Appendix C: Atlas of channel changes

This appendix describes morphologic channel changes and development on the gravel reach for much of the 20th century (from 1912 to 1999). The descriptions of change are based on interpretations from the available maps and airphotos over this period of record, and there is no means to confirm that any of the patterns of development discussed are assuredly real. The following narrative discussion is broadly similar to that presented in Chapter 6, but links between specific erosion and deposition sequences are more difficult to make because of widely varying flow conditions and a less regular (and generally longer) timeframe between successive mapping dates. Descriptions of change are organized from the earliest to most recent mapping, and proceed in a downstream direction. Although not specifically discussed, major channel developments are accompanied by significant alterations in channel shape, which can be examined from the cross-section plots presented in Appendix A. Finally, it should be noted that much of the following discussion is based on text first presented by Church and Ham (2004) but has been modified by condensing the original discussion and adding some new observations.

C.1 Historic channel changes in the 20th century

The general morphologic pattern has remained fixed at least since the middle of the 19th century, when large mid-channel island and bar complexes near present-day Herrling and Greyell Islands were already well established. Nevertheless, there have been significant alterations in morphology because of long-term trends in flood flows, continued accumulations of coarse sediments, and anthropogenic impacts that have permanently altered the nature of channel-floodplain interaction. Possibly the most important impact over this period has been the introduction of large (albeit unknown) quantities of coarse sediment to the channel from placer mining in the Fraser Canyon and on principal river tributaries in the mid- 1800s, with further sedimentation disturbances related to road and rail construction over the following century (Church et al., 2001). Given a gravel celerity of 3-5 km per year (McLean, 1990), these impacts would have led to accelerated bed material influx to the lower gravel reach by the date of the earliest photography. Although it is not known whether these disturbance continue to influence present morphologic development, there is evidence to suggest that the contemporary sediment influx remains high, but is strongly influenced by local channel alignment.

Patterns of erosion and deposition, hence morphologic change, are examined from 1912, when the first reliable map of the river was published and continuous gauging records became available. The period of study, extending to 1999, includes several cycles of below- and above-average flood flows, and is much longer than the decadal scales within which major sequences of erosion and deposition are completed (McLean and Church, 1999). To simplify the discussion, the gravel reach is subdivided into four major zones extending from Laidlaw downstream to Mission, the boundaries of which roughly correspond to the thirteen morphology-based reaches presented in Chapter 2 (see Figure C-1). Common place names referred to in the text are provided in Figure C-1 for reference.

C.2 Hunter Creek to Spring Bar: Figures C-2 to C-5

The upper 8 km of the reach from Hunter Creek downstream to Wahleach Bar is partly confined by non-alluvial materials and has remained fairly stable over the period of record, although prominent right bank sidechannels at Vasasus (1) and Wahleach Islands (2) were much more active in the early part of the 20th century than in recent decades. Downstream, Maria Slough (3) was a major distributary channel up to 300 m wide within which several islands were found, but upstream access was cut-off by railway construction in the late 1800s and considerable siltation and narrowing of this channel had occurred by 1928. From 1912 to 1928, considerable bank erosion is observed at the upstream end of Peters Island (4), while two large scallops were eroded along Seabird Island. Maximum lateral erosion of 1000 m (5) and 500 m (6) at these sites is the highest recorded within the entire gravel reach. Using an approximate basal gravel thickness of 5 m, an estimated 10 million m^3 of bed material was eroded from Seabird Island, while 15 million m^3 was eroded in the entire sub-reach. It is probable that significant volumes of this material were stored along the reach, but high water conditions in 1928 preclude confirmation. The growth and coalescence of islands near Spring Bar (7) provides the only direct evidence of sediment storage.

Lateral erosion continued at Peters Island and along the two large scallops to 1940, albeit at a reduced rate. Erosion at scallop (8) directed flows towards the erosion-resistant left bank, hence directly towards the head of the Spring Bar Islands (9) which was destroyed. Some of this material was likely deposited at an emerging mid-channel bar downstream (11). This erosion also enlarged the left bank channel (10), increasing the flow directed at the upstream end of Herrling Island. By 1949, modest erosion continued along Peters Island, and an additional 400 m was eroded at Seabird Island (12). Low water conditions in 1949 reveal major bar accumulations above and below Peters Island that forced the high erosion rates observed over previous decades. However, sediment accumulations near modern Peters Bar (13) limited further erosion at Seabird Island as this alignment has forced the channel towards the left bank, eroding Spring Islands (14). Another large sediment body along the right bank of Spring Islands (15) produced the significant scallop erosion observed over previous decades, but little additional erosion is observed as the left bank channel had become dominant.

Channel changes had become less active by 1962, although significant erosion continued along Peters Island because of the predominant flow alignment just upstream. Erosion also continued along Seabird Island (17) but the downstream channel was maintained along the left bank, causing minor erosion at the head of Spring Islands. This circumstance allowed continued sedimentation and growth of vegetation at Spring Bar (18), an indication that the right bank channel was increasingly becoming abandoned. Erosion continued at Peters Island by 1971 but a large lateral bar had formed (19), directing the main flows away from the island towards the non-alluvial right bank. Downstream, further sediment accumulations at Seabird Island (20) prevented continued erosion along the right bank. Modest vegetation growth continued at Spring Bar. The middle of Peters Island continued to erode and by 1983 was close to becoming bisected, threatening Peters Indian Reserve lands on the left bank floodplain (21). Several small islands were also eroded at the head of Spring Islands (22) but, otherwise, colonizing vegetation continued to grow. Overall, observed changes since 1962 are very modest given the passage of large floods in 1964, 1967, 1972 and 1974.

Since 1983, there have been few major changes in reach morphology. Riprap placed along Peters Island eliminated further erosion there while, downstream, the growth of vegetation continued. The overall appearance of an increasingly stable reach over this period is consistent with generally below average flood flows. However, the formation and alignment of channel bars upstream of Spring Islands (23) suggests that flow into the right bank channel had increased. The low water conditions in the 1999 photo confirm that the right bank channel (24) had become enlarged because of a change in upstream flow alignment. Consequently, there was trimming along the edge of Spring Bar (compare with 1971 low water image) but compensating right bank erosion, as seen prior to 1949, is not observed because of outer bank hardening.

The 1999 photos also reveal that the right channel enlargement (24) is coincident with the development of a regular meandering thalweg extending from the upstream end of Wahleach Island to the downstream end of Spring Island over the past several decades. The length of the meander is roughly ten times channel width, near modal values for alluvial channels (Leopold and Wolman, 1957; Knighton, 1998). This indicates that the pattern may be reasonably stable, though some additional narrowing or increasing sinuosity may occur. The transition to a dominantly single-thread meandering channel is consistent with previous observations (Chapter 4) that the channel is degrading. Overall, the channel has become increasingly narrow as the area of islands has increased, but outer banks have remained fairly stable since the 1960s, a further demonstration of degradation. This circumstance would also promote vegetation growth and expansion, as bar deposits would become inundated less frequently. The morphologic development in the reach provides direct evidence that the supply of bed material is in decline. This reduction is caused in part by the near elimination of bank erosion through extensive bank hardening, but primarily reflects the reduction of the upstream supply. Although erosion in the reach is comparatively modest today, the large volumes of material eroded and transported since 1912 have certainly influenced the morphologic development downstream.

C.3 Herrling Island to Carey Point: Figures C-6 to C-9

Within this reach are two large, unstable sedimentation zones separated by a narrower transport zone near the Agassiz-Rosedale Bridge. Large islands are visible at these locations in an 1859 sketch map of the gravel reach, suggesting that these features may be centuries old. The 1912 survey shows the downstream continuation of Maria slough, and numerous interconnected sidechannels within the left bank floodplain that demarcated channel islands at high flow. Several smaller sidechannels were also active on the right bank. By 1928, significant morphologic changes are observed throughout the reach. There was some consolidation of island deposits at upper Herrling Island (1) but corresponding erosion occurred downstream at the site of contemporary Tranmer Bar (2) as diagonal bars deflected flows across the channel, then south towards middle Herrling Island (3). Immediately downstream of Tranmer Bar in the main channel near lower Seabird Island, several new islands had formed.[1] Possibly, these were bars that had become vegetated over this period (the 1928 channel alignment is consistent with point bar development) but no bars are shown on the 1912 map. Channel alignment upstream of Herrling Island also maintained considerable flow to the large left bank channel behind the island, causing significant left bank retreat at lower Herrling (4). Near the downstream end of Herrling Island, a large medial

1. Some observed changes from 1912 to 1928 may be an artefact of mapping omission or registration inaccuracies associated with the 1912 survey. Although the outline of Herrling Island and location of outer banks appears credible, the apparent erosion and deposition of some smaller islands may be false.

bar complex formed in the lee of an extensive riffle and forced the channel towards the right bank (5). The bank eroded up to 500 m laterally, greatly increasing channel width. This sediment, plus material eroded from lower and mid Herrling Island, was likely deposited downstream at Powerline Bar (6) which was partly established in 1912, and at Ferry Island (7).

