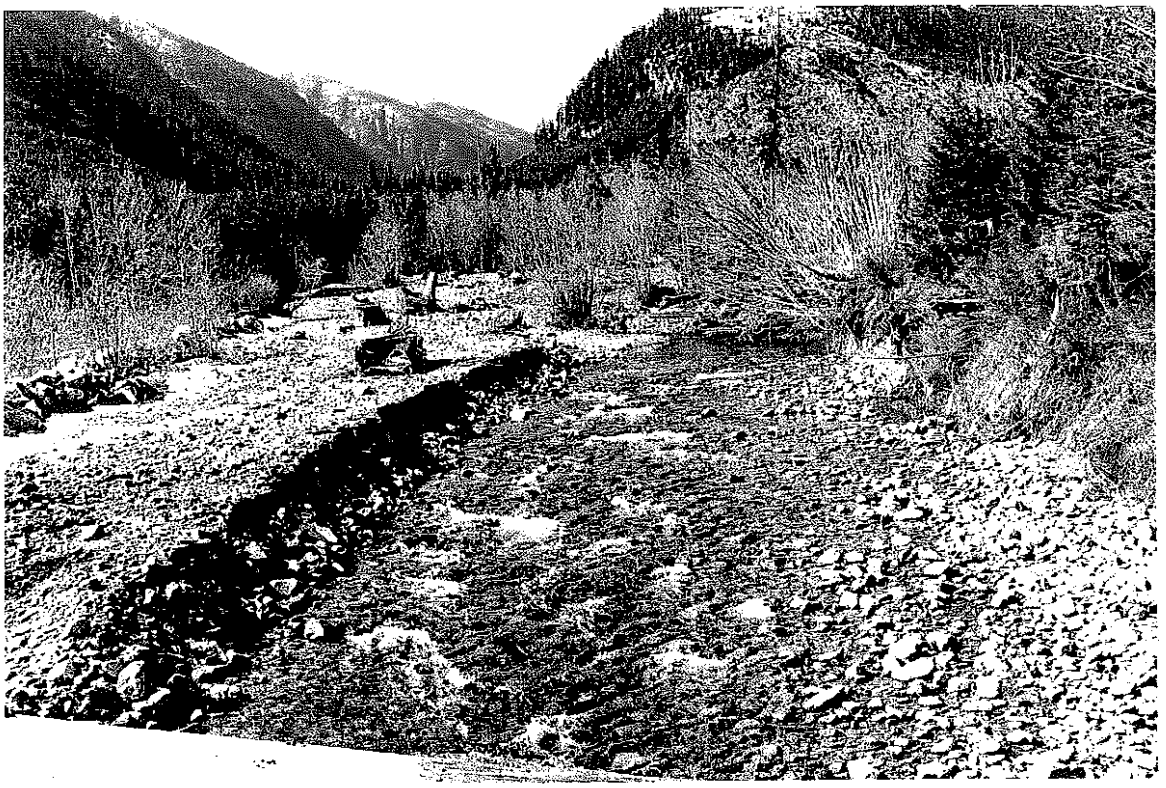

PHOTO 1: KIYU CREEK, SOUTH CHANNEL, LOOKING UPSTREAM

PHOTO 2: KIYU CREEK, LOOKING DOWNSTREAM AT THE CHANNEL SPLIT

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MINISTRY OF PARKS

NIMPKISH RIVER ECOLOGICAL RESERVE

PHOTOGRAPHS 1 AND 2

PROJECT NO.

Since reverting back to the south channel, the stream has downcut into the bed by approximately 1 m, Photo 1. This downcutting has been accompanied by the meandering of the low flow channel with significant erosion of the right bank. These locally eroded sediments have been deposited on the fan at the mouth, extending the bar into the Nimpkish and resulting in the erosion along the north side of the island. Up to 30 m has been lost from the north east corner of the reserve since 1984.

Flow in the south channel of Kiyu Creek has not yet reached a state of equilibrium and further local erosion can be expected.

