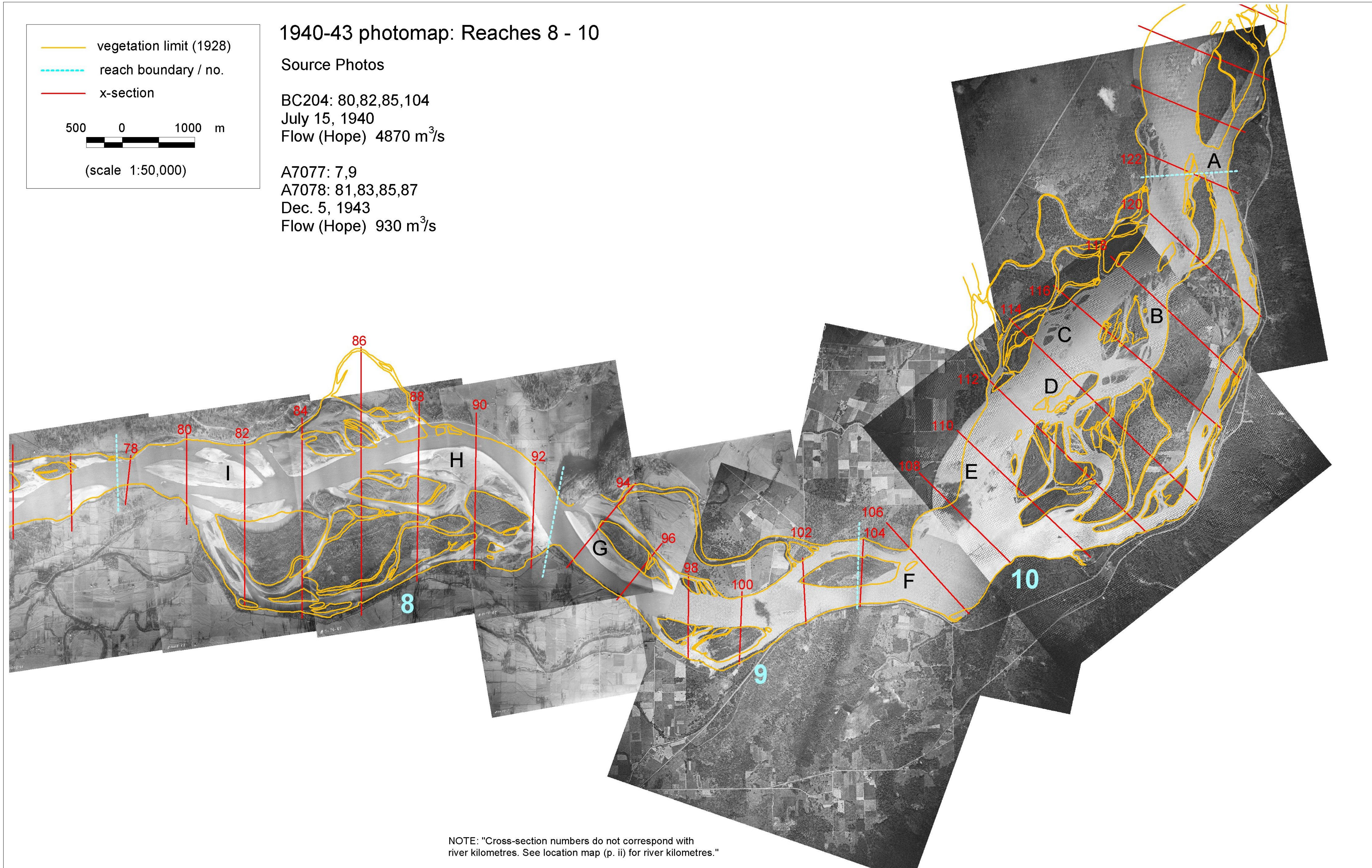
i) Summary

The main features of the 20th century development in subreaches 10 to 8 were major instability at mid- and lower Herrling Islands early in the period, continued in the form of the development of Tranmer Bar over the last 50+ years, and the persistence of major instability in subreach 8. Major channel shifts in subreach 8 have become more frequent after 1971. This development probably is related to the channel realignment at the lower end of Herrling Island, permitting increased bed material transport through reach 9 to the Hamilton-Gill-Greyell area. The increased sedimentation in reach 9 itself is an associated development. Over the long-term, significant island building occurred at lower Herrling Island (XS 106, 108) and at Gill Islands.

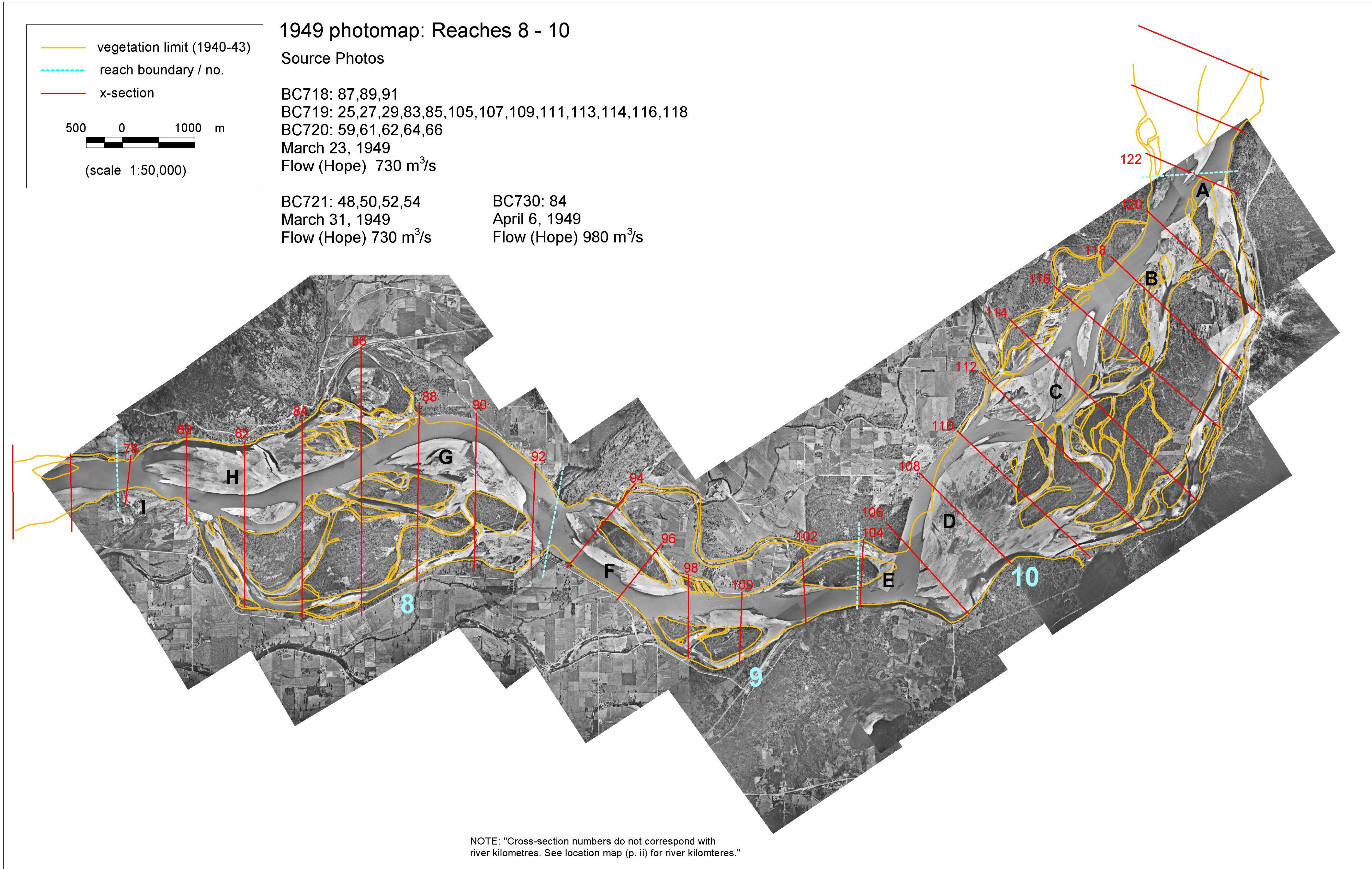



1999 base photomap: Reaches 8 - 10
Source Photos
BCB99001: 17,18,19,20,22
March 20, 1999
Flow (Hope) 700 m³/s
riprap
dykes
railway
reach boundary / no.
x-section
N
500 0 1000 m
(scale 1:50,000)
Pitt Lake
Stave Lake
Alouette Lake
Chehalis Lake
Harrison Lake
Chehalis R.
Harrison R.
Harrison Mills
Stave Falls
Mission City
RIVER
Mission
Sumas Mtn.
Sumas R.
Cultus Lake
Chilliwack
Agassiz
Laidlaw
Hope
Wahleach Lake
River
Chilliwack Lake
Reach 8 - 10
Floodplain areas
Distances along Fraser River in kilometres
Kilometres
Mt. Woodside
Carey Bar
Gill Is
Hamilton Bar
Hopyard Hill
Maria Slough
Tranmer Bar
Cheam Slough
Powerline Bar
Upper Herrling Is
(Cheam View)
Mid Herrling Is
Foster Bar
Carey Point
Greyell Is
(Jesperson)
Hopyard Is
Big Bar
Ferry Is
Lower Herrling Is
(Popkum)
8
9
10
78
80
82
84
86
88
90
92
94
96
98
100
102
104
106
108
110
112
114
116
118
120
122


1928 photomap: Reaches 8 - 10
vegetation limit (1912)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
Source Photos
A288: 66,68,70,72,74,76,78,79,80,82,83,84,86,87
A296: 55,57,59,61,63,65,67,72,74,76,78,80,82
July 15, 1928
Flow (Hope) 5780 m^3/s
122
120
B
118
116
A
114
C
112
110
D
108
E
106
104
F
G
10
102
100
98
96
H
94
9
92
I
90
88
86
J
84
82
80
78
L
K
8
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."



NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."


vegetation limit (1940-43)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1949 photomap: Reaches 8 - 10
Source Photos
BC718: 87,89,91
BC719: 25,27,29,83,85,105,107,109,111,113,114,116,118
BC720: 59,61,62,64,66
March 23, 1949
Flow (Hope) 730 m^3/s
BC721: 48,50,52,54
March 31, 1949
Flow (Hope) 730 m^3/s
BC730: 84
April 6, 1949
Flow (Hope) 980 m^3/s
A
B
C
D
E
F
G
H
I
8
9
10
78
80
82
84
86
88
90
92
94
96
98
100
102
104
106
108
110
112
114
116
118
120
122
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilomteres."

1962 photomap: Reaches 8 - 10

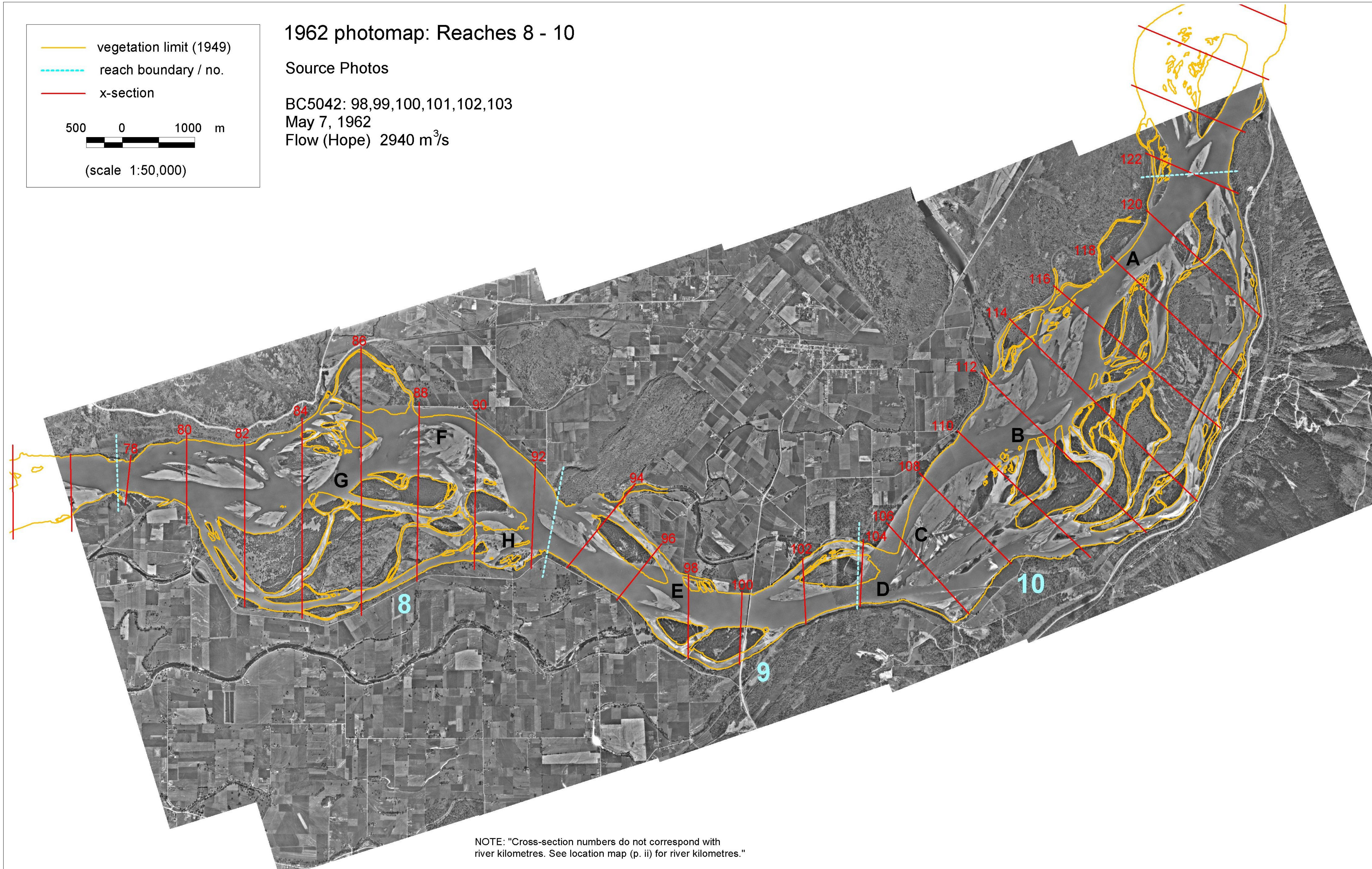
Source Photos

BC5042: 98,99,100,101,102,103
May 7, 1962
Flow (Hope) 2940 m^3/s

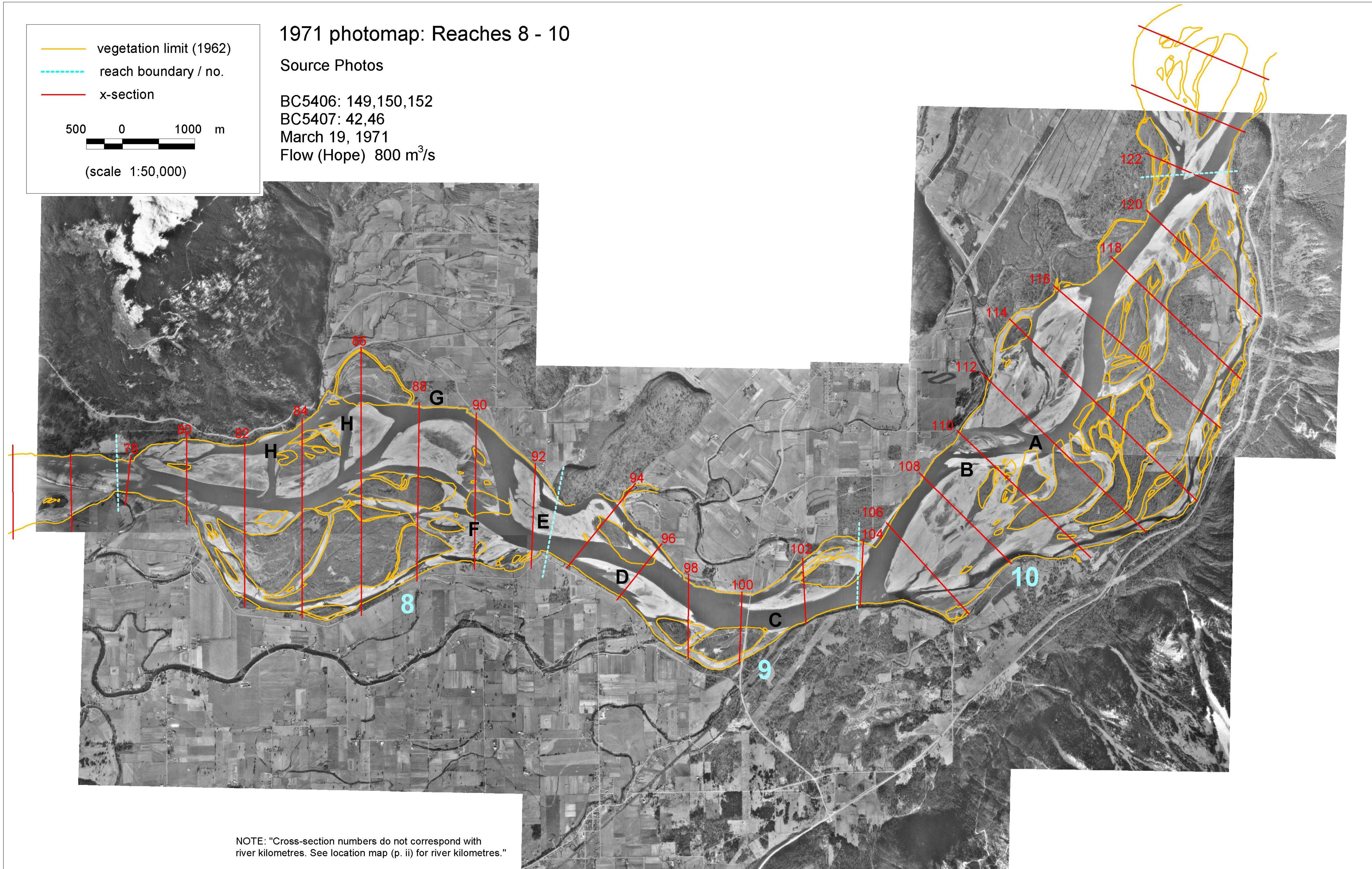
vegetation limit (1949)
reach boundary / no.
x-section

500 0 1000 m

(scale 1:50,000)



NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."



