Precision Identification Biological Consultants

HEMMERA

northwest hydraulic consultants nhc

FINAL REPORT

DELTAPORT THIRD BERTH
ADAPTIVE MANAGEMENT STRATEGY
2008 ANNUAL REPORT

Prepared for:
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HEMMERA

September 30, 2009
File: 499-002.11

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Attn: Carolina Eliasson, Environmental Specialist

Dear Ms. Eliasson:

Re: FINAL – ADAPTIVE MANAGEMENT STRATEGY 2008 ANNUAL REPORT, DELTAPORT THIRD BERTH

Hemmera is pleased to provide you with eight paper copies and one electronic copy of the Final - Adaptive Management Strategy, 2008 Annual Report completed as part of the Deltaport Third Berth construction project.

We appreciate the opportunity of working with you on this project and trust that this report is satisfactory to your requirements. Please feel free to contact the undersigned at 604.669.0424 regarding any questions or further information that you may require.

Regards,
HEMMERA

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EXECUTIVE SUMMARY

At the request of the Vancouver Fraser Port Authority (VFPA), Hemmera Envirochem Inc. (Hemmera), Northwest Hydraulics (NHC) and Precision Identification (Precision) are pleased to provide the 2008 Adaptive Management Strategy (AMS) 2008 Annual Report for the Deltaport Third Berth (DP3) construction project. This report documents the findings of the second year (2008) of the AMS program. The objective of the annual report is to provide a summary of the information attained in 2008 along with interpretation of these results, and recommendations for adapting the program for the third year of monitoring.

The main components of the AMS monitoring program include monitoring of coastal geomorphology, surface water and sediment quality, eelgrass distribution, benthic community structure, and coastal seabird/shorebird composition. It is challenging to resolve specific effects related to DP3 construction versus natural environmental variability. However, through monitoring a variety of factors such as physical conditions as well as biological conditions at various levels (primary producers, secondary and tertiary consumers), it is believed that the overall results will provide an early indication of impending negative effects that would warrant proactive response. To date, the overall findings do not suggest emerging negative trends within the inter-causeway area related to DP3 construction activities.

COASTAL GEOMORPHOLOGY

The coastal geomorphology portion of the AMS included the following activities:

- Monitoring of the area around the Crest Protection Structure (Q1-Jan 21, Q2-April 9, Q3-July 3 and Q4-October 17);
- Automated monitoring of turbidity in the water column on the tidal flats(Q1-Jan 21, Q2-April 9, Q3-July 3 and Q4-October 17);
- Monitoring of erosion and deposition on the tidal flats in the immediate vicinity of the new terminal(Q1-Jan 21, Q2-April 9, Q3-July 3 and Q4-October 17);
- Collection and analysis of sediment samples for changes in grain size and organic carbon content (Q2-April 9 and Q4-October 17);
- Interpretation of orthophotographs for the purpose of detecting large-scale geomorphic adjustments to the study area; and
- Coastal geomorphology mapping, consisting of hydrographic and topographic surveys.

The results of the second year of geomorphology monitoring indicated that the magnitude of sediment deposition and erosion within the study area continued to be typically less than 10 cm and within the expected range. Similarly, suspended sediment concentrations were within the typical range.

Construction-related activities in 2007 at the DP3 perimeter dike generated a series of new drainage channels in the vicinity of the dike. However, the area of new drainage channels appear to have stabilized. The expansion of the channels ceased once the supply of water draining from the DP3 perimeter dike was stopped by pumping dredgeate into the footprint area in June of 2007. Since that time, the steep-sided cross-section shape of the channels evolved into a gently-sloping rounded cross-section shape, typical of landforms that are no longer active. Observations in the field indicated that small amounts of sediment were transported within the channels. Mapping from the orthophotos showed that the position of the channels had not changed between the time that the 2007 and 2008 photos were taken, and the depth of disturbance (DoD) rod data indicates a low level of erosion and deposition in this area.