A logging road crosses Kiyu Creek between the mouth and the split in the channels. The bridge over the northern dry channel was apparently shortened or replaced after the flow reverted back to the south channel. Evidence of this change can be seen in the field and the aperture under the northern bridge is now 50% of the opening under the southern bridge.

Left in its present state further erosion in Kiyu Creek south channel will enlarge the bar deposited at its mouth, squeezing the low flow channel of the Nimpkish River against the island and exacerbating the erosion.

3.2 Erosion Along the West Side - B

The west side of the island has a slightly concave shape in plan opposite a large point bar and treed terrace on the left or mainland side. Flows are concentrated against the island opposite the point bar and some erosion is evident, Photo 5. Although some trees have fallen, the erosion is not as severe as along the north east corner.

Extensive erosion is also evident upstream of the point bar on the outside of the large bend where the stream turns around the south west corner of the island. Considerable debris is evident in the channel and there is a potential for a log jam to develop, Photo 6. In its present state, gradual erosion along the concave section of the bank along the west side of the reserve will likely continue. However, it is not possible to predict future changes since obstructions such as log jams and sediment bars can lead to dramatic changes in the position of the low flow channel.

3.3 The Southeast Corner - C

The south side of the island faces the outflow fan of Sebalhall Creek, a short stream which drains Vernon Lake. The lake lies in a valley which roughly parallels the upper Nimpkish, the two valley floodplains merging in a "Y" at the location of the island. The main stem of Sebalhall Creek enters the Nimpkish just upstream of the reserve.