Another large deposit had formed near Big Bar (8) creating a relatively straight channel alignment directed at the right bank (9), eroding up to 400 metres. Deposition of this material near Mt. Woodside (10) reduced capacity in a major right bank slough and forced the channel towards lower Greyell Island (11) which was extensively eroded (up to 400 m). The developing convex alignment at (9) also created favorable conditions for sediment deposition (point bar growth) along the northeast margins of Greyell Islands (12) where several new islands had developed. Flows were also reduced through secondary channels within the Greyell Island complex (13) allowing smaller islands to coalesce. Also evident in the 1928 photography is the reduction in flow capacity within the sloughs and sidechannels (relative to 1912) along the left bank floodplain near Greyell Island because of artificial constrictions. Apparent shifts in the position of these features are an artefact of mapping errors and registration difficulties.

By 1940, erosion at Spring Bar created a major secondary channel which caused erosion along the upstream end of Herrling Island (14) and forced the channel towards the right bank. Downstream deposition (15) protected mid Herrling Island from further erosion, but a growing diagonal bar/riffle (16) forced the channel south, destroying a major island, then west towards the right bank where an additional 375 m was trimmed (18). A small island and the upstream end of Powerline Island were also eroded. This material may have been deposited upstream of Hopyard Hill (19) where a large lateral bar formed along the edge of the island[2]. Downstream, the growing point bar along Greyell Island forced the flow into the right bank and adjacent small islands to maintain conveyance. This also directed flows toward lower Greyell Island (21), creating a more sinuous thalweg. A major medial bar complex had established downstream of these sites. In general, the lack of major changes in morphology downstream of Ferry Island is a consequence of reduced lateral instability near Herrling Island, since material eroded there is deposited in the downstream reach. The reduced activity is consistent with the mostly below-average floods during this period, but the relatively straight channel alignment along the right bank in the upstream reach

2. The appearance of major bars on the west half of the reach is due to a change from higher water 1940 photography to lower water 1943 photography. A large gap in the 1940 photo coverage necessitated this change.

also reduced bank erosion. A reduced sediment load is commonly associated with increasing channel sinuosity.

Significant erosion continued along the head of Herrling Island to 1949 as the upstream channel alignment was maintained (22). Sedimentation immediately downstream produced minor compensating right bank erosion, while the network of small sidechannels had largely become infilled. The developments at mid Herrling Island (23) were much more dramatic. Extensive lateral and mid-channel bar development at what is today Tranmer Bar forced the main channel 150 metres to the left into mid Herrling Island. Material eroded here was deposited along an extensive growing bar at lower Herrling (24) forcing the current across to the right bank, eroding an additional 300 m. Sedimentation at lower Herrling extended to the left bank, effectively blocking the downstream end of the large secondary channel which was becoming silted up. The massive bar development at lower Herrling also caused additional erosion at the head of Powerline Island, while a bar on the south side of the island expanded downstream. Ferry Island remained stable, but lateral bar growth there (25) and near Hopyard Hill (26) produced minor compensating erosion on opposite channel banks. At Greyell Island, additional expansion of the point bar caused a further 100 metres of right bank erosion and destruction of two smaller islands in the Gill Island complex (28). This material was deposited at the expanding Carey Bar (29), consolidating several individual bars into a larger bar complex, causing limited left bank erosion at Carey Point (30).

By 1962, lateral bar accretion near upper Herrling Island (31) caused limited right bank retreat opposite the bar, which aligned the current more directly towards the Tranmer Bar complex, where several islands were destroyed and the secondary channel behind the largest island became enlarged (32). Since the main channel continued to flow against the right bank, the extent and consolidation of vegetation at upper Herrling continued, while erosion at the island head abated. Downstream, additional growth of Tranmer Bar into the main channel caused an additional 100 m of erosion at mid Herrling Island (33), contributing to increased sedimentation along the northern edge of the convex bar at lower Herrling. Consequently, this extension forced the channel westward, eroding the right bank floodplain and the head of Powerline Island (34), thereby reducing the angle of the sharp bend that had formed near Powerline Island in 1949. Below Ferry Island, a crescentic mid-channel bar (35) — the origin of contemporary Big Bar — caused extensive erosion at Hopyard Island, and led to the extension of a downstream diagonal bar/riffle (36) that increased flow into the head of Greyell Island. This in turn caused extensive local erosion and enlargement of the secondary channels (37). Extension of the large point bar attached to

Greyell Island (38) caused another 150 m of erosion on the right bank, directing the flow towards the head of Gill Island. This removed about half the established island area and re-established the secondary channel behind the complex on the right bank (39). The net effect of these changes was to restrict flow conveyance through the lower part of the reach, providing favorable conditions for increased sedimentation.

Upper Herrling Island remained very stable to 1971, the only change being increased vegetation growth, but further expansion of Tranmer Bar continued the trend of erosion along mid Herrling Island where an additional 100 m of retreat was recorded (40). Since there was no erosion at upper Herrling Island, this material likely derived from Spring Bar in the upstream reach. Despite the downstream development of a mid-channel bar and a distinct lobate bar (41) that reduced conveyance and directed flows into the right bank, bank protection prevented any erosion. Lower Herrling Island also became increasingly stable with island consolidation and expansion occurring, and the rate of erosion on the right bank (42) was greatly reduced from previous decades. Although modest, this erosion increased the flow towards Powerline Island, significantly eroding the island head, enlarging the secondary channel along the right bank and forming a lateral bar extending to the bridge. Material eroded from Powerline Island was deposited near Big Bar (43) causing compensating erosion on Hopyard Island and extension of a lateral bar along the right bank past Hopyard Hill. This deposition reduced the flow through the north channel, causing major erosion at the head of Gill Islands (44) and expanding the size of the secondary channels. Nevertheless, flow along the north bank remained sufficient to further erode the right channel bank, but was then directed into bedrock at Mt. Woodside. This alignment produced a backwater effect creating sufficient hydraulic head to erode two distinct south flowing channels at Carey Bar (45).

The two large floods in the early 1970s caused very little change along Herrling Island to 1983. This stability implies a low input of bed material, most of which was deposited on growing Tranmer Bar, resulting in lateral erosion up to 200 m at mid Herrling Island. Sediment exchange at Tranmer Bar appears to have been more dynamic than in the previous period, as erosion and construction of vegetated surfaces and movement of minor channels is evident (46). Riprap on the right bank downstream of Herrling Island prevented any further erosion there. Powerline and Ferry Islands also remained stable, but the elongated lateral bar at Ferry Island promoted the destruction of the remaining right bank island (47). The morphology of the Gill/Greyelll complex continued to evolve. The westward secondary channel (48) continued to expand, while a more prominent northwest trending channel developed, eroding through a former large bar (49). This increased the flow along the right bank, causing further erosion of islands near Mt. Woodside and enlarged the size of the channel flowing southwest through Carey Bar (50). This resulted in erosion along the western tip of Greyell Island, and at Carey point along the left bank.

By 1991, extensive vegetation growth reveals that Tranmer Bar had become increasingly stable, though bar extension along the downstream margin drove erosion at mid to lower Herrling Island (51). Lateral trimming of the major bar deposit at lower Herrling is also apparent. Some of this material was deposited along the downstream end of Powerline Island, and the north sidechannel also experienced increased sedimentation (52). Major islands downstream to Hamilton Bar experienced considerable expansion, while further sediment accumulated within the channel behind Hamilton Bar (53), likely extending the deposit to the right bank at low discharge. The two major channels that had established in the Greyell/Gill complex by 1983 (48, 49) continued to grow, causing further erosion along established islands. Deposition on the wide shallow distributary channel through Carey Bar (54) effectively reduced this to a high water channel. At Carey Point, a further 125 m of bank was removed, but the erosion occurred further downstream than in 1983 as the north channel rotated north-westward, trimming the edge of Carey Bar (55). The paucity of significant morphologic changes from 1983 to 1991 reflects a lack of large floods and correspondingly modest rates of sediment transfer that allowed the area of establishing vegetation to greatly expand.

There were no major changes in channel morphology near Herrling Island by 1999. Modest additional growth at lower Tranmer Bar continued to produce opposite bank erosion at mid Herrling Island of 75 m. The low water condition of the photographs reveals that Tranmer Bar was a well consolidated deposit, although a small right bank channel remains (56). Overall, the upper reach has developed a regularly sinuous thalweg similar in character to that described upstream, suggesting that the main locus of channel instability is prograding downstream towards Greyell and Gill Islands as the upstream supply of sediment declines. Downstream, the extension of bar deposits at Powerline Island drove compensating erosion at Ferry Island (57), while additional sedimentation at Big Bar forced the main channel to flow along the right bank towards Hopyard Hill, thence directly west where the flow continued to split at the head of Gill Islands. Lateral growth at Hamilton Bar forced the larger northern channel to the southwest, causing significant erosion of Gill Island (58) with this material being deposited immediately downstream. The smaller southern channel continued to flow mainly westward, causing minor bank erosion on both Gill and Greyell Islands. The development of a highly sinuous bend around Hamilton Bar and recent sedimentation there and at Gill Island are an indication that an avulsion through the Greyell/ Gill complex appears likely. Indeed, low-water 2003 photography reveals that a prominent channel has formed here, but the north channel has not been abandoned. Minor erosion also occurred at Carey Point as Carey Bar experienced additional lateral extension.