1971 photomap: Reaches 8 - 10
Source Photos
BC5406: 149,150,152
BC5407: 42,46
March 19, 1971
Flow (Hope) 800 m³/s
vegetation limit (1962)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
78
80
82
84
86
88
90
92
94
96
98
100
102
104
106
108
110
112
114
116
118
120
122
A
B
C
D
E
F
G
H
H
8
9
10
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

1983 photomap: Reaches 8 - 10

vegetation limit (1971)
reach boundary / no.
x-section

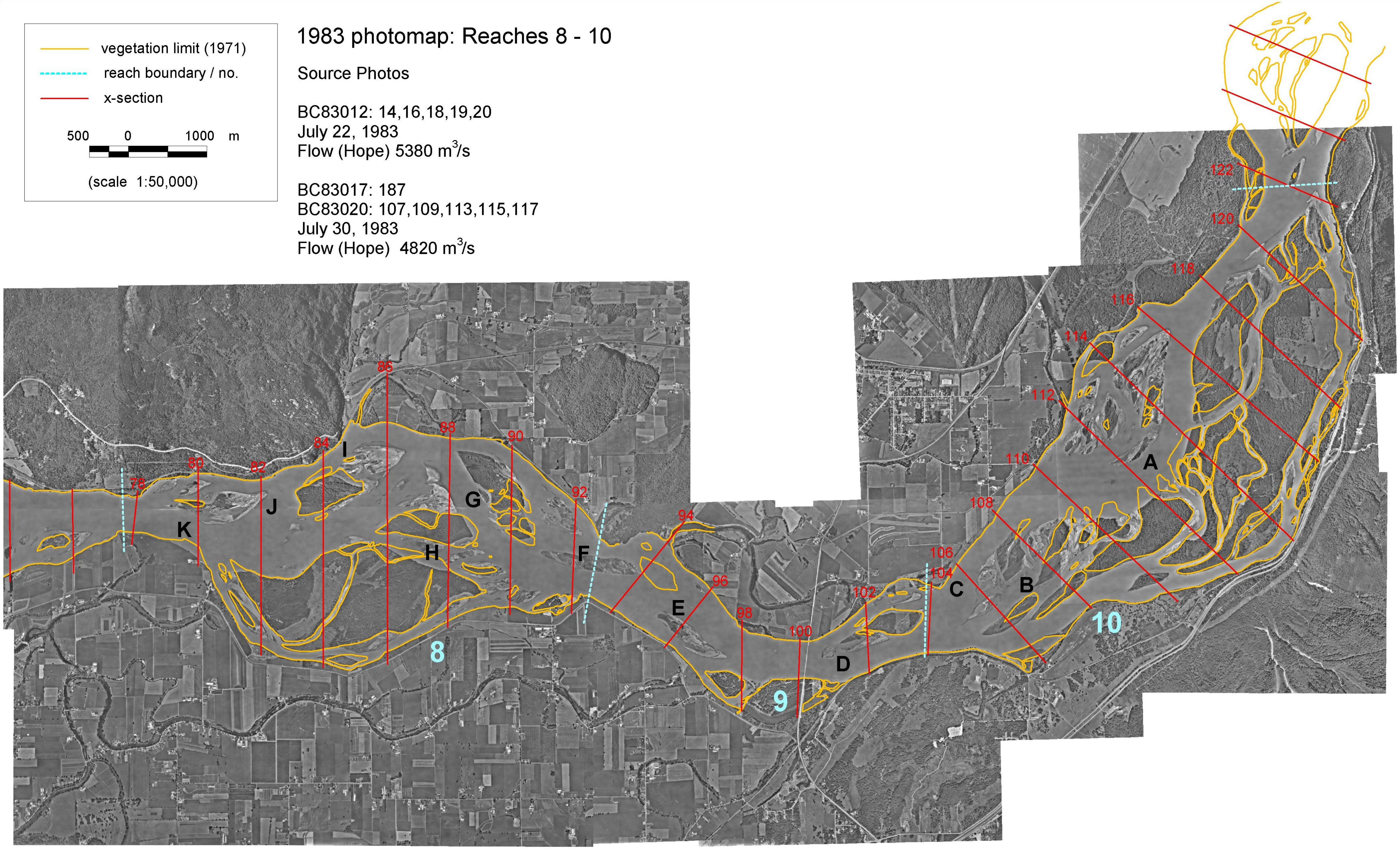
500 0 1000 m

(scale 1:50,000)

Source Photos

BC83012: 14,16,18,19,20
July 22, 1983
Flow (Hope) 5380 m^3/s

BC83017: 187
BC83020: 107,109,113,115,117
July 30, 1983
Flow (Hope) 4820 m^3/s



NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

1991 photomap: Reaches 8 - 10

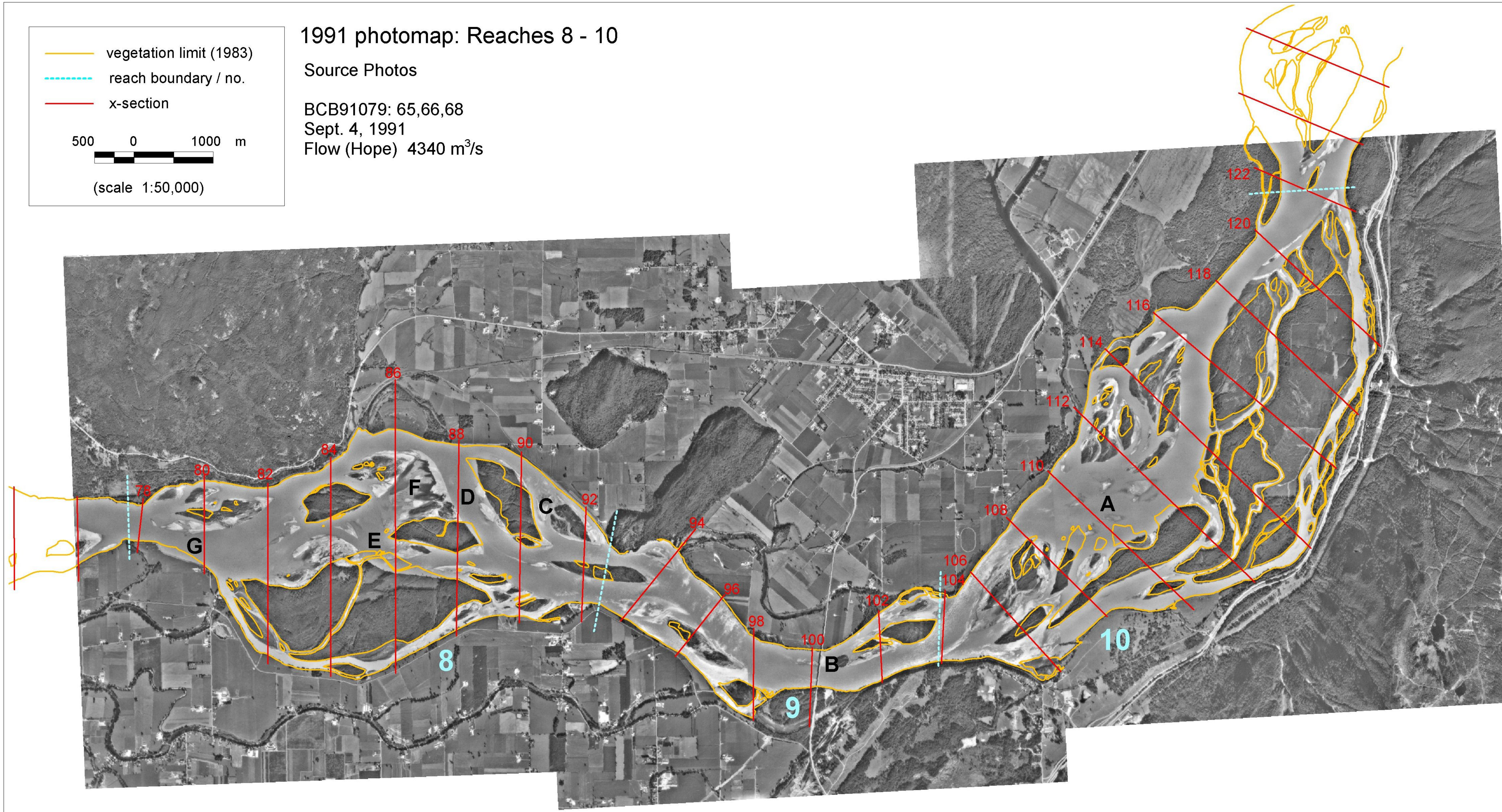
Source Photos

BCB91079: 65,66,68
Sept. 4, 1991
Flow (Hope) 4340 m^3/s

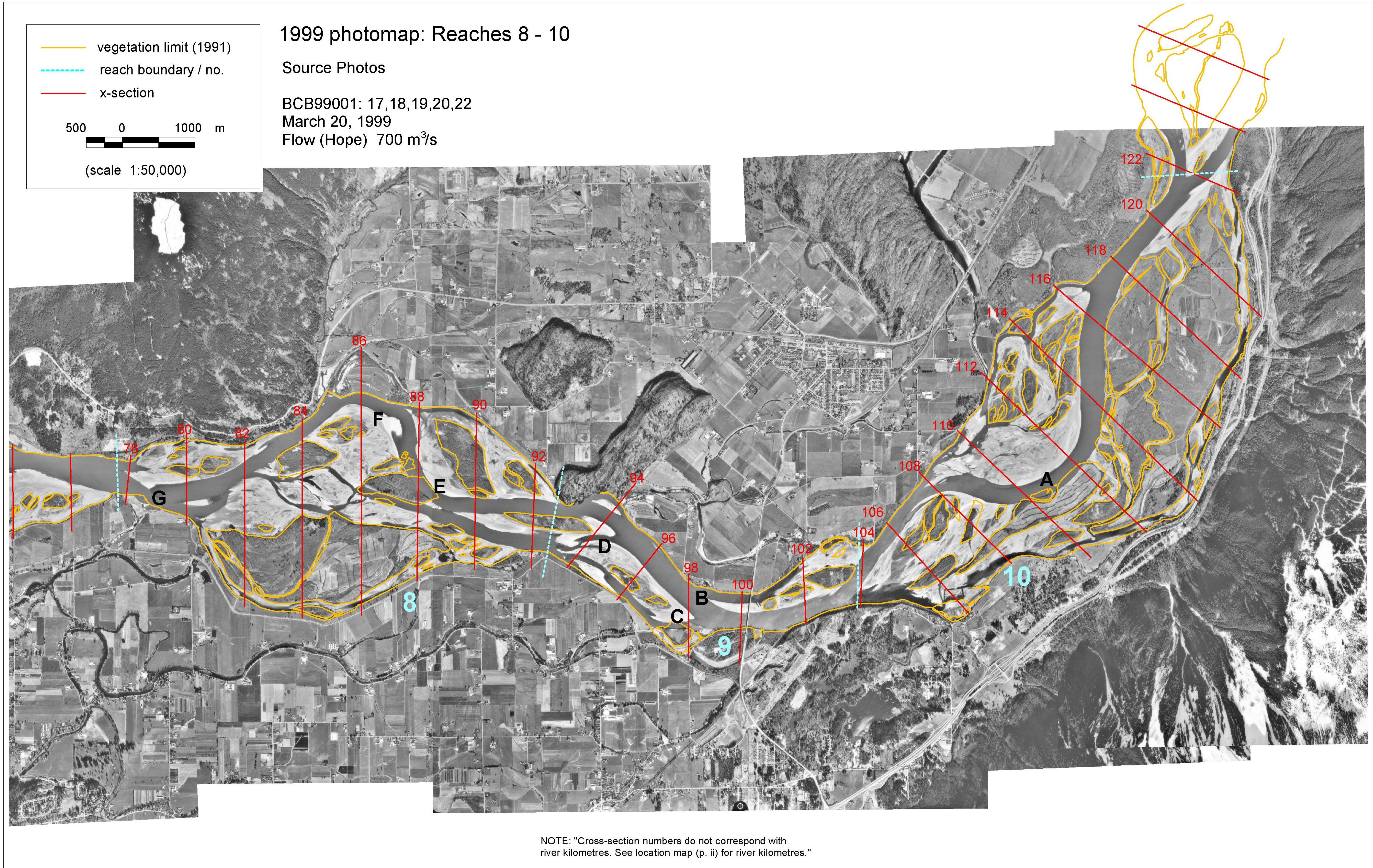
vegetation limit (1983)
reach boundary / no.
x-section

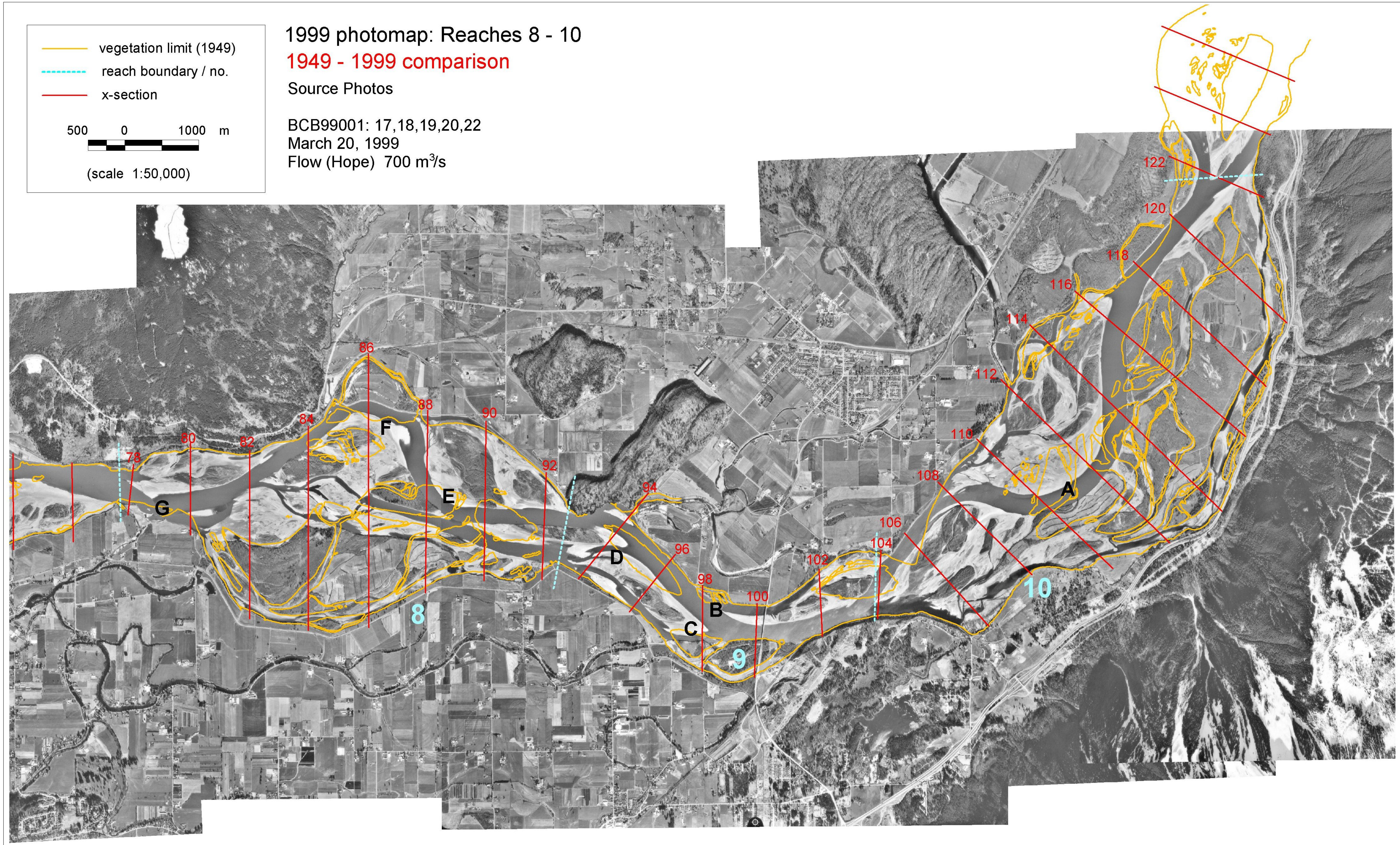
500 0 1000 m

(scale 1:50,000)



NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."


vegetation limit (1991)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1999 photomap: Reaches 8 - 10
Source Photos
BCB99001: 17,18,19,20,22
March 20, 1999
Flow (Hope) 700 m³/s
78
80
82
84
86
88
90
92
94
96
98
100
102
104
106
108
110
112
114
116
118
120
122
A
B
C
D
E
F
G
8
9
10
NOTE: "Cross-section numbers do not correspond with
river kilometres. See location map (p. ii) for river kilometres."



NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

Reaches 5 - 7 (FosterBartoLowerYaalstrick Bar)

Subreach 7 includes the confluence of Harrison River, one of only two significant tributaries in the entire alluvial gravel-bed reach. Most of the major features of the river channel have changed during the 20th century, yet the outer banks of the channel zone have not greatly moved. In part this is because the channel is constrained by bedrock at Harrison Knob and at ChilliwackMountain (and, downstream, at SumasMountain), and partly it may be because extensive riprap protection has been constructed in this reach over the years.

a) 1912 - 1928

Readers should note that registration of the 1913mapproved difficult for this reach because of map distortion, so that only apparently major changes can be accepted as assuredly real.

The 1928 channel gives the appearance of very low sinuosity, with 4 major island groups, each defining a major riffle. These occurred at Harrison River (28A) and Lower Minto Islands (28B), both in subreach 7, at Wellington Islands (28D) in subreach 6, and at (Upper) Yaalstrick Islands (28E) in subreach 5. Elements of all four groups have persisted to this day. Substantial developments occurred in all four groups between 1912 and 1928. Atthe mouth of Harrison River, island growth forced the river to move left, creating up to 575 m of erosion on the left bank. Erosion extended upstream as far as the site of modern Foster Bar. Much of the mobilised sediment undoubtedly was deposited in the Minto Islands, causing further left bank erosion downstream from the early settlement at Minto Landing. The left bank channel moved as much as 650 m into the left bank, creating a much more circuitous path around the islands. In 1912, the river appears to have passed mainly to the left of the Minto Islands but, by 1928, the islands were a mid-channel group with a developing right bank channel north of them. This development was possibly the consequence of increasing resistence to flow in the increasingly curved left-bank channel. Immediately downstream from Minto Islands (28F), a small mid-channel bar in the right-bank channel represents the first development of modern Queen's Bar. A major reorganization of the channelwasunderwayhere as the river developed a new path past a major, late 19th century diagonal riffle that passed from the downstream end of Shefford Slough via theMintoIslands to the tip of Harrison Knob (see North and Teversham, 1979). A consequence of this reorganization was that the land area delimited by Shefford Slough (28C) was by 1928 in a late stage of island consolidation and well on its way to becoming incorporated into the adjacent floodplain (today known as Island 22).

Downstream, there was persistent erosion between 1912 and 1928 extending the entire length of subreach 6 along the front of upper Nicomen Island. This resulted in 100 to 200 m retreat on the right bank over a distance of 5 km (net land loss about 75 ha), whilst sedimentation occurred on the right bank. In mid-channel, a series of small islands appeared at the present-day position of Wellington Bar and were evidently part of a newly forming diagonal riffle that, today, runs from Chilliwack Rock through Wellington Bar to Queen's Bar. The inception of this riffle turned the main river current to the right across it, so that erosion and dissection of the Yaalstrick Islands group (28E) occurred in the period, including erosion on the bank of Nicomen Island. In 1928, though, the main flow of the river still passed along the upper side of the riffle, against the left bank. ChilliwackMountain is able to resist erosion, but the area immediately downstream suffered significant erosion in this period. The erosion was likely matched by substantial bar accumulation in the considerably widened subreach, but this is not evident in the high contrast 1928 photographs.

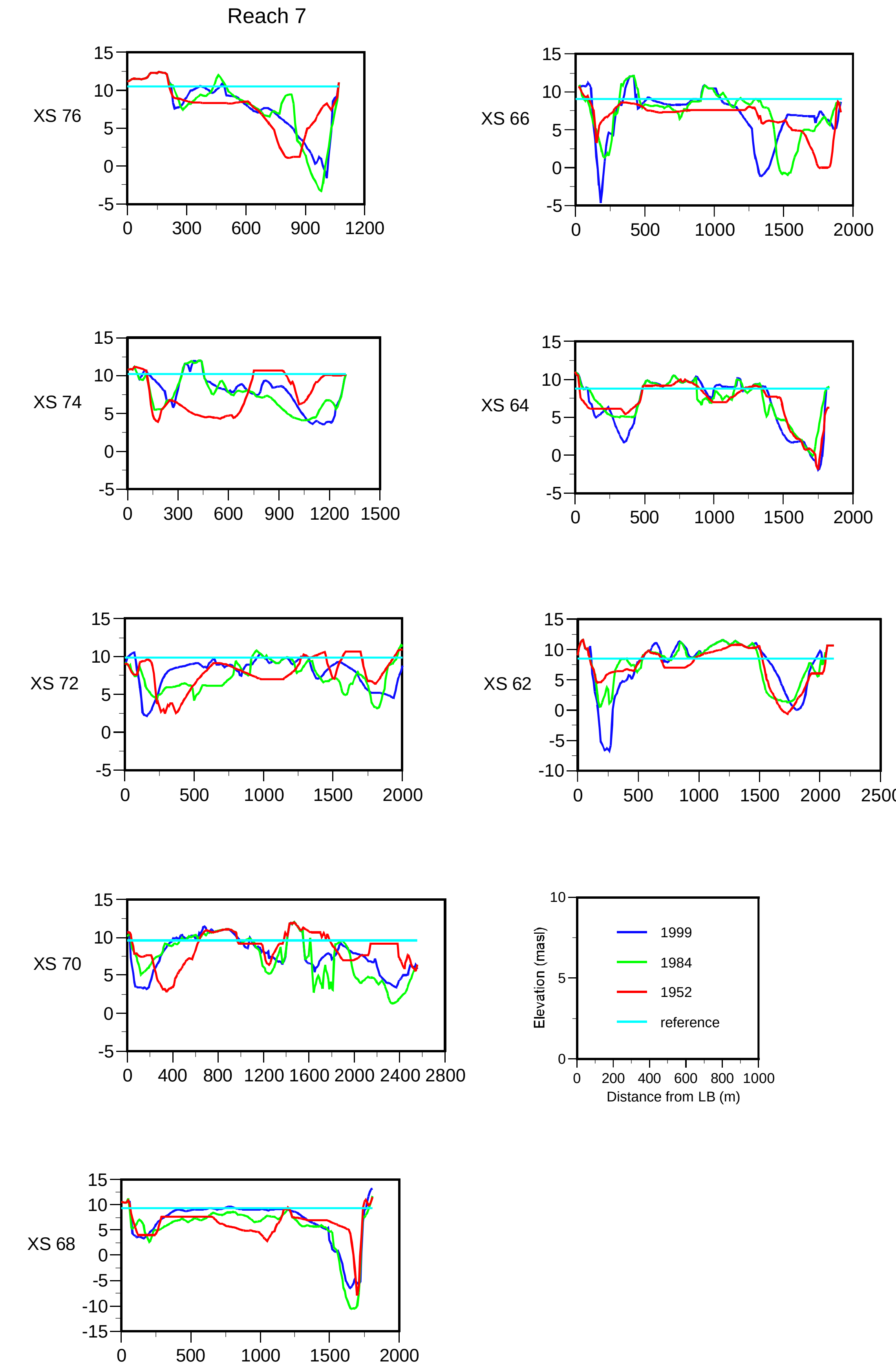
b) 1928 - 1938

The 1938 photographs reveal substantial sedimentation upstream from the Harrison River mouth. Opposite the mouth of Harrison River, where there had been major left bank erosion in the preceding period, a large mid-channel bar (38B) developed adjacent to the Harrison Islands. This forced one branch of themainrivertoflowbetweentheHarrison Islands, establishing a sharp corner against Harrison Knob, at the mouth of Harrison River. Another branch flowed into former sloughs, establishing what has since become upper Minto Channel. By 1943, this left-bank branch had become dominant, so that the river performed a large S-bend (in effect, a well-defined meander) in front of Harrison River mouth (see inset map on the 1938 photomap). Continued sedimentation around Harrison Islands and on the mid-channel bar here consolidated a major sediment body immediately upstream of the mouth of Harrison River. The Minto Islands area (down-stream portion of subreach 7) is adjacent to the major settlement of Chilliwack. Photography from April, 1938 shows that the left hand channel about the islands (38A; modern lower Minto Channel), formed only within the preceding two decades, had already silted to the point that it was now only a summer channel. The river passed by the islands in a straight channel against the rock-bound right bank. (Greater details of the developments described in this paragraph are given in a report by Church and Weatherly, 1998.)