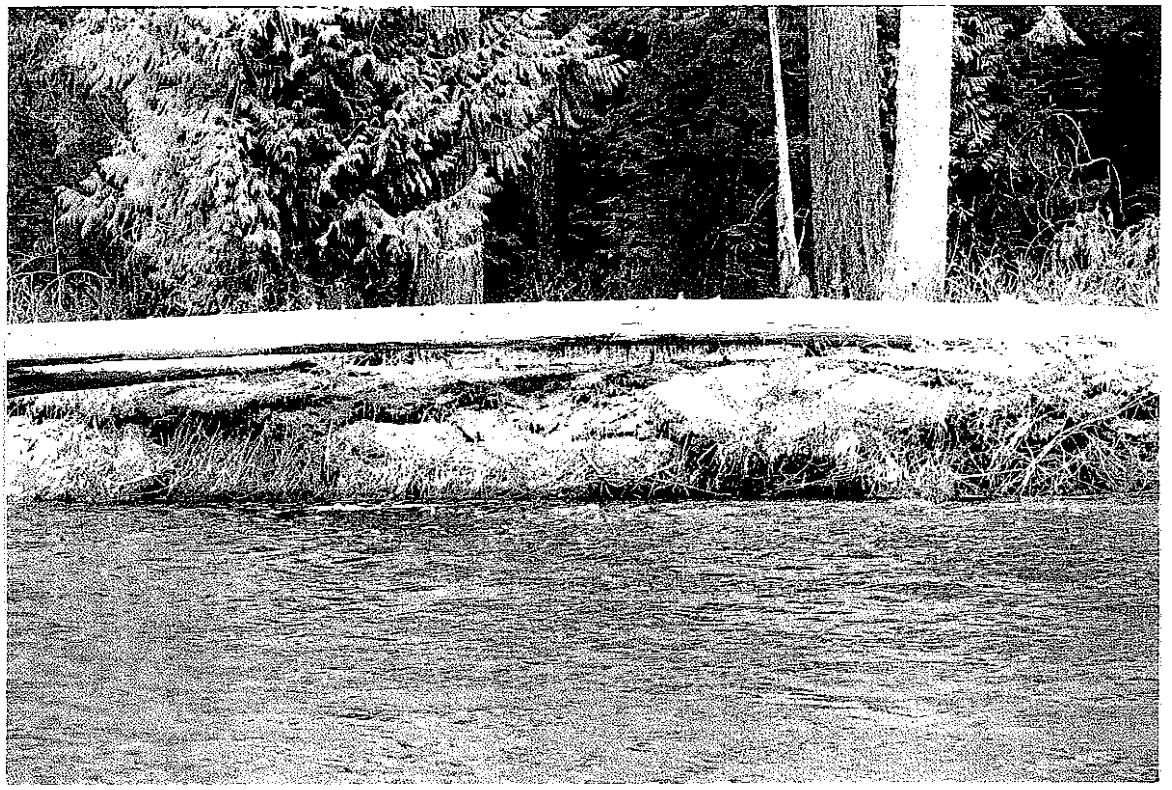

PHOTO 5. ERODING BANK. WEST SIDE OF ISLAND

PHOTO 6. LOOKING UPSTREAM ALONG WEST SIDE OF ISLAND. NOTE LOG DEBRIS

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NIMPKISH RIVER ECOLOGICAL RESERVE

PHOTOGRAPHS 5 AND 6

PROJECT NO.

Several braided side channels lead from the right bank of the Nimpkish opposite Sebalhall Creek across to the south east corner of the island where they discharge into the cutoff channel forming the east side of the reserve. Two other small cutoff channels lie further to the east leading from the mouth of the Sebalhall Creek. Although these channels are obviously active at high flows, the conveyance capacity is limited by in-channel growth and debris.

Apparently, a storm in December, 1980 resulted in a log jam commencing just downstream of the south east corner of the island. Subsequent flows consolidated the jam leading to increased flows down the cutoff channel. By 1986, severe local erosion had resulted in the loss of approximately 20 m of bank around the south east corner of the reserve. Remedial action was undertaken in the late summer of 1987. The eroded area was partly backfilled with debris and gravel and protected by a 1 m thick riprap blanket around the outer face, Photo 8. The log jam was dismantled and the unmerchantable timber and debris used to form a barrier across the entrance to the cutoff channel. Gravel was used to cover the barrier and so create a berm approximately 300 m long forming the right bank of the Nimpkish River, Photo 7. The crest was constructed higher than the left bank and a saddle or overflow area left across the central part at the entrance to the cutoff channel.

Although the berm has streamlined the channel along the south side of the island it has been constructed from light weight or transportable materials and cannot be expected to withstand overtopping or to have significant longevity. The gravel covering the downstream 50 m of the berm appears to have been washed out, leaving the mass of debris exposed.

There is no immediate threat to stability of the island's perimeter along the southeast corner and south side. In the event of the berm overtopping, the riprap will provide protection to the section of bank previously eroded.

3.4 East Side

The east side of the island is formed by an active cutoff channel connecting the two legs of the U shape of the main channel. The cutoff channel is straight, approximately trapezoidal in shape with 2.5 m high banks. The conveyance capacity of the channel is approximately 1/2 to 1/3 of the capacity of the main channel around the other three sides of the island and should it see either a requisite or higher proportion of flow, gradual erosion along the east side can be expected. In the event of high flow severe local erosion would result, with trees being undercut and falling into the stream. The mouth of the cutoff channel is currently controlled by a large log jam resulting from the erosion of the northeast tip of the island opposite Kiyu Creek.