The main change over the period of record in the upper reach was the establishment of Tranmer Bar, the growth of which drove erosion at mid and lower Herrling Island. This development, largely established by 1949, resulted in an estimated loss of 5 million m^3 of sediment at Herrling, which amounts to roughly half the estimated influx past Agassiz-Rosedale Bridge (Table 5-6). The progression toward a regularly sinuous channel thalweg parallels developments upstream. Erosion has continued here to 2003, causing the recent high sediment influx downstream, but the pattern will become disrupted within a few years as a new channel(s) develops through Herrling Island towards the left bank. Downstream morphologic development has been more dynamic and complex since 1949, the consequence of increased sedimentation as upstream reaches have degraded. While it is expected that the upstream trend of increased morphologic stability will eventually propagate into the lower reach, further instability is expected as the considerable volume of stored channel deposits is reworked.

C.4 Foster Bar to Lower Yaalstrick Bar: Figures C-10 to C-13

This reach is characterized by a large, unstable sedimentation zone in the upper half, with a series of smaller, narrower accumulation zones downstream. Harrison River (1), the largest tributary in the gravel reach, enters Fraser River near the upstream of this subreach but its impact on downstream morphology is limited because it does not introduce additional bed material. There were no large established channel islands shown on the 1859 sketch map (as in the Herrling Island to Carey Point reach) but large floodplain islands near Chilliwack and Nicomen Island downstream must certainly predate the map. The 1912 survey shows an extensive network of sloughs and sidechannels within the floodplain along both banks that had been artificially closed by 1928 because of flooding concerns. The apparent shift in location of most sidechannels near Chilliwack (2) is the consequence of map registration difficulties rather than actual change.

In general, the 1928 map depicts a low sinuosity channel with four diagonal island groups defining large riffles. Superimposition of recent (1999) banklines reveals that parts of these islands have persisted, and form the nucleus of modern deposits. Near Harrison confluence, a large bar/ island deposit forced the channel hard along the left bank causing significant erosion of up to 600 m, from where the channel flowed towards the right, encountering the next major island group. Although a major island was removed and the north bank channel was enlarged, the position of the riffle at lower Minto (4) was predominantly maintained by deposition of material supplied from upstream erosion. This alignment resulted in up to 650 m of further left bank erosion to maintain flow conveyance. The material likely was deposited downstream on a large point bar that has become Island 22 (5) and at Wellington Bar (6). Although the flow along the right bank was sufficient to laterally erode several kilometres along the edge of Nicomen Island, Wellington Bar forced the main channel against the left bank, eroding 250 m of floodplain and destroying a mid-channel island. This development resulted in the main current being directed hard against the upstream limit of Chilliwack Mountain producing a significant backwater effect. Significant channel widening is also observed immediately below Wellington, with erosion along both banks. Another major riffle at Yaalstrick Island was maintained (7) although the south side was extensively eroded. The erosion likely occurred in the early 1920s following the passage of several large floods.

The low water conditions of the 1938 photos reveal significant deposition throughout the reach. A large mid-channel bar at upper Minto (9) split the flow into two main branches. To the north, a tight bend formed through islands near the mouth of Harrison River, causing minor local erosion and establishing a hard turn south against Harrison Knob. Downstream, lateral bar deposits were established in the lee of bedrock outcrops at Calamity Bar (10) and Queens Island (11), which persist to the present day. The other branch was directed into a former slough on the left bank, causing further erosion there (12) before sweeping north to join the other branch near Calamity Bar. The 1943 inset map shows this development more clearly. Consolidation of sediment immediately downstream at lower Minto (13) formed a large point bar attached to the island with the left bank (Minto) channel remaining inactive at low flow. A major mid channel bar accumulation near Island 22 forced the main channel into the island, eroding up to 200 along the edge of the deposit. Further downstream, extensive deposition also occurred at Wellington Bar (14) where the current was forced against bedrock on the left bank and deflected across the channel into Yaalstrick Islands (15), enlarging a secondary channel. This alignment also promoted downstream lateral deposition at Webster Bar (16). The source of this material is not clear, as a large gap in photo coverage masks details of upstream morphologic development. There was also extensive sedimentation near lower Yaalstrick (17) with compensating bank erosion.

By 1949, the sinuous north channel at Harrison had become infilled (18), leaving a single dominant thalweg channel along the left bank. As a consequence of this sedimentation, Harrison River extended its channel south to Harrison Knob. Upstream, a new lateral bar had formed at the head of the reach (19), now called Foster Bar, protecting the site from further erosion. Downstream, the channel migrated north through the former large mid channel bar towards Calamity Bar, possibly driven by increased deposition at upper Minto (20). These developments created a less tortuous thalweg with increased sediment transport capacity. Material eroded from the mid-channel bar was deposited at Queens Bar (21) where extensive lateral development can be seen, attaching the bar to the right bank. Growth of one of the recent elongated gravel sheets caused more than 150 m of lateral erosion at Island 22 and the deposit was within 200 m of the left bank. Erosion concerns at this site have persisted to the present day and the channel currently has a very similar morphology. Downstream at Wellington Bar (22) several mid-channel bars are clearly visible for the first time in the photo sequence. The left bank channel had reduced in size since 1928, while the middle channel removed a small mid-channel island and eroded upper Yaalstrick Island (23), maintaining the existing right bank secondary channel. The dominant left bank channel remained along the front of Chilliwack Mountain where currents were deflected across to Yaalstrick Island, eroding 100 metres. Major sediment accumulations at Webster Bar and lower Yaalstrick were relatively stable, although sedimentation at the latter site continued to erode an additional 300 on the left bank (24). This erosion likely occurred in the years immediately following 1938, when the channel was more directly aligned towards the floodplain.

Lateral accretion at Foster Bar by 1962 had increased the flow along the right bank, eroding the head of one island and enlarging the right bank channel. This sediment was deposited as a new gravel sheet at the downstream end of the Harrison Islands (26) forcing compensating left bank erosion. Mobilization of sediments in this region increased sinuosity at the head of Minto Islands, now similar to the alignment observed in 1943. Channel morphology remained stable downstream to below Island 22, indicating a modest influx of sediment through the conjestion point near the mouth of Harrison River. At Wellington Bar, sedimentation along the southern channel (27) allowed the northern channel to capture additional flow and become dominant. This event, combined with mid-channel bar deposition at lower Wellington (28) maintained flow to the north which caused extensive erosion at upper Yaalstrick Islands. That material, along with sediment eroded from Webster Bar, was deposited on the tail of lower Yaalstrick (29) causing additional left bank retreat.

By 1971, an extension of Foster Bar forced the mouth of the main channel westward into Harrison Islands (30), eroding a large volume of sediment that was subsequently deposited on the downstream bar (31). This created a highly sinuous south channel and increased flow through Minto Channel (32 - compare to low water 1949 photo). However, as Foster Bar continued to expand, the flow was increasingly forced directly west, activating the channel to the right (north) of Harrison Island. Correspondingly, the south bank channel declined in prominence. Although the development of this partial avulsion was certainly promoted by erosion at Carey Bar and subsequenty by deposition at Foster Bar, the pre-existing morphology created substantial flow resistance. This configuration elevated water levels at the south channel entrance maintaining flow spillage to the north, hence helped precipitate the evolution. The downstream channel remained stable to Island 22, although lateral deposition at Queens Bar directed flow towards the left bank (33), while the right bank channel at Wellington Bar became a site of increased sedimentation (34) and erosion at Yaalstrick Island was accordingly reduced. Low water conditions reveal a major bar accumulation at lower Yaalstrick Bar (35). While details of bar morphology reveal significant remobilization of sediment (compare with 1949 low water photos) there was little change to the outer banks, likely the result of bank hardening.

Following the large flood of 1972, the avulsion upstream from the Harrison River mouth was completed and right bank channel at Harrison had become the dominant channel for the first time during the period of record. The increased flow caused extensive erosion among the established islands (36). The alignment of the current against Harrison Knob also increased flow resistance, creating an upstream backwater effect similar to that observed at Chilliwack Mountain. This encouraged spillover flow into the south channel, while siltation in the former channel bend (37) began to amalgamate major island groups above and below. The expansion of vegetative cover in this area is also evident. The channel remained stable downstream to Wellington Bar, where the north channel had again become more dominant, resulting in the erosion of a small mid-channel island (38), and the trimming of Upper Yaalstrick Island (39). It is not clear whether lateral deposition on the north flank of Wellington Bar, or erosion of lower Queens Bar caused this evolution because of the high discharge at the time of photography. There was also minor island erosion at lower Yaalstrick (40) but the channel was otherwise stable.