The only change recommended for the coastal geomorphology program was to measure tidal currents with an Acoustic Doppler Current Profiler (ADCP) in the summer of 2009 to verify the results of the numerical modelling studies included in the Coastal Geomorphology Study (NHC, 2004).

SURFACE WATER AND SEDIMENT QUALITY

The AMS program includes eight surface water and sediment quality monitoring stations: one in the ditch that drains into the inter-causeway area near the base of the BC Ferries Causeway (DP01); five inter-causeway stations (DP02, DP03, DP04, DP05, and DP08); and two distant reference stations (DP06 and DP07). Stations DP05 and DP07 are closest to the Georgia Strait. At DP05 and DP07, water samples were collected at two depths: A Level (1 metre below the water surface) and the B Level (2 metres above the sediment). Station Q8 was only monitored for surface water and sediment quality during Q1 in DP08. The quarterly monitoring events took place on the following dates:

- Q1-2008: March 3 to 5, 2008
- Q2-2008: May 29 to 30, 2008
- Q3-2008: September 20 and 21, 2008
- Q4-2008: November 26 and 27, 2008

Surface water and sediment samples were analyzed for metals and nutrients. Data evaluation included screening against applicable regulatory guidelines and standards, as well as a review of temporal and spatial trends.

Surface Water

Total copper, mercury, and zinc concentrations were sporadically found to exceed the BC Water Quality Guidelines in surface water at DP01, DP06, and DP07. With the exception of mercury exceedances identified at station DP02 in Q3-2008 and at station DP06 in Q2-2008, mercury concentrations were less than the regulatory criteria and the analytical detection limit. Copper and zinc exceedances identified in surface water at station DP01 (ditch discharge from upland area) are more likely linked to upland inputs than to DP3 construction, as there were no copper or zinc exceedances in surface water collected from the other stations in the inter-causeway area. The boron, total iron, and vanadium exceedances in surface water are typical of local marine surface waters and have been noted consistently during each quarter.

The highest metal concentrations in surface water were observed at station DP01 where water enters the inter-causeway area from the adjacent uplands, while the lowest concentrations were observed at stations DP05A and DP05B. Metal concentrations at the reference stations were generally similar to or greater than metal concentrations in the inter-causeway area. Metal concentrations at stations DP06 and DP07A showed similar temporal trends, likely as a function of influence from the Fraser River, a major contributor to regional water quality in the Georgia Basin. In contrast, temporal trends at DP07B (the deep water sample) showed greatest resemblance to trends at DP05A and DP05B, suggesting a greater influence from the waters of Georgia Strait.

The highest nutrient concentrations were measured at station DP01, likely as a result of upland agricultural inputs. Phosphate and nitrate concentrations were greater at the intertidal inter-causeway stations than at the reference stations.

Sediment

There were no metal exceedances in sediment during 2008. The lowest metal concentrations were measured at DP01 (closest to the ditch) and the highest at DP05 (closest to the turning basin). However, the application of a lithium geonormalizing technique suggested that metal concentrations measured in 2008 were representative of background. Metal concentrations have not exhibited a clear temporal trend.

As with surface water, nutrient concentrations were higher in sediments in the inter-causeway than at the reference stations. This is likely a function of the higher level of biological activity in the sheltered environment created by the two causeways as opposed to being specifically related to DP3 construction.

Continued monitoring of the nutrient and metal concentrations in surface water and sediments is recommended for 2009.

EELGRASS

The eelgrass survey was done on August 14 through 17, 2008. The assessment of epiphyte load and absence of *Beggiatoa* sp. indicate that the eelgrass habitat was considered to be in good condition.

The productivity of eelgrass was greater in 2008 than in 2007 and 2003 at all sites except Site 1. Site 1 is located in the intertidal zone of the inter-causeway, adjacent to the Deltaport Causeway. The density of eelgrass in the transition zone between Site 1 and the sand lobe has converted from continuous to patchy, as has the adjacent *Z. marina* bed. The sand lobe has evolved from a series of dendritic channels in the inter-causeway that originally developed during the 1980s. The sand lobe complex is characterized by highly mobile sand surface sediments that are exposed more frequently than the eelgrass beds that previously occupied this area. The sand lobe continues to expand and convert *Z. marina* habitat to sand flat. It is likely that the evolution of the sand lobe contributed to the declines observed at Site 1.