PHOTO 7: NIMPKISH RIVER. LOOKING DOWNSTREAM ALONG 1987 BERM

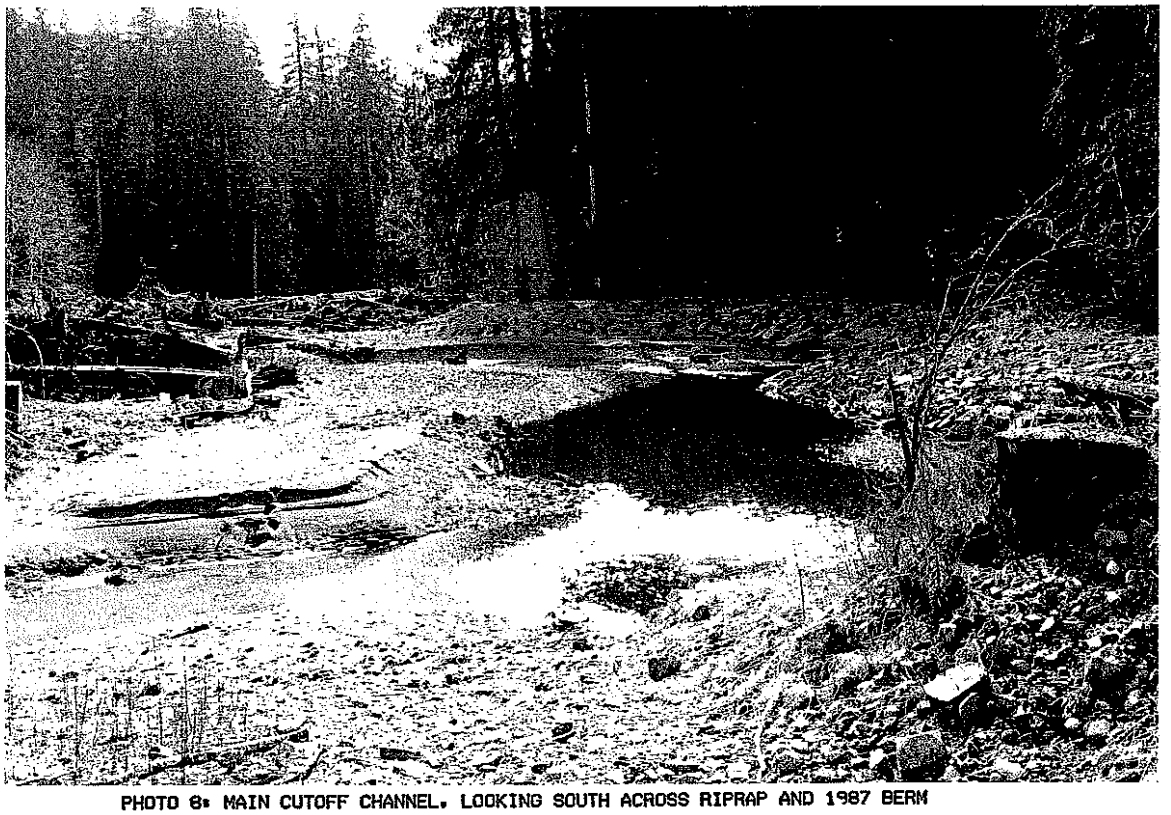

PHOTO 8: MAIN CUTOFF CHANNEL. LOOKING SOUTH ACROSS RIPRAP AND 1987 BERM

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NIMPKISH RIVER ECOLOGICAL RESERVE

PHOTOGRAPHS 7 AND 8

PROJECT NO.

4 PROTECTION CONCEPTS

The island has been deemed an ecological reserve in recognition of its unique and outstanding growth of large healthy trees representative of a floodplain environment. The island's ecological foundation is, no doubt, supported by occasional flooding and channelling of overflows through the island importing nutrients and sediments. Preservation of these features and the island's natural setting is critical in developing protection concepts. This task is complicated by the induced changes to the natural setting through thirty years of logging activity which is now threatening the stability of the island. Two philosophies for preserving the Island can be considered:

1. altering the geomorphic characteristics in the vicinity and

2. providing selective erosion protection around the perimeter.

4.1 Geomorphic Alterations

The threat to the island is the large sediment load and increased velocities during flow events in the river channel around its periphery. Controlling these factors should allow the island to revert to the previous state of equilibrium that likely existed prior to logging. The island is in a unique geomorphic position at the junction of two valleys creating a wide flat floodplain. Flows could be diverted, to essentially, but not completely bypass the island.

The essential features of this concept would be to open up a cutoff channel east of the island with an appropriate diversion structure at the upstream end. The structure would allow a portion of low flows to continue to pass around the island and to permit overtopping during extreme events so the island is still flooded by backwaters and supplied with nutrients and fine sediments. The location of a bypass channel is influenced by the following factors :

- use of existing channels to minimize excavation volumes

- recognition of habitat value in existing channels

- ease of splitting flows with diversion structures

In consideration of these factors, several options become apparent:

1. Widening the existing channel along the east side of the reserve with the addition of some armouring along the left bank of the channel, Figure 3.