There were significant developments downstream as well. The small mid-channel bars at Queen's had grown extensively, though a low-flow winter channel remained along the right bank. Therewasalsosubstantial growth by 1938 of the mid-channel bar off Island 22 (38C). These developments forced the main channel hard against the left bank along Island 22, leading to 100 m of lateral erosion along a 1200 m length. The 1938 photomap also shows for the first time major bar accumulations at Wellington and Yaalstrick Islands, and near modern Webster Bar (38D). Sedimentation at Webster Bar was promoted by slack water after the main left-bank current was directed off the upstream end of Chilliwack Mountain toward the Yaalstrick Islands. As these bars have grown, erosion of adjacent islands and floodplain deposits (100 to 150 m) has occurred. Extensive mid-channel sedimentation downstream from Yaalstrick Islands (38E), in the downstream portion of subreach 5, promoted erosion up to 150 m on the adjacent left bank. and along the right bank further downstream. Much of the extensive bar sedimentation evident in the 1938 map probably dates from before 1928. The high flow depicted in 1928 having obscuredmuchbar detail.

c) 1938 - 1949

Following the developments described in the last paragraph, the 1949 photomap shows the main channel in the upstream part of subreach 7 along the left bank. At the upstream limit of the reach deposition on the site of earlier erosion (49A) represents the beginnings of Foster Bar. The channels amongst the islands at the mouth of Harrison River (49B)



silted up, leaving a single major Fraser River channel in front of Harrison Rivermouth. Harrison River had in effect extended its channel to join the main channel at the south corner of Harrison Knob. The Fraser channel still has a meander form, but it is less tight than in 1938 or 1943, the change having been accomplished by erosional trimming of the medial bar (49C1) and compensating sedimentation on the Minto Islands side (49C2). The 1949 scene shows the completion of the processes of the preceding 21 years, the erstwhile mid-channel bar (49B) having become part of a large, right bank bar Harrison Bar immediately upstream of the Harrison mouth. These changes led to a substantial reduction in flow through the Minto Islands so that extensive siltation occurred there. The source of the sediments that were deposited in Harrison Bar and between the Minto Islands was the upstream erosion in the preceding years at Greyell Island and Carey Point.

In subreach 6, continuing sedimentation occurred at Queens Bar (49D), the material being moved downstream from the Harrison Bar area. By 1949, there was only a summer channel to the right of the bar so that it had essentially become the right bank lateral bar it still is today. The sedimentation caused further erosion of the left bank on Island 22. At the downstream end of subreach 6 the channel was extensively reorganized between 1928 and 1949 at Wellington Bar (note that 1938 photos do not cover this area). Whilst the bar and islands there had significant channels on both sides in 1928, by 1949 the left bank channel was much reduced and a new channel had cut through the middle of the bar, eroding away much of the preexisting island group (49E). This channel itself divided into two branches, with most water being directed toward the left bank, where it encountered the non-erodible shore at Chilliwack Mountain. These developments directed substantial flow toward the Yaalstrick Islands, causing considerable erosion there (49F). The right bank channels at Yaalstrick Islands was also active in this period as the result of water being fed in from the right-bank channels at Wellington Island (49G) so that there was substantial net loss from the islands. There was also further sedimentation on the left bank in front of Chilliwack Mountain (Webster Bar, near 49F), the material being derived from changes at Wellington Bar. The lower end of Yaalstick bar continued to expand downstream (49H). An additional 300 metres of lateral erosion along the left bank is not clearly associated with this bar growth, but probably occurred in preceding years when local channel alignment was more directly onshore.

There were significant changes throughout this reach between 1928 and 1949, implying that there was a relatively high transfer of sediment through the reach, but much sediment was also mobilised within the reach as the result of the major changes in the vicinity of Harrison River. It is interesting to note that most of the observed changes occurred in the first decade (to 1938) despite the passage of the 1948 flood. This illustrates that, although big floods may transfer large volumes of sediment, significant changes in channel alignment occur slowly over years to decades.

d) 1949 - 1962

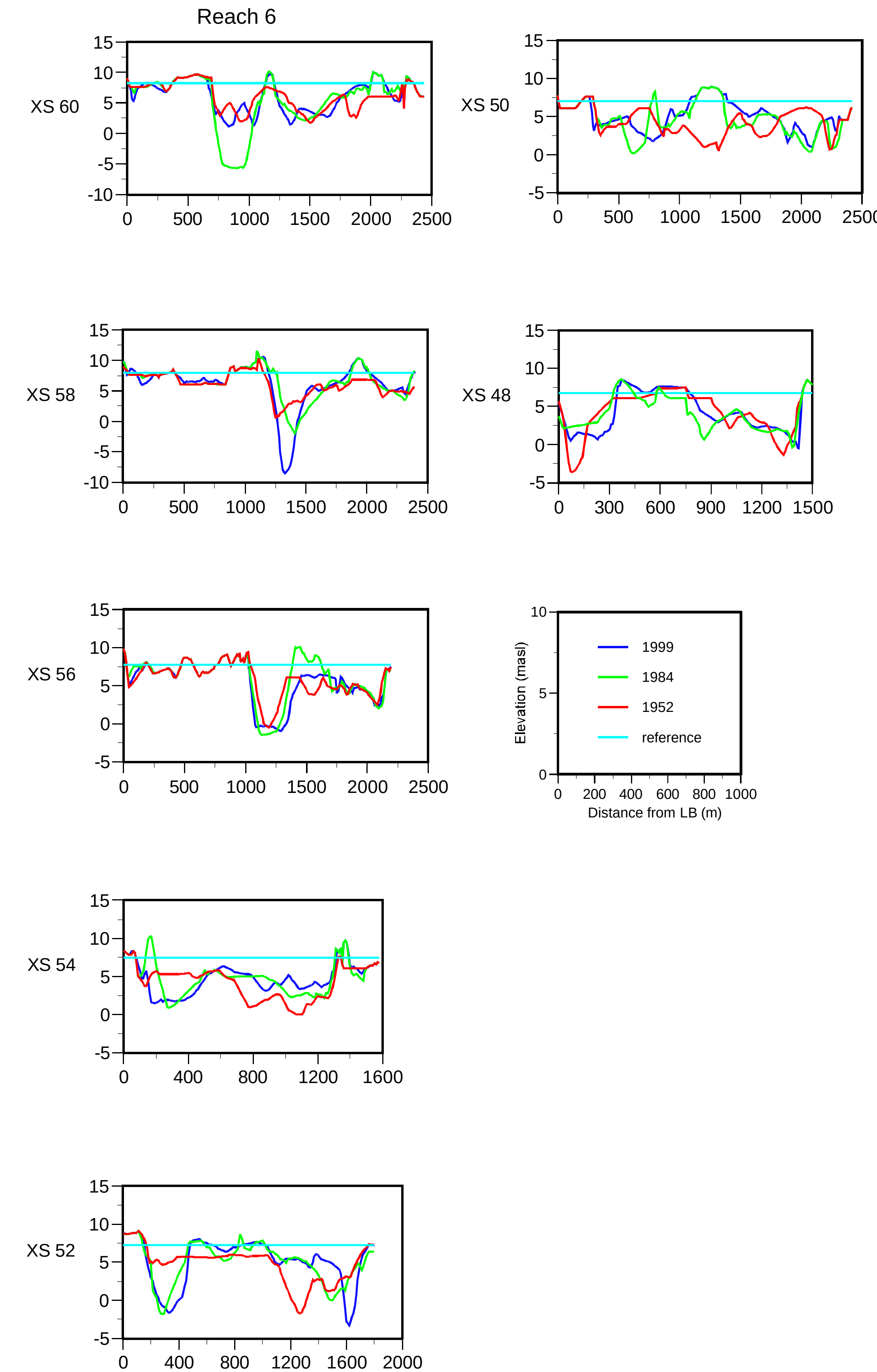
Between 1949 and 1962, trends established in the preceding period persisted. Foster Bar grew modestly, forcing the river to begin eroding into the Harrison bar (62A). Some of the eroded material was deposited at the riverbend around the bar (62B), promoting erosion of the left bank and renewed tightening of the river bend at the head of the Minto Islands. (The river moved back toward the configuration it had in 1943, with upper Minto Channel remaining a part of the main channel.) This brought the river against Harrison Knob, where it was forced to resume the 1949 alignment. As the result, the succeeding 8 km reach, to the tail of Wellington Bar, experienced relatively little change throughout the period. (Flow is relatively high in the 1962 photos, so that substantial apparent reduction in bar areas appears to have occurred, but is simply an artifact of the water level.) At Wellington Bar, the right bank channel captured the larger part of the flow during the 1950s, whilst mid-channel sedimentation at the tail of Wellington Bar (62C) held the flow against the right bank so that rapid erosion of the Yaalstrick Islands continued.

Persisting in its alignment along the Yaalstrick Islands, the river also effected erosion of Webster Bar at Chilliwack Mountain (62D) and continued to erode the left bank downstream (62E). Up to 150 m of land was lost there and the bank has subsequently been riprapped to discourage further erosion. During this period, it appears that the Harrison confluence area was becoming a choke point for sediment movement downstream, so that the several kilometre reach below that point experienced only limited sedimentation or erosion.

e) 1962 - 1971

During the period 1962-1971, Foster Bar grew dramatically (71A), much of the sediment probably deriving from the actively eroding Gill Islands area upstream (71F: Herrling Island to Cary Point map). This activity pushed the entrance to upper Minto Channel, then the main channel, downstream. It was thereby forced into Harrison Bar, leading to major erosion of the bar. The eroded material was deposited on the left side of Harrison Bar a short distance downstream (71C), forcing the left bank channel into a more contorted configuration, and increasing the flow spilling into lower Minto Channel. At this stage, there was the possibility that lower Minto Channel might have become the main channel of the river. However, sedimentation at Foster Bar also pushed the main channel to the right, initiating the development of a deep channel against the right bank (see XS76). Water directed along this bank promoted the reopening of the right bank channel behind Harrison Bar (71B) and considerably relieved the high flow conveyance in the left-bank channels. It is likely that the right-bank channel reopening was also encouraged by high flow resistance through the tight bends, leading to backwater and high water levels near the channel entrance. Flow came together again at the tip of Harrison Knob and, with the main channel still guided by the Knob, there was again little change in the ensuing 5 km, to lower Queen's Bar. During the period of stability past Queen's Bar and Island 22, there was a deep central channel (XS58, 60).

The channel alignment past Queen's Bar encouraged flow into the left arm about Wellington Bar, promoting sedimentation in the right arm (71D; see also XS52) and sedimentation near the left bank immediately upstream of Chilliwack Mountain to establish Grassy Bar (71E). This development, as well as the right bank alignment adopted by 1962, discouraged further major erosion at Yaalstrick Islands (71F). A notable part of this development was the stabilization of the secondary channels behind the islands. However, by 1971 it was clear that a very long



diagonal riffle had developed across the river from Queen's Bar to Chilliwack Rock (the downstream end of Chilliwack Mountain: 71H) so that the river became very shallow through this reach. Significant sediment accumulated below the riffle (71G) and there was some erosion of the bars on the left bank side. However, the channel zone generally remained stable through this period in the distal part of subreach 5.

f) 1971 - 1983

At Harrison Bar, the major flood of 1972 caused the river to shift back into the right bank channel (83A) it had partly occupied much earlier in the century (refer to 1912 banklines on 1928 photomap), whilst the highly sinuous left bank channel proceeded to silt up (83B). Significant erosion occurred on the old islands near the mouth of Harrison River while vegetation extended over the bar surface to the south. These developments set in train the amalgamation of Harrison and Minto Islands into a single “super-island”, and assured that the Minto Channel would remain a secondary channel for decades to come. However, it also established two sharp corners at the mouth of Harrison River and at the corner of Harrison Knob, substantially increasing flow resistance and upstream backwater, and also inducing lateral flow oscillation downstream. The initial result of this was increased sedimentation immediately downstream of the Harrison Knob corner at Calamity Bar (83C), but the longer term consequence was the beginning of movement of the main channel to the left (see XS66). At this time, the ensuing 4 km to Queen's Bar still remained stable. In the longer term, significant sedimentation occurred on the upstream end of Minto Island, on what is known as the modern Harrison Bar (83A).

At Wellington Bar, some reconfiguration of the islands occurred, with both erosion and sedimentation. Renewed erosion on outer Yaalstrick Islands (83D) indicates an increase in current attack in this area. The water level in the 1983 photos is too high for the causes to be discerned in detail, but XS44 shows a dramatic rightward shift in the deepwater channel location. In fact, a significant chute developed through the diagonal bar at 83E, directing flow from the left channel branch directly toward the islands. At Lower Yaalstrick, high surfaces were eroded (83F) but there was continued sedimentation onto bars at lower elevation.

g) 1983 - 1991

By 1991, an island was well established at Foster Bar, but sediment was added to the bar edge. Substantial sedimentation occurred on modern Harrison Bar, so much so that the major island (91A) was consolidated here during the decade. The massive erosion at Carey Point fed these developments and the choke represented by the sharp river bends at the Harrison River mouth encouraged sediment deposition. Vegetation also prograded at the upstream end of the Minto Islands as summer channels through the islands silted up. Calamity Bar developed significantly in this period (91B) but the channel downstream otherwise continued to be stable through the 1980s, a period of dominantly low floods.

Upper bar surfaces were not so frequently inundated during the decade and significant extension of vegetation is evident on Queen's and Wellington Bars as well. Below Wellington Bar, flow continued to impinge on the outer Yaalstrick Islands (91C), and continued erosion occurred at a modest rate. At Lower Yaalstrick, island formation began with the main channel passing to the left (see XS38). Low floods during the 1980s created the conditions for substantial island establishment and extension during this period since bartop vegetation was left to develop relatively undisturbed.

h) 1991 - 1999

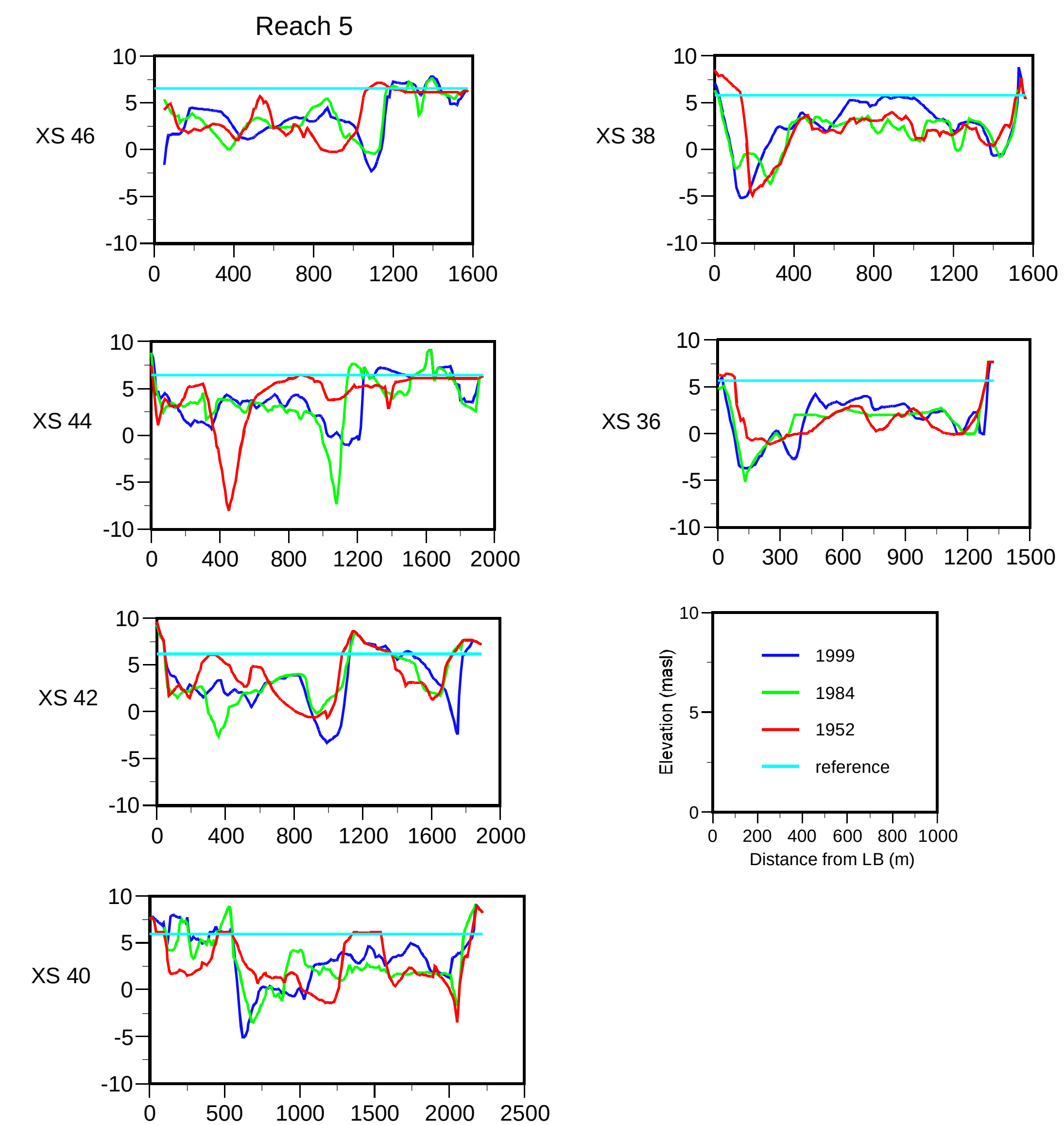
During the 1990s sedimentation persisted at Harrison Bar, which had now become a part of the Minto superisland, with the channel to the right of it. Foster Bar essentially became a part of the overall sedimentation zone upstream of the Harrison River confluence, with upper Minto Channel reduced to being a summer channel across the bar surface (99A). Calamity Bar grew substantially and the flow oscillation established by the corner at Harrison Knob made itself evident by erosion on Minto Island opposite Calamity Bar (see XS66 for lateral channel movement) and corresponding deposition 1 km downstream in a new left-bank lateral bar (99B: known, at this writing, as Bar “N”). A further part of this phenomenon was the inception of erosion along upper Queen's Bar (99C) after several decades of stability and the growth of a lobe of sediments downstream along the edge of Queen's Bar. That, in turn, pushed the river left so that a deep channel formed along the Island 22 bank (XS58) and erosion of the bank was initiated. This instability may be expected to propagate farther downstream. The wavelength of the transverse oscillation (measured to the downstream end of Wellington Bar) is 4.8 km, giving a ratio to channel width of about 9.5 not significantly different than that observed in the Spring Bar-Hunter Creek reach upstream, so it is apt to represent a stable meander mode of the river. Sometime between 1984 and 1999 significant deepening also occurred in Minto Channel (see XS66 - 62), but there were no significant changes in position.

