Quaamitch Slough Erosion

prepared for
Ministry of Environment, Lands and Parks
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Purpose and organization of this report

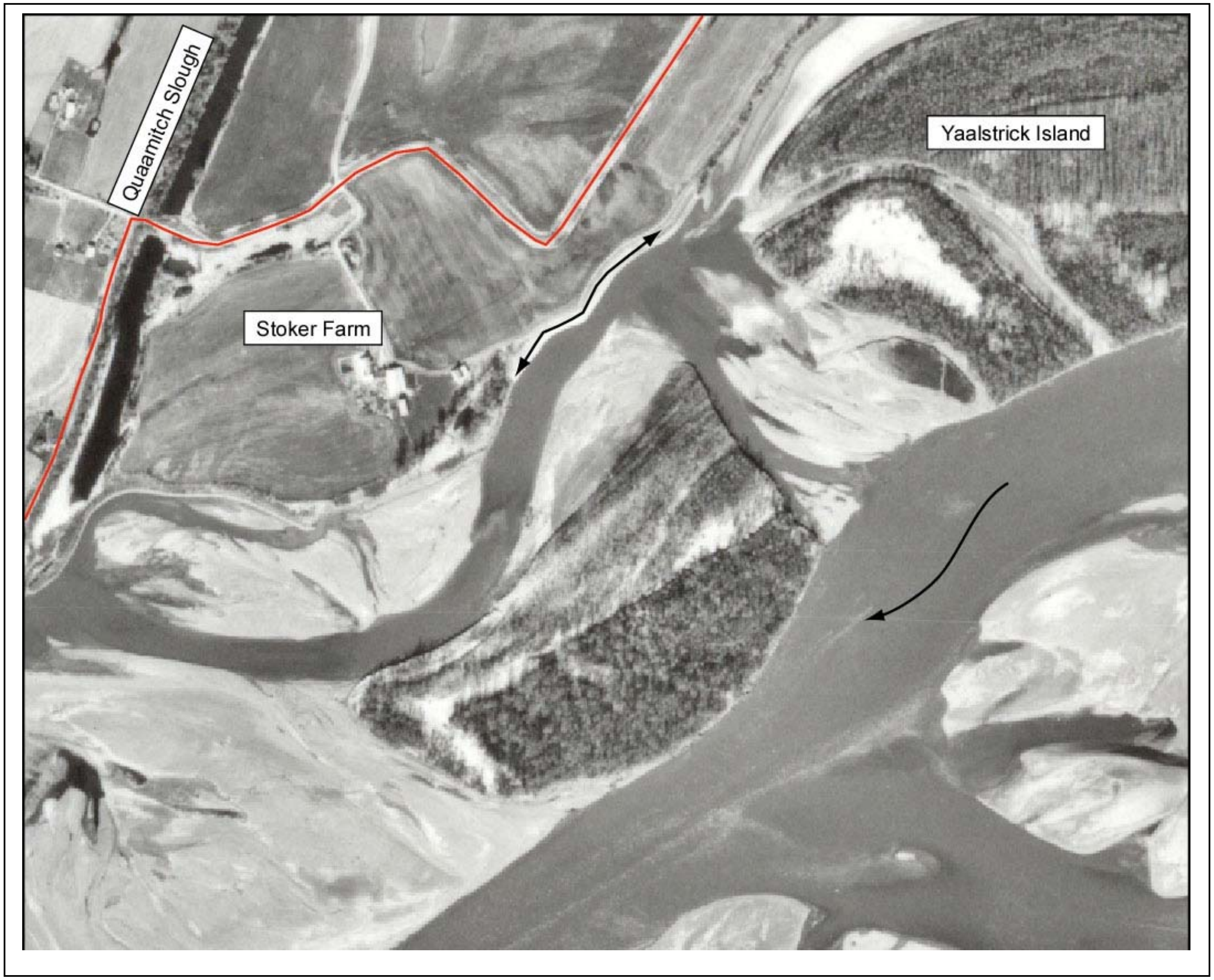
In recent years, erosion along the right (north) bank of Fraser River opposite Chilliwack Mountain has been of concern to local landowners and the British Columbia Ministry of Environment, Lands and Park (MELP). The area in question is located near the downstream end of the Yaalstrick Island complex, in the vicinity of Quaamitch Slough (Figure 1). Significant erosion at the site in the early 1990's prompted MELP to protect the bank with approximately 200 m of riprap during the winter of 1996. High flows during the subsequent freshet resulted in renewed erosion up and downstream of the site, as well as undermining of the newly emplaced riprap. The situation was monitored for several years until the winter of 1999 when sufficient funding was obtained to address the issue. At this time, the existing riprap was repaired and 200 m of additional armouring was constructed. However, the problem has not been resolved, with bank erosion now occurring downstream of the bank protection.