2. Clearing and enlarging one of the smaller existing cutoff channels, Figure 4.

3. Creating a new cutoff channel through the floodplain east of the island and west of the outlet of Sebalhall Creek, Figure 5.

4. Creating a new channel allowing Sebalhall Creek to flow around the island and directing the Nimpkish through the cutoff channel, Figure 6.

Clearing out the existing smaller cutoff channels without widening the channels installing a diversion structure is considered ineffective. The channels would have small conveyance capacity and thus would not significantly reduce flows or relieve erosive stress around the island.

The outflow from Kiyu Creek will still present a problem in the long term as more sediments are deposited on the bar and the mouth migrates south towards the reserve. Shifting Kiyu Creek back to its northern channel and moving the gravel bar at its mouth against the island would enhance the stability of the north side of the reserve.

4.2 Selective Protection

Whereas altering the geomorphic structure around the island attempts to address the underlying problem, selective protection of the island's perimeter addresses the symptoms of the problem. Until the island is completely encircled with protective structures critical erosion areas may develop along the unprotected stretches as the channel reacts to the imposed loads of sediments, debris, and magnitudes and durations of flows.

The concept of selective protection would thus require periodic site inspections to assess the critically eroding sites on the island. Protection concepts have been developed for each of the existing critical sites and are detailed in the following paragraphs.

The Southeast corner of the island is currently protected by the gravel and debris berm constructed by Water Management Branch in 1987. This berm is currently experiencing erosion and will at some future time be breached, allowing more water to flow down the main cutoff channel. Two options are available at this site:

- leave the berm as it is and address future breaching when it becomes critical, or

- reconstruct the berm now to create a stable structure.

Fixing up the berm would require installation of a riprapped overflow channel on the berm and some reinforcement of the berm with larger non-erodable material.

The main cutoff channel on the east side of the reserve has experienced erosion although the flow of water through this channel has been restricted by the berm constructed by WMB. If this channel is to be considered as providing overflow flood relief to the main Nimpkish channel in the future, bank protection should be considered along its entire length. As previously discussed, the bank protection could consist of either riprap or spur groynes. Unfortunately, the main cutoff channel is not wide enough to excavate gravel from the river bed and fill against the eroding bank, and the protective measures would be left exposed.

The protection concepts are summarized in Table 1.

Table 1: Protection Concepts Summary

Concept		Objective	Cost
Independent Short Term Concepts			
A	Divert Kiyu Creek	Relieve stress on NE corner of Island	$12,000.00
B	Relocate Gravel Bar At NE Corner	Shift channel away from island	$25,500.00
C	Relocate point bar West side of Island	Shift channel away from Island	$21,000.00
Long Term Enhancement Options			
D	North End Riprap protection	Insurance against loss of gravel bar	$220,000.00
E	North End spur groynes	Alternative to D	$140,000.00
F	West side of Island Riprap protection	Insurance against loss of gravel bar	$165,000.00
G	West Side spur groynes	Alternative to F	$120,000.00
H	Main Cutoff Channel Riprap protection	Required if berm at SE corner overtops	$292,000.00
I	Main Cutoff Channel Spur groynes	Alternative to H	$120,000.00
Geomorphic Alteration Alternatives			
J	1. Enlarge Cutoff Channel and construct new berm	Main Cutoff Channel used for diversion	$230,000.00 + riprap
K	2. Enlarge east cutoff channel, construct berm	East cutoff channel used for diversion	$310,000.00
L	3. Excavate new channel, construct diversion berm	Develop a new diversion channel	$370,000.00
M	4. Enlarge east channel with new entrance and berm at upstream end	Nimpkish River and Sebalhall Creek flows split	$320,000.00

Note: costs exclude living expenses during construction, contingencies, engineering fees and costs for a new bridge over Kiyu Creek.

5 IMPLEMENTATION PLANS

Several implementation plans are possible by combining the various protection concepts summarized in Table 1. Six plans are presented encompassing three basic approaches or philosophies:

1. Address immediate problems with short term protection and ensure long term stability through regular monitoring and maintenance.

2. Enhance the selective protection in the first approach with long term backup protection as insurance against critical future maintenance.

3. Convert the short term protection works in the first approach into long term features by diverting flow to bypass the island through geomorphic alterations.

The components and phasing of the six plans are described in Table 2. Detailed cost estimates for each plan are outlined in Appendix A.

Table 2: Implementation Plans

Plan	Approach	Year	Cost	Title & Components	
1	1			Short Term Selective Protection	
		1	$63,000	Concepts A + B (Table 1) Divert Kiyu Creek to the dry north channel and replace the existing bridge; push the gravel bar at the mouth of Kiyu Creek against the north eroding bank of the reserve.	**Fig. 7**
		2	$36,000	Concept C Straighten channel along west side by pushing point bar against eroding section of reserve.	**Fig. 9**
		3		Strengthen existing berm at the southeast corner of the reserve.	

Table 2 continued

Plan	Approach	Year	Cost	Title & Components	
2	2			Long Term Selective Protection	
		1	$355,000	Concepts A + B + D or E Divert Kiyu Creek to the dry north channel and replace the existing bridge; riprap or construct spur groynes along the eroding north bank of the reserve; push the gravel bar at the mouth of Kiyu Creek across the river to cover the protection works.	Fig. 7
		2	$260,000	Concepts C + F or G Riprap or construct spur groynes along the eroding west side; straighten the channel by pushing the point bar to cover the protection works.	Fig. 9
		3		Strengthen existing berm at the southeast corner of the reserve.	
3	3			Geomorphic Option 1	Fig. 3
		1	$63,000	Concepts A + B Divert Kiyu Creek to the dry north channel and replace the existing bridge; push the gravel bar at the mouth of Kiyu Creek against the north eroding bank of the reserve.	
		2	$36,000	Concept C Straighten channel along west side by pushing point bar against eroding section of reserve.	
		3-5	$710,000	Concepts H or I + J Riprap or construct spur groynes along the east side of the reserve; construct diversion structures; excavate to enhance entrance to main cutoff channel and widen channel.	

Table 2 continued

Plan	Approach	Year	Cost	Title & Components	
4	3			Geomorphic Option 2	**Fig. 4**
		1	$63,000	Concepts A + B Divert Kiyu Creek to the dry north channel and replace the existing bridge; push the gravel bar at the mouth of Kiyu Creek against the north eroding bank of the reserve.	
		2	$36,000	Concept C Straighten channel along west side by pushing point bar against eroding section of reserve.	
		3-5	$430,000	Concept K Excavate to enhance entrance to east cutoff channel and widen channel; construct diversion structure.	
5	3			Geomorphic Option 3	**Fig. 5**
		1	$63,000	Concepts A + B Divert Kiyu Creek to the dry north channel and replace the existing bridge; push the gravel bar at the mouth of Kiyu Creek against the north eroding bank of the reserve.	
		2	$36,000	Concept C Straighten channel along west side by pushing point bar against eroding section of reserve.	
		3-5	$510,000	Concept L Excavate new channel across floodplain east of reserve; construct diversion structure.	

Table 2 continued

Plan	Approach	Year	Cost	Title & Components	
6	3			Geomorphic Option 4	**Fig. 6**
		1	$63,000	Concepts A + B Divert Kiyu Creek to the dry north channel and replace the existing bridge; push the gravel bar at the mouth of Kiyu Creek against the north eroding bank of the reserve.	
		2	$36,000	Concept C Straighten channel along west side by pushing point bar against eroding section of reserve.	
		3-5	$440,000	Concept M Widen east cutoff channel and excavate new entrance upstream of Sebalhall Creek; construct diversion structure.	

5.1 Maintenance and Monitoring

Whilst fallen trees, logging debris and excess sediments continue to affect the channel around the island, there will be a need for periodic monitoring and maintenance to ensure integrity of the Nimpkish River Ecological Reserve. Log jams have the greatest potential for local erosion and shifts in the low flow channel, and a program of log jam removal should be implemented to reduce these potential threats.

Monitoring for the selective protection concepts should initially be undertaken annually in late summer or early fall, to check for gradual erosion and re-survey appropriate cross-sections, to identify new areas of stress and to note the state of logs and debris in the channel. Maintenance to reduce the potential for log jams should be undertaken so that no obvious features are available for winter rain on snow events to dramatically alter the channel regime. An inspection in the spring would also be warranted if any large winter flows occurred. Necessary maintenance could then be planned and executed during the July to September construction window.

The anticipated maintenance of the protection works would be replacement or upkeep of the gravel bars covering the eroded sections of bank and areas where exposed riprap has been undermined or outflanked. The need to undertake such work in any year would be less critical if the option to install riprap protection against the bank is initially employed. The

frequency of inspections could be adjusted to suit any patterns of change that develop with visits adapted to predicted alterations in the channel regime.

Diversion of the high sediment load and debris in the Nimpkish River to bypass the island in the geomorphic concepts will allow the channel around the island to quickly reach a new state of equilibrium. Changes to the channel regime should then be infrequent and inspection visits could be tailored accordingly. Initially visits should be undertaken annually to monitor the diversion structures and the channel stability.

6 CONCLUSION

The perimeter of the Nimpkish Ecological Reserve, a 17 ha old growth forest, is eroding as a result of morphological change within the Nimpkish River. The changes, which have been mostly brought about through 30 years of logging activity, amount to widening of the channel under increased sediment load and local erosion from debris jams. Left unprotected, the island will continue to erode until an equilibrium is achieved within the new morphological regime. The extent of such erosion cannot be predicted.

Erosion protection can be affected through two philosophies; selectively addressing the symptoms or altering the river morphology to remove the potential stress from the island. Several concepts within the two philosophies have been presented in this report and six plans have been proposed for implementing erosion protection. Selective protection which does not address the cause of the erosion may eventually lead to complete protection of the island's perimeter.

No recommendations are made as the choice of plan is dependent on the philosophy to be followed, available funds and habitat constraints.

Appendix A

Detailed Cost Estimates

Table A3: Long Term Protection Along North Side

Item	Description	Est. Qty.	Unit	Rate	Amount
	Divert Kiyu Ck.				
1	Excavate to fill	24	hr.	150.00	3600.00
2	Rock protection	200	m^3	40.00	8000.00
3	Riprap eroding bank	5500	m^3	40.00	220000.00
4	Excavate new channel through gravel bar and push fill against eroding bank	170	hr	150.00	25500.00
5	Living expenses	270	day	60.00	16200.00
			SUBTOTAL		273300.00
			Contingency, 20%		54660.00
			Engineering Fees, 10%		27330.00
			TOTAL		355290.00

Table A4: Long Term Protection Along West Side

Item	Description	Est. Qty.	Unit	Rate	Amount
1	Riprap eroding bank	4100	m^3	40.00	165000.00
2	Excavate new channel through gravel bar and push fill against eroding bank	140	hr	150.00	21000.00
3	Living expenses	180	day	60.00	10800.00
			SUBTOTAL		196800.00
			Contingency, 20%		39360.00
			Engineering Fees, 10%		19680.00
			TOTAL		255840.00

Table A5: Geomorphic Option 1

Item	Description	Est. Qty.	Unit	Rate	Amount
1	Riprap the reserve side of the cutoff channel	7300	m^3	40.00	292000.00
2	Widen channel	402	hr	150.00	60300.00
3	Construct diversion structure	90	hr	150.00	13500.00
4	Haul excavated material to disposal (7 trucks working @ 1/2 hr turnaround)	2812	hr	55.00	154660.00
5	Living expenses	390	day	60.00	23400.00
			SUBTOTAL		543860.00
			Contingency, 20%		108772.00
			Engineering Fees, 10%		54386.00
			TOTAL		707018.00

Table A6: Geomorphic Option 2

Item	Description	Est. Qty.	Unit	Rate	Amount
1	Widen channel	550	hr	150.00	82500.00
2	Construct diversion structure	90	hr	150.00	13500.00
3	Haul excavated material to disposal	3850	hr	55.00	211750.00
4	Living expenses	360	day	60.00	21600.00
			SUBTOTAL		329350.00
			Contingency, 20%		65870.00
			Engineering Fees, 10%		32935.00
			TOTAL		428155.00

Table A7: Geomorphic Option 3

Item	Description	Est. Qty.	Unit	Rate	Amount
1	Excavate new channel	655	hr	150.00	98250.00
2	Construct diversion structure	90	hr	150.00	13500.00
3	Haul excavated material to disposal	4655	hr	55.00	256025.00
4	Living expenses	360	day	60.00	21600.00
			SUBTOTAL		389375.00
			Contingency, 20%		77875.00
			Engineering Fees, 10%		38938.00
			TOTAL		506188.00

Table A8: Geomorphic Option 4

Item	Description	Est. Qty.	Unit	Rate	Amount
1	Excavate entrance and widen channel	565	hr	150.00	84750.00
2	Construct diversion structure	90	hr	150.00	13500.00
3	Haul excavated material to disposal	3955	hr	55.00	217525.00
4	Living expenses	360	day	60.00	21600.00
			SUBTOTAL		337375.00
			Contingency, 20%		67475.00
			Engineering Fees, 10%		33738.00
			TOTAL		438588.00

Nimpkish River Ecological Reserve Erosion Protection Plan
(a draft copy)

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reviewed by

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The Nimpkish River Ecological Reserve, conserving a sample of Canada's tallest Douglas-fir forest on a 18 hectare island, deserves a reasonable protection from water erosion while maintaining its natural character. Although this forest is not a self-perpetuating system, i.e., in the absence of disturbance shade-tolerant western redcedar will replace eventually shade-intolerant Douglas-fir, long-term (approximately 100 years) protection measures are warranted as the majority of Douglas-firs are relatively young, have excellent vigour (see Klinka *et al.* 1981. Supplement to Land Manage. Rep. No. 6, B.C. Min. of For. Victoria, B.C. 49 pp.) and are quite windfirm (excluding the unavoidable potential for top breakage) (K. Moore 1987. An unpublished report for the Ecological Reserve Unit. 11 pp.)

The Nimpkish River Ecological Reserve Erosion Protection Plan (the protection plan) outlines multiphase long-term measures to preserve integrity of the island's heritage. It is a concise, well documented, and innovative professional report that includes a brief synopsis of the geomorphology of the surrounding area, describes and identifies in detail the present erosion process, and presents protection concepts in the context of a diversified long-term implementation plan.

As a minor recommendation for the final report, (i) figures should indicate an approximate scale and (ii) Figure 1 should give locations of points used for taking photos and indicate their direction. Furthermore, Table 1 as well as the implementation plan should be restructured so that it clearly indicates different protection options, objectives, and costs, thus facilitating management decision-making.

The protection plan presents two concepts -- geomorphic alterations and selective protection -- each recognizing the role of occasional overflows and channeling of overflows through the island in maintaining ecological site quality of the reserve. Four options of geomorphic alterations address the underlying problem of bank erosion, whereas the selective protection of the island's perimeter addresses the symptoms of the problem. The selective protection measures are conceptually similar to, but more 'natural' and not so extensive and probably expensive as, the riprapping the perimeter of the island proposed by D.E. Reksten (Hydrology Section, Water Management Branch). He also considers as sufficient protective measures relatively small-scale, continuous

remedial actions consisting of removal log debris, maintaining the existing bank protection berm (shown gravel being washed out after two years in the protection plan, p 4), removing material in the main channel to maintain a safe flow path around the island, and diverting Kiyu Creek.

In view of unpredictability of major hydrological events and changes in main flow channels, the most attractive long-term protection measure appears to be the proposed geomorphic option No. 1, i.e., widening the existing channel along the east side of the reserve with (i) addition of some armoring along the left bank of the channel protection and (ii) shifting Kiyu Creek back to its northern channel and moving the gravel bar at its mouth against the island. I agree with the conclusion of the protection plan suggesting that the 'changes to the channel regime will allow the channel to quickly reach a new state of equilibrium resulting in infrequent changes and less demand for inspection visits and monitoring.