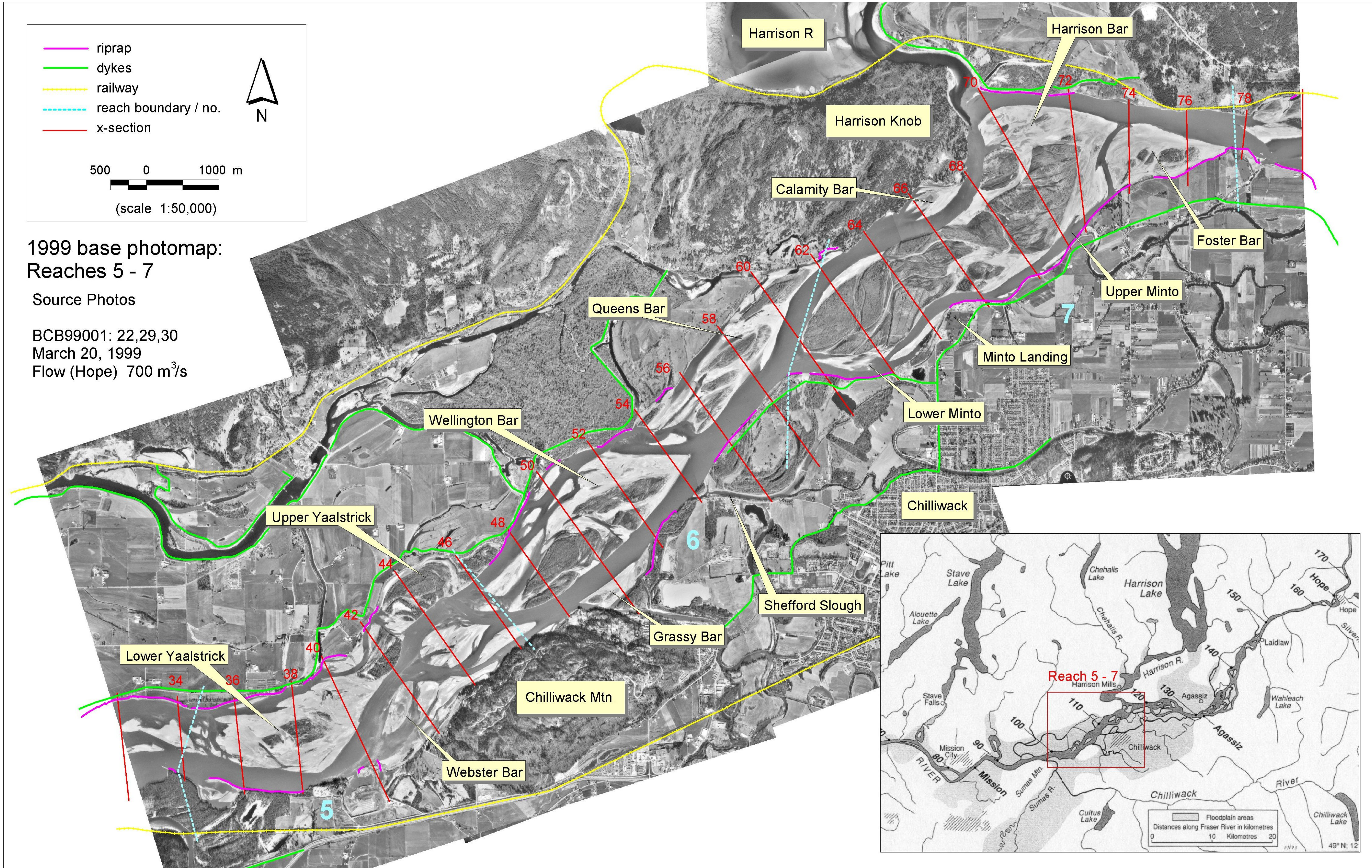
At Wellington Bar the extension of the island continued, expanding the island area. The left channel was clearly dominant and continued to swing across the major riffle below Wellington Bar to attack Yaalstrick Islands (99D). However, the main channel past the Yaalstrick Islands was now firmly established on the right hand side of the channel, so the extensive area of sedimentation in front of Chilliwack Mountain (99E: Webster Bar) was beginning to consolidate into a very large lateral bar. Lower Yaalstrick Bar (99F) now formed an equally large lateral bar on the right bank with an established island core so the channel became markedly sinuous here as well. However, there was very limited erosion of outer channel banks during this period.

i) Summary

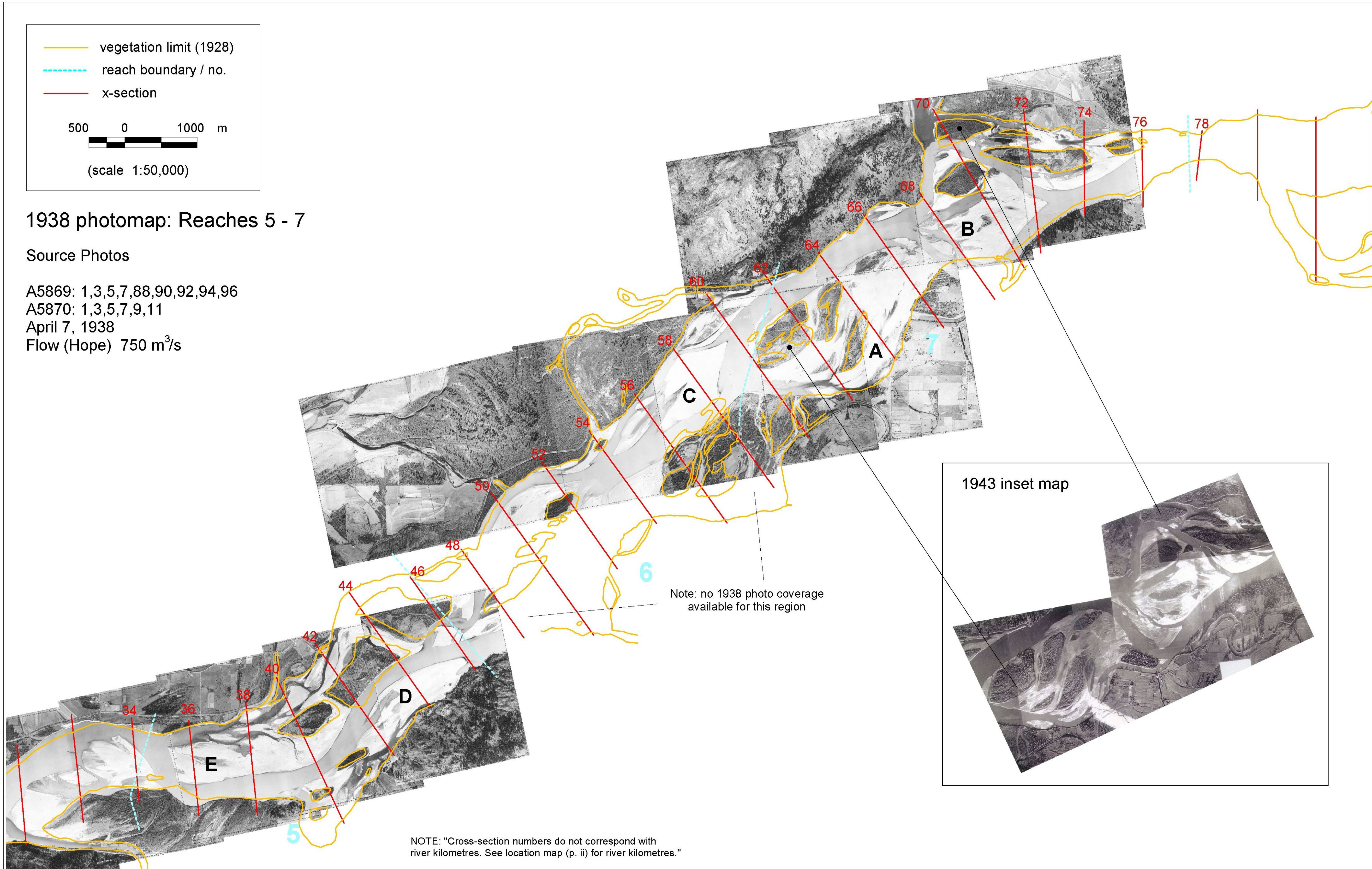
In subreach 7 there have been dramatic changes over the period of study, including major sedimentation above Harrison River confluence, repeated realignment of the main channel, and the eventual consolidation of Minto Islands and and Harrison Bar into a single “super-island”. For much of the period, the river was unusually stable between Harrison Knob and Wellington Bar, probably because of limited bed material passage at the mouth of Harrison River. At present, the river is forced into two sharp corners around Harrison Knob, created high flow resistence and upstream backwater while, downstream, the river has begun to oscillate with wavelength about 4.8 km another indication of limited sediment input. However, the oscillation mobilizes material from eroding banks as the bends develop, so that meander-style instability is now developing in lower subreach 7 and subreach 6.

Wellington Bar is a persistent mid-channel feature, but there have been repeated flow switches about it. These several realignments of the main flow about Wellington Bar have contributed to continuing instability in the Yaalstrick Island - Chilliwack Mountain area (upper subreach 5), which includes persistent direct attack on the Yaalstrick Islands in recent decades. However, the outer banks of the river, now extensively riprapped, have remained relatively stable in most places since 1949. In the most recent decade, lateral bar developments in subreach 5 have also established a 5 km meander scale, but the current morphology is one-half cycle out of phase with that upstream. This circumstance, and further development of the transverse oscillations, promise continued instability in subreaches 5 and 6.




riprap
dykes
railway
reach boundary / no.
x-section
N
500 0 1000 m
(scale 1:50,000)
1999 base photomap:
Reaches 5 - 7
Source Photos
BCB99001: 22,29,30
March 20, 1999
Flow (Hope) 700 m3/s
Harrison R
Harrison Bar
Harrison Knob
Calamity Bar
Foster Bar
Upper Minto
Minto Landing
Lower Minto
Queens Bar
Wellington Bar
Upper Yaalstrick
Lower Yaalstrick
Chilliwack
Shefford Slough
Grassy Bar
Chilliwack Mtn
Webster Bar
5
6
7
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
Reach 5 - 7
Harrison Lake
Harrison R.
Harrison Mills
Chilliwack
Agassiz
Hope
Laidlaw
Mission City
Mission
Stave Lake
Alouette Lake
Pitt Lake
Chehalis Lake
Chehalis R.
Stave Falls
Sumas Mtn.
Sumas R.
Cultus Lake
Chilliwack River
Chilliwack Lake
Wahleach Lake
Silver
Floodplain areas
Distances along Fraser River in kilometres
0 10 Kilometres 20
49° N; 12


vegetation limit (1912)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1928 photomap: Reaches 5 - 7
Source Photos
A288: 45,51,53,54,56,58,60,62,64,66
A296: 34,36,38,39,41,43,45
July 15, 1928
Flow (Hope) 5780 m³/s
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
A
B
C
D
E
F
5
6
7
NOTE: "Cross-section numbers do not correspond with river kilometres. See base map (p. ii) for river kilometres."
In addition, many small displacement errors remain because of registration difficulties with the 1912 base map. Only major movements in bankline position should be accepted as real.


vegetation limit (1928)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1938 photomap: Reaches 5 - 7
Source Photos
A5869: 1,3,5,7,88,90,92,94,96
A5870: 1,3,5,7,9,11
April 7, 1938
Flow (Hope) 750 m^3/s
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
A
B
C
D
E
5
6
7
Note: no 1938 photo coverage available for this region
1943 inset map
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

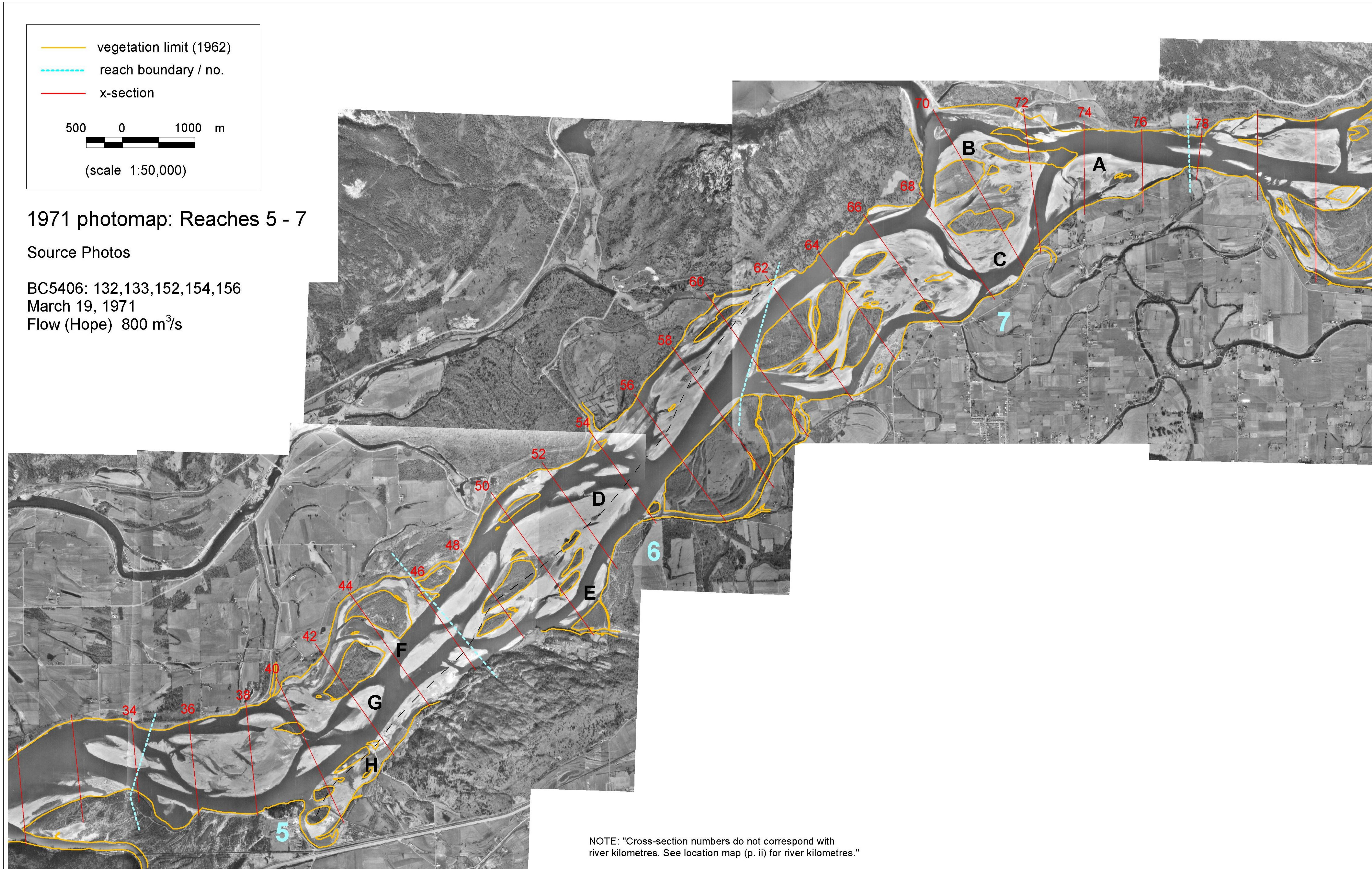
1949 photomap: Reaches 5 - 7

Source Photos

BC718: 29,30,32,34,35,37,39,41,42,44,46
March 28, 1949
Flow (Hope) 720 m^3/s

BC720: 107,109,111,113,114,115,116,118
BC721: 2,3,4,5,6,7,8,54,65,67,69,73,75
March 31, 1949
Flow (Hope) 730 m^3/s


vegetation limit (1949)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1962 photomap: Reaches 5 - 7
Source Photos
BC5042: 92,94,96,97
May 7, 1962
Flow (Hope) 2940 m^3/s
70
72
74
76
78
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
A
B
C
D
E
5
6
7
NOTE: "Cross-section numbers do not correspond with
river kilometres. See location map (p. ii) for river kilometres."


vegetation limit (1962)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1971 photomap: Reaches 5 - 7
Source Photos
BC5406: 132,133,152,154,156
March 19, 1971
Flow (Hope) 800 m³/s
A
B
C
D
E
F
G
H
5
6
7
34
36
38
40
42
44
46
48
50
52
54
56
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66
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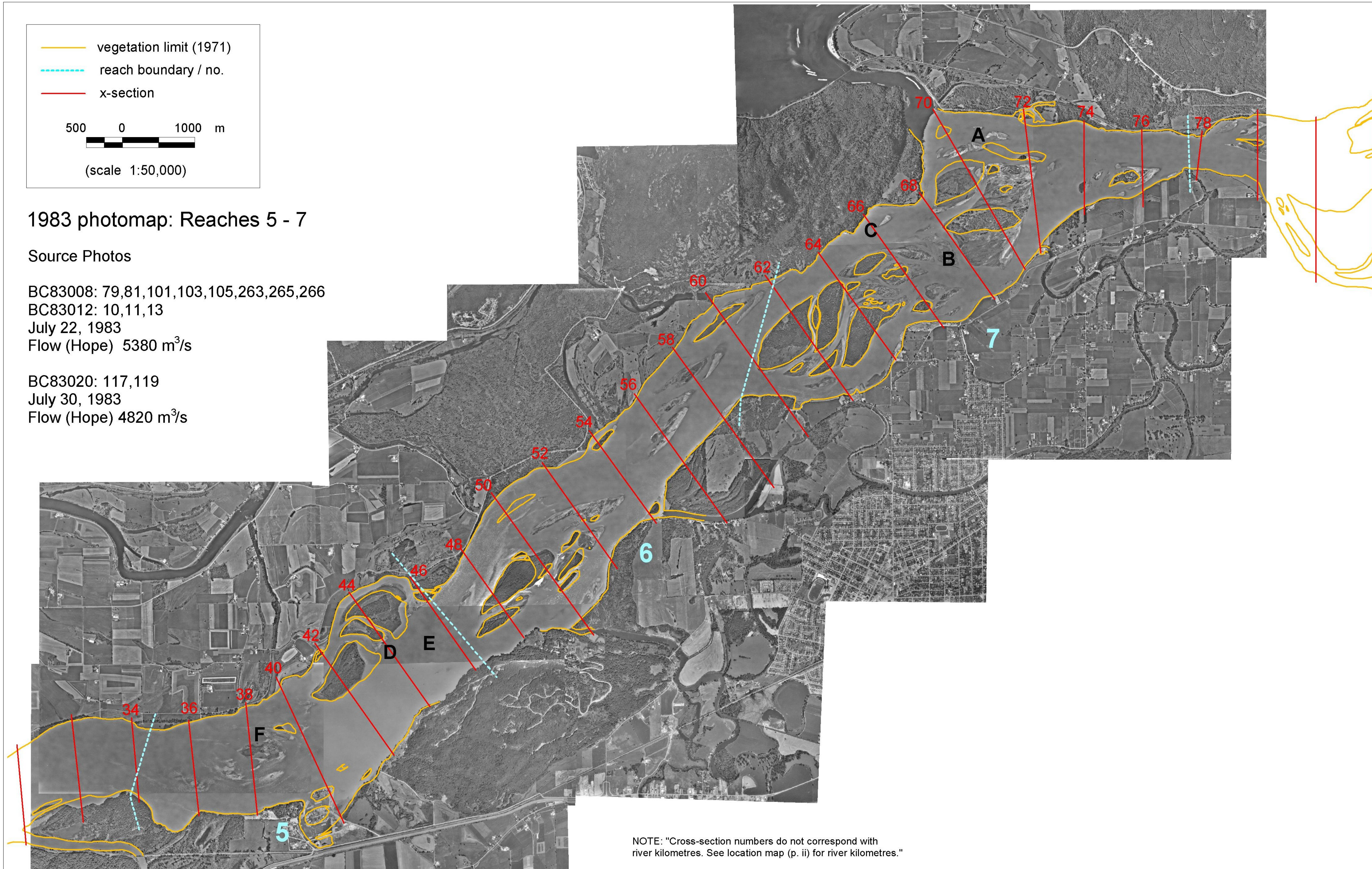
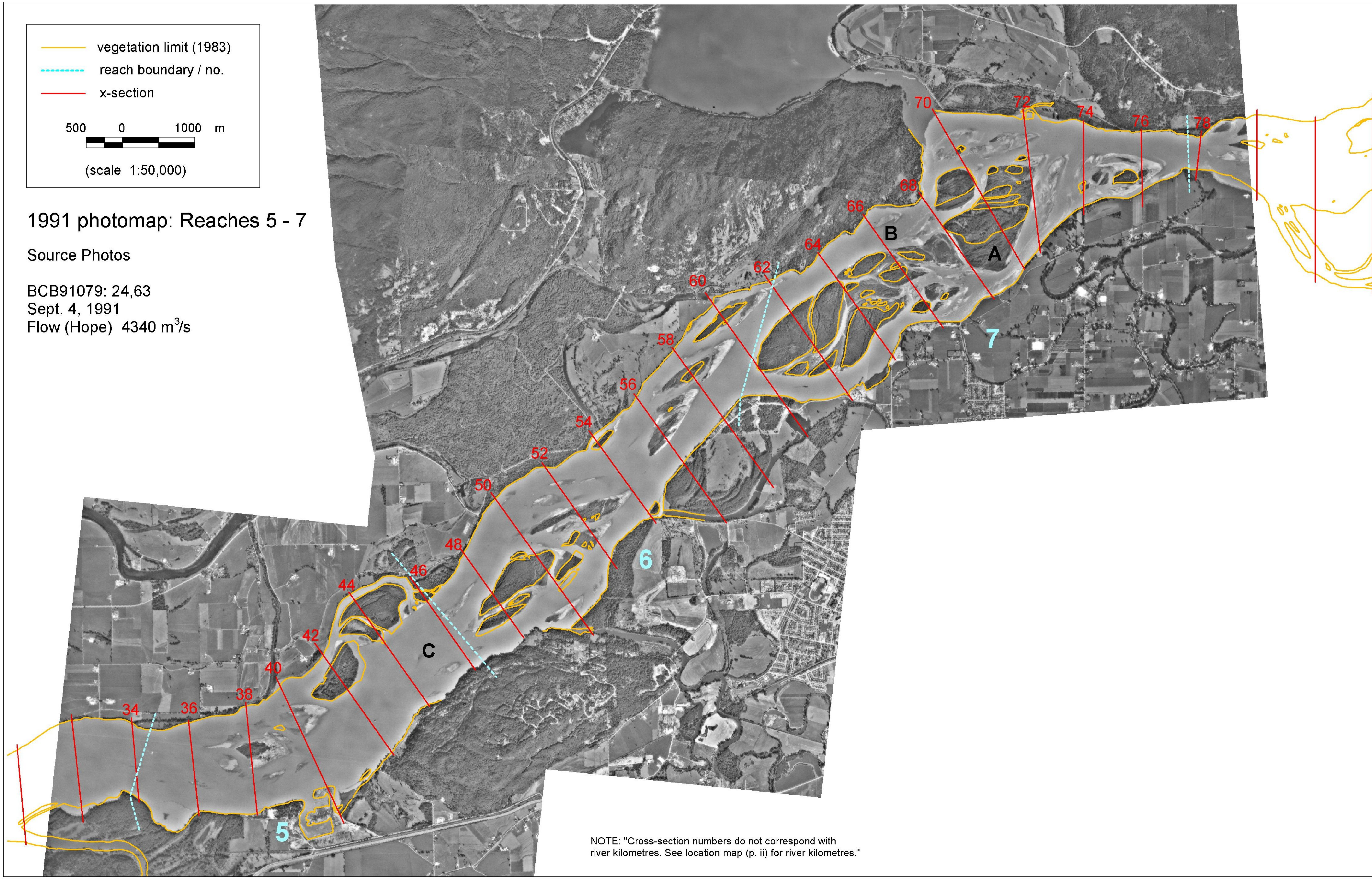
72
74
76
78
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."


vegetation limit (1971)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1983 photomap: Reaches 5 - 7
Source Photos
BC83008: 79,81,101,103,105,263,265,266
BC83012: 10,11,13
July 22, 1983
Flow (Hope) 5380 m³/s
BC83020: 117,119
July 30, 1983
Flow (Hope) 4820 m³/s
34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78
A B C D E F
5 6 7
NOTE: "Cross-section numbers do not correspond with
river kilometres. See location map (p. ii) for river kilometres."