Figure 2 is a close-up view of the study site, showing the present extent of bank protection and the dyke, which is situated within 90 m of the active channel. Dykes surrounding Nicomen Island protect agricultural land and are of a lower standard than a majority of dykes in the area. Contemporary management objectives for the river are focused on the need to prevent flooding outside the channel zone of the river, and to discourage erosion beyond the active channel zone. Continued erosion at this site is in conflict with these objectives. There is also the potential for loss of property, with Stoker Farm situated immediately downstream of the site (Figure 2).

MELP has requested a report that documents channel changes in this reach during the recent past and considers potential future developments. The basis of this analysis is an ongoing study of the sediment budget (volumetric channel changes derived from channel surveys), and changes in channel morphology of Fraser River between Laidlaw and Mission. This recent work updates a previous study of similar scope conducted between 1982 and 1987 (cf. McLean and Mannerstrom, 1984; McLean and Church, 1999).

Figure 1.Quaamitch Slough and vicinity, March 20, 1999; Mission flow 699 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks. Scale is approximately 1:35,000. To facilitate comparisons, a similar scale is maintained for Figures 3 through 7. Numbered cells are sediment budget accounting units while the red lines represent dike locations. The outlined area is the extent of Figure 2.

Figure 2. Detailed view of study site, March 20, 1999. The black line shows the limit of bank protection constructed in 1996 and 1999. Bank erosion is now occurring downstream of the armouring. Scale is approximately 1:10,000.



Historical changes in the vicinity of Quaamitch Slough

In comparison with upstream reaches, the channel zone around Quaamitch Slough and Yaalstrick Island has remained relatively unchanged over the past half century. This reflects the downstream position of the site in relation to gravel transport. As gravel is transported out of the steep reaches of the Fraser Canyon, it is deposited in a confined gravel fan that extends from Laidlaw to the downstream end of Sumas Mountain, a distance of about 60 km. Gravel deposits build up because the gradient of the river declines so that the flow is no longer sufficiently powerful to wash the entire sediment load farther downstream. Gradients are sufficiently low downstream of Sumas Mountain that gravel transport ceases and the bed changes to sand. Because the study reach is near the distal end of the confined gravel fan, it represents the last significant area of gravel deposition and island formation. Gravel transport does occur downstream of the Sumas River confluence (Figure 1), but at very low rates (Church et al., 2000).

A comparison of the reach in 1949 and 1999 illustrates the relative continuity of deposits (Figures 1 and 3). The low flow of the 1949 photography reveals Wellington Bar, Yaalstrick Island and significant gravel bars on the flanks of Chilliwack Mountain and downstream of Yaalstrick – major channel elements that persist in 1999. Major differences between these dates are that a major channel divided Wellington Bar in 1949 and Yaalstrick Island was significantly larger (Figure 3). In addition, in 1999 a major channel sweeps along the western end of Wellington Bar to attack the bank of Yaalstrick Island (near the study site), and a flood channel carries the current past the island to impinge on the study site.

During the 1950's gravel was deposited at the upstream end of Wellington Bar, redistributing flow through the upper end of the study reach. By 1962 the major channel that flowed through the bar complex had been cut off and more flow was being directed toward the outer banks of the river on either side of Wellington Bar, although a majority of the flow was contained in the northern (right bank) channel (Figure 4). Because more flow was being directed along the right bank, the south side of the Yaalstrick Island complex came under attack with significant erosion, particularly at the downstream end. The direction of flow against the southern bank of the Yaalstrick Island complex was also aided by the downstream growth of Wellington Bar, probably the deposit of material eroded upstream.

Figure 3 Quaamitch Slough and vicinity, March 23, 1949; Hope flow 733 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks. The outlined area is the approximate extent of Figure 2.