The channel remained hard against Harrison Knob by 1991, but there was substantial bar deposition at Harrison Bar (41), a consequence of the backwater effects. The period 1983 to 1991 was characterized by mainly below average flood flows, and extensive colonization and extension of vegetation on elevated bar surfaces is evident throughout the reach. Smaller islands began to amalgamate and expand at both Harrison and Minto Island groups, while increased siltation between them (42) portends the emergence of a single ‘mega’ island. Near Wellington Bar, the main channel was maintained along the right bank and there was further erosion along the edge of upper Yaalstrick Islands (43) with deposition of this material downstream (44). Vegetation had also established on lower Yaalstrick, but removal of a small island may indicate development of a small secondary channel through these deposits. By 1999, further accumulations at Foster Bar nearly extended the deposit into the major Harrison sedimentation zone, greatly reducing discharge into Minto channel (45). Similar accretion at upper Harrison coalesced this deposit to the channel islands, while continued vegetation growth had reduced the network of smaller sidechannels to minor high water channels only.

Below Harrison Knob, a small point bar (Calamity Bar) had become well established, as evident by the spread of young vegetation (46). This caused compensating erosion on the north bank of Minto Island, with deposition of a lateral bar immediately downstream. This in turn forced the channel towards the right bank, eroding bar material at the head of Queens Island which created an elongated lobe below (47). This lobe directed the current towards the left bank at Island 22, scouring the bed and partly undermining existing riprap. The regular 1500 m spacing of these features extending to Harrison Bar was likely forced by current oscillations induced where the river turns abrubtly south at Harrison Knob. Wellington Bar remained stable and the island area expanded. The left bank channel was consequently maintained, and continued to be deflected across the river into upper Yaalstrick Island, causing extensive erosion of existing islands and enlarging the size of the secondary channel. A growing point bar along the lower extent of Chilliwack Mountain (48; Webster Bar) helped to maintain this alignment as the establishment of a small upstream bar (49; Grassy Bar) reduced the flow against the bedrock. Sedimentation also continued downstream at lower Yaalstrick (50), where an even larger point bar was developing. Outer banks continued to remain stable, however, because of extensive hardening.

The main changes over the period of record include the establishment and consolidation of major deposition zones at Harrison and Minto Islands, and the persistent, dynamic development of the large Wellington and Yaalstrick bar complexes. Changes along the outer channel banks have been comparatively modest — bedrock constrains the channel at several locations, fixing the general morphology, while bank protection is extensive along most of the alluvial floodplain. From Wellington bar downtream, these developments led to the formation of a fairly regular sinuous channel thalweg, similar in character to that observed in the reaches upstream of Hopyard Hill. The increasing sinuosity is a likely response to declining bed material transport rates. Most of the material entering the top end of the reach was subsequently deposited in the Minto-Harrison Islands, with limited continuation of transport further downstream. A regularly sinuous thalweg had also become established in the reach from Harrison River confluence to the upstream extent of Wellington Bar, but with a much smaller radius of curvature than is observed elsewhere. By progressing the wavelength of Yaalstrick-Wellington meanders upstream, a possible line of morphologic evolution includes thalweg migration across upper Wellington Bar to the right bank, continuing around the secondary channel at Queens Bar, across to the old channel separating Minto and Harrison Island groups, then up Minto Channel and through Foster Bar (refer to dashed line, Figure 6-7). Expected continued sedimentation at Harrison Bar could precipitate this sequence by forcing an avulsion into the upstream end of Minto Channel.

C.5 Vedder River to Mission Railway Bridge: Figures C-14 to C-17

The morphologic character of this reach is somewhat distinct from that of upstream reaches because the gradient is reduced and there is a transition to a dominantly single-thread, irregularly sinuous channel. Although gravels persist along the bed and exposed bars, the dominant bed material load becomes sand. A second major tributary, Vedder River / Canal, enters the upstream end of the reach but does not introduce material larger than coarse sand. Lateral movement in the reach is constricted along the left bank by Sumas Mountain, while railway construction and extensive riprap constrains lateral erosion on both banks downstream near Matsqui Bend.

By 1928, extension of an established point bar near the mouth of Vedder Canal (1) displaced the tributary outlet more than a kilometre downstream and caused compensating right bank erosion on Nicomen Island. Up to 600 m was eroded along nearly 4 km of shoreline, and was likely deposited as a mid-channel bar near modern Strawberry Island (3). The large secondary channel to the north of this deposit was active, and there was compensating erosion of 150 m on lower Nicomen Island while an additional 400 m along was eroded over 2 km of left bank floodplain in front of Sumas Mountain. As there are no emergent bars immediately downstream, this material must have been distributed over the deep river bed, or passed through the reach entirely (although nearly 100 m of right bank floodplain was established immediately upstream of Hatzic Slough). Lateral erosion of up to 100 also occurred on the left bank above and below Matsqui Bend (5), the former erosion a probable consequence of the floodplain growth.

There was minor erosion of the recent point bar deposits near Vedder Canal by 1940 (6) but otherwise this deposit stabilized and became incorporated into the left bank floodplain. Erosion continued on the opposite bank (7) because of upstream bar growth, but the magnitude was considerably less than in preceding decades. No further sedimentation is apparent at Strawberry Island, but young vegetation spread over an increasingly large area (8). Minor erosion continued at Matsqui Bend (9) because of the prevailing flow alignment. There were remarkably few changes to reach morphology by 1949 despite the passage of the 1948 flood. The low water conditions reveal new deposits at Vedder Canal (10) and in front of Sumas Mountain (11) but there was no compensating erosion on the opposite bank. Additional sedimentation at Strawberry Island consolidated former unit bars and the new bar complex (12) became attached to the right bank at Nicomen Island, extending downstream to the slough.

Very minor changes occurred from 1949 to 1962. Additional vegetation growth to the north of Strawberry Island reduced the secondary channel around the deposit to a minor high flow channel. There was also extension of vegetation along the right bank immediately upstream, while several small islands established on the formerly bare bar at the head of the main island. This growth was the consequence of vertical aggradation of finer sediments deposited by large floods in the early 1950s, while mainly below average flood flows in following years provided an opportunity for expansion. As the outer extent of remaining bare surfaces is similar to that shown in 1949 when water levels were much lower, these deposits must also be elevated and continued vegetation colonization is likely. Additional erosion of 50 m also continued along Matsqui Bend (14).

The low water conditions in the 1971 photos reveal a morphology very similar to 1949, although there was minor additional bar accumulation near Vedder Canal and further consolidation of vegetation at Strawberry Island. However, there was minor shoaling at the downstream end of Sumas Mountain and an emergent mid-channel bar formed immediately below (15). Riprap protection along Matsqui Bend nearly eliminated further lateral erosion there. Despite the passage of the large flood in 1972, the only major change to 1983 was floodplain erosion near the mouth of Vedder River (16). The appearance of several small scallops may be the consequence of oblique helical currents along the left bank. Extension of lower Yaalstrick bars probably forced this development, but high water at the time of photography obscures any detail. Downstream, vegetation continued to expand at Strawberry Island, creating a nearly consolidated single island. A narrow high water channel maintained separation from Nicomen Island, however.

The scallop erosion continued to 1991, with up to 100 m of additional shoreline loss related to shallow offshore bar deposits. There was no further consolidation at Strawberry Island, but there was siltation of the secondary channels, and vegetation began to encroach upon them. Further downstream, an elongated mid-channel sand bar had formed extending towards the right bank apex of Matsqui Bend (17). The origins of this feature can be traced back at least to 1979, when crescentic dunes were visible in the low water photos. Additional growth of this feature by 1999 narrowed the channel, forcing additional flow towards the left bank (18) and two small scallops had formed, undermining existing riprap protection. Upstream, there was further erosion on the left bank floodplain at Vedder Canal, but the reach otherwise remained stable.

There have been no dramatic changes in this subreach since 1928, when considerable erosion on outer channel banks near Vedder Canal created a large mid-channel bar downstream. Since 1928, additional sedimentation and vegetation growth at this site have created modern Strawberry Island, now nearly fully consolidated with Nicomen Island. Extensive bank hardening to protect the railway and flood dykes have limited lateral erosion of the floodplain. Consequently, the only other notable changes have been sedimentation and erosion near Vedder Canal, and the recent development of bar deposits near the right bank at Matsqui Bend.

C.6 Appendix references

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[6] Leopold, L.B. and Wolman, M.G. (1957). River channel patterns: braided, meandering and straight. U.S. Geological Survey Professional Paper 282-B.