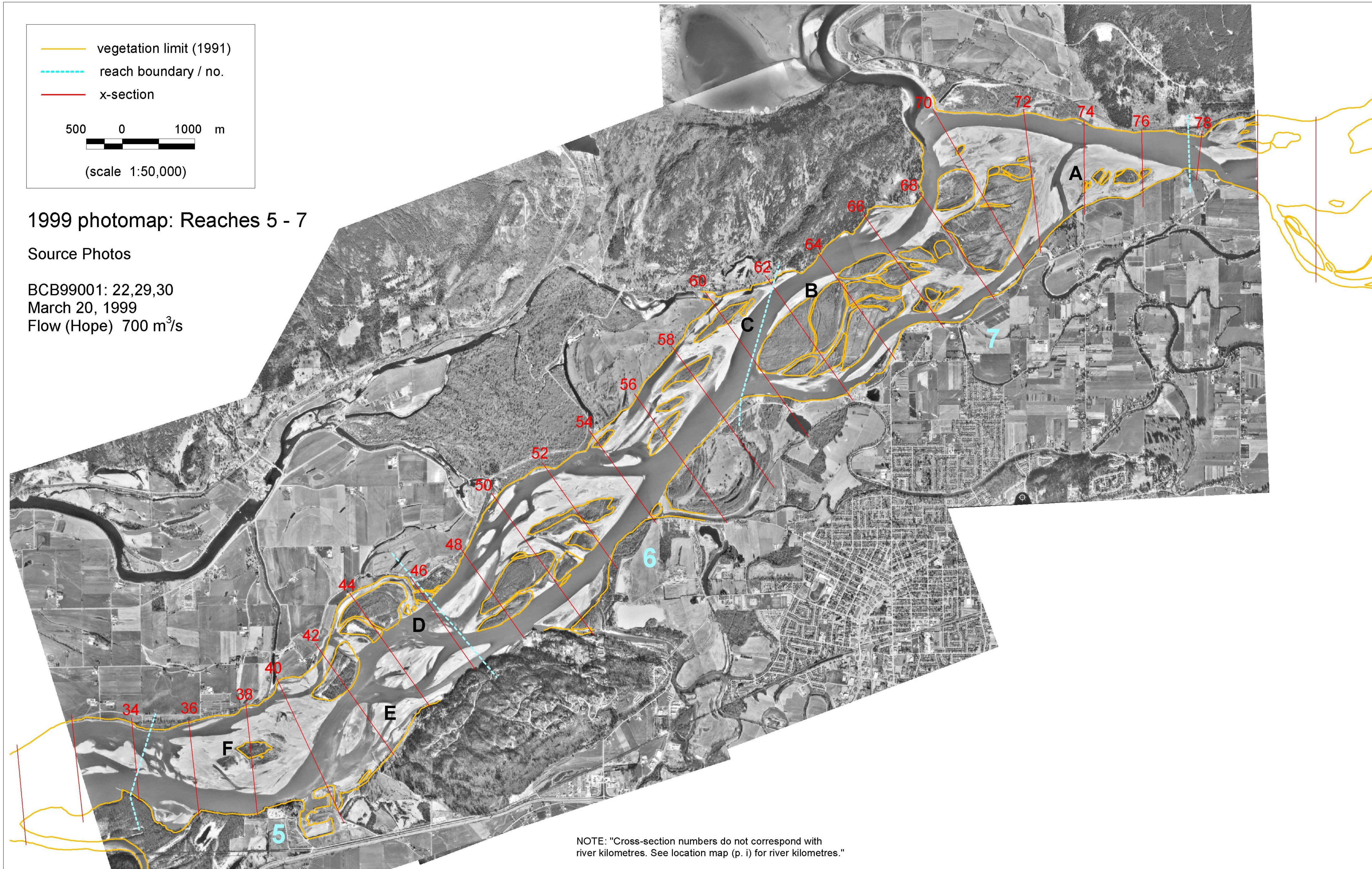
1991 photomap: Reaches 5 - 7

Source Photos

BCB91079: 24,63
Sept. 4, 1991
Flow (Hope) 4340 m^3/s



NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."


vegetation limit (1991)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1999 photomap: Reaches 5 - 7
Source Photos
BCB99001: 22,29,30
March 20, 1999
Flow (Hope) 700 m³/s
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
A
B
C
D
E
F
5
6
7
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. i) for river kilometres."


vegetation limit (1949)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1999 photomap: Reaches 5 - 7
1949 - 1999 comparison
Source Photos
BCB99001: 22,29,30
March 20, 1999
Flow (Hope) 700 m³/s
A
B
C
D
E
F
5
6
7
34
36
38
40
42
44
46
48
50
52
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NOTE: "Cross-section numbers do not correspond with
river kilometres. See location map (p. i) for river kilometres."

Reaches 1- 4 (Vedder River to Mission Old Bridge)

In these reaches the river undergoes the transition from multi-thread, gravel-bed channel to dominantly single-thread, sand bed channel. The channel-pattern transition occurs near the mouth of Nicomen Slough (river km 97), but gravel persists in the bed sediments into the upstream limb of Matsqui Bend (km 90). It is possible that over the course of the 20^{th} century, there has been downstream progradation of the gravelwedge.

a) 1912 - 1928

The river in 1912 appears to have had the same general alignment as today with the main exceptions that there was a substantially larger reentrant at the mouth of Vedder (Chilliwack) River and that the main channel occupied the area known today as Strawberry Island. Between 1912 and 1928 significant sedimentation occurred in both these areas, with compensating erosion on the opposite bank of the river. At the mouth of Vedder River, in subreach 4, sedimentation over an area of 88 ha displaced the tributary mouth downstream by 1 km (28A), whilst erosion of up to 600 m occurred along a 3.9 km stretch on Nicomen Island (28B) (115 ha lost). Five kilometres downstream, at the mouth of Nicomen Slough, bar sedimentation created the foundation for Strawberry Island (28C) whilst, on the opposite bank, erosion of up to 450 m occurred along 3.75 km of floodplain in front of Sumas Mountain (28D; 59 ha). Much of the material at Strawberry Island probably came from area B. These processes represent the intrusion of fine gravel into subreaches 3 and 4 and appear to represent fresh disturbance. Farther downstream, there was erosion on the left bank on both limbs of Matsqui Bend, amounting to bank line retreat of up to 100 m in the period, and minor erosion on the right bank in subreach 1. Otherwise, subreaches 1 and 2 were stable, implying that material eroded from area D was either distributed over the bed of the river or was evacuated from the reach. It likely was largely sand. In these reaches the river has a dominantly sand bed and sand banks with significant vegetative reinforcement. At Mission, the railway bridge had been in place since the end of the 19^{th} century with strong bank reinforcement holding the river in position.

b) 1928 - 1940

Between 1928 and 1940, minor erosion occurred of the recently deposited sediment body at the mouth of Vedder River, but there continued to be erosion, averaging about 100 m along a 2 km front, on the right bank opposite (40A) as mid-channel gravel bars grew downstream into the reach from Yaalstrick Islands. On the opposite bank (40B), minor erosion occurred on the upstream limb of the remaining floodplain remnant in front of Sumas Mountain. In subreach 3, Strawberry Island became well-established with immature vegetation extending over a growing area and a bar beginning to extend upstream. Minor erosion (less than 50 m) occurred on the upstream limb of Matsqui Bend (40C), as would be expected for this position on a regular river bend. Otherwise, subreaches 1 and 2 remained stable.

c) 1940 - 1949

From 1940 to 1949, the channel shows remarkably little change despite the passage of the very large 1948 flood. No significant erosion is observed along outer channel banks or established islands. The main changes appear to be new sandy bar deposits at and near the mouth of Vedder River (49A) and downstream of the formerly eroded floodplain along the front of Sumas Mountain (49B). These deposits may have existed at the time of the 1940 photography but higher water levels on that date preclude confirmation. A large bar was by now fully formed on the upstream end of Strawberry Island and extended into the back channel (49C). The downstream portion of the backchannel carried Nicomen Slough drainage to the main river, as it does today, whilst sand bar growth occurred in the downstream lee of the island.

d) 1949 - 1962

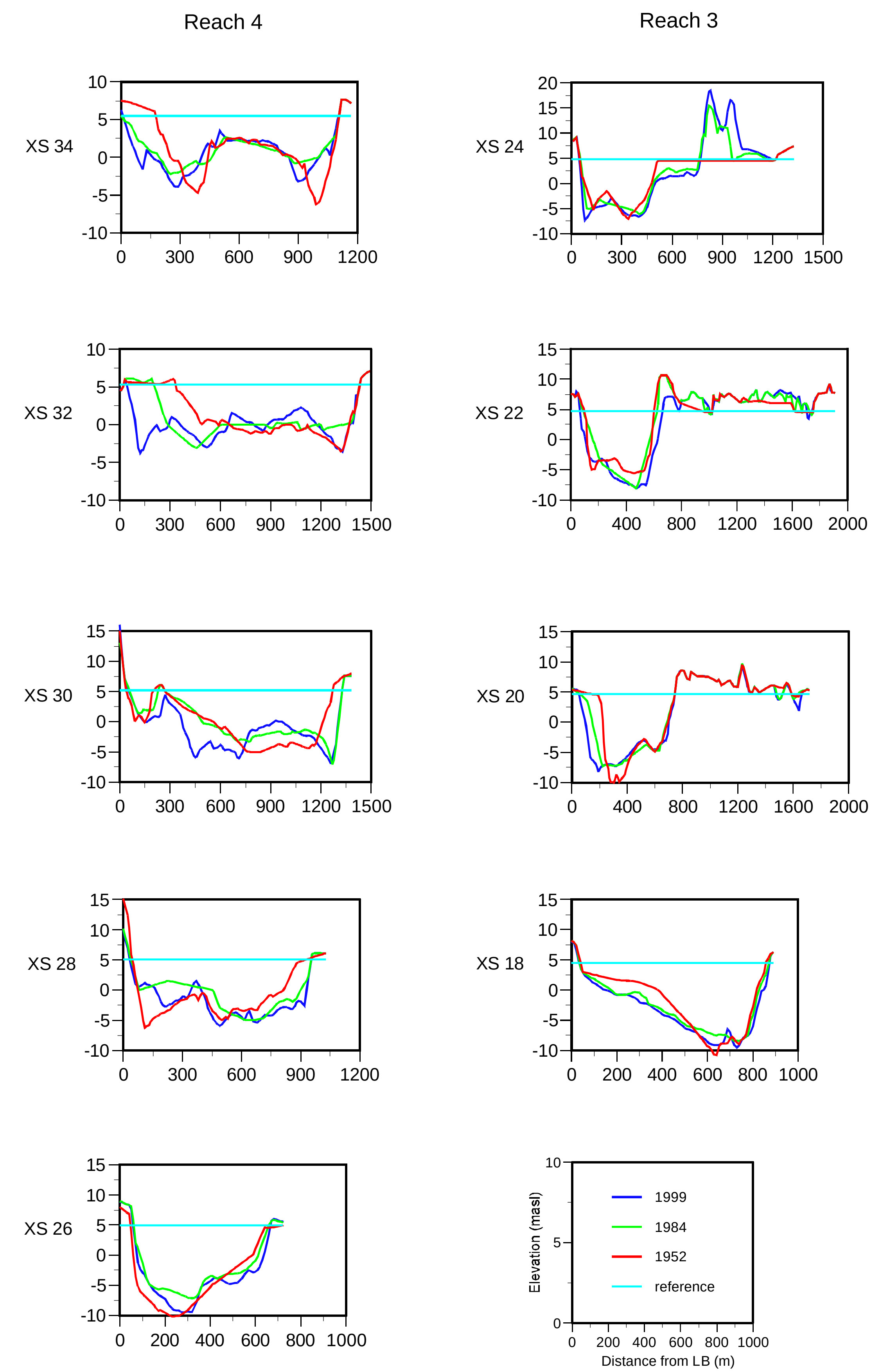
The 1962 map reveals only minor changes in the reach, with changes in detail of bars at the mouth of Vedder River, minor erosion at some points along Nicomen Island, further consolidation of Strawberry Island, and some erosion on the upstream limb near the apex of Matsqui Bend (see XS8 and 10). The channel behind Strawberry Island has been reduced to a summer channel. Stage is higher in the 1962 photomap than in 1949, and bar features are partly hidden.

e) 1962 - 1971

The 1971 map is again a low stage map and many of the bar features are revealed to be surprisingly unchanged from 1949 (see features at 71A and B). However, a newly developed bar appears for the first time in the channel opposite the downstream end of Sumas Mountain in subreach 2 (71C). XS14 reveals the feature to have been present, however, since before 1952 and not to be developing rapidly. Minor erosion is evident on the apex of Matsqui Bend but, by this date, the bend was protected by riprap.

f) 1971 - 1983

Stage is high in the 1983 photos and details of the relatively low bars are hidden. The only notable shoreline change occurred immediately upstream from the mouth of Vedder River, where an erosional “scallop” developed in the shoreline (83A). This oddly shaped development must be the consequence of offshore bar development (hidden from view) producing eddying flow along the shoreline. Minor erosion occurred again in front of Sumas Mountain (see XS20), which is rock-defended at the upstream end. Strawberry Island was, by this date, effectively amalgamated into Nicomen Island. The channel remained relatively stable in this period despite the occurrence of two major floods.



[g) 1983 - 1991]

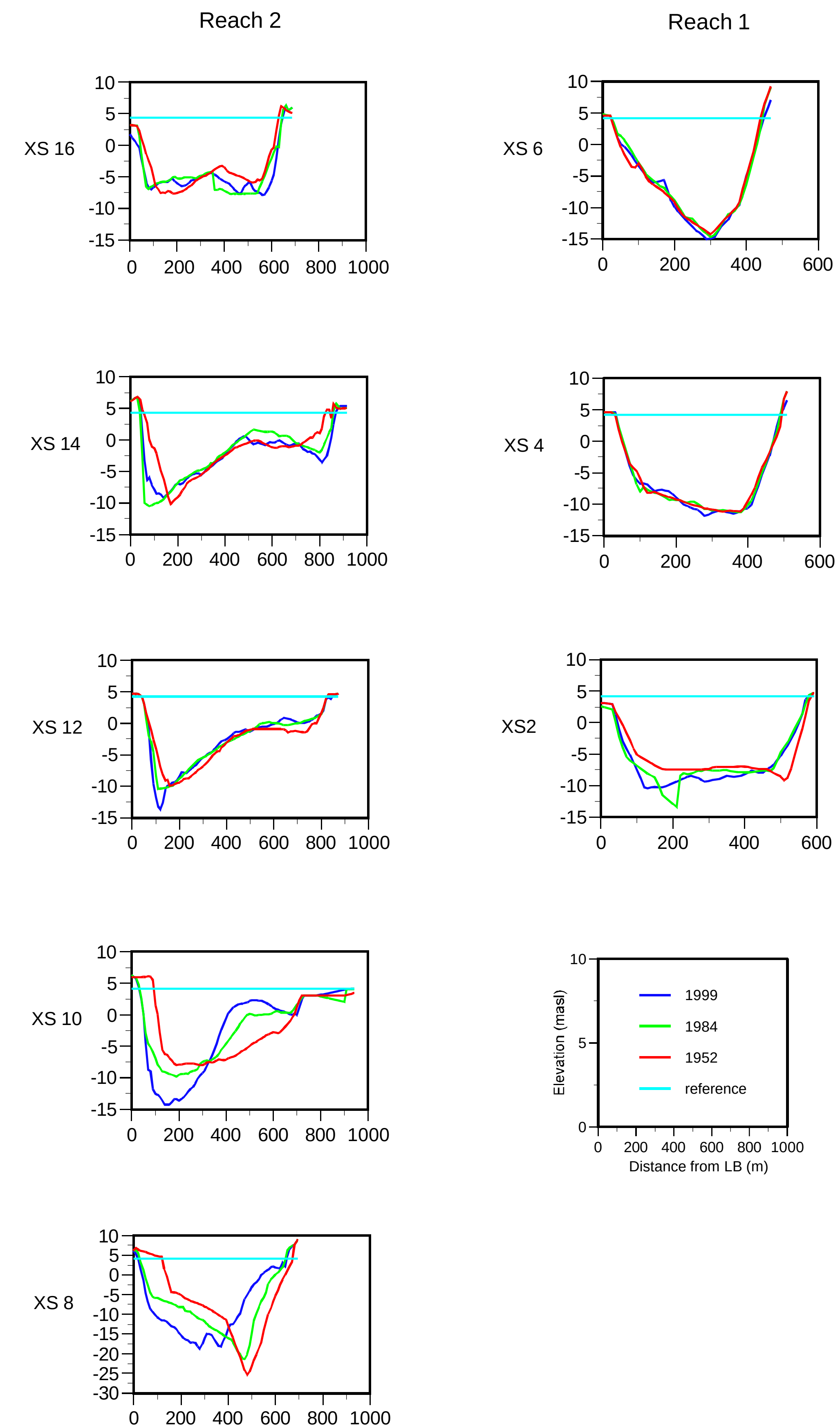
The 1991 map, again, reveals few details of bar deposits. By this date, however, there were extensive low bar deposits as far downstream as the mouth of Vedder River (see XS30-34) and continued erosion occurred near Vedder mouth (91A; well illustrated by XS32). Farther down-stream, an offshore bar appeared opposite the upstream limb of Matsqui Bend, extending downstream into the apex of the bend near the right bank. XS10 reveals this to be a new feature building significantly before 1984 and a 1979 low flow photograph shows an extensive sand dune field exposed in this location.

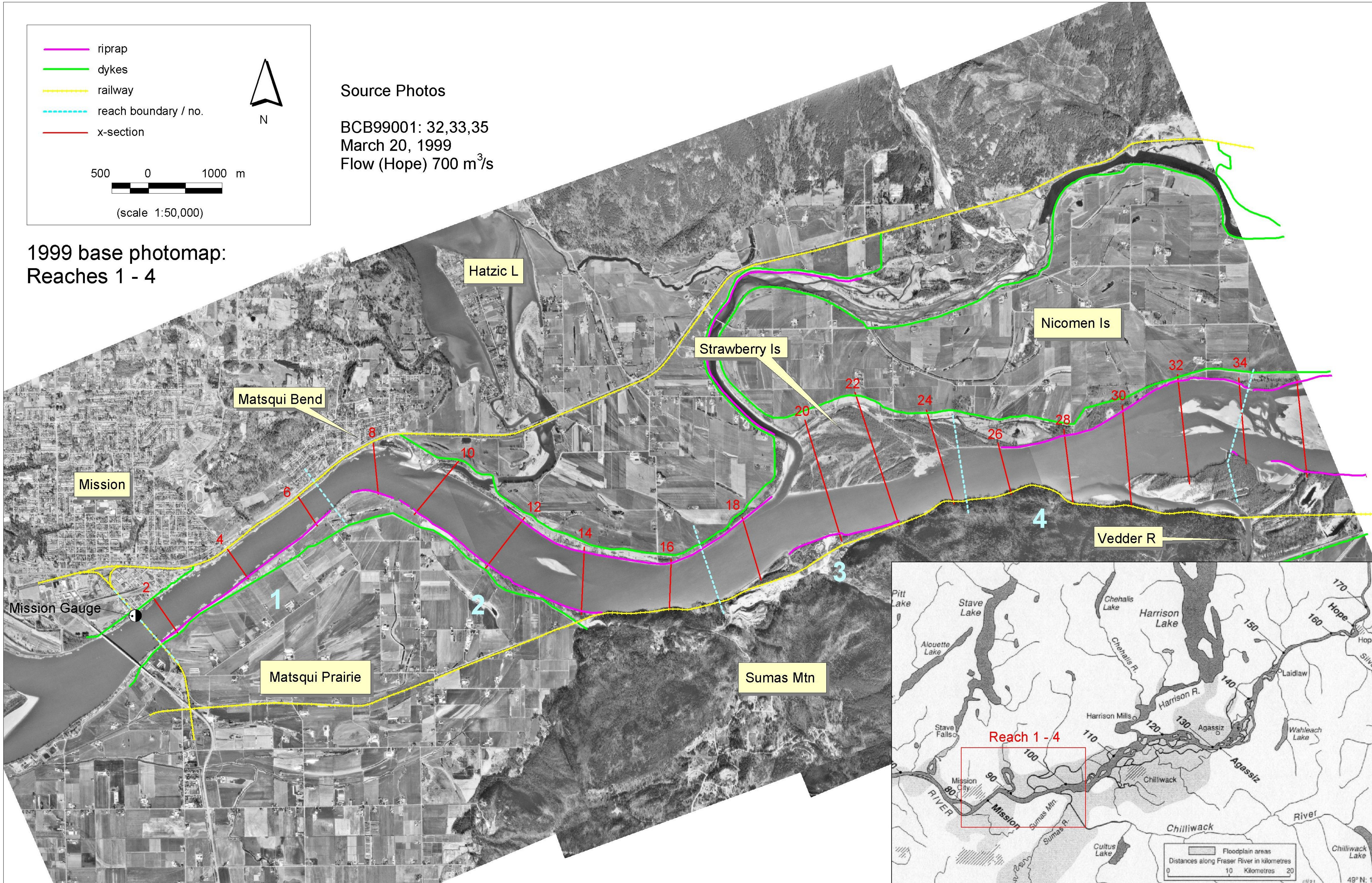
h) 1991 - 1999

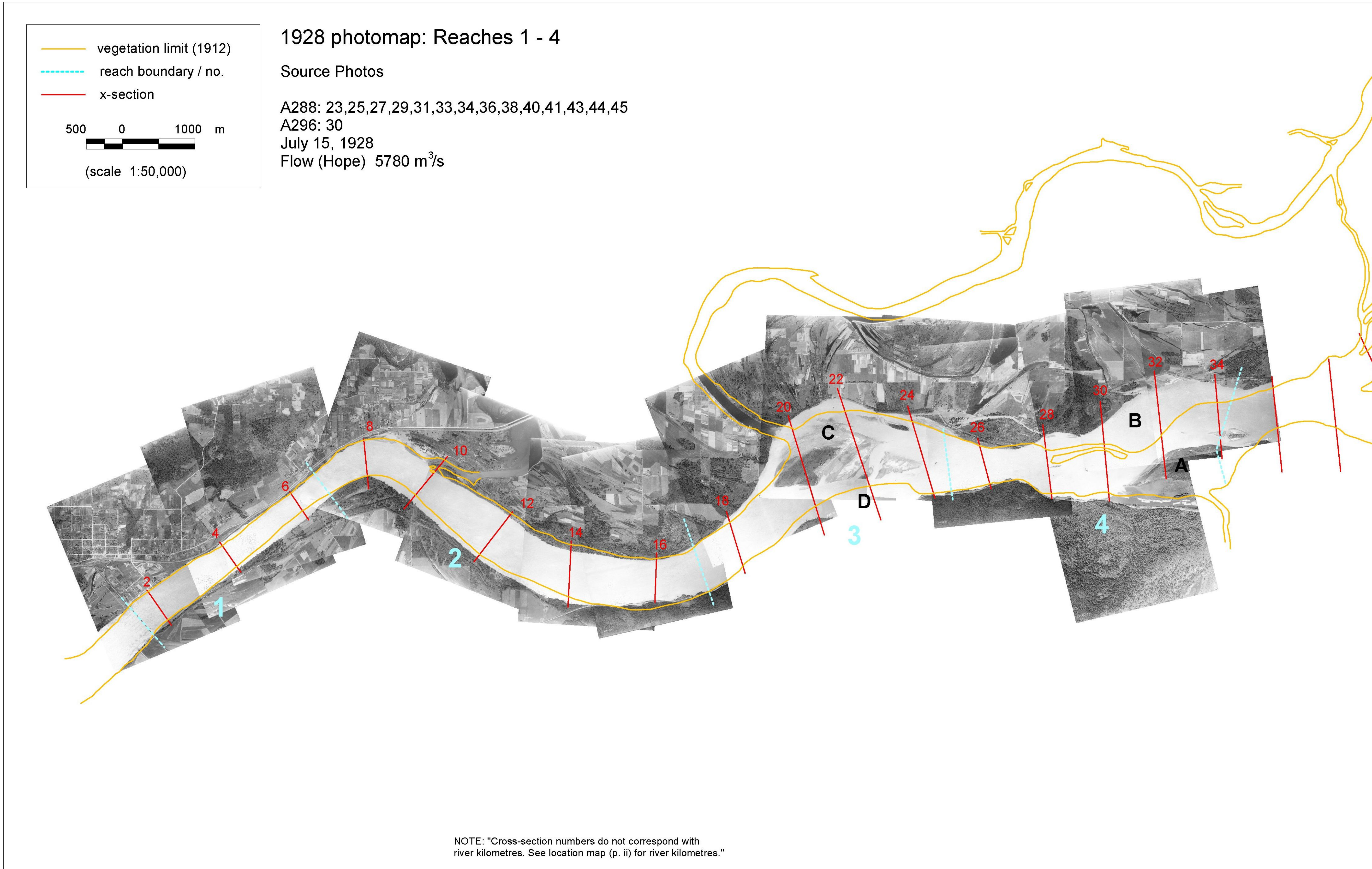
There was limited further change to 1999, with minor erosion near the mouth of Vedder River and an apparent extension of sedimentation in Matsqui Bend. The growth of the bar in Matsqui Bend has dramatically narrowed and deepened the channel here (see, especially XS10), moving the deep water toward the inside of the bend even at the bend apex (XS8). In response, small rotational failures have occurred on the left bank (see inset figure on 1999 photomap). These developments may portend future stability problems at the bend. The general stability of subreach 1 is evident by XS2-6.

i) Summary

The most significant changes in this reach of the river occurred before 1950. Since then, bank protection has played some role in the stabilization of the channel. Erosion and sedimentation appear to have been increasingly limited to bar features within the channel. The most notable feature of that development was the appearance of mid-channel bars in the upstream limb of Matsqui Bend. These are sandy gravel or gravelly sand deposits of the gravel/sand transition. Their appearance may signify downstream progression, by as much as 5 km, of the gravel limit during the 20th century. Restriction of sedimentation to the current channel zone has also encouraged compensating erosion in the thalweg (XS 8, 10, 12) which threatens to undermine the left bank at Matsqui Bend. Indeed, local slumping of the bank has been experienced here in the late 1990s.




riprap
dykes
railway
reach boundary / no.
x-section
N
500 0 1000 m
(scale 1:50,000)
Source Photos
BCB99001: 32,33,35
March 20, 1999
Flow (Hope) 700 m3/s
1999 base photomap:
Reaches 1 - 4
Hatzic L
Nicomen Is
Strawberry Is
Matsqui Bend
Mission
Mission Gauge
Matsqui Prairie
Sumas Mtn
Vedder R
1
2
3
4
Reach 1 - 4
Harrison Lake
Stave Lake
Alouette Lake
Pitt Lake
Chehalis Lake
Harrison Mills
Agassiz
Chilliwack
Cultus Lake
Chilliwack Lake
Wahleach Lake
Laidlaw
Hope
Mission City
Stave Falls
Floodplain areas
Distances along Fraser River in kilometres


vegetation limit (1912)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1928 photomap: Reaches 1 - 4
Source Photos
A288: 23,25,27,29,31,33,34,36,38,40,41,43,44,45
A296: 30
July 15, 1928
Flow (Hope) 5780 m3/s
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
1
2
3
4
A
B
C
D
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

1940 photomap: Reaches 1 - 4

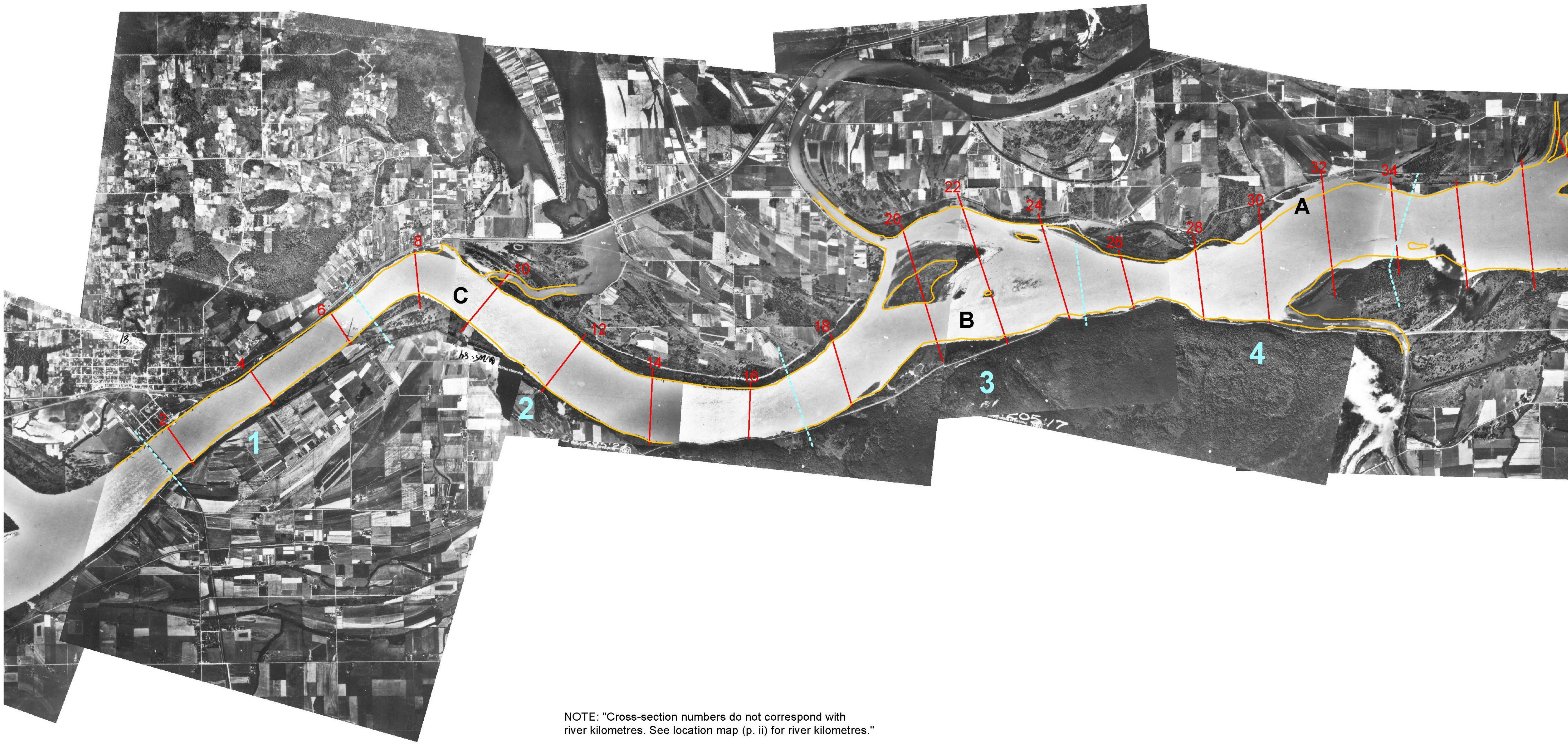
vegetation limit (1928)
reach boundary / no.
x-section

500 0 1000 m

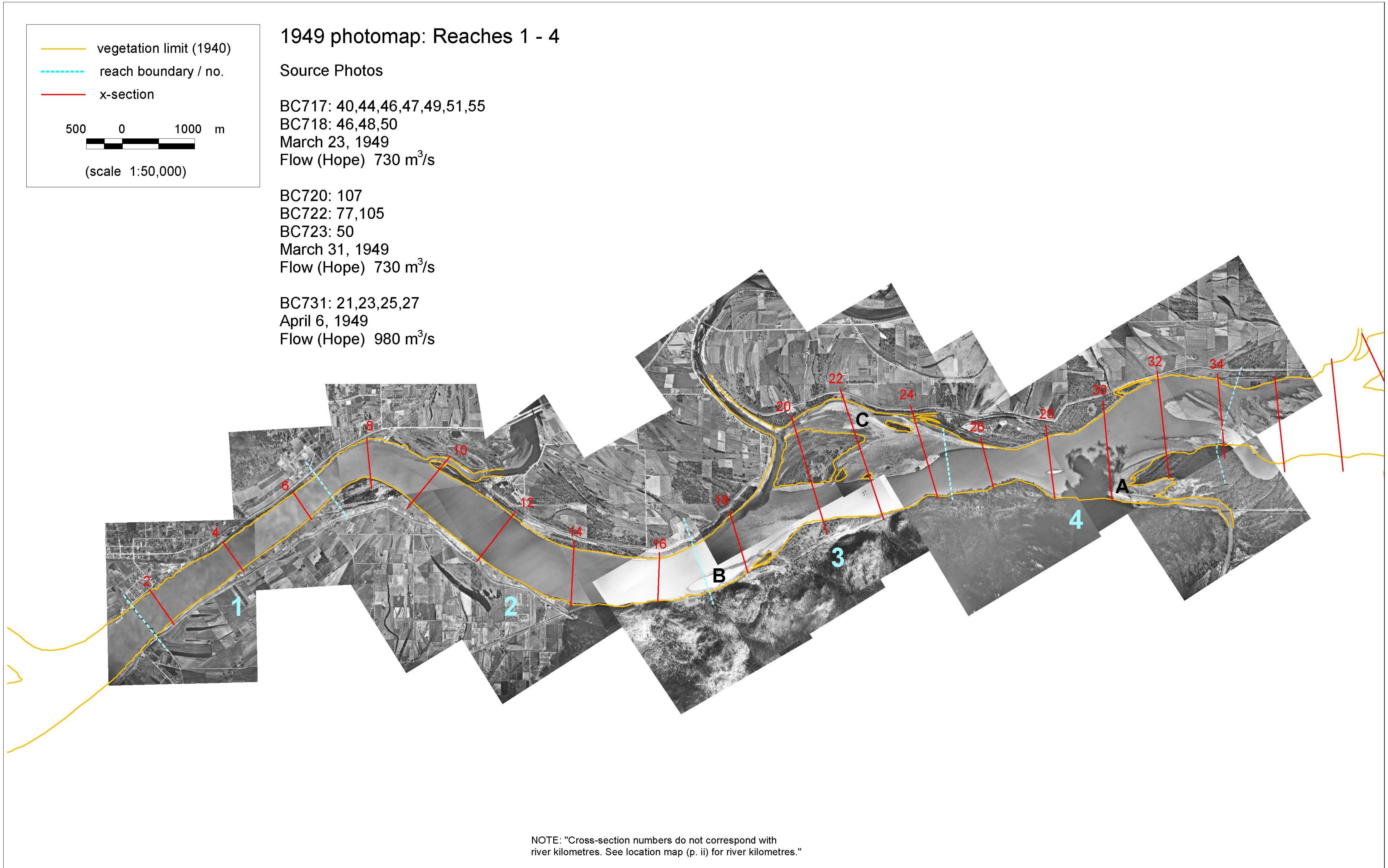
(scale 1:50,000)

Source Photos

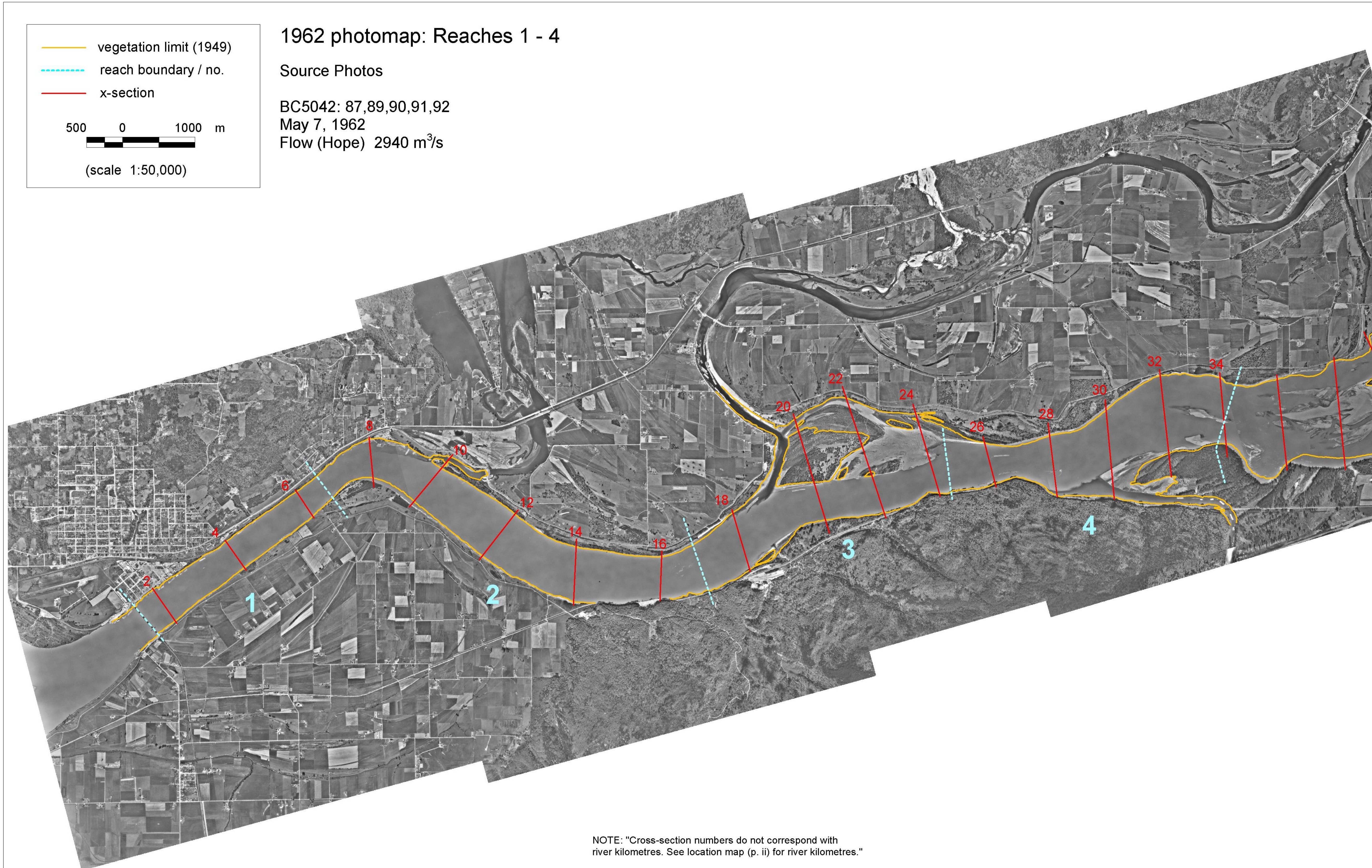
BC205: 15,17,19,21,23,25,81,84
July 15, 1940
Flow (Hope) 4870 m^3/s



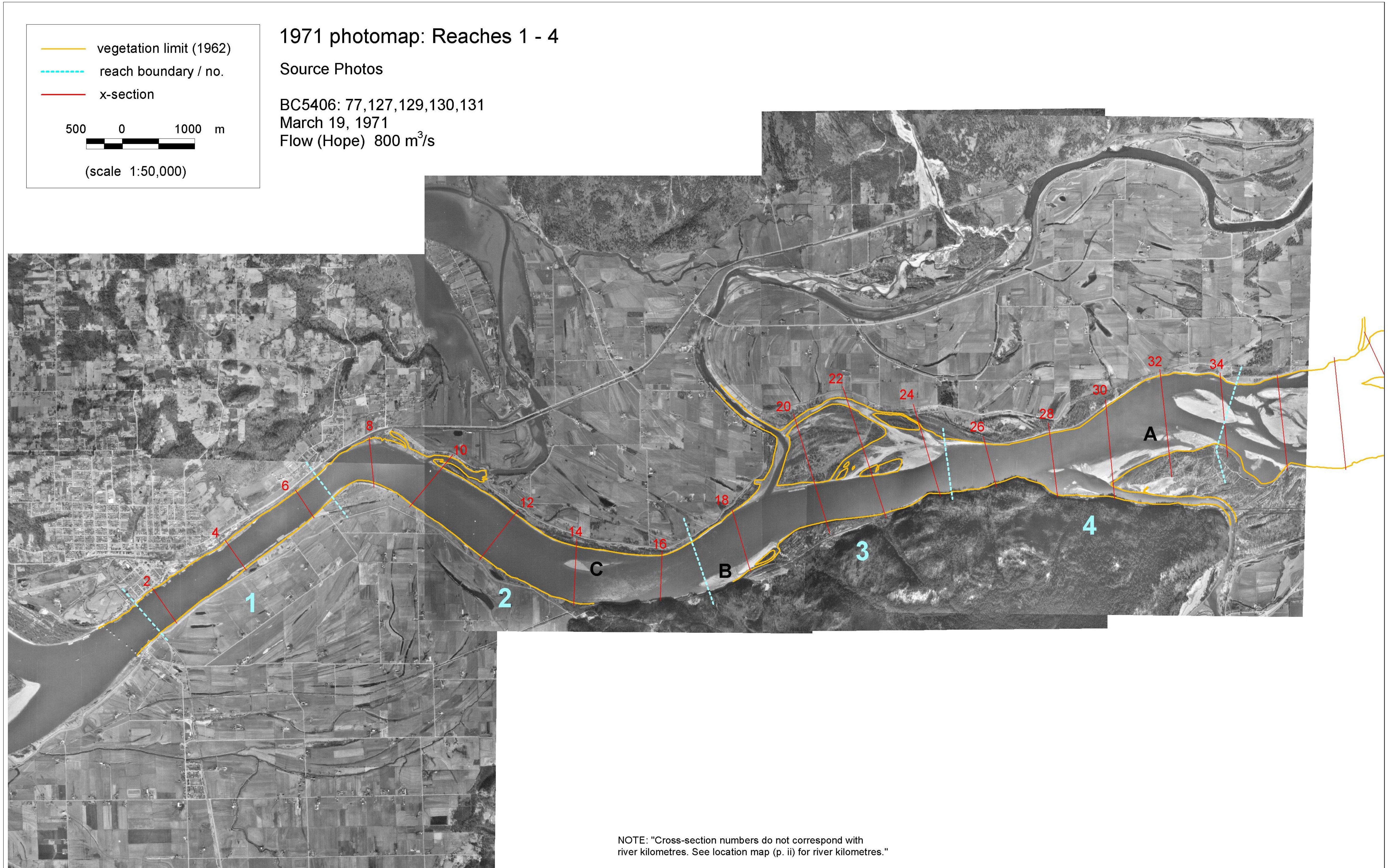
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."



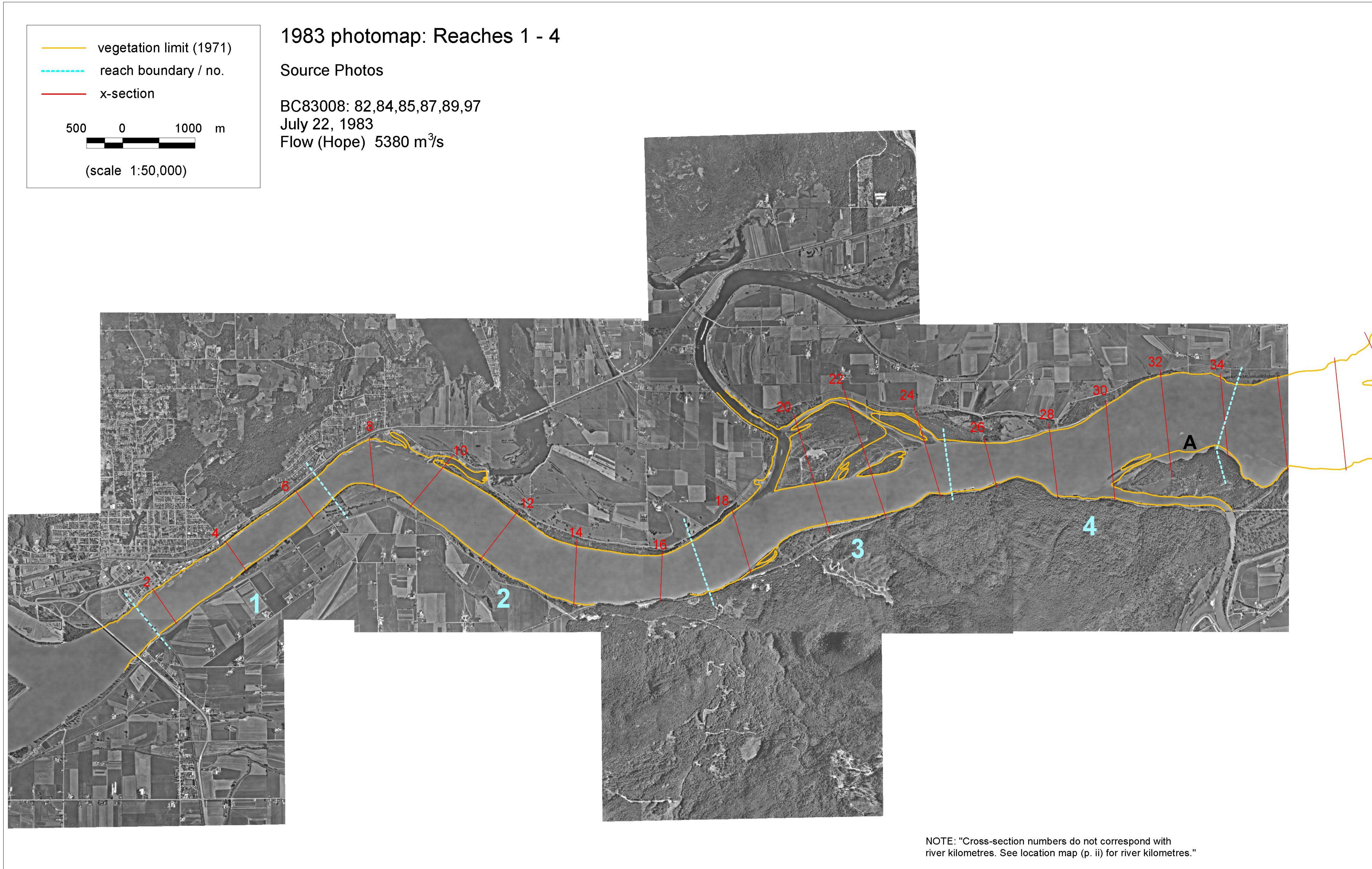
vegetation limit (1940)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1949 photomap: Reaches 1 - 4
Source Photos
BC717: 40,44,46,47,49,51,55
BC718: 46,48,50
March 23, 1949
Flow (Hope) 730 m³/s
BC720: 107
BC722: 77,105
BC723: 50
March 31, 1949
Flow (Hope) 730 m³/s
BC731: 21,23,25,27
April 6, 1949
Flow (Hope) 980 m³/s
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
1
2
3
4
A
B
C
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

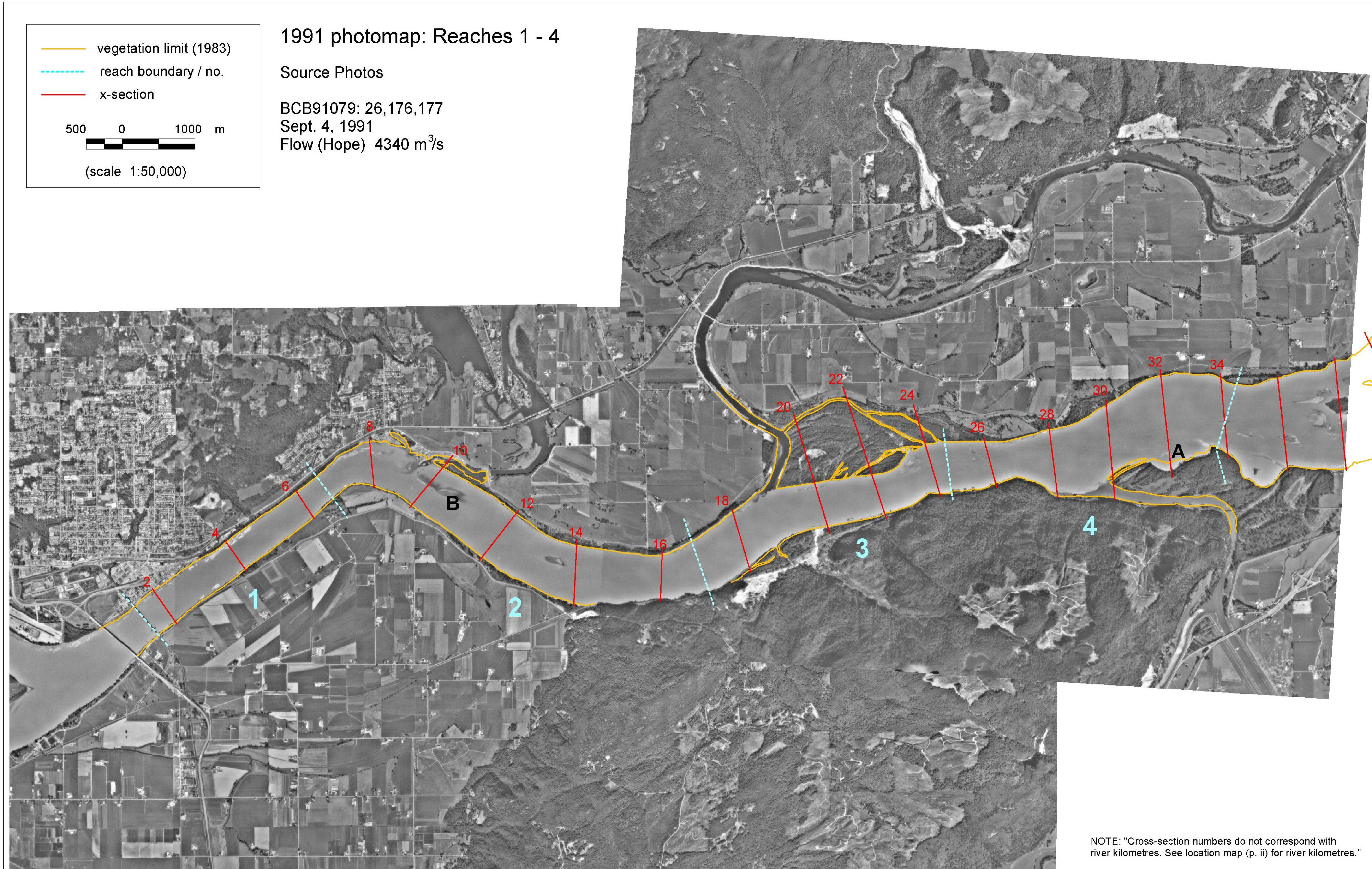


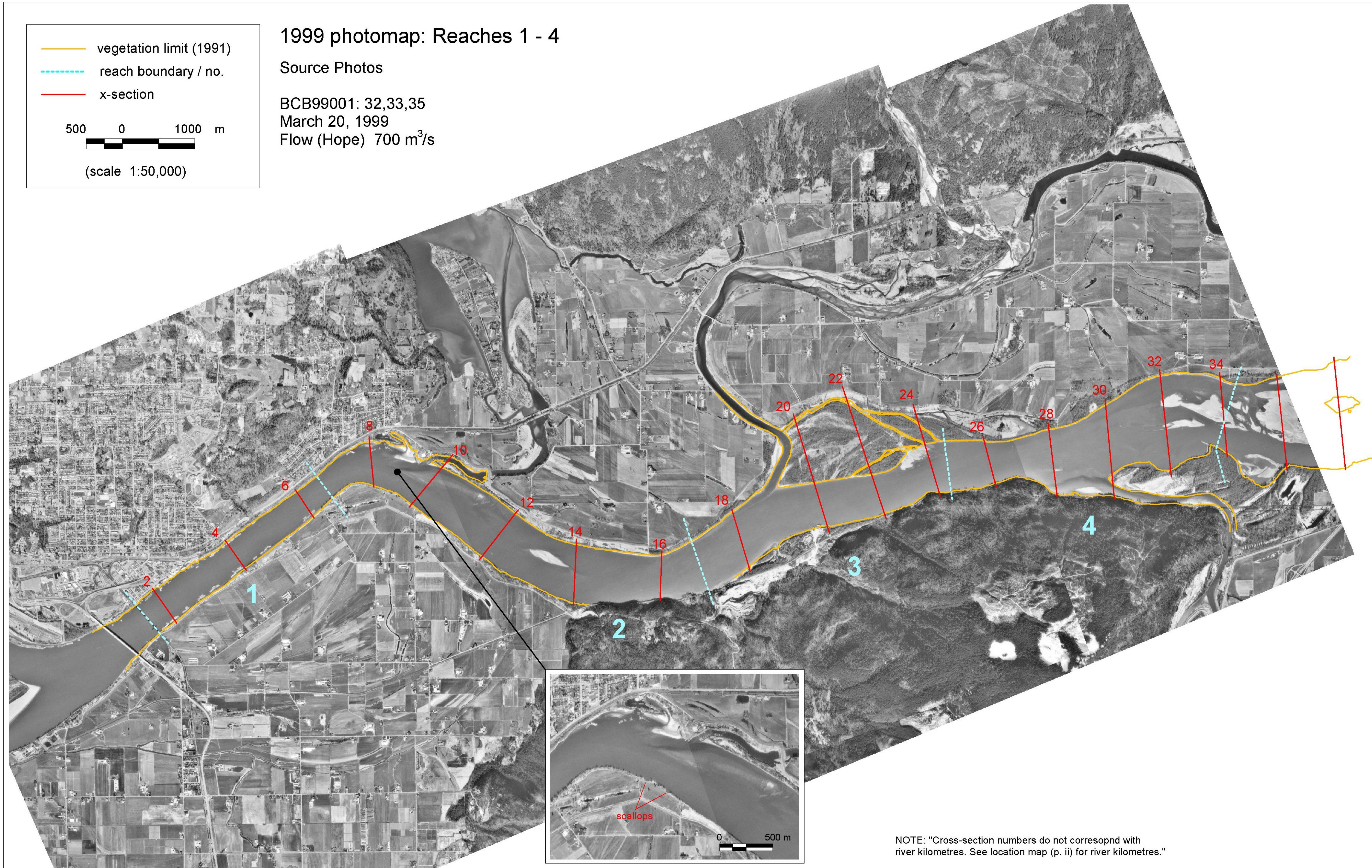
vegetation limit (1949)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1962 photomap: Reaches 1 - 4
Source Photos
BC5042: 87,89,90,91,92
May 7, 1962
Flow (Hope) 2940 m³/s
1
2
3
4
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."

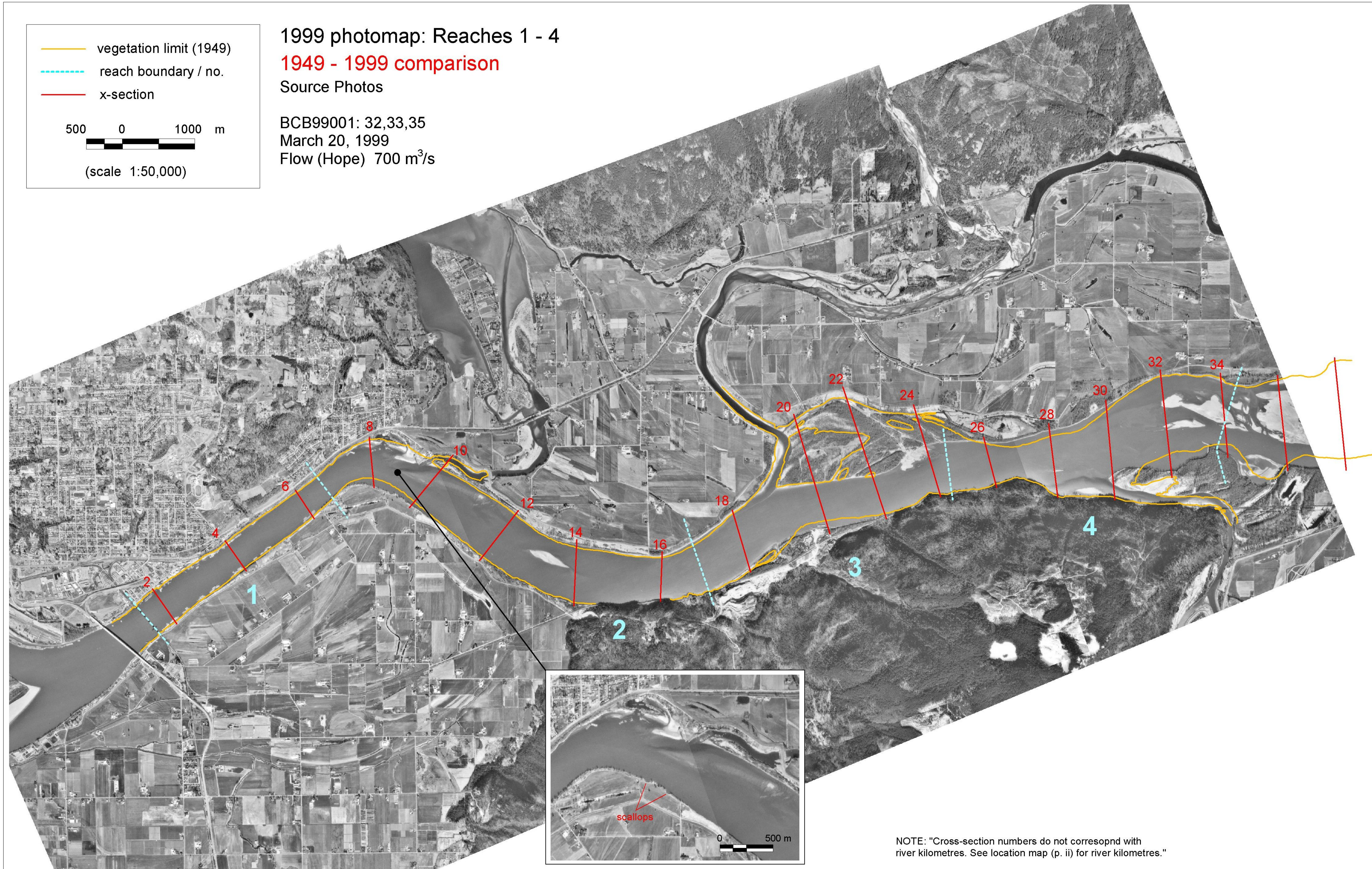


vegetation limit (1962)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1971 photomap: Reaches 1 - 4
Source Photos
BC5406: 77,127,129,130,131
March 19, 1971
Flow (Hope) 800 m³/s
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
1
2
3
4
A
B
C
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."


vegetation limit (1971)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1983 photomap: Reaches 1 - 4
Source Photos
BC83008: 82,84,85,87,89,97
July 22, 1983
Flow (Hope) 5380 m³/s
1
2
3
4
A
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
NOTE: "Cross-section numbers do not correspond with
river kilometres. See location map (p. ii) for river kilometres."


vegetation limit (1983)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1991 photomap: Reaches 1 - 4
Source Photos
BCB91079: 26,176,177
Sept. 4, 1991
Flow (Hope) 4340 m³/s
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
1
2
3
4
A
B
NOTE: "Cross-section numbers do not correspond with river kilometres. See location map (p. ii) for river kilometres."


1999 photomap: Reaches 1 - 4
Source Photos
BCB99001: 32,33,35
March 20, 1999
Flow (Hope) 700 m3/s
vegetation limit (1991)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
1
2
3
4
scallops
0 500 m
NOTE: "Cross-section numbers do not corresopnd with river kilometres. See location map (p. ii) for river kilometres."


vegetation limit (1949)
reach boundary / no.
x-section
500 0 1000 m
(scale 1:50,000)
1999 photomap: Reaches 1 - 4
1949 - 1999 comparison
Source Photos
BCB99001: 32,33,35
March 20, 1999
Flow (Hope) 700 m³/s
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
1
2
3
4
scallops
0 500 m
NOTE: "Cross-section numbers do not coresopnd with
river kilometres. See location map (p. ii) for river kilometres."

Talweg and long profile

The "talweg" (also 'thalweg') of a river channel is the path of the deepest part of the channel. Because of bed undulations associated with the bars, it is not a continuous line in the gravel bed reach. However, with some generalization, a continuous path of deep water can be drawn satisfactorily. The talweg is shown in Figure 4 for the three dates of riverbed survey.

Upstream of mid-Herrling Island (upper subreach 11) the talweg position has been essentially constant, except for minor movement at Peters Island, for half a century. This appearance emphasizes the tendency for degradation and channel stabilization in this reach -- gravel input to the reach is passed through or, at least, exchanged with an equivalent amount of gravel entrained locally, so no significant, new, channel-deflecting accumulations of gravel have developed within the period of the surveys. Despite the appearance of channel switching about Spring Island, the talweg has remained consistently in the left branch so that the regular meander represented by the right branch is not yet fully expressed. A reason for this may be heavy bed armouring with the coarsest, least mobile gravel in this degrading reach, leaving the river with limited capability to scour deeply. A steep riffle in the entrance of the bend is direct evidence for this.

Again, in subreaches 1-4 there have been only minor changes in the talweg position over half a century, chiefly at Strawberry Island and in the apex of Matsqui Bend. This reach lies near and beyond the limit of significant gravel transport and deposition, while the river remains competent to transport sand. There has been very little lateral instability in this reach either, so that the stability of the talweg is consistent with planform stability.

Subreaches 5-11 represent the reaches in which the main gravel deposition has occurred during the second half of the 20th century, and they have experienced dramatic lateral instability. Notable maxima of transverse shifting are located at Big Bar, Hamilton Bar, Gill Island, Carey Bar, Harrison Bar, Wellington Bar and Yaalstrick Islands. These are the places where significant changes have been described in the foregoing text. Interestingly, a quasi-regular meander pattern between Agassiz and Harrison River has reversed phase in the period, so that the 1999 channel is in anti-phase with respect to the 1952 channel.

Between Harrison Bar and Queen's Bar, the channel was anomalously stable (for this reach) during the period. That probably is because the river has remained hard against Harrison Knob throughout the period, and because a reduced bed material load has been transported past Harrison River mouth. Downstream from Wellington Bar, the channel has shifted irregularly, though it has remained on the left side of the channel past Yaalstrick Islands.

The long profile of the riverbed is conventionally the variation in river bed elevation along the talweg. Figure 5 (next page) shows long profiles for the three survey dates. The sharp low points in the profile represent deeply scoured pools along the channel. Most of these are located on the outside of sharp bends where the current is forced to "turn over" against a bank. Near the upstream and downstream limits of the reach, pools have been stable, at least in location, over the 50-year period. However, in the intervening, unstable reach of the river, pools have filled, some to the point of being replaced by riffles, in the period. This observation is consistent with the unstable, aggrading character of the midreach of the river.

A discernable trend over the period is that pools are becoming shallower, except that there is little change in the upstream stable pools. Correspondingly, riffles have been becoming higher, as well (Figure 5). Both features are consistent with aggradation in the reach. As a reach-wide average, the aggradation amounts to 40 cm over the period 1952-1999 (Church, Ham and Weatherly, 2001), but material in fact accumulates locally, chiefly on riffles and bar surfaces, some of which have been persistent, and some of which have changed over the period.

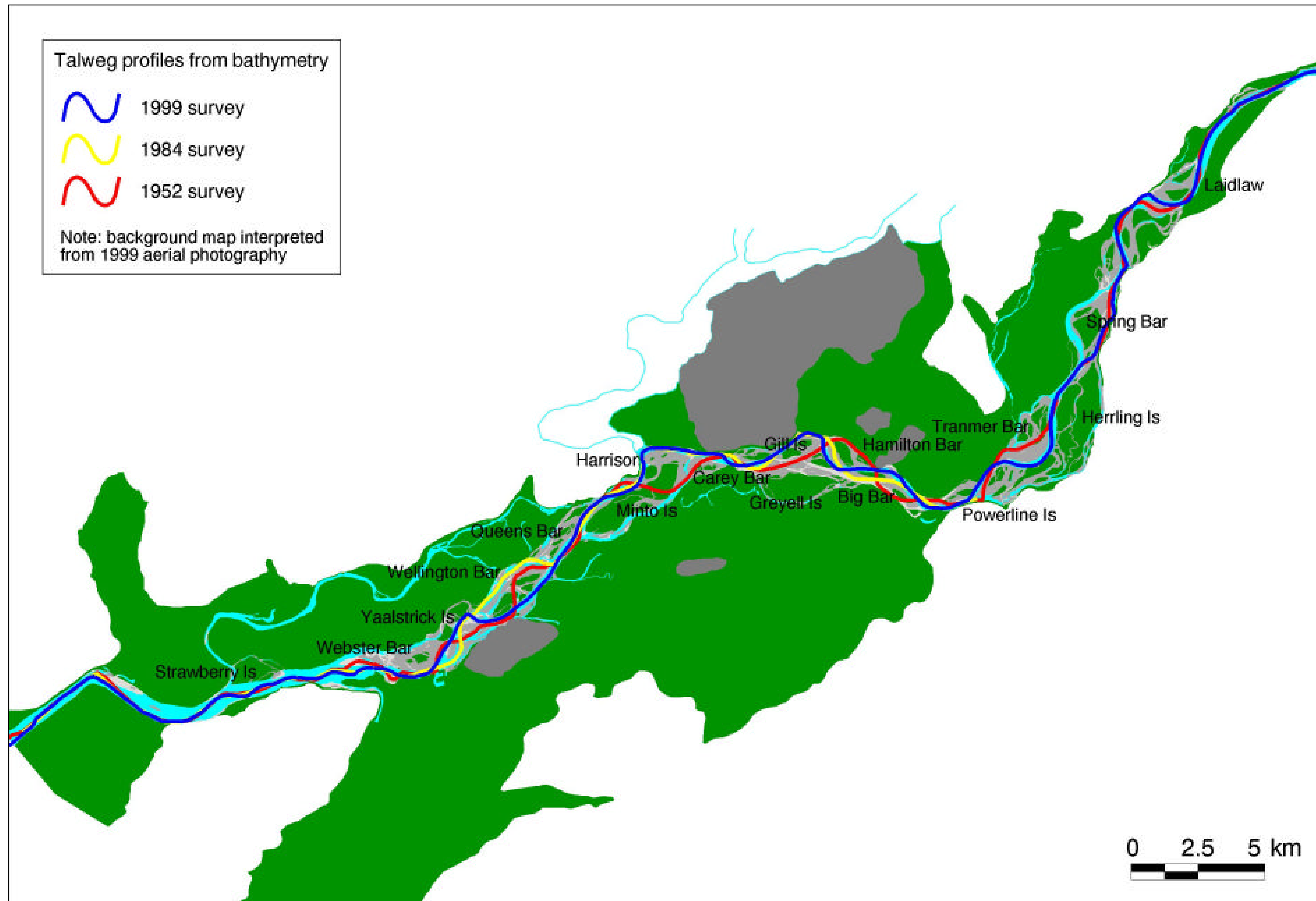


Figure 4: Talweg profiles for 1952, 1984 and 1999 from bathymetric data.

Bedmaterial grain size

The river deposits its gravel sediment load between Herrling Island and Sumas Mountain, and this is the fundamental reason for long-term aggradation in the reach. On a depositional gradient, the largest and, therefore, comparatively the least mobile material is deposited first. Hence, we expect bed material size to be larger at the upper end of the reach than at the lower end. This comparison may become more pronounced if degradation occurs (as it has) at the upper end of the reach since the finer part of the material deposited there is preferentially re-entrained and moved farther downstream.

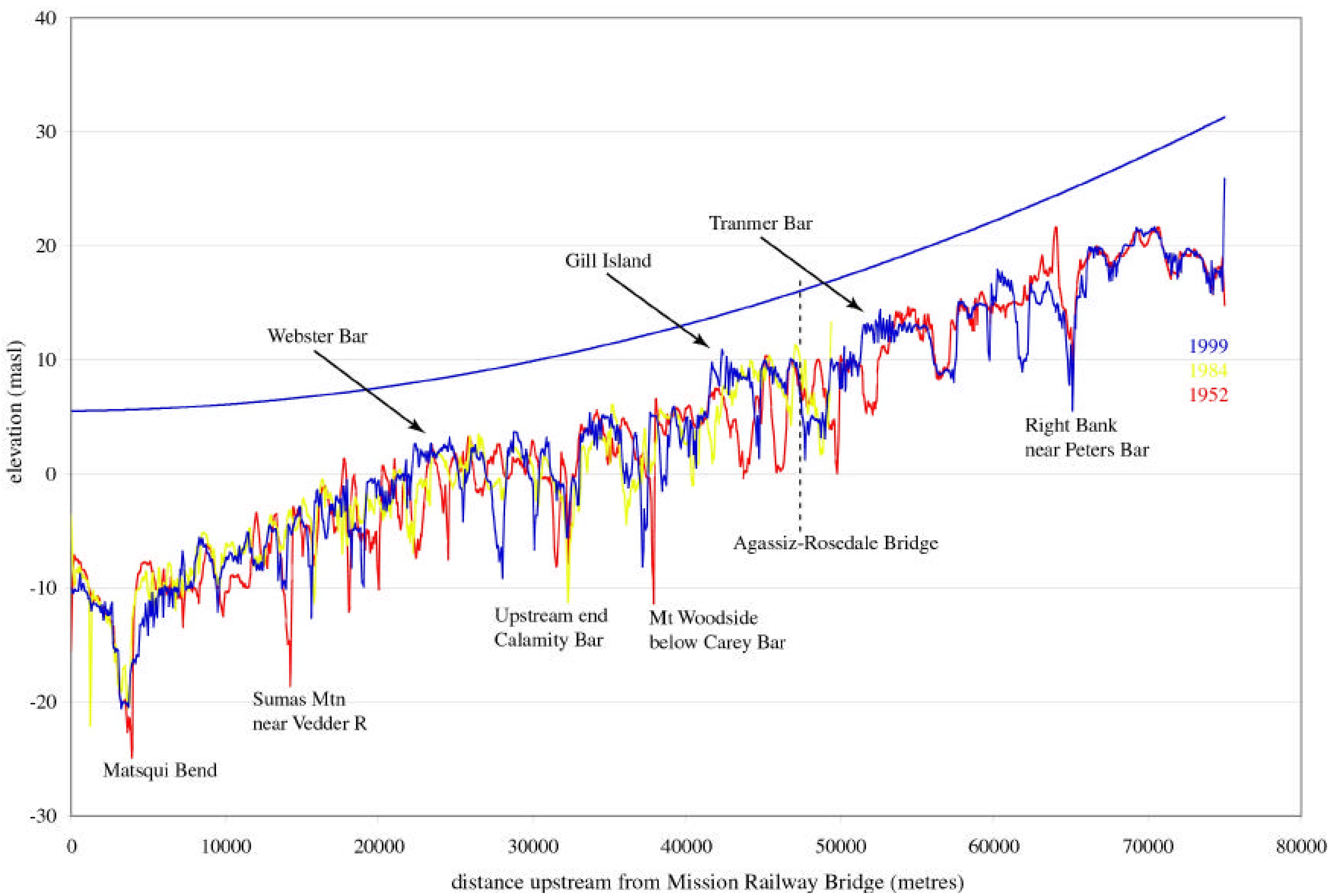


Figure 5: Superimposed longitudinal profiles showing variability in the location of riffle and pools. Arrows indicate prominent riffles that have deposited by 1999 (the approximate location of several prominent pools is also given). The smooth line above the bed profile corresponds to the water surface profile (~7000 m^3/s) in 1999 and is shown for reference.

In gravel-bed rivers, we also expect some differences to appear between the material exposed on the surface to the full force of the flow, and material under the surface, into which sand has infiltrated through the pore spaces in the gravel. Hence, separate sampling is conducted for surface and subsurface material. Finally, it is clear to anyone who looks that there is large variation in the texture of the river deposits within the confines of a single bar. That is because currents, and the movement of sediment over the bar are made highly variable by the fact of the pre-existing topography of the bar. So there is large local variation in sediment size, typically as great as the total variation in the mean grain size right through the reach.

Our sampling has been restricted to bar top and bar edge surfaces since the deep channel of the river, always under flowing water, remains inaccessible unless very elaborate and expensive procedures are undertaken. At any individual location, there is also a wide range of grain sizes present. The range of sizes at a sampling location is recorded as a distribution of sizes. Indices of grain size are extracted from the distribution in the form of grain size "percentiles", for example the median size (the size than which 50% of the grains is finer).

Figure 6 (next page) shows the distribution of surface grain size down the reach. In particular, the median size (D_{50}) and the D_{90} size, the size than which 90% of the grains is finer, are graphed. The D_{90} size is an index of the largest sizes present. The large scatter of data reflects the bar-scale variability mentioned above. Nonetheless, there are evident downstream fining trends in both sizes, reflecting the depositional gradient of gravel along the river.

Subsurface material is displayed in Figure 7. Both D_{50} and D_{90} are finer than their surface counterparts. The subsurface material is considered to reflect the grain size distribution of the material being transported along the river, the surface representing a winnowed subset of the full range of sizes. The subsurface plots show less local variability than the surface plots and the downstream fining trends are clear.

The fraction of subsurface sediment that is finer than 2 mm, the sand fraction, is displayed in Figure 8. It rises slowly downstream as there is less and less gravel remaining in the sediment load. It finally increases abruptly near km 100 where the bed undergoes a transition from being dominantly gravel to being dominantly sand.

The data displayed in these plots have been collected over a period of about 20 years but, since bed sediment is moved onward only slowly, it is not expected that changes would be detected within 50, or even 100, years, in comparison with the large local variability. An exception to this statement is the possibility to detect the progression of gravel into the sand reach at the downstream limit of the gravel, but 20 years of sampling is too short a period even for this.

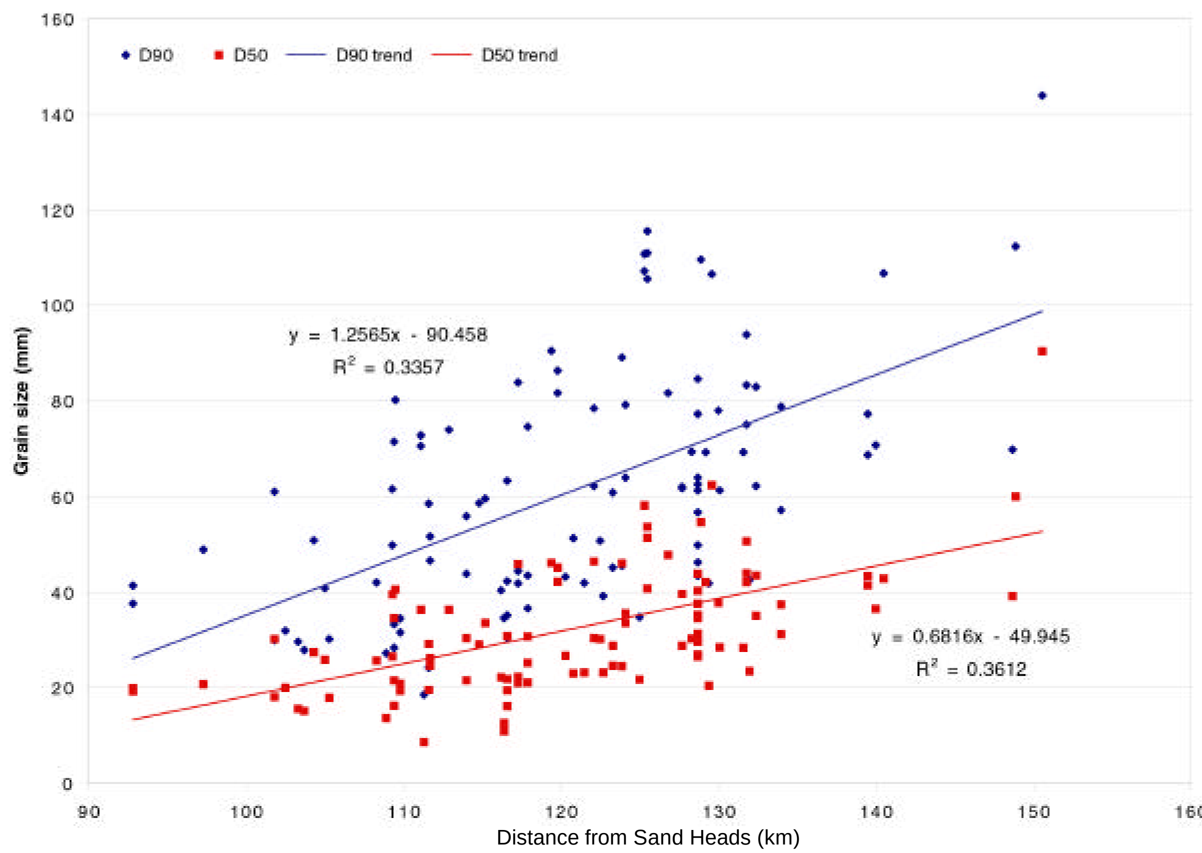


Figure 6: Fraser River surface grain size (mm) versus distance upriver (km). Data collected in 1983/84 and 2000.

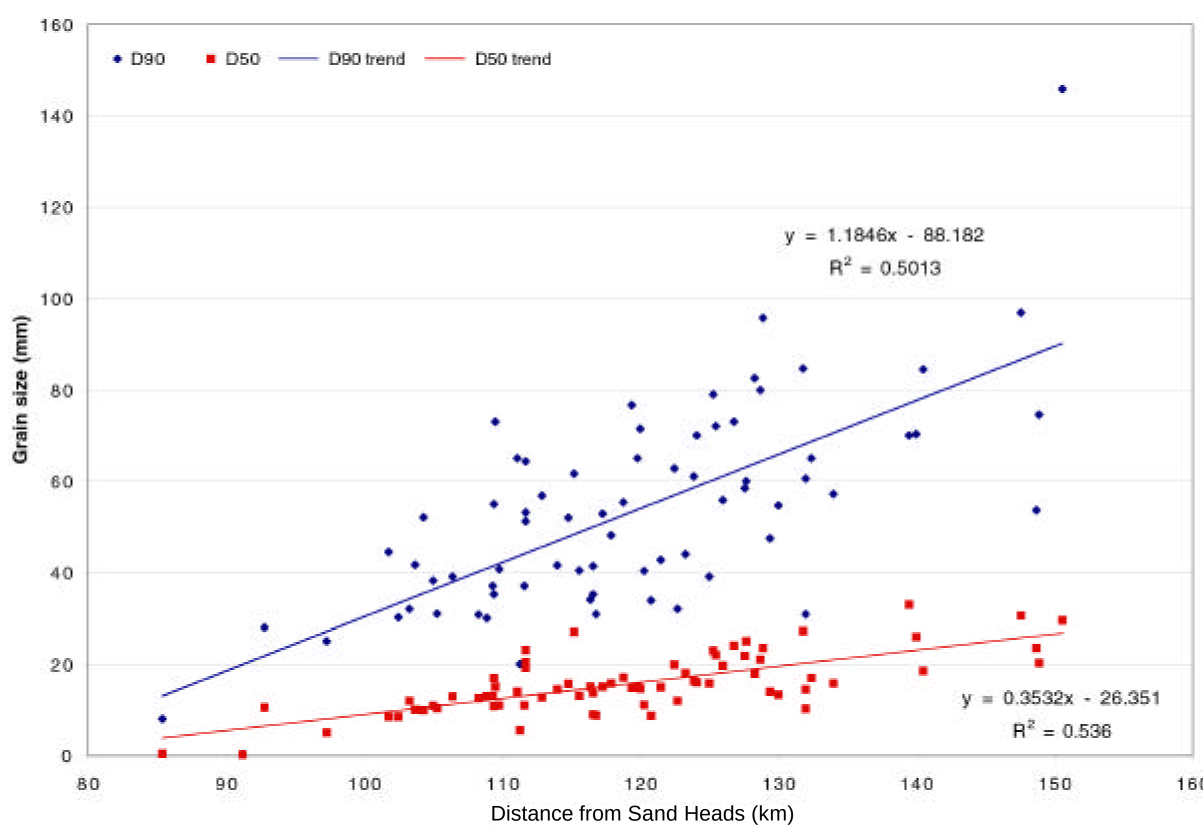


Figure 7: Fraser River subsurface grain size (mm) versus distance upriver (km).

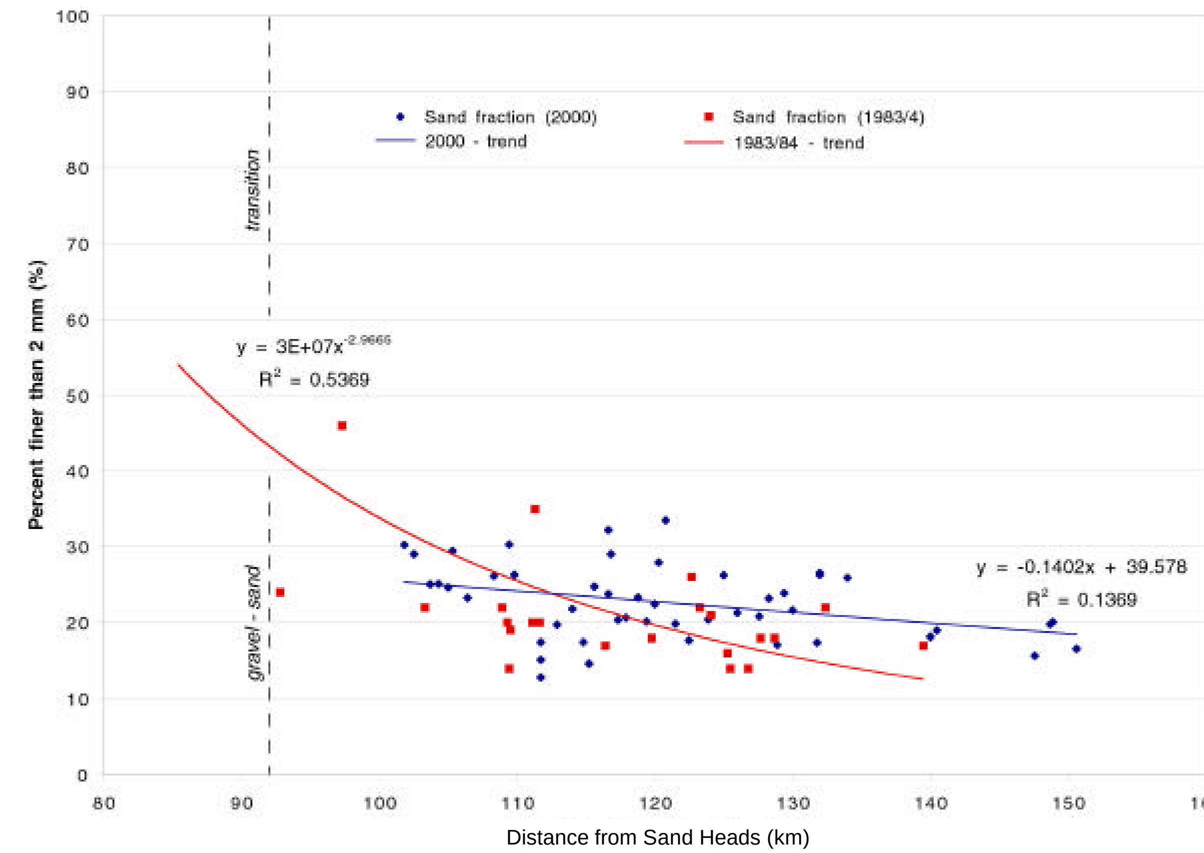


Figure 8: Fraser River subsurface sand fraction (%) versus distance upriver (km).

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* Church,M., Ham,D. and Weatherly,H. 2001. Gravel management in lower Fraser River. Report to the City of Chilliwack: 110pp.

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* available at http://www.geog.ubc.ca/fraserriver