The *Z. marina* distribution in the new drainage channel area adjacent to the DP3 footprint has increased and is similar in area to that documented in 2003.

There are no indications that the development of DP3 has negatively affected the inter-causeway eelgrass habitat.

It is recommended that the survey in 2009 includes Site 1 and adds an additional station between Sites 1 and 2 that is representative of dense, continuous *Z. marina* habitat.

BENTHIC INVERTEBRATE COMMUNITY

The benthic invertebrate sampling was completed during Q1-2008: March 3 to 5, 2008. The benthic invertebrate populations in both the inter-causeway area and the reference area appeared diverse. Polychaete-amphipod ratios increased at some stations and decreased at others between 2007 and 2008. The data do not suggest a trend towards eutrophication. Variations in total abundance and the number of taxa also did not appear to be directly influenced by substrate type. One intertidal station (DP08) was added to the benthic community sampling for 2008. The Scientific Advisory Committee has recommended the addition of a ninth station (DP09) to the benthic community sampling program in 2009 in the vicinity of the new drainage channels as noted above in the Coastal Geomorphology section.

COASTAL SEABIRDS / SHOREBIRD COMPOSITION

Coastal seabirds/shorebird composition, relative abundance, and use of the inter-causeway area were very similar in 2008 to that documented during 2007.

Impacts to coastal seabirds and waterfowl appear limited to direct habitat loss associated with the DP3 footprint as predicted by the environmental assessment. Observations during the 2008 survey period indicate that, in response, birds used alternative habitat available within the inter-causeway area.

The second year of the AMS implementation has incorporated several adaptations to the original bird monitoring program, and it is recommended that this current monitoring program be continued through 2009.

ACKNOWLEDGEMENTS

Hemmera gratefully acknowledges the contributions of additional project team members including:

Coastal Geomorphology:	Northwest Hydraulic Consultants Ltd. 30 Gostick Place North Vancouver, BC V7M 3G2
Eelgrass Assessment:	Precision Identification 3622 West 3rd Avenue Vancouver, BC V6R 1L9
Vessel Services:	Ross Wetzel 18341 72nd Avenue Surrey, BC V4N 3G6
Analytical Laboratory:	ALS Environmental 1988 Triumph Street Vancouver, BC V5L 1K5
Biological Laboratory:	Biologica Environmental Services Ltd. Suite H50 Nootka Ct. 634 Humboldt Street Victoria, BC V8W 1A4

In addition, Hemmera would also like to acknowledge the effort and contributions of the following individuals:

Vancouver Fraser Port Authority:	Darrell Desjardin, Director of Environment Carolina Eliasson, Environmental Specialist Carrie Brown, Environmental Specialist
Scientific Advisory Committee:	Rowland Atkins, M.Sc., P.Geo. Senior Geomorphologist, Golder Associates Ltd. Terri Sutherland, Ph.D. Research Scientist, Science Branch, Department of Fisheries and Oceans Ron Ydenberg, Ph.D. Department of Biological Sciences, Simon Fraser University

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GLOSSARY OF TERMS

ADCP	Acoustic Doppler Current Profiler
AWAC	Acoustic Wave and Current Meter
AMS	Adaptive Management Strategy
BC	British Columbia
BCF	BC Ferries
CCME	Canadian Council of Ministers of the Environment
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSR	Contaminated Sites Regulation
CT	Caisson Trench
CWS	Canadian Wildlife Service
DF	Difference Factor
DP	Deltaport
DP3	Deltaport Third Berth
DFO	Department of Fisheries and Oceans
DO	Dissolved Oxygen
DoD	Depth of Disturbance
DQO	Data Quality Objectives
EAO	Environmental Assessment Office
EC	Environment Canada
Hs	Wave Height
LAI	Leaf Area Index
MAL	Marine Aquatic Life
MEDS	Marine Environmental Data Service
NHC	Northwest Hydraulics
NTU	Nephalometric Turbidity Units
PC	Point Count
PDA	Personal Digital Assistant
PDO	Pacific Decadal Oscillation
QA/QC	Quality Assurance/Quality Control
RDL	Reported Dection Limit
RPD	Relative Percent Difference
RTK GPS	Real-Time Kinematic Global Positioning System
SAC	Scientific Advisory Committee
SARA	Species at Risk Act
$SedQC_{ss}$	Sediment Criteria for Sensitive Marine and Estuarine Sediments
SEM	Standard Error of the Mean