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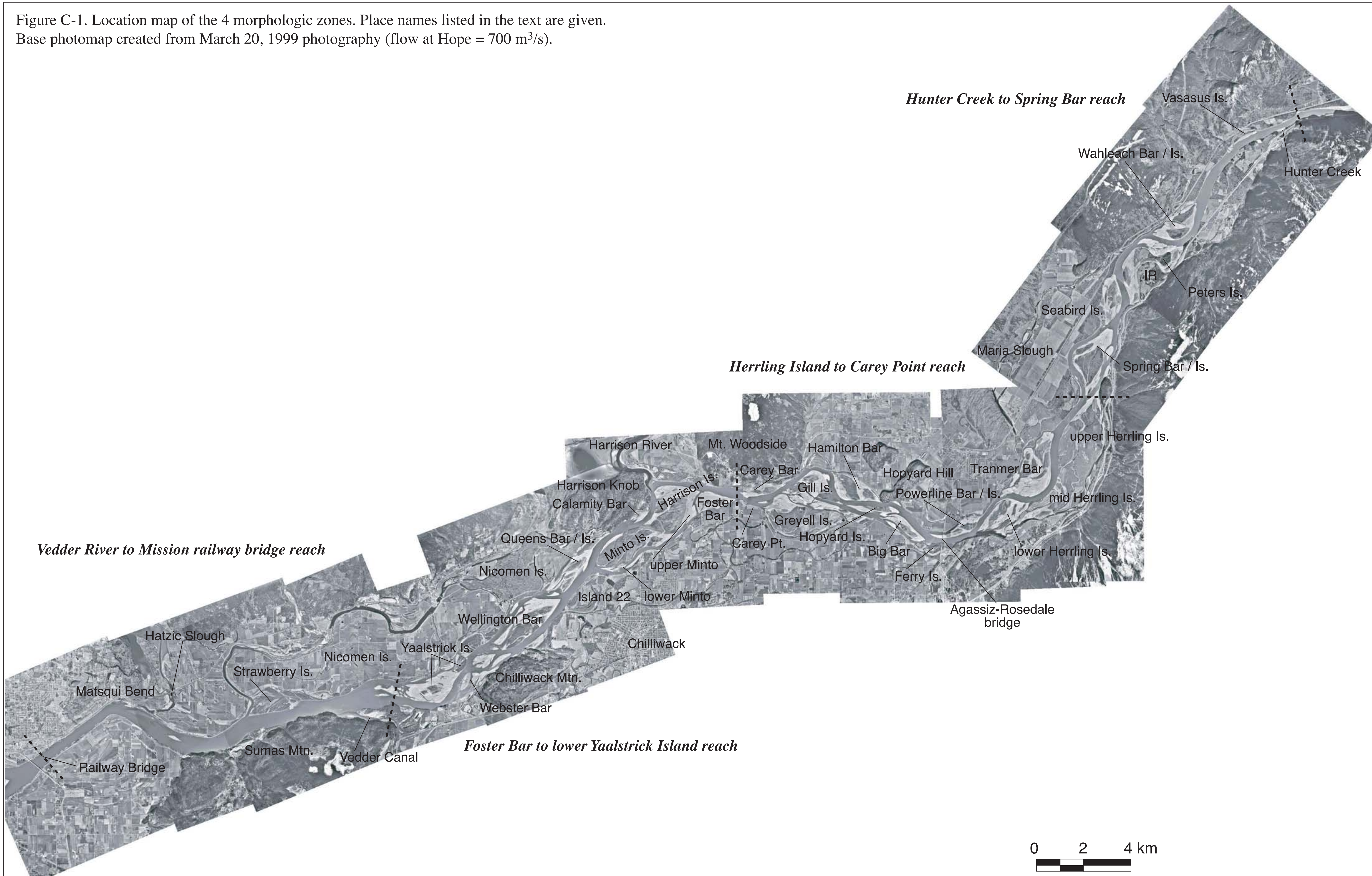
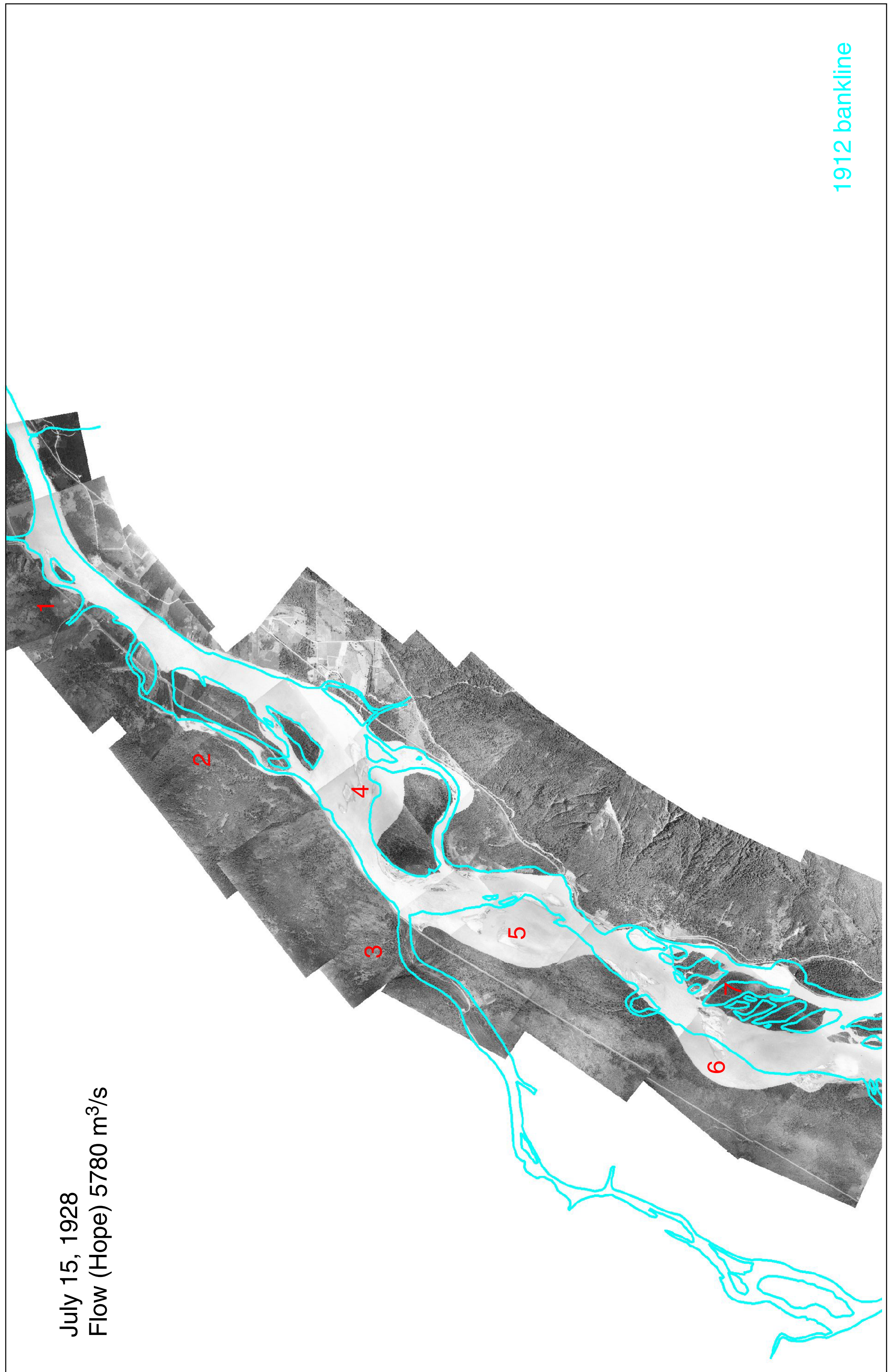
[9] Weatherly, H. and Church, M. (1999). Gravel extraction inventory for lower Fraser River (Mission to Hope) -- 1964 to 1998. Report prepared for District of Chilliwack, March 15, 18 p.

Figure C-1. Location map of the 4 morphologic zones. Place names listed in the text are given.
Base photomap created from March 20, 1999 photography (flow at Hope = 700 m^3/s).