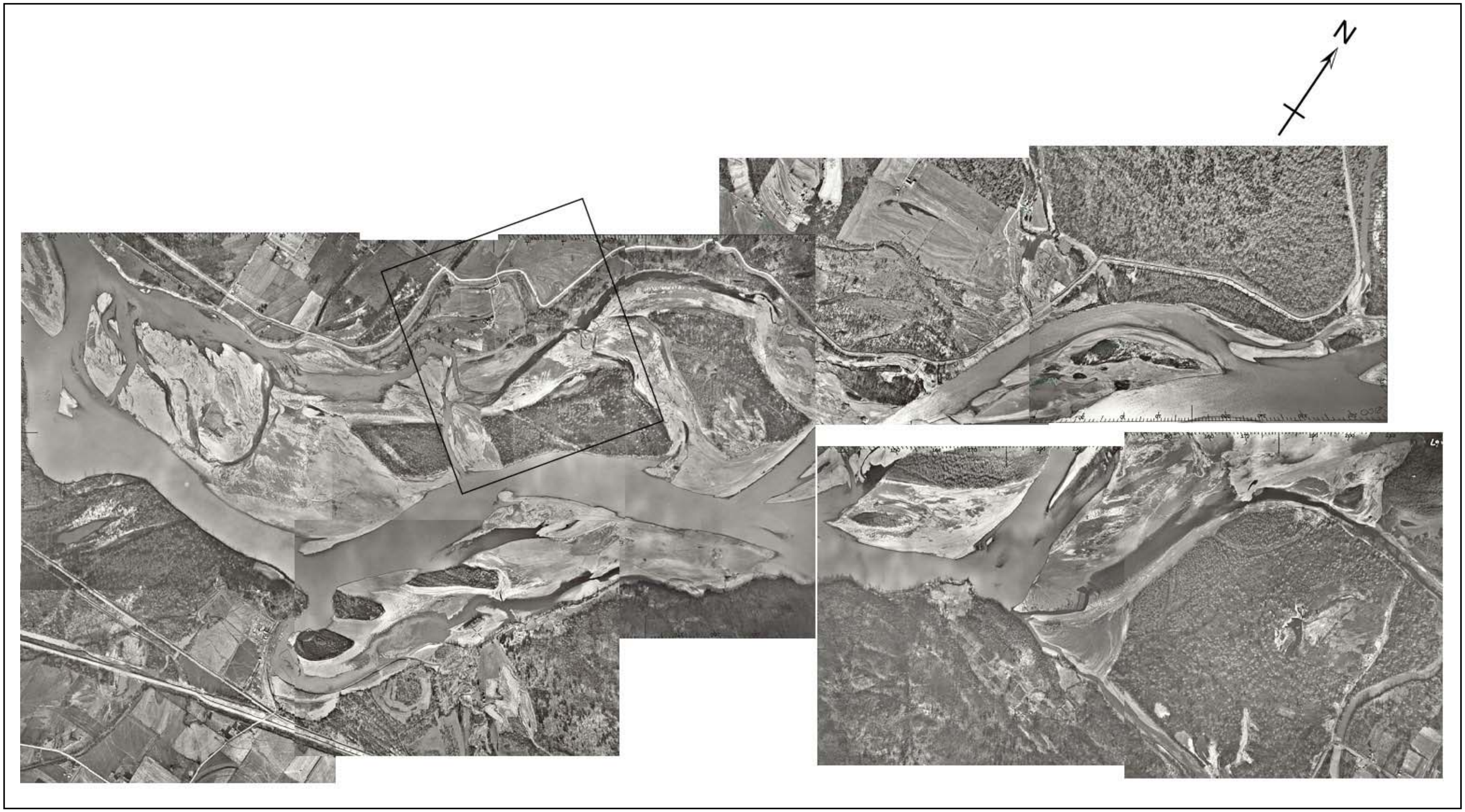


Figure 4 Quaamitch Slough and vicinity, May 7, 1962; Hope flow 2,940 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks.

The higher stage of the 1962 photography gives the appearance that the side channel behind Yaalstrick Island had abstracted increased flow between 1949 and 1962, but flow stage in the successive airphotos makes strict comparison difficult. A better comparison is with the 1971 photography, which was taken at a flow similar to that of 1949 (Figure 5). In both years the side channel appears as a narrow wetted channel, indicating a relatively shallow depth. A gravel bar was located immediately downstream of the study site in the 1949 photography. By 1971 the northern portion of the downstream island had grown toward the right bank, forcing the thalweg of the side channel against the bank downstream of the study site. However, no bank erosion occurred as a result of this minor channel adjustment.