SIMS	Seabed Imaging and Mapping System
TFN	Tsawwassen First Nation
TKN	Total Kjeldahl Nitrogen
Tp	Wave Period
TSS	Total Suspended Solids
VFPA	Vancouver Fraser Port Authority
WHSRN	Western Hemispheric Shorebird Reserve Network
WQG	Water Quality Guidelines

1.0 INTRODUCTION

At the request of the Vancouver Fraser Port Authority (VFPA), Hemmera Envirochem Inc. (Hemmera), Northwest Hydraulics (NHC) and Precision Identification (Precision) are pleased to provide 2008 Annual Report for the Adaptive Management Strategy (AMS) for the Deltaport Third Berth (DP3) construction project. This report documents the second year of implementation of the AMS. The objective of the report is to provide a summary and interpretation of the results from the quarterly monitoring programs completed in 2008 at Deltaport.

1.1 BACKGROUND

1.1.1 DP3 Project Description

Deltaport is a marine container terminal located on Roberts Bank in Delta, BC (**Figure 1**). The DP3 project consists of construction to accommodate an additional ship berth along with approximately twenty hectares of land for an expanded container storage yard. It will also include dredging to deepen the existing ship channel and creation of an adjacent tug moorage area. Rail and road improvements will also be required along the Deltaport Causeway to minimize project impacts on existing traffic flow.

The major construction activities and their schedule at Deltaport during 2008 included the following:

- Dredging (disposal & fill) – caisson trench — April 2007 – February 2008
- Tug Basin Construction — March 2007 – July 2008
- Marine densification — August 2007 – June 2008
- Terminal In-fill — September 2007 – August 2009
- Caisson recovery, repair, and placement — April 2008 – August 2008
- Tied bulkhead construction — January 2008 – March 2009
- Caisson mattress rock placement — January 2008 – May 2008
- Surplus mattress rock removal — February 2008 – September 2008
- Ballast addition — May 2008 – December 2008
- Berm rock placement — May 2008 – December 2008
- Turning basin dredging — June 2008 – September 2008
- Construction of perimeter drain pumping station — June 2008 – December 2008
- Installation of caisson lids — July 2008 – December 2008
- Concrete pours — November 2008 – December 2008

A complete timeline of construction activities in presented in **Table 1.1-1**.

Table 1.1-1 Timeline of Construction Activities

Site Activities	Time Period 2008			
	Q1	Q2	Q3	Q4
FRPD *Columbia* - Off-site River Sand Dredging	River dredging completed March 15th			
Tied Bulkhead Construction	Sheetpile driving complete	Stage 1 fill	Stage 2 fill	
Seaspan Tug Basin Relocation		Seaspan relocation - pile removal		
Caisson Recovery from Mulberry Harbour		Caisson recovery commenced	Caisson recovery complete	
Caisson Marine Concrete Repairs		Caisson repairs commenced June	Caisson repairs complete	
Dredging in Caisson Trench (CT) for Ocean Disposal	Dredging completed February			
Replacement Fill in CT	Fill completed March			
Marine Densification – CT	Densification continued	Densification completed		
Mattress Rock Placement – CT	Rock placement continued	Rock placement completed May		
Removal Surplus Mattress Rock	Surplus removal commenced February	Surplus removal continued	Surplus removal complete September	
Caisson Levelling Course Placement		Levelling course placement	Levelling course placement complete	
FRPD *Titan* - Import Sand	Import sand underwater stockpile			
FRPD *Columbia* - Suction Dredge Sand Transfer	Sand transfer February	Sand transfer to Fill Area 2 June		
Caisson Placement in CT		Caissons placed moving north	Caisson placement complete	
Caisson Ballast Rock Addition		Ballast addition commenced May	Ballast addition continued	Ballast addition complete December
Berm Rock Placement		Berm rock placement commmeced May	Berm rock placement continued	Berm rock placement continued

Site Activities	Time Period 2008			
	Q1	Q2	Q3	Q4
Berm Filter Placement		Berm filter placement commenced May	Berm filter placement continued	Berm filter placement continued
Containment Dike 2 Construction		Construction in May		
Containment Dike 3 Construction			Construction in August	
General Fill of CT			Fill C17 to C19 August to September	Fill C20 to C26 September to December
Sheet Pile Wall Installation at Mouth of CT				Sheet pile wall installation December
Land-based Densification			Trials commenced September	Densification within CT behind C17 to C23
POD 4 Perimeter Drain Pumping Station		Construction commenced in June	Contruction continued	Construction continued
Coring Tie in works at C16				October and November
Precast Caisson Lids + Installation			Commenced in July	Continued until December
Precast Keyways + Installation			Commenced in July	Continued until November
Cast in Place Formwork			Commenced in September	Continued through December
Connecting Slabs Concrete Pours				Completed November and December
Cope Wall and Crane Wall Concrete Pours				Completed for C17 in December
Turning Basin Dredging		Commenced in June	Completed by September	
Turning Basin Slope Protection				Rock placement commenced
Scour Protection			Commenced in August	Continued rock placement

The DP3 project was subject to both the provincial *British Columbia Environmental Assessment Act* and the federal *Canadian Environmental Assessment Act*. The environmental assessment involved a large number of studies including coastal geomorphology, water quality, sediment quality, marine resources, coastal seabirds and waterfowl, vegetation and wildlife, archaeology, socio-economics, noise, visual and lighting, air quality, and road, rail and ship traffic. This report is available from the BC Environmental Assessment Office (EAO) website (http://www.eao.gov.bc.ca/). As part of the acceptance of the environmental assessment by the BC Environmental Assessment Office were recommendations by Environment Canada – Canadian Wildlife Service (CWS) that an AMS be developed to provide practical advance warning of potential emerging negative ecosystem trends during project construction and operation. The current AMS program is being implemented by a project team led by Hemmera with subcontractors NHC and Precision.

1.1.2 AMS Project Objectives

The objectives of the AMS project are to undertake a science based systematic approach to Roberts Bank inter-causeway ecosystem to reduce uncertainty and assess the potential for negative trends in the ecosystem from marine eutrophication and dendritic channelization. This approach should:

1. Provide practical advance warning of potential emerging negative ecosystem trends during DP3 construction and operation, and
2. Establish actions that VFPA would undertake to prevent or mitigate negative trends that exceed applicable thresholds and may be linked to the DP3 project.

The AMS includes monitoring methods to specifically identify and mitigate potential environmental effects in the following areas of concern (the AMS project team member completing the work is shown in brackets):

- Coastal geomorphology (NHC);
- Surface water quality (Hemmera);
- Sediment quality (Hemmera);
- Eelgrass distribution (Precision);
- Benthic community structure (Hemmera); and
- Coastal seabird / shorebird composition (Hemmera).

1.2 SCOPE OF WORK

The AMS support program has been implemented to address concerns and meet requirements of stakeholders such as Environment Canada (EC), the Department of Fisheries and Oceans (DFO) and the CWS as well as other legislation, guidelines, and best management practices applicable to the work. The AMS involves the identification, management, prevention, and mitigation of environmental effects that may result from DP3 construction. The AMS program also undergoes an independent peer review by a Scientific Advisory Committee (SAC), comprised of scientists with expertise in the various study areas of the AMS, appointed by VFPA and EC.

The scