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TSAWWASSEN INDIAN RESERVE FLOOD CONTROL WORKS

post-project environmental analysis

D.J.BERNARD and V.G.BARTNIK
MARCH, 1987

Inland Waters and Lands
Pacific and Yukon Region
Vancouver, B.C.

ENVIRONMENT CANADA
CONSERVATION AND PROTECTION
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D.J. BERNARD
V.G. BARTNIK

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ABSTRACT

The Tsawwassen Indian Reserve Flood Control Works were initiated under the Canada-British Columbia Fraser River Flood Control Agreement (1968) to complete the ring of dykes protecting Delta municipality from flooding by the sea. Sea dyke construction along the seaward edge of a natural salt marsh, the largest in the Fraser River estuary, started in 1975 but was halted by Environment Canada because it would have alienated some 200 acres (81 hectares) of productive intertidal wetlands. An environmentally-preferred dyke alignment located further inland along a road traversing the Indian Reserve was not an acceptable alternative to the Tsawwassen Indian Band. The elevated road would have affected their sea views and divided their land. The resulting impasse lasted for nine years, but was finally resolved by the development of a unique, although more costly, flood control design. The design includes a breakwater with several openings in it to permit tidal inundation. It provides the required flood protection without the social impacts of elevating the Reserve road and still provides free tidal exchange between the salt marsh and adjacent tidal flats. The project was successfully completed in the spring of 1986 at a cost of approximately $2.0 million.

Environmental surveillance and inundation monitoring were undertaken during construction of the project. The report documents that all mitigating measures identified by government resource agencies, during the environmental screening process, were conformed with and observed to be effective. The success of the project design is confirmed by tidal inundation monitoring results. The Tsawwassen salt marsh continues to be an integral part of the Roberts Bank tidal flat ecosystem providing detritus-based nutrients, fish-food organisms and a refuge for fish species. The salt marsh also remains a valuable wildlife habitat for waterfowl, shorebirds and large numbers of great blue herons. The report also reviews the retreat of the leading edge of the salt marsh which has occurred over past decades and discusses the long term erosion protection that the flood control design will likely provide. Government agencies continue to monitor the success of this unique project which incorporates flood control with wetland preservation.

RESUME

Le projet de lutte contre les inondations de la réserve indienne de Tsawwassen a été entrepris dans le cadre de l'accord fédéral-provincial de lutte contre les inondations du Fraser dans le but de compléter l'endiguement protégeant la municipalité de Delta, en Colombie-Britannique, contre les inondations maritimes. La construction d'une digue en bordure du plus gros marais maritime de l'estuaire du Fraser débuta en 1975. Toutefois cette construction fut aussitôt arrêteé par Environnement Canada parce qu'elle aurait aliéné 200 acres (81 hectares) de marais intertidal productif. Par contre, il aurait été préférable, du point de vue de l'environnement, de placer la digue à l'intérieur de la réserve indienne de Tsawwassen sur le chemin qui la traverse, mais cette solution n'était pas acceptable pour les amérindiens. La digue aurait diminué la vue qu'ils avaient de la mer et divisé leur territoire. L'impasse dura neuf ans mais elle fut finalement résolue par le développement d'un modèle unique, mais plus coûteux, qui assura la protection contre les inondations. Ce modèle comprend un brise-lames avec plusieurs ouvertures qui permettent à la marée d'inonder le marais maritime Tsawwassen. Cet ouvrage protège la réserve contre des inondations causées par des vagues de marée trop élévées et permet le mouvement journalier de la marée entre le marais maritime et la plaine côtière; les répercussions d'ordre social qu'aurait comportées le relèvement du chemin sont ainsi évitées. Le projet fut completé avec succès durant le printemps de 1986 au coût approximatif de 2 millions de dollars.

Le présent rapport décrit la supervision du projet et la surveillance des inondations qui ont été effectuées durant la construction de l'ouvrage pour répondre aux exigences environnementales. Ce document confirme aussi que toutes les mesures d'atténuations recommandées à la suite de l'examen préalable du projet par les agences gouvernementales furent appliquées et se montrèrent efficace. Le succès de ce projet unique se confirme par les résultats de la surveillance des inondations. Le marais maritime de Tsawwassen continue de faire partie intégrale de l'écosystème de la plaine côtière du banc Roberts; il est une source d'éléments nutritifs à base de détritus, ainsi qu'une source de nourriture et un refuge pour les poissons. Le marais intertidal reste un habitat précieux pour les oiseaux d'eau et de rivage ainsi que pour un grand nombre de hérons gris-bleus. Le rapport étudie aussi l'érosion du marais qui s'est produite depuis les dernières décennies et démontre que cet ouvrage de protection contre les inondations protégera, probablement, le marais maritime contre l'érosion. De toute façon les agences gouvernementales continuent de surveiller le fonctionnement de cet ouvrage qui incorpore le contrôle des inondations avec la préservation des terres humides.

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I. INTRODUCTION

The Tsawwassen Indian Reserve Flood Control Works was a project initiated under the 1968 Canada-British Columbia Fraser River Flood Control Agreement. It is located in the municipality of Delta and completes the flood control works designated under the Agreement for the municipality.

The project area, commonly known as the Tsawwassen salt marsh, is primarily within the Tsawwassen Indian Reserve and includes the 200 acre (81 ha) accretion[1] west of the Indian Reserve road, between the Roberts Bank and Ferry Terminal causeways (Figure 1).

The flood control works initially started in March 1975 and consisted of a dyke alignment along the seaward edge of the marsh to enclose the accreted land. This alignment was used as the Tsawwassen Indian Band would not accept construction of a higher dyke on the Reserve road which would affect their view of the sea and divide the Reserve. However, construction was stopped by the federal Minister of the Environment on June 30, 1975. The stop-order was issued in response to public opposition and environmental concerns arising from the alientlon of some 81 ha of potential fish and wildlife habitat. Construction had consisted of stripping topsoil along 2.6 km of the alignment, placing it in a windrow towards the landside and loading sand on the alignment as the first dyke lift. The main tidal channel of the marsh was untouched by the 1975 construction but the smaller tidal channels were blocked. After the stop-order, two blocked channels were reopened to permit some tidal exchange.

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1 The accreted land was transferred by British Columbia to Canada in 1973 for the use of the Tsawwassen Indian Band.

FIGURE 1 Location map of the Tsawwassen Indian Reserve Flood Control Works (aerial photo date 1971). Inset aerial photo (dated Sept. 27, 1974) looking north at the Tsawwassen salt marsh prior to 1975 dyke construction. The salt marsh is west of the Indian Reserve Road and bounded to the north and south by the Roberts Bank and Ferry Terminal Causeways. Photo courtesy of Delta Municipality

Subsequently, from 1975 to 1984 many meetings were held among representatives of the federal departments of Indian Affairs and Northern Development (DIAND), Fisheries and Oceans (DFO), and Environment (DOE), the Tsawwassen Indian Band and the Fraser River Joint Advisory Board to reach an agreement on an acceptable flood control design. The alternatives discussed and investigated had to satisfy the following:

1. flood protection needs of the Band and municipality;
2. the Band's restriction of not allowing construction of a higher dyke on the Reserve road; and,
3. resource agencies' concerns to conserve and protect the ecological integrity of the salt marsh.

In early 1984 a more costly design, described in Section II, was agreed to by all the concerned parties. DIAND agreed to contribute to the higher project construction costs of this design thus providing flood protection for the Band but avoiding the social impacts that the less costly design (raising the Reserve road) would have had.

In accordance with the Environmental Assessment and Review Process (EARP) Guidelines Order-in-Council (1984) and prior to project implementation, the concept and the detailed design were screened for environmental effects. Inland Waters and Lands (IW/L) screening procedures were followed (IWD 1985) and the screening was carried out with the cooperation of several federal and provincial resource agencies. The results were as follows:

> Preliminary screening completed March 18, 1985 (Screening Report No. WPM-84-01 filed in the IW/L screening registry) gave approval-in-principle to the design concept; and,

Formal screening completed June 27, 1985 (Screening Report No. WPM-85-01 filed in the IW/L screening registry) gave approval to implement the project with the incorporation of monitoring and mitigating measures.

The project was constructed during the period of July 5, 1985 to March 3, 1986.

As a follow-up to project screening, and in accordance with the EARP Guidelines Order-in-Council and the departmental environmental screening guidelines, IW/L initiated environmental surveillance of the project construction. This report describes the surveillance activity undertaken to ensure conformance with the required mitigation and monitoring, and also discusses the environmental benefits of the flood control design.

II. THE PROJECT

The project design includes a breakwater along the seaward edge of the salt marsh to dissipate wave action (Figure 2). Several openings in the breakwater permit tidal flow to inundate the marsh. All openings are appropriately sized to allow the natural tidal regime within the salt marsh to continue essentially unchanged. The openings include one 60 ft. (18.3 m) gap in the breakwater coinciding with the location of a natural major tidal channel and six large culverts positioned to coincide with smaller tidal channels. Toe ditches along the landward side of the breakwater facilitate tidal flows between channels in the marsh and the culverts. In addition, the project raises the Reserve road nominally to provide an inshore still-water protection dyke. A new pump-floodbox station at the intersection of Brandrith and Reserve roads, to meet the drainage requirements of the surrounding farmland, is also included. A proposed 800 ft. (243.8 m) interconnecting ditch between drainage areas of the salt marsh has been deferred for two years pending review of inundation monitoring. Detailed design plans are not included in this report but are available from IW/L.

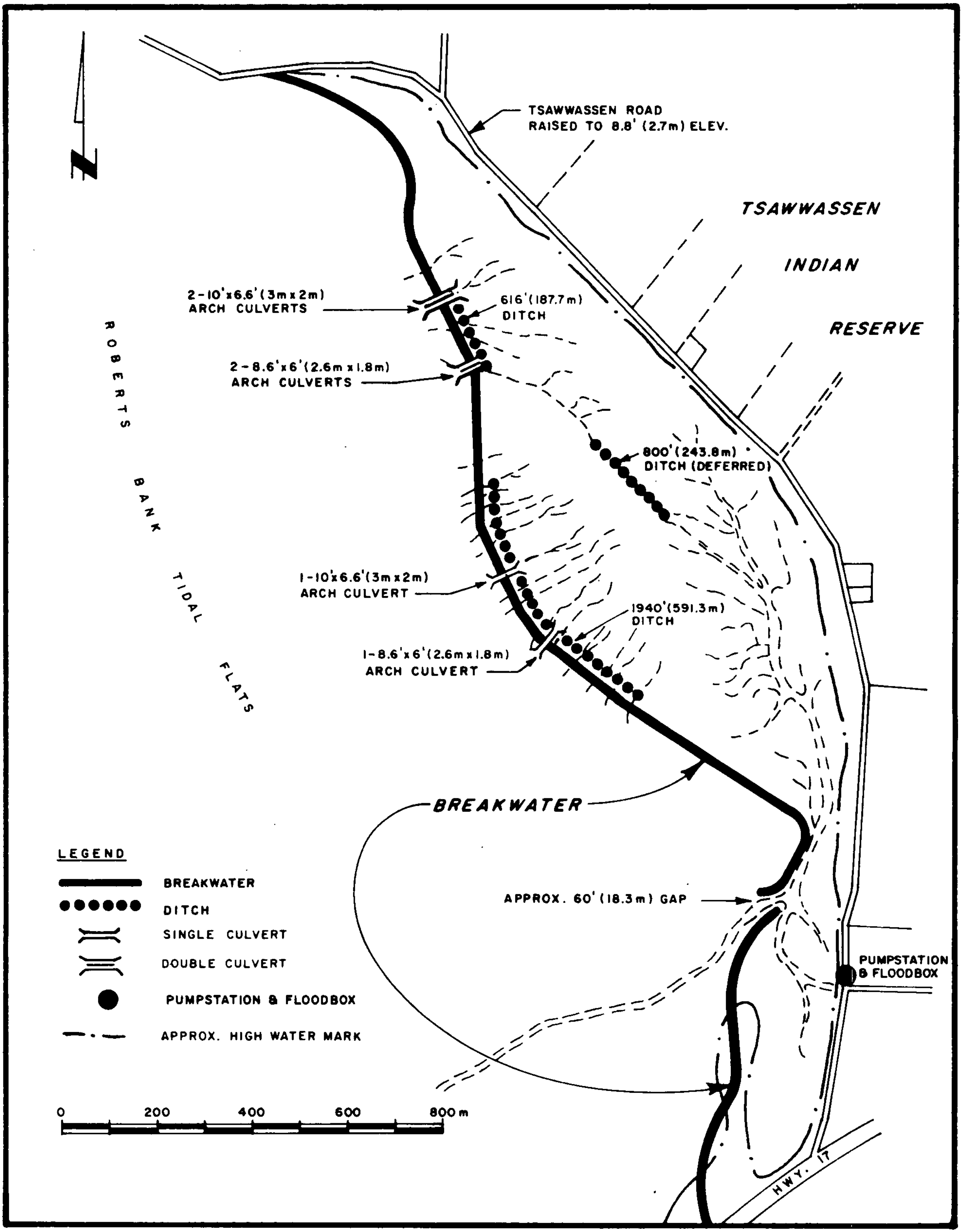


FIGURE 2 SCHEMATIC PLAN OF THE TSAWWASSEN INDIAN RESERVE FLOOD CONTROL DESIGN.

III. ENVIRONMENTAL FOLLOW-UP

A. Required Mitigation and Conformance

During the formal environmental screening of the project, required mitigating measures were identified by the Department of Fisheries and Oceans (DFO), Canadian Wildlife Service (CWS) and B.C. Fish and Wildlife Branch (F&WB). These were incorporated during project construction, together with the terms and conditions pertaining to mitigation given in the Tender Document (1985). These mitigating measures were observed and documented for conformance during the approximately 35 site visits initiated under the environmental surveillance activity of the project. The results of this activity are summarized in Table 1 and the accompanying Plates (1-14). For more details on mitigation, IW/L Screening Report No. WPM-85-01 and the Tender Document (1985) should be consulted.

The mitigating measures stipulated by the government resource agencies were implemented as shown in Table 1. For the most part this was performed expeditiously and from the onset of the construction activity. However, as mentioned in Table 1, a few deviations were identified immediately, due to IW/L surveillance activity, and were resolved or rectified as required. These deviations were as follows.

1. During construction of the southern section of the breakwater, waste material had been sidecast on top of a windrow remaining from the 1975 construction. Although this sidecast material was removed by the contractor to pre-1985 condition (Plate 15), DFO and F&WB also requested removal of the 1975 material to grade level. This additional work was carried out (see Plate 16) to the satisfaction of DFO and F&WB.

TABLE 1

SUMMARY OF MAJOR MITIGATING MEASURES AND CONFORMANCE.
Note DFO - Department of Fisheries and Oceans, CWS - Canadian Wildlife Service and F&WB - B.C. Fish and Wildlife Branch

Mitigating Measures Specified	Agency	Conformance	Plate No.
1. Construction Timing		1.	
In-water activities to be undertaken September 1 to February 28; no objection to commencement of controlled construction activities in mid-July.	DFO and F&WB	Construction began after July 5, 1985 on high ground along 1975 dyke alignment. In-water activities such as excavation for bank protection were done from late August on and during low-tide periods to minimize sediment generation.	-
2. Site Preparation		2.	
a) Clearing and stripping for the breakwater to be confined to area between waterside and landside toes.	DFO and CWS	a) Activity remained within the confines of the staked toe area except for an initial problem on the southern section of the breakwater which was remedied (see p. 7).	1
b) Pushing, stockpiling or burning of any debris or waste material on salt marsh or mud flat not permitted.	DFO and CWS	b) Debris and waste material were kept within staked toe area and trucked off-site to an approved disposal site on the Indian Reserve.	2
3. Breakwater Construction & Road Base Preparation		3.	
a) All borrow material other than from land-based sources to be referred to DFO.	DFO	a) All borrow material was from land based sources.	-
b) Sidecasting or stockpiling of fill material, topsoil and waste material not permitted on mud flat or salt marsh.	DFO and CWS	b) Waste material was hauled out to approved disposal site. Fill and topsoil hauled in as needed. Some initial problems of encroachment on salt marsh by road base preparation were corrected (see p. 14).	3 & 4
c) Rip-rap placed to avoid burial of marsh along the seaside toe of the breakwater.	DFO and F&WB	c) Construction method for slope preparation and placement of rip-rap avoided burial of marsh. Materials were unloaded on breakwater and placed on slope by backhoe.	5

TABLE 1 (Continued)

Mitigating Measures Specified	Agency	Conformance	Plate No.
d) To prevent erosion and sediment generation, place fill and compact it immediately following stripping and clearing; grass-seed landslide and rip-rap seaside slopes as soon as possible.	DFO	d) Complied as expeditiously as possible but some delay in seeding due to inclement weather in fall of 1985. Rip-rap was placed before the high tides and storms of fall of 1985.	6
4. Toe Ditches and Culvert Installation		4.	
a) Waste material from toe ditch excavation be removed from site to approved disposal area.	DFO and CWS	a) Waste material was hauled to approved disposal site on the Indian Reserve.	-
b) Invert of culverts and toe ditches not higher than invert of dendritic channels.	DFO	b) Culverts assembled next to site, lowered into place by dragline and surveyed to meet designated elevations as approved by DFO.	7 to 10
c) Dendritic channels blocked off during 1975 dyke construction be opened to culverts and ditch system.	DFO and CWS	c) Blocked dendritic channels within the culvert/ditch system were opened.	11 & 12
5. Floodbox/Pumpstation Construction		5.	
Care to minimize release of sediment during placement and removal of cofferdams.	DFO	Cofferdams placed above and below work area at low tide and removed after floodbox completion at low tide to prevent sediment generation. Water from existing drainage system bypassed construction area and discharged over grassed area below construction area to reduce erosion and sediment generation.	-
6. Dredging Floodbox/Pumpstation Outfall Channel		6.	
Care to minimize release of silt or silt-laden water into the main channel.	DFO	Dredging done at low tide by a dragline and dredgate disposed at approved disposal site on Indian Reserve.	13 & 14

PLATE 1 8 July 1985

Backhoe used alongside the bulldozer for stripping activity to ensure better edging control along the staked toes of the breakwater.

PLATE 2 8 July 1985

Debris and waste material were piled and kept within the stacked toes of the breakwater. Disposal was to an inland Indian Reserve site. No burning of debris was done on-site.

PLATE 3 22 July 1985

Near the mainchannel, where there was no prebuilt 1975 base, the backhoe worked from the constructed base pad and did not encroach on the marsh beyond the staked toes of the breakwater. There was no side casting or stockpiling of material as trucks would haul in fill and on return trip would haul out excavated material to the approved disposal site.

PLATE 4 27 September 1985

Placement of topsoil on the landslide slope of the breakwater. Topsoil was trucked in as needed (no stockpile on the marsh) and scooped from the truck with a backhoe and placed directly on the slope.

Note area adjacent to landslide toe of breakwater can be seen revegetating after remedial action removed material pushed beyond staked toe (see section III.A.2).

P L A T E 5 20 September 1985

To prevent impacts and burial of the marsh along the seaside toe, all bank protection work was done with a backhoe and trucks working from the top of the breakwater. The toe trench was excavated during low tide to prevent sediment generation. Excavated material was either used as topsoil or fill, as suitable.

P L A T E 6 2 June 1986

The landslide slopes of the breakwater were grass-seeded in early 1986 after some delay due to inclement weather (heavy rains and frost) in the autumn of 1985. Note the lack of vegetation in the collection ditch due to the daily tidal action through the culvert in the background.

P L A T E 7 12 July 1985

Temporary culverts were installed at two dendritic channels which had been reopened to the sea following the 1975 partial dyking. This ensured maintenance of the status quo of the marsh in this area prior to the installation of the large arch culverts.

P L A T E 8 12 September 1985

Installation of galvanized (asphalt-coated) arch plate type culverts. The breakwater was excavated to the designated surveyed depth ensuring proper drainage between dendritic channels, toe ditches and culverts.

PLATE 9 12 September 1985

During the installation of culverts excavated material was stockpiled on the breakwater for later use in backfilling.

PLATE 10 20 September 1985

Installed single arch culvert depicting the system of dendritic channel (left), toe ditch (centre) and culvert (right).

PLATE 11 29 August 1985

View of a typical dendritic channel that was blocked by the 1975 partial dyke construction. The soil plugs were left until the ditches and culverts were installed to prevent sediment generation. These plugs were then removed by dragline and direct tidal exchange was restored.

PLATE 12 6 December 1985

View of opened dendritic channel of Plate 11 once tidal exchange had been restored [photo taken during an observed tide of 5.6 ft (1.71 m) GCS at Point Atkinson].

PLATE 13 27 September 1985

Outfall channel below the floodbox/pumpstation showing the silted-in condition that had built up over the years. Dredging of 700 ft. (213.4 m) of channel bottom was requested to provide an effective low-level drainage channel to the sea.

PLATE 14 9 October 1985

The outfall channel was dredged with a dragline operating from moveable pads on the channel bank, thus protecting marsh vegetation from damage. Dredged material (soft silt) was moved by the dragline, in a 4 day period, in progressive steps within the channel with final trucking for disposal at an approved disposal site on the Reserve. Release of silt into the main channel was minimized by operating at low-tide only.

PLATE 15 6 December 1985

View of the sidecast area remaining from 1975.

PLATE 16 28 February 1986

View of the same sidecast area as shown above (Plate 15) but after remedial work to remove the windrow remaining from 1975 sidecasting.

2. At another location, waste material was pushed beyond the staked landside toe of the breakwater and covered marsh vegetation (Plate 17). Remedial action was immediately taken. The waste material was removed with due care not to alter the underlying vegetation and disposed of at an approved site on the Reserve. This area, as illustrated in Plate 4, quickly revegetated without further intervention.

3. There was also some encroachment by fill material on the marsh side of the Reserve road during the road base preparation [ie. raising the road nominally to an elevation of 8.8 ft. (2.68 m) GSC]. This occurred at the junction of Highway 17 and the Reserve road, and at 4 lay bys. In addition, construction of three Reserve parking lots (unassociated construction activities but undertaken by the same project contractor) did result in some encroachment on marsh habitat. Remedial action in terms of modifications to the extent of fill was undertaken to the satisfaction of DFO.

4. During installation of a double culvert on the northern section of the breakwater, DFO raised some concerns respecting the alignment of the culverts especially in relation to the seaside drainage channel (Plate 18). It was feared that the off-alignment would promote the erosion of the seaside channel, and possibly lead to the creation of a new drainage channel at the expense of marsh habitat. An on-site meeting to address this issue was immediately arranged among DFO, IW/L and consultant project engineers. A decision was made on-site, with no project delays, to leave the alignment as proposed but provide adequate rip-rap protection to the seaside channel banks adjacent to the culverts. All work was done as DFO requested. Follow-up inspection in December 1986 found no erosion had occurred.

PLATE 17 10 July 1985

View of the stripped material pushed onto the marsh beyond the stacked landside toe of the breakwater.

PLATE 18 13 September 1985

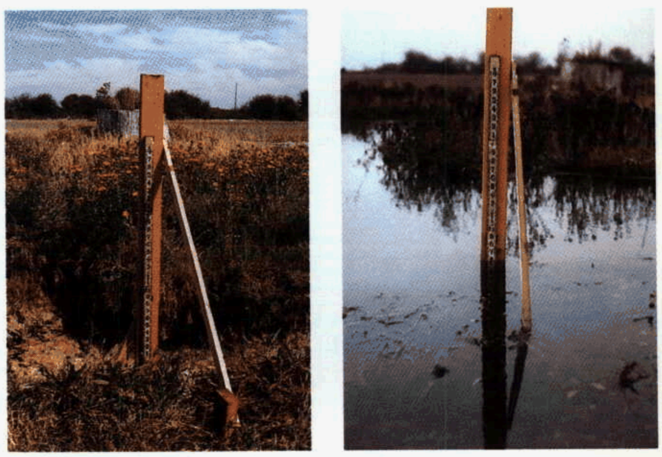
On-site meeting between DFO, IW/L and consultant project engineers of Associated Engineering Limited to resolve DFO concern with the alignment of a double culvert. Natural seaside drainage channel in background.

PLATE 19 13 September 1985

Dredging of a natural seaside channel at a double culvert location. The dragline used moveable pads and worked at low-tide.

PLATE 20

A water level gauge, set at geodetic datum, used to monitor salt marsh tidal inundation. See section on Inundation Monitoring.



5. The seaside tidal channels at the double culverts were heavily laden with soft sediments and were up to 0.5 m above the seaside invert of the culverts. In order to provide unrestricted tidal flow through the channels servicing the culverts, DFO granted permission to dredge the channels with a dragline. The work was performed as follows to minimize environmental impacts on the marsh and water quality:

   - the dredging was done at low tide only and with a dragline sitting on moveable pads to prevent damage to marsh vegetation (see Plate 19);

   - the work was started from the tidal flat area working towards the culvert. Excavated material was moved within the channel area until it could be loaded into trucks on the breakwater; and,

   - the excavated material was disposed of at an approved site outside the tidal flat area.

   The work was done quickly and resulted in negligible impacts to the foreshore marsh.

B. Inundation Monitoring and Results

a. Pre-Construction Inundation

The 200-acre (81 ha) accretion between the Roberts Bank and Ferry causeways and west of the Indian Reserve road is commonly known as the Tsawwassen salt marsh. The highest ground in the marsh area is the Tsawwassen Indian Reserve road [elevation 7-8 ft. (2.1-2.4 m) GSC]. The salt marsh has internal ridges [about 4.5 ft. (1.37 m) GSC elevation] which divide the marsh into four drainage areas: northern, western, central and southern which drain through tidal channels onto the adjacent Roberts Bank tidal flats (see Figure 3). At tidal elevations greater than 4.5 ft. (1.37 m) GSC an overflow occurs across these internal ridges.

As a result of construction of the 1975 partially completed dyke, with an average elevation of approximately 7.0 ft. (2.13 m) GSC, tidal blocks had resulted. The northern area was isolated from inundation except when tides exceeded 4.5 ft. (1.37 m) GSC [14.0 ft. (4.27 m) tides] and spill-over from the central area occurred. Similarly a seaward barrier was created across the western area. Most of the dendritic tidal channels were blocked in this area except for two which were reopened, after the 1975 stop-order, to permit some tidal exchange. The main tidal channel carrying seawater into the central and southern areas was untouched by the previous (1975) dyking.

Past studies describing the vegetation of the salt marsh were carried out by Hillaby and Barrett (1976) and Olmsted and Fink (1982). Vegetation mapping by Moody (1986) detected successional change toward more terrestrial communities in the northern and western sectors since 1975, as a result of limited wetting of the salt marsh in these areas.

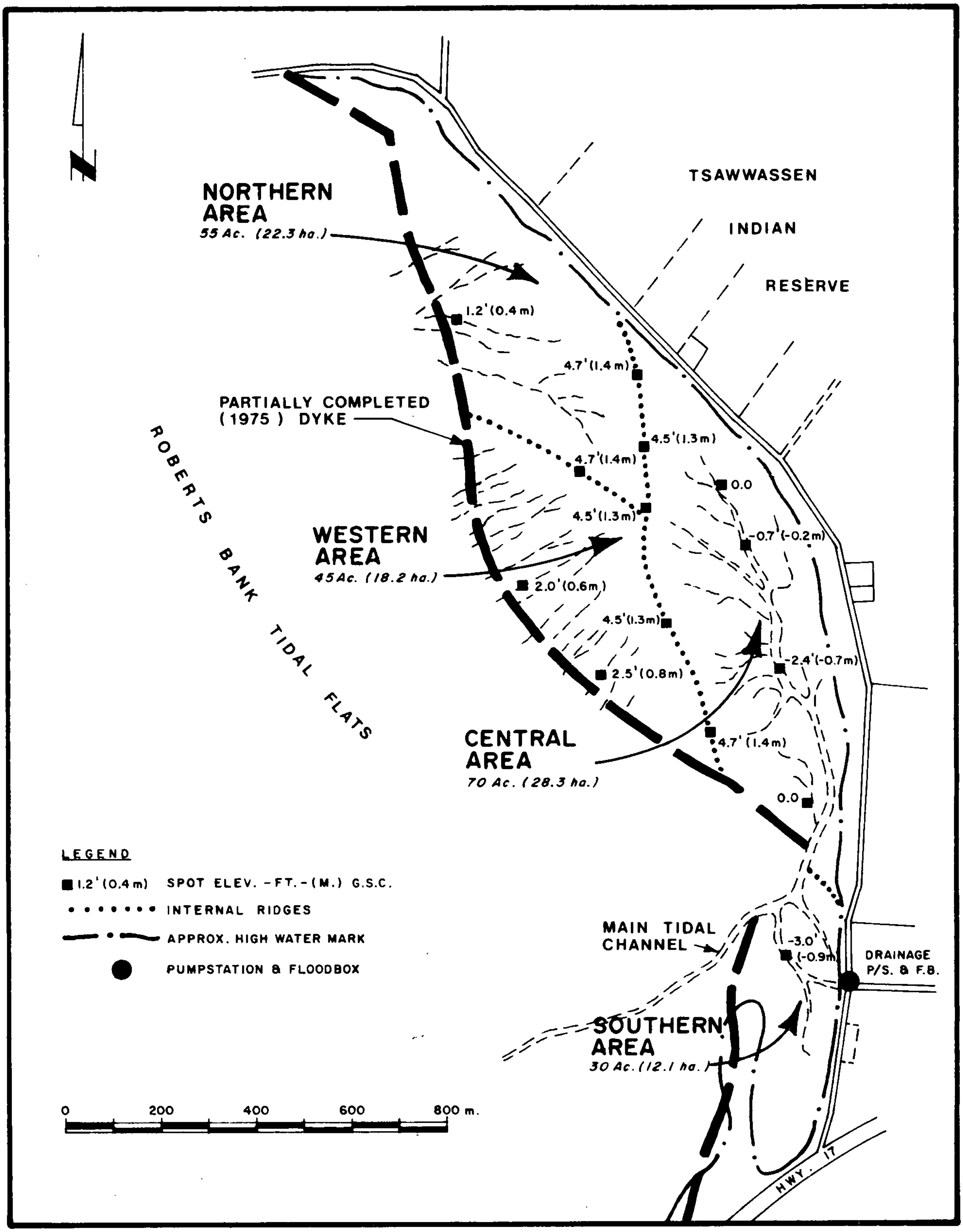


FIGURE 3 THE TSAWWASSEN SALT MARSH DRAINAGE AREAS (adapted from Associated Engineering Ltd. 1984).

b. Inundation Monitoring

During the environmental review phase, the Department of Fisheries and Oceans (DFO) was concerned that the flood protection breakwater design could reduce the water exchange in the marsh. Accordingly DFO specified two areas of follow-up monitoring to be undertaken during the construction of the breakwater.

i) Breakwater Gap at the Main Tidal Channel

DFO recommended a monitoring program be integrated with the staged construction activities to determine the effectiveness of the design gap size in maintaining daily tidal flows to the marsh.

DFO was concerned that the breakwater gap at the main tidal channel might be too restrictive on incoming tides in the range of 4.5 ft. (1.37 m) GSC and thereby affect water levels and duration of inundation in the marsh. DFO added the stipulation that if monitoring results demonstrated that tidal inundation was altered, then modifications to the gap size would have to be made.

ii) Interconnecting Ditch

DFO recommended a maximum two year monitoring program be initiated to assess the efficiency of the reopened channels in the northern and western areas in restoring pre-1975 tidal inundation to these areas.

The design had specified construction of an 800 ft. (243.8 m) interconnecting ditch linking the central and northern drainage areas (Figure 2). The purpose was to improve the inundation and the flushing of water and detrital matter from the two drainage areas to the sea. However, DFO subsequently requested that the construction of the interconnecting ditch be deferred due to the difficulty in getting construction equipment to the site without causing damage to the marsh. Another reason for the deferment was that an interconnecting ditch could become superfluous once the blocked channels in the northern and western drainage areas were returned to full function by the culvert/toe ditch system. DFO indicated that the need for the interconnecting ditch would be determined by the results of the monitoring program.

The monitoring program conducted was a joint undertaking between the project consultant engineer and IW/L environmental staff. The detailed results are reported in the Associated Engineering (1986) post-construction hydraulic report. The monitoring program was designed to:

- observe under different project construction stages, water level changes in the marsh for tides in the range of 4.5 ft. (1.37 m) GSC;
- report on the effectiveness of the gap/culvert/toe ditch system in restoring, to pre-1975 conditions, the daily tidal exchange to all drainage areas of the marsh.

Water level gauges set at geodetic datum (Plate 20) were installed at internal channels of the southern, central and northern drainage areas as shown in Figure 4. These gauges were read simultaneously at 10 minute intervals during the rise and fall of a high tidal cycle. The readings were taken on July 18, August 27 and November 15, 1985 when high tides were predicted to reach or exceed 4.5 ft. (1.37 m) GSC. These monitoring dates also corresponded to three different stages of completion of the breakwater/gap/culvert/ toe ditch system. The results of the water level monitoring along with the corresponding marsh inundations are shown in Figure 4.

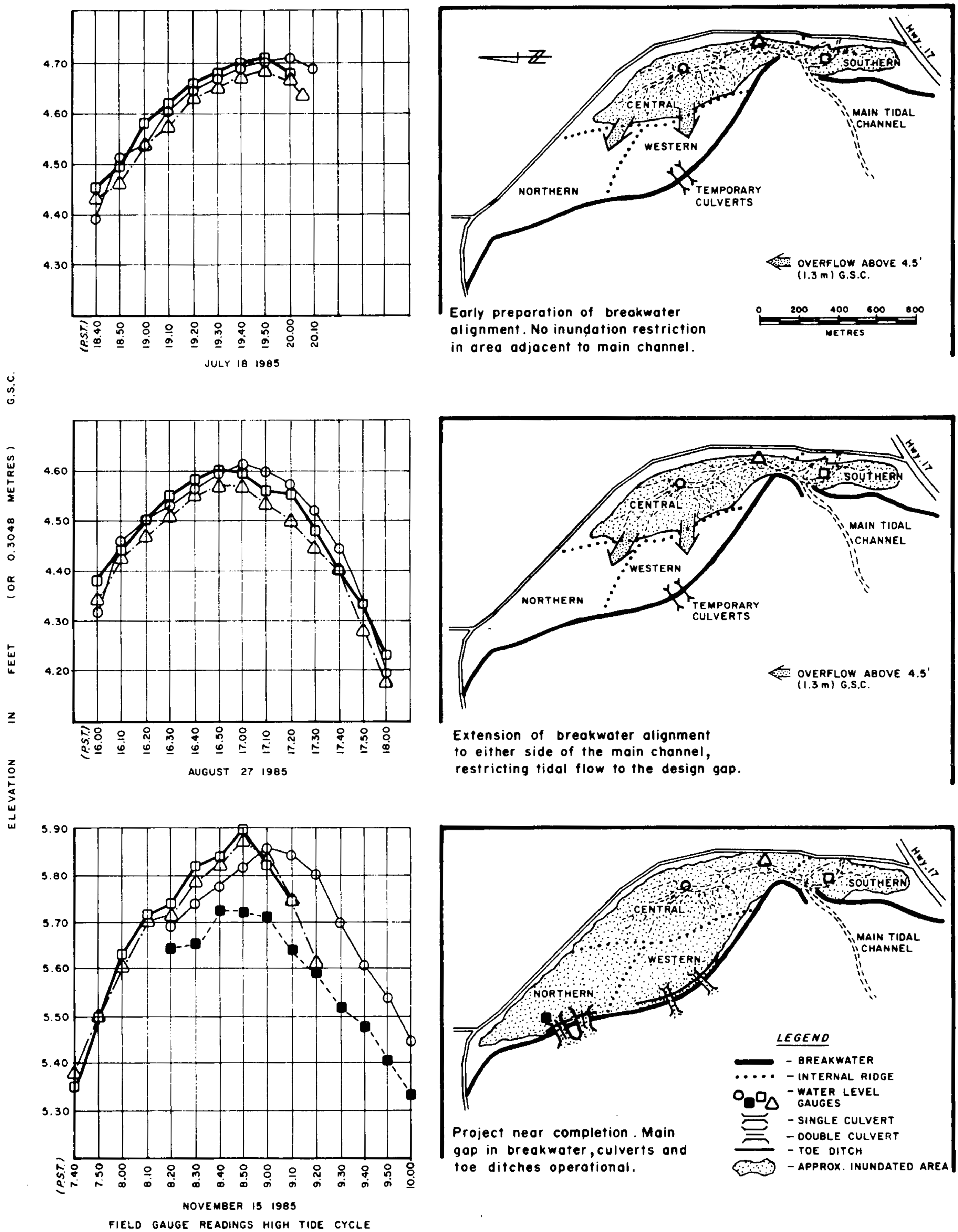


FIGURE 4 HIGH TIDAL CYCLE WATER LEVEL READINGS FROM MONITORED GAUGES (on the left) AND THE CORRESPONDING INUNDATION OCCURRING (on the right) AT THREE DIFFERENT STAGES OF PROJECT CONSTRUCTION (adapted from Associated Engineering Ltd. 1984 and 1986).

c. <u>Construction and Post-Construction Inundation</u>

At all three different stages of construction negligible differences in water levels were recorded in the southern and central areas of the marsh. In particular, no discernible differences in water levels occurred after tidal flows in the area of the main channel were restricted to the design gap (compare July 18 and August 27 water levels in Figure 4). On all three monitoring dates the observed tidal peaks in the marsh agreed closely with the recorded tidal gauge station readings at Point Atkinson.

After the culvert/toe ditch system was completed direct tidal access was restored to the northern area but water levels were about 0.1 ft. (3.05 cm) lower than those recorded at other gauges for most of the high tidal cycle (see Figure 4). The difference was almost 0.2 ft. (6.10 cm) lower during the 20-minute peak flooding period. This difference in water level was likely due in part to retardation of the spill-over across the internal ridge by marsh vegetation. In addition, the inverts of the double culverts providing flows to the northern area were at a slightly higher elevation because they had been placed to suit existing marsh tidal channel inverts. Until the culvert/toe ditch drainage system became operational, inundation of the northern area was dependent on overflow across the internal ridge from the central area [at tidal elevation 4.5 ft. (1.37 m) GSC or greater]. The western area similarly depended on overflow from the central area but had some direct tidal access to the foreshore through two small temporary culverts installed during construction. The completion of the culvert/toe ditch system greatly improved the inundation of both of these areas, as shown by the approximate inundation pattern of November 15 (see Figure 4). On that date the high tide was estimated to cover between 66.8 to 70.8 ha of the 81 ha marsh (AEL 1986).

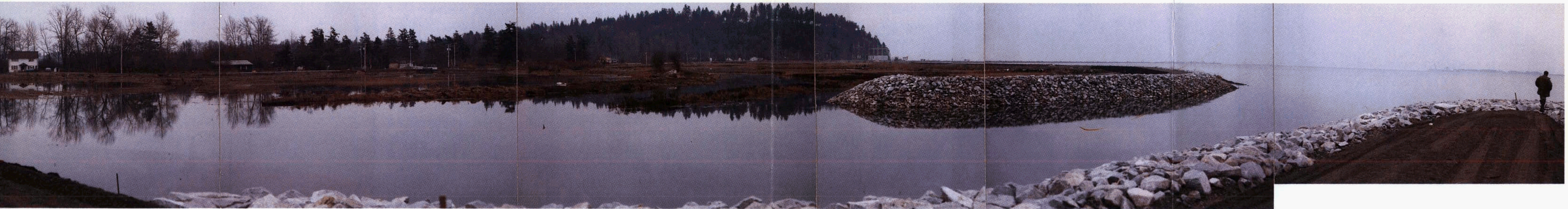
The areal extent of the inundation and movement of water into the marsh is illustrated in Plate 21. These panoramic pictures show a gentle transfer of water through the gap in the breakwater at the main channel [a maximum observed velocity of 2.8 ft./sec (0.8 m/sec) AEL 1986], overbank flow of the channels and a gradual spreading of seawater through the marsh vegetation. Velocities in the toe ditches, culverts and channels also appeared to be low [less than 3 ft./sec (0.9 m/sec) AEL 1986]. During the monitoring program only a slight head differential was observed across the culverts, confirming the adequacy of the sizing of the culverts.

d. Monitoring Conclusions

The results of the monitoring program indicate that the design of the flood control works has not altered the tidal inflow and outflow of the southern and central areas of the marsh. The exchange of water in the northern and western areas is virtually restored to natural (pre-1975) conditions by the culverts, toe ditches and the dendritic channels opened to them. During ebb tide cycles the return flows through the installed culverts fan out onto the tidal mud flats. These results were re-confirmed by helicopter survey of the marsh during a predicted Point Atkinson high tide of 5.3 ft. (1.61 m) GSC on November 7, 1986. However, aerial survey did reveal that tidal exchange of the northern area could be even further enhanced by extending the toe ditch north beyond the double culvert to include two blocked channels. This extension of the toe ditch is under review by the resource agencies. An added benefit of the toe ditch extension would be to eliminate conditions which now make this area prone to mosquito rearing.

PLATE 21

PANORAMIC VIEWS OF TSAWWASSEN SALT MARSH INUNDATION AT HIGH TIDE



View looking south at the gap in the breakwater and the inundation of the southern drainage area at high tide on December 14, 1985. Predicted high tide of 6.3 ft. (1.92m) G.S.C. at Point Atkinson.

View looking south at the inundation of the central drainage area at high tide on December 6, 1985. Predicted high tide of 5.2 ft. (1.58m) G.S.C. at Point Atkinson.

PLATE 21

IV. POST PROJECT-ENVIRONMENTAL ANALYSIS

A. Erosion Protection

Historical studies have used aerial photographs to establish whether the leading edge and areal extent of the Tsawwassen salt marsh has changed over time. Medley and Luternauer (1976) compared aerial photographs spanning a 20-year period from 1954 and observed a retreat of some 20 m of the seaward edge of the salt marsh. Beak (1977) compared 1932 and 1977 aerial photographs and reported an approximate 15 ha reduction in marsh area. Although this retreat was occurring at certain sites prior to construction of the Ferry Causeway (1960) and Roberts Bank Superport (1970), Luternauer (1976) concluded that the Roberts Bank Superport causeway probably contributed to the apparent retreat by blocking or deflecting the suspended sediment which would have migrated into the area. This isolation of the Tsawwassen salt marsh from longshore drift and river sedimentation processes is clearly visible in Figure 1.

Despite the documented historical retreat of the Tsawwassen salt marsh, Moody (1985) believed that, apart from some erosion at three locations, the leading edge of the marsh had remained stable since 1975. The Department of Fisheries and Oceans (Ennis 1983) when reviewing the proposed flood control options, was not convinced that there was any appreciable net loss of the marsh occurring. Yet, in 1976, the truncation and collapse of the leading edge of the salt marsh near local promontories had been noted by Luternauer (1976). These same erosional processes were still observed by the authors in 1984, prior to the construction of the Tsawwassen Indian Reserve Flood Control Works (compare Plate 22 and Plate 23).

PLATE 22

1976 photograph of the active process of truncation and collapse of the leading edge of the Tsawwassen salt marsh near local promontories (photo courtesy of J.L. Luternauer, Geological Survey of Canada, Vancouver, B.C.)

PLATE 23

1986 photograph illustrating the same 1976 erosional processes shown above. The survey pin demarcates the leading edge of the local promontory as of June 2, 1986.

PLATE 24

Photograph of the same location and reference pin shown in Plate 24 above, but taken approximately 8 months later on February 5, 1987. The leading edge of the promontory had eroded back by 35.7 cm.

PLATE 25

Illustration of the erosion survey techniques used to map the leading edge of the Tsawwassen salt marsh on the seaside of the breakwater (photo April 23, 1986).

To confirm these observations of progressive erosion, baseline surveys were conducted using a survey instrument (Kern K1-RA Theolodite) set on bench marks established on top of the breakwater (see Plate 25). The configuration and location of the leading edge of the marsh was mapped at four selected areas, such that future detailed resurvey could provide quantification of erosion (see Figure 5). The surveys were carried out between April 15 and May 30, 1986.

During the baseline surveys a total of seven steel rods were also installed and surveyed in as reference pins to demarcate the leading edge of local promontories. The reference pins were located 23 to 75.5 m from the top of the breakwater. After approximately eight months, inspection of the reference pins indicated measurable erosion had already occurred at promontories in the four areas. The erosion measured at area one was 2 and 12.5 cm, at area two, 30.5 and 35.7 cm, at area three 10.7 cm and at area four 3.7 and 26.9 cm. A comparison of photographs taken of the same reference pin at area two shows how the leading edge of the promontory had eroded back by 35.7 cm (compare Plate 23 and Plate 24).

The initial observations indicate that the erosion of marsh promontories is progressing, probably due to the focusing of wave energy. If the heterogeneity of marsh material is preventing a stable marsh front from being established then it is likely this erosion will continue until arrested by the newly-constructed flood control breakwater. The breakwater will then serve to secure the areal extent of the marsh now protected by it.

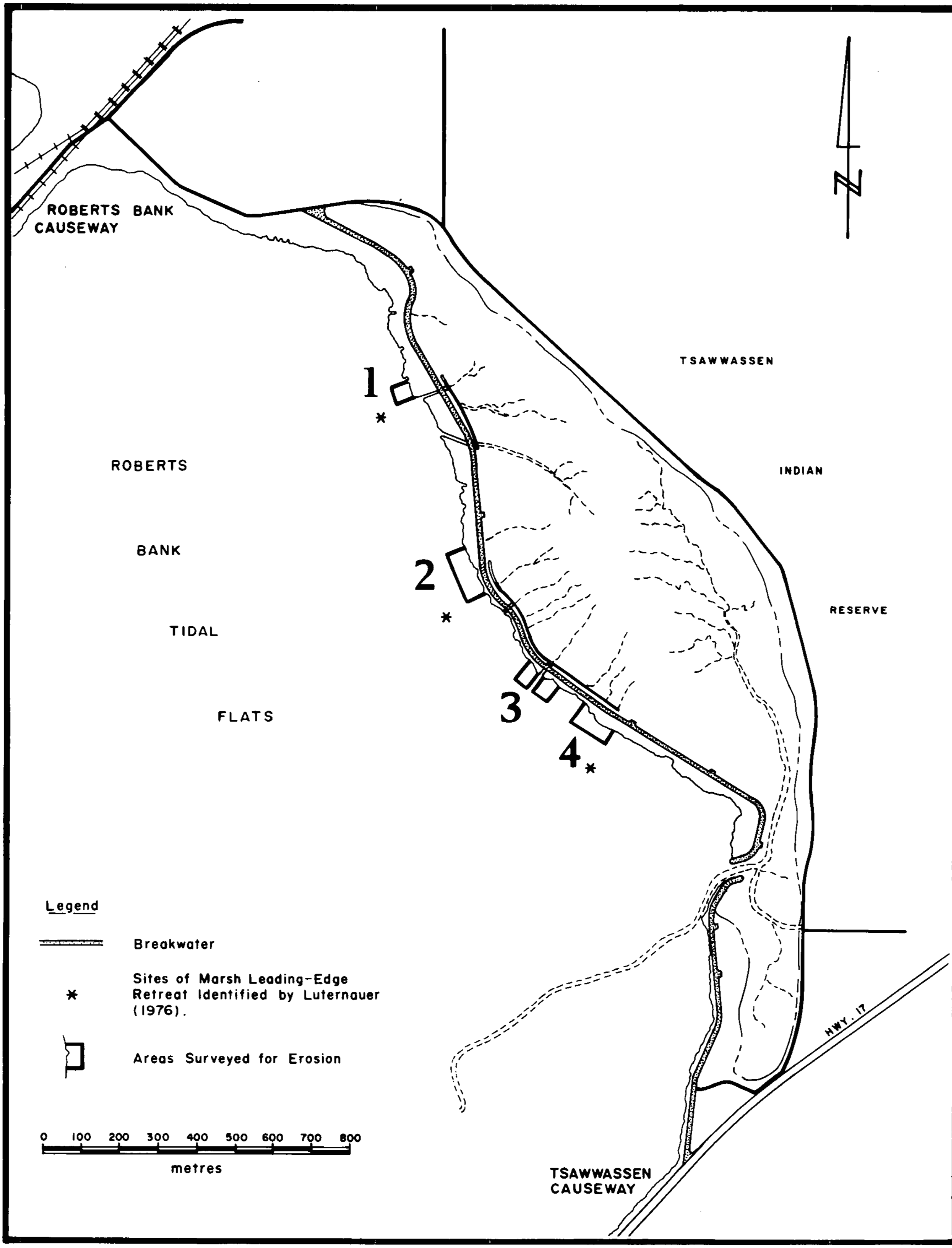


FIGURE 5 AREAS SURVEYED FOR EROSION ALONG THE LEADING-EDGE OF THE MARSH.

B. Ecological Integrity of the Salt Marsh

Preservation of the Tsawwassen salt marsh, the largest marsh of its type in the Fraser River estuary, is an additional major benefit of the flood control project. By facilitating tidal exchange between the salt marsh and the adjacent tidal flats, the project's design will reverse a trend towards an upland plant community. Further, fish are provided access to tidal channels, the possibility of fish stranding is prevented and detrital inputs to the nearby mud flats are enhanced, thus contributing to productivity in the estuary. Permitting full tidal inundation ensures that the important role of the marsh in the context of fish-food cycles is protected. The preservation of the ecological functioning of the salt marsh - tidal mud flat ecosystem will also secure the quality of habitat utilized by fish species, large numbers of great blue herons and other wildlife. The net effects of the project will be an overall improvement to the productive capacity of the salt marsh and estuary.

C. Summary Statement

The Tsawwassen Indian Reserve Flood Control Project reported on here demonstrates a model approach to the resolution of flood control, social and environmental conflicts. The approach and results achieved are complementary to other federal wetland protection strategies and could be applied in other estuarine and coastal areas.

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