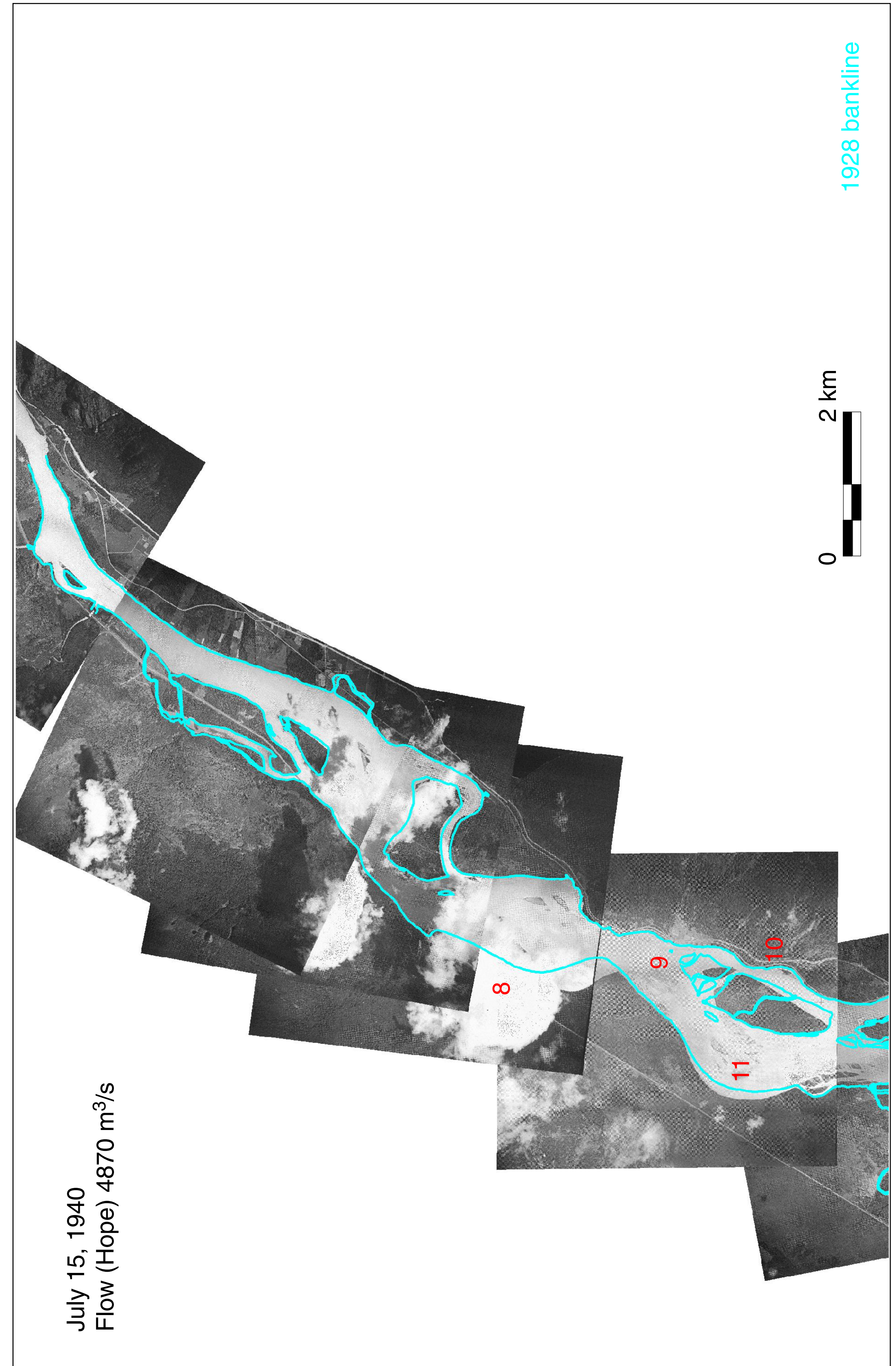


Figure C-2. Hunter Creek to Spring Bar reach, 1928 - 1940

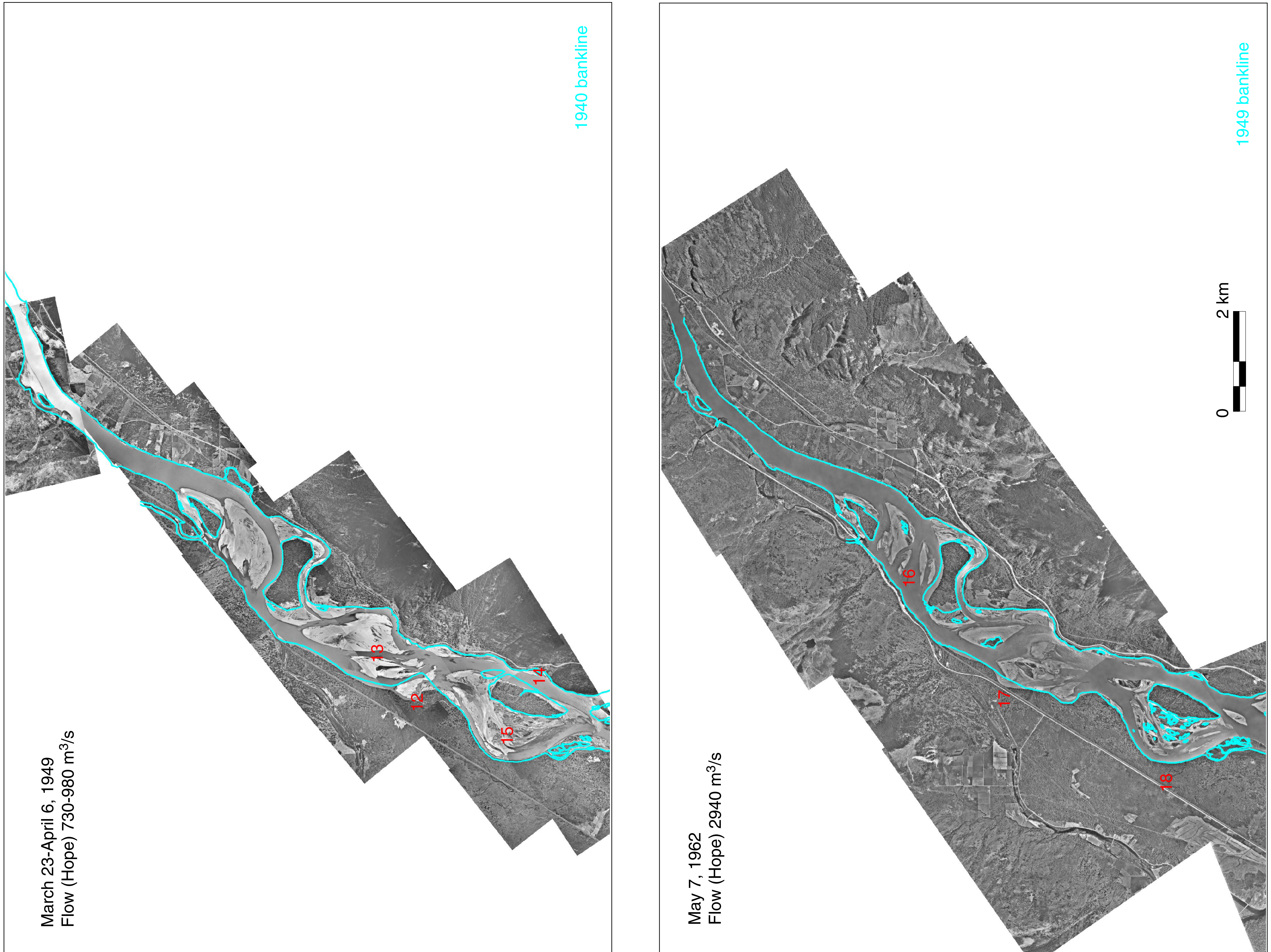


Figure C-3. Hunter Creek to Spring Bar reach, 1949 - 1962

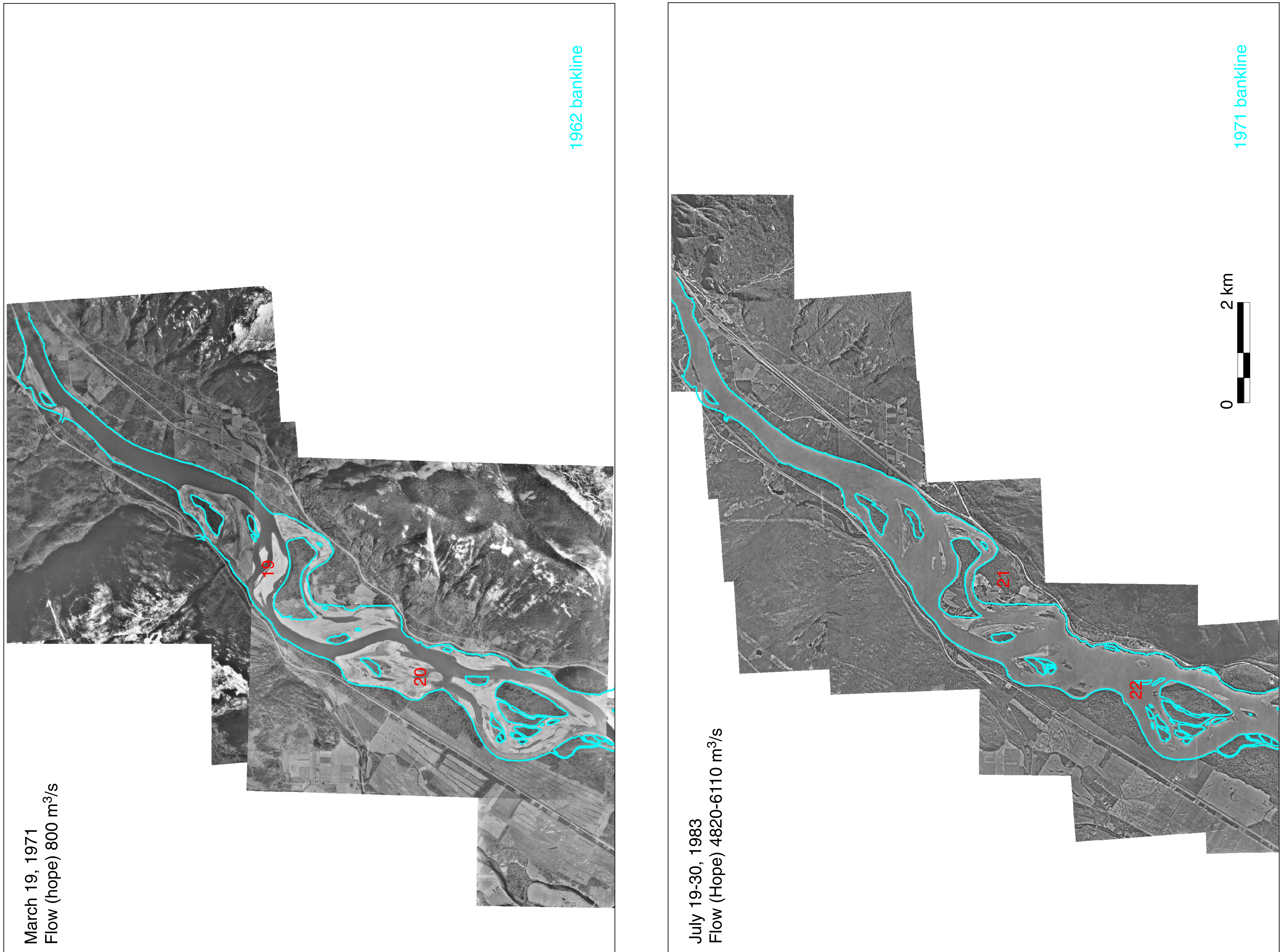


Figure C-4. Hunter Creek to Spring Bar reach, 1971 - 1983

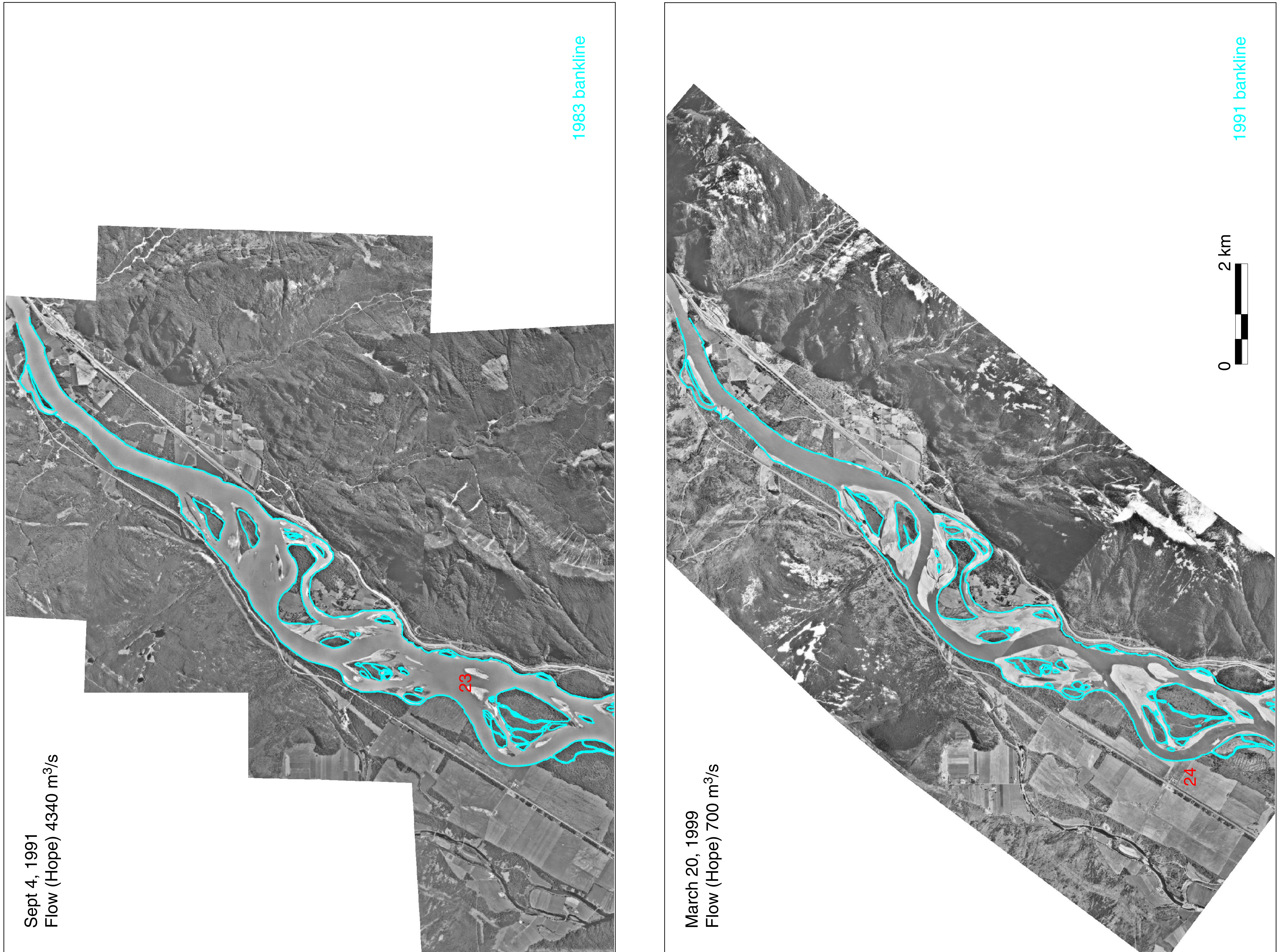


Figure C-5. Hunter Creek to Spring Bar reach, 1991 - 1999

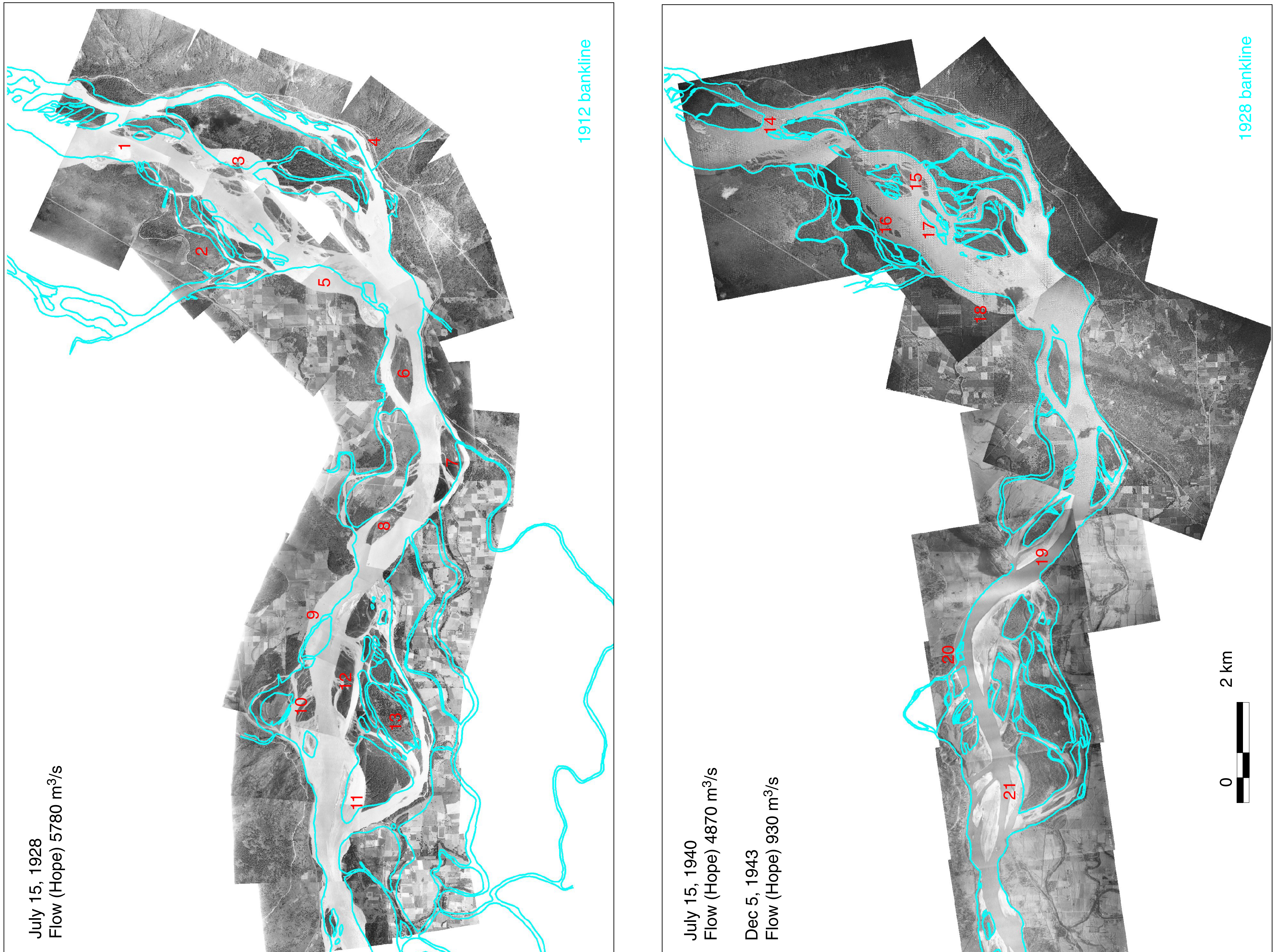


Figure C-6. Herrling Island to Carey Point reach, 1928 - 1940.

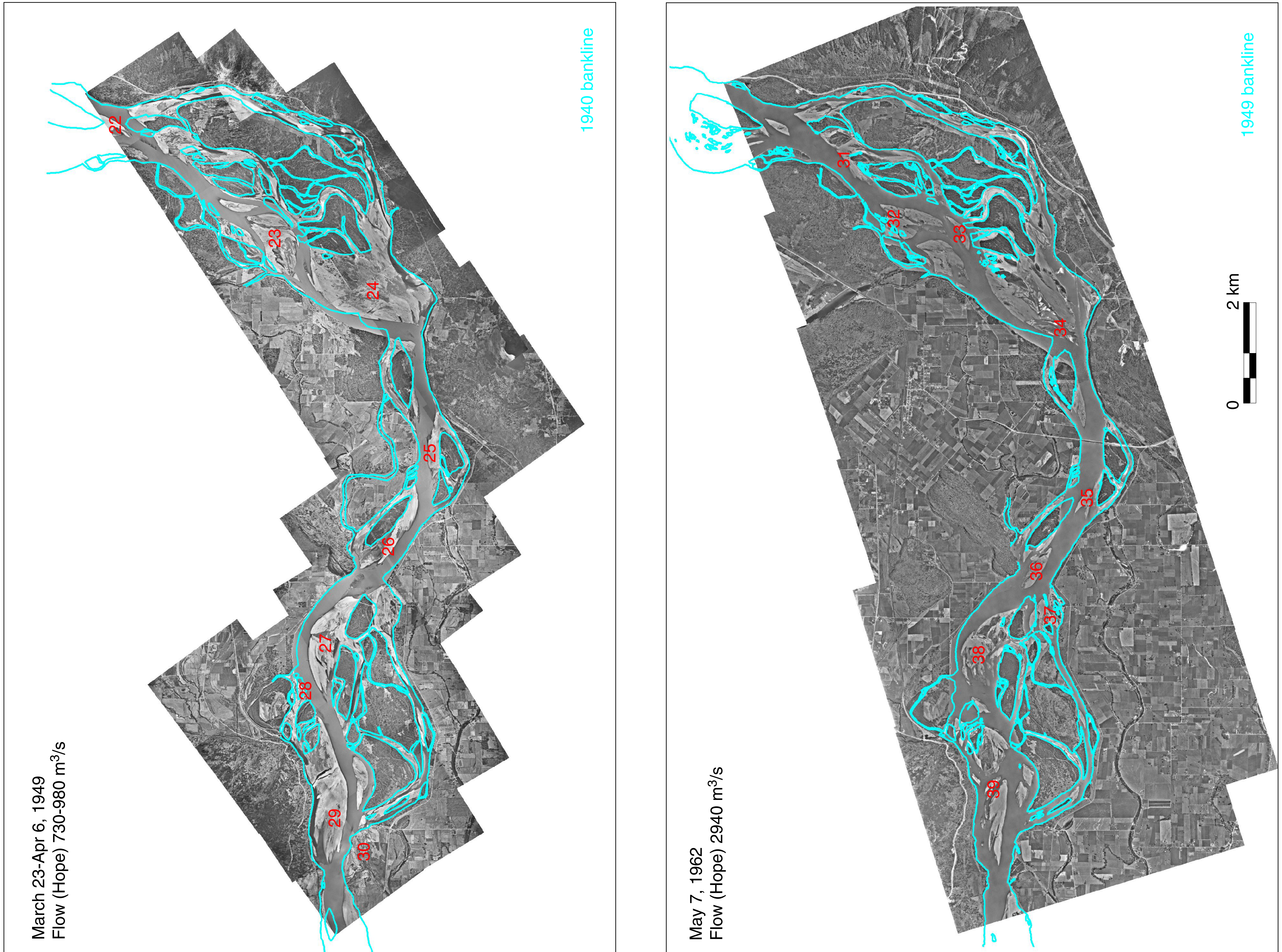


Figure C-7. Herrling Island to Carey Point reach, 1949 - 1962.

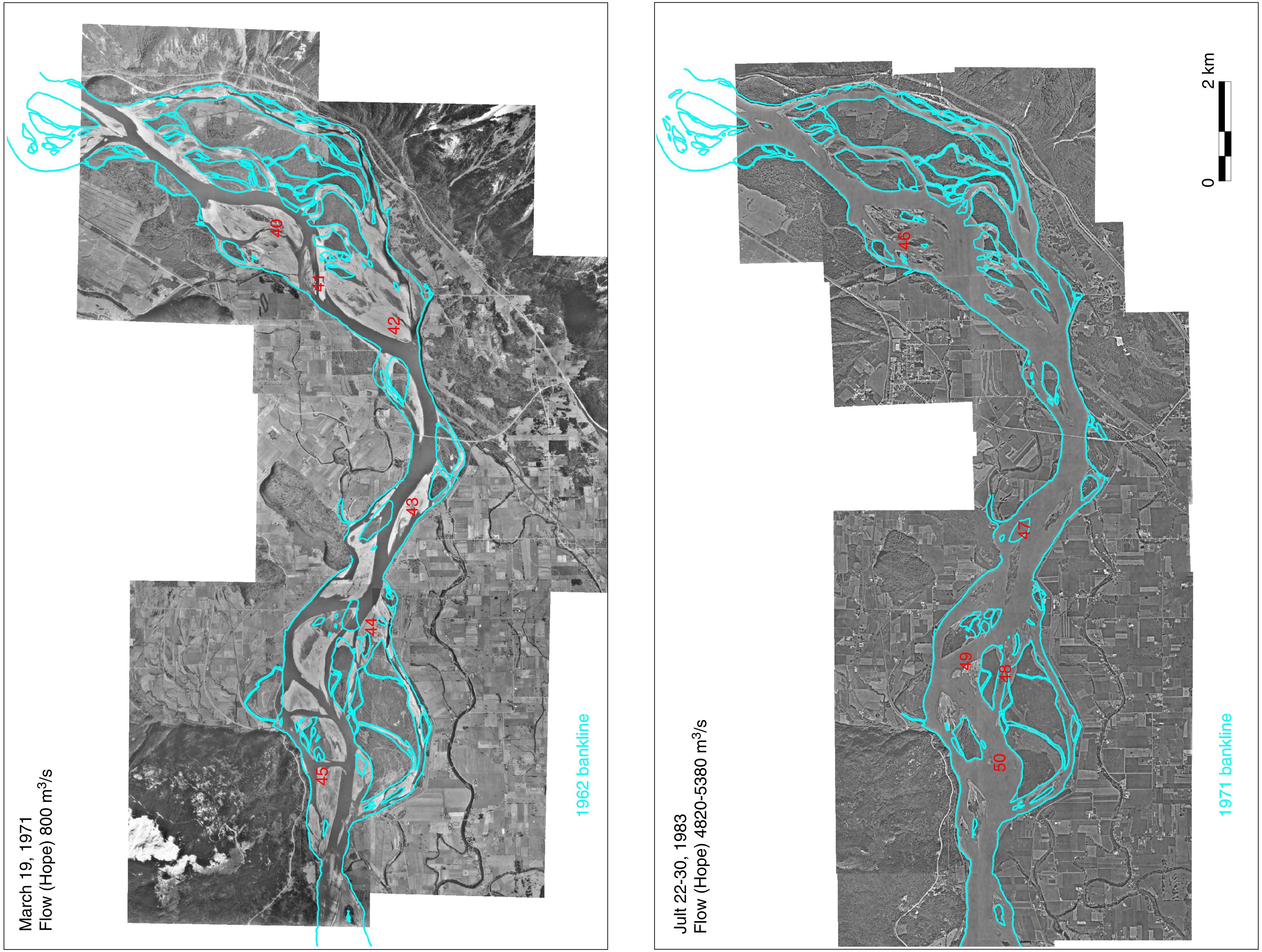


Figure C-8. Herrling Island to Carey Point reach, 1971 - 1983.