In the main channel, there were few major changes between 1962 and 1971. Wellington Bar continued to stabilize with gravel deposition on its flanks and central portions, while minor trimming continued off Yaalstrick Island. The 1971 photography illustrates how the deposits at the downstream end of Wellington Bar assisted in forcing flow against Yaalstrick Island, although flow was somewhat divided through this section by 1971 with some flow escaping through the downstream end of the bar complex (Figure 5). Also apparent are medial bars at the downstream end of the Yaalstrick Island complex. Material eroded from upper and mid portions of the island would likely have been deposited at this location between 1949 and 1971.

Of particular note on the 1971 photography is the development of several gravel bars in the northern channel (right bank) at the upstream end of Wellington Bar (Figure 5). Deposition continued in this area between 1971 and 1979, forcing more of the flow into the southern channel (Figure 6). Flow in the southern channel proceeded in a southwesterly direction until it encountered the hard, high ground of Chilliwack Mountain. In 1971, this southern flow was directed away from Yaalstrick Island by a gravel bar at the downstream end of Wellington Bar. However, by 1979 this bar had been eroded by increased flows and a majority of flow was directed toward the west, directly against Yaalstrick Island (Figure 6). This configuration resulted in direct erosion of Yaalstrick Island between 1983 and 1999 (Figure 8c). No significant changes appear to have occurred between 1979 and 1991, although the high stage of the 1991 photography makes comparison difficult (Figure 7)

The new configuration of the river due to increased flows in the southern channel is most apparent on the low flow photography of 1999 (Figure 1). Here flow in the southern channel encounters Chilliwack Mountain and significant gravel deposits, forcing a majority of the flow toward Yaalstrick Island. This configuration has resulted in flows being directed between the two islands of the Yaalstrick complex, allowing increased flows into the side channel and bank erosion at the study site. Despite the low flow of the 1999 photography, it is apparent that the side channel at the study site is considerably larger than in previous years.

Because flow in the southern channel tends to impinge on Chilliwack Mountain at an angle, not all of the flow is forced directly west toward Yaalstrick Island. Some of the flow passes through parallel to the bedrock, cutting through gravel deposits off Chilliwack Mountain. This division of flow is aided by gravel deposits at the Chilliwack Creek confluence, which force the flow offshore and allow more of it to run past the mountain (Figure 1).

Figure 5 Quaamitch Slough and vicinity, March 19, 1971; Hope flow 799 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks.

Figure 6 Quaamitch Slough and vicinity, March 22, 1979; Hope flow 1,010 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks.

Figure 7 Quaamitch Slough and vicinity, September 5, 1991; Hope flow 4,410 m^3/s. Source Resource Surveys and Mapping Branch, British Columbia Ministry of Environment, Lands and Parks.

The changes described above can be assessed quantitatively by using historic maps of channel, bar, island and bankline positions. By digitizing airphotos for the gravel reach of Fraser River, channel maps for 1949, 1962, 1983, 1991 and 1999 have been created. Bankline positions from these years for the study site have been plotted on Figure 8a to 8d. Erosion of the study site and Yaalstrick Island between these dates is as follows:

Table 1 Historic erosion in vicinity of Quaamitch Slough.

Period	*Yaalstrick Island erosion (m^2)*	*per year (m^2)*	*study site erosion (m^2)*	*per year (m^2)*
1949 – 1962	-146,135	-11,240	-	-
1962 –1983	-175,220	-8,345	-	-
1983 – 1991	-70,115	-8,765	-20,170	-2,520
1991 – 1999	-21,555	-2,695	-41,850	-5,230

The active erosion of Yaalstrick Island between 1949 and 1983 is a product of more flow being abstracted by the northern channel past Wellington Bar, thereby attacking the southern bank of the island complex. Erosion since 1983 is a result of more flow shifting into the southern channel and being directed against the island by Chilliwack Mountain and its associated gravel deposits. This latter channel configuration is also responsible for increased erosion at the study site, as more flow is being directed into the side channel. Between 1983 and 1991, most of the erosion in the side channel occurred at the downstream end of the island complex, but up to 25 m of lateral erosion did occur at the study site (Figure 8c). After 1991 bank erosion at the study site was more significant with up to 75 m of erosion.

It should be noted that the deposition and erosion areas shown on Figure 8 refer to island/floodplain creation and destruction. They do not refer to within channel changes, such as from gravel bar to channel or gravel bar to island. Such changes have no reference on these maps since each year represents a different flow level (for example, 1991 was a year of high flow and hence there is little gravel bar area showing in comparison with other years).

Changes in channel alignment are a product of aggradation within the reach, as illustrated by the growth of Wellington Bar. These aggradational changes have been assessed quantitatively by comparing bathymetric surveys completed in 1952, 1984 and 1999 (Church et al., 2000). In this analysis, the gravel reach was broken up into a number of computational cells and volume changes were determined for each cell by overlaying the surveys in a GIS environment. For the study reach the relevant sub-reaches are 19 to 25 (Figure 1).

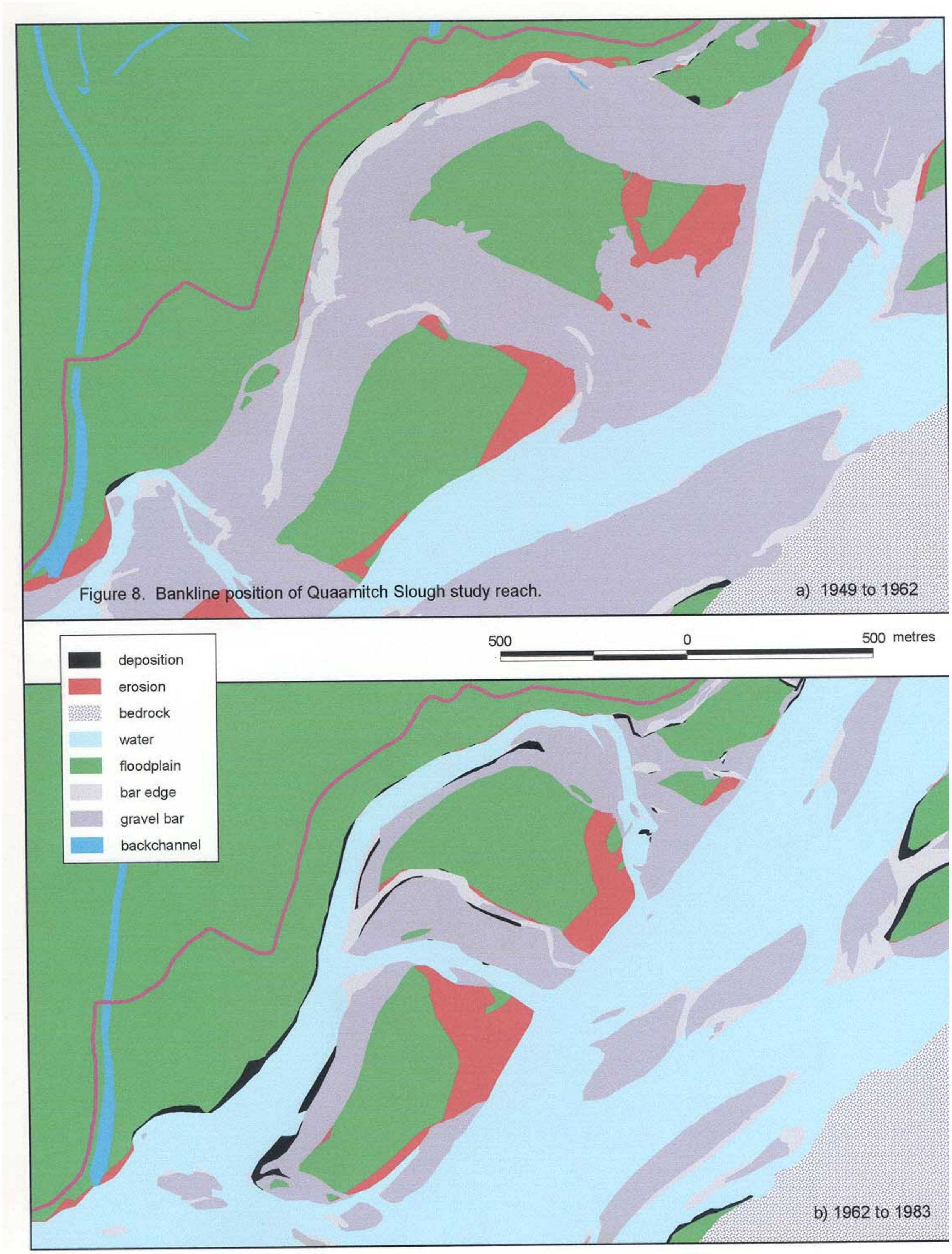


Figure 8. Bankline position of Quaamitch Slough study reach.

Figure 8 Bankline position of Quaamitch Slough study reach.

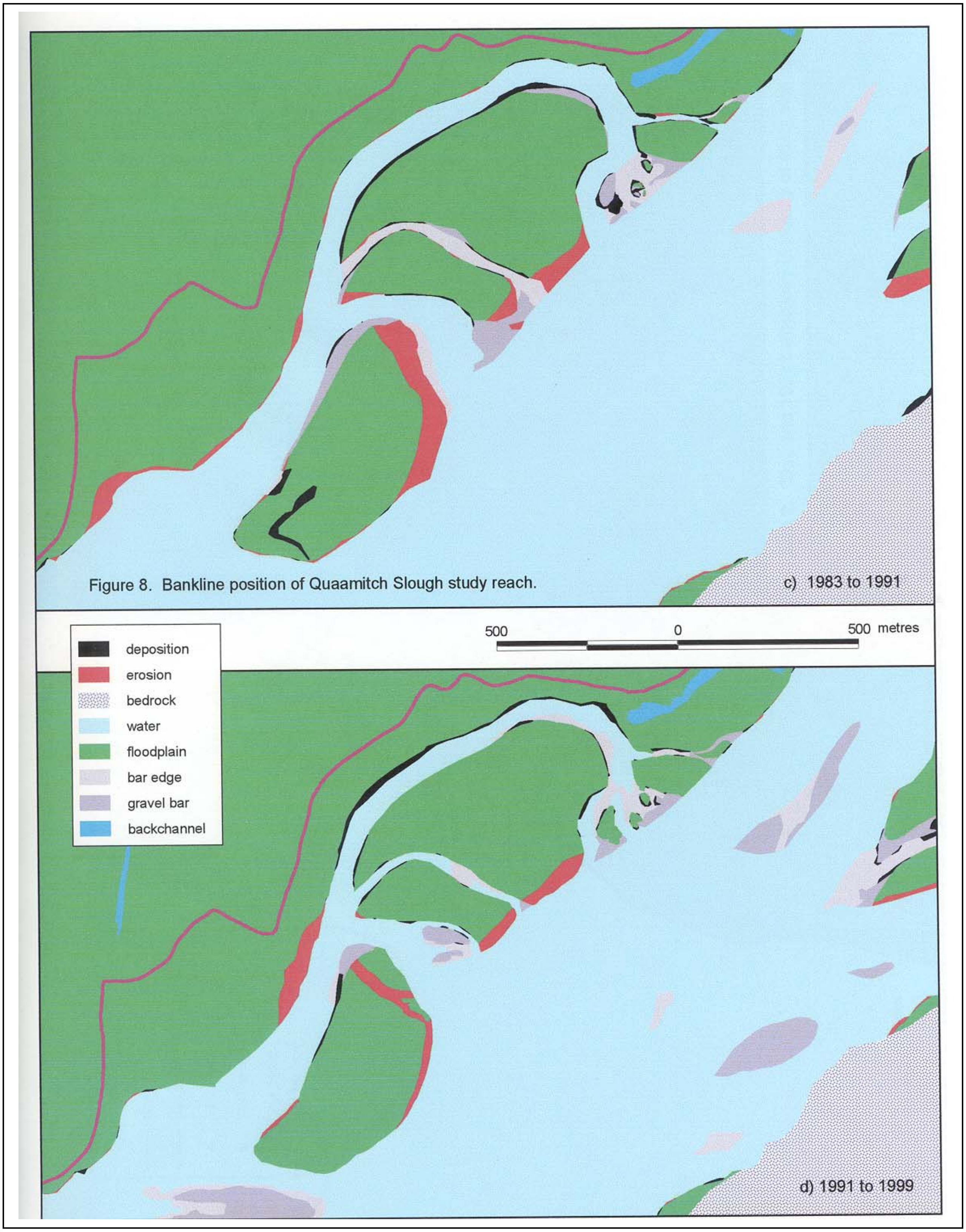


Table 2 Sediment volume changes in sub-reaches 19 to 25, 1952 to 1999. The bold row indicates the location of the study site.

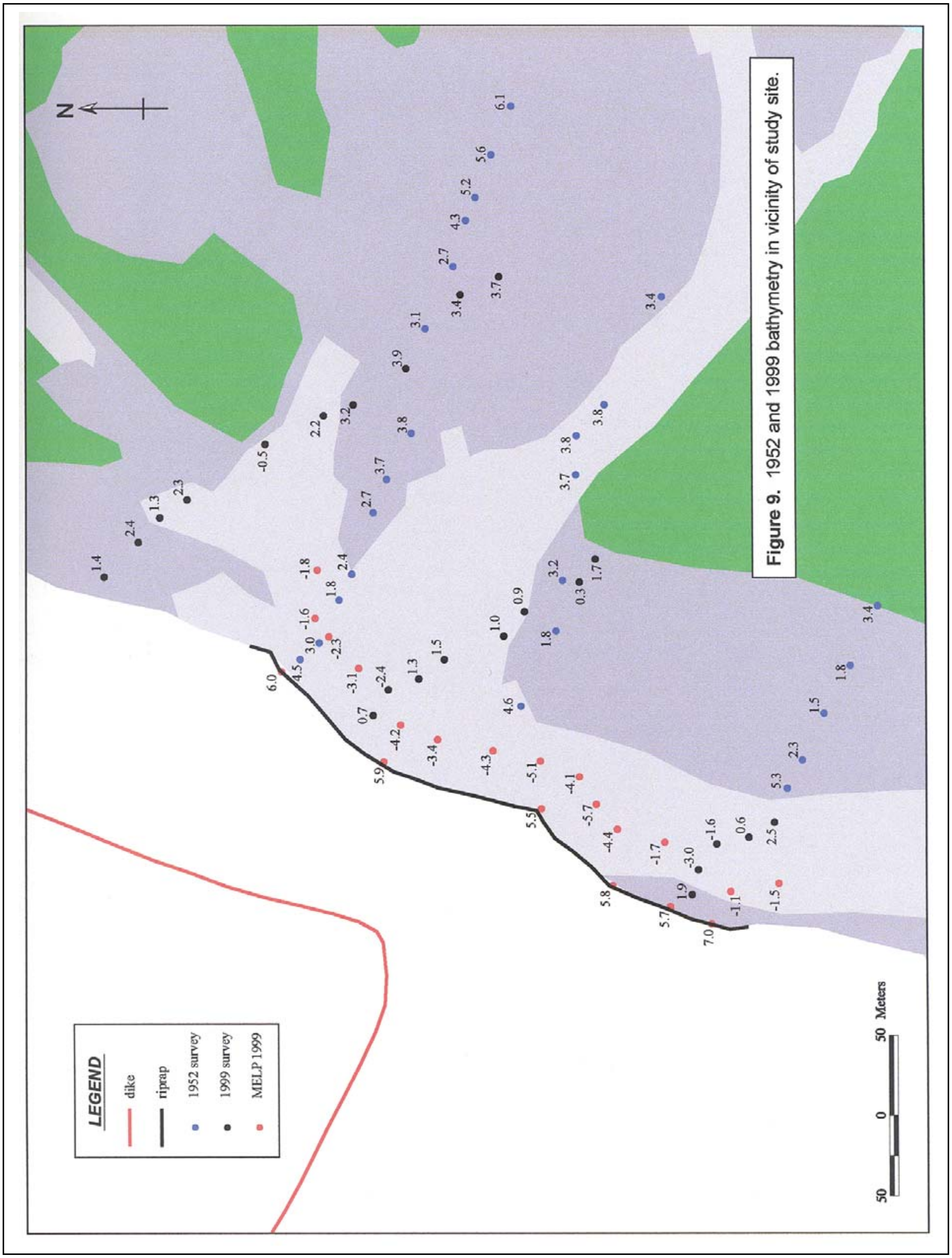
Cell	1952 – 1984 (10^3 m^3)	1984 – 1999 (10^3 m^3)	1952 – 1999 (10^3 m^3)
19	-748	1185	456
20	-627	340	-296
21	**-488**	**384**	**-106**
22	-884	332	-458
23	107	184	418
24	991	81	942
25	968	-37	878
total	*-681*	*2,469*	*1,834*

In the early part of the period (at least to 1984), there was significant deposition at the upstream end of Wellington Bar. This aggradation was responsible for the changes in channel alignment described above. The aggradation appears to have starved downstream subreaches, which were actively degrading during this period. After 1984, however, sedimentation trends appear to have been almost purely aggradational, apart from minor erosion at the upper end of Wellington Bar. Since 1984 much of the deposited material moving into the reach must have been originating upstream of Wellington Bar since the survey comparisons do not indicate significant sediment exchange within the study reach.

Significant aggradation in the last twenty years is consistent with a program of scuffle dredging off Chilliwack Mountain. This area has required regular dredging to allow tug boats with log booms enough depth to pass through the sequence of bars. The program was terminated a few years ago but the situation became critical during September 2000 when logs could not be towed past Chilliwack Mountain despite relatively high flows. After consultation with DFO personnel, permission was given by MELP to dredge a small channel through the bar complex off Chilliwack Mountain (Figure 1). Approximately 100,000 tonnes of sand and gravel were moved to the side of the excavated channel, rather than removing the material from the river. This allowed tug boats enough room to pass through this section of the river. However, by January 2001, the situation was again critical.

At a more local scale, increased flows to the study site can be assessed by comparing bathymetric data acquired in 1952 and 1999 (the 1984 bathymetric survey did not go into this back channel because of low flow depths). The 1952 data show that the side channel was relatively shallow, while the 1999 data indicate increased scour depth that is consistent with increased flows into the side channel (Figure 9). The 1999 bathymetric survey was acquired in 200 m transects so data parallel to the study site are limited. However, MELP commissioned a surveyed of this section during the winter of 1999 prior to the repair and placement of riprap. These data indicate scour depths of up to –5.7 m, up to 6 m deeper than maximum depths recorded in 1952.

Figure 9 1952and 1999bathymetry in vicinity of study site.



Possible future developments in the vicinity of Quaamitch Slough

Channel alignment around Wellington Bar is presently exercising control on the pattern of flow in the vicinity of the study site. As noted, more of the flow is presently entering the southern channel (left bank) where it flows in a southwesterly direction toward Chilliwack Mountain. When the river reaches the hard, high ground of the mountain and its associated gravel deposits, a majority of the flow is forced to the west directly toward Yaalstrick Island. This has resulted in increased flows into the side channel behind Yaalstrick Island and subsequent erosion at the study site, which lies opposite a major flood entrance to the side channel (Figure 1).

The question is whether this alignment is expected to persist for a number of years. If the alignment does persist, we expect that present flows to the side channel will continue, if not increase. This will lead to continued erosion downstream of the present bank protection. However, there is evidence to suggest that more of the flow may be directed away from Yaalstrick Island in the next decade. At present when the southern channel reaches Chilliwack Mountain, some of the flow is passing through the gravel deposits situated adjacent to the mountain, thereby bypassing mid and upper portions of Yaalstrick Island (Figure 1). This would suggest that the southern channel alignment is straightening to flow more parallel to the mountain. This realignment may be driven by deposition at the downstream end of Wellington Bar, where dredging was required to allow tugboats passage through this reach. Deposition in this area is obvious on the 1999 airphotos and represents the formation of a large-scale riffle. If deposition were to continue in this area (as the 1984 to 1999 bathymetric survey comparison would suggest), the southern channel could realign itself so that a majority of flow was not forced in a westerly direction toward Yaalstrick Island.

Local dyking authorities have asked whether introducing more flow into the side channel entrance at the upper end of Yaalstrick Island would reduce the hazard of further erosion. Changing the distribution of flow in the northern channels would not appreciably reduce the present erosion hazard since the hazard is a result of flow in the southern channel. In fact, directing more flow into the side channel could induce bank erosion downstream of the entrance where there is a large bend in the side channel.

Potential actions to mitigate the current problem are as follows:

1. *Because navigation through this reach is an ongoing problem, dredging of the gravel deposits off Chilliwack is a potential action. If dredging were concentrated on the south (left bank) side of the large medial bar downstream from Wellington Bar, it would encourage more of the flow into the southern channel and away from Yaalstrick Island. Observations noted above indicate that a change in alignment may be occurring naturally and dredging would accelerate this realignment. The practicality of such a proposal would depend on the feasibility of navigating along the south side of the river. Furthermore, such a realignment could eventually become a problem downstream of Yaalstrick Island where the Nicomen Island dyke is situated immediately adjacent to the right bank (Figure 1). A large channel flowing through the deposits off Chilliwack Mountain would potentially be directed against*

the large gravel bar at the downstream end of the Yaalstrick Island complex. Subsequent erosion of this deposit could result in flows being directed against the right bank.

2. *If the main channel were to maintain its present configuration, an alternative solution may be to build a rock spur off the downstream end of the riprap at the study site. This would guide the flow away from the unprotected banks. A rock spur would not have to be constructed to withstand excessive flows, since the side channel abstracts a relatively minor portion of the total flow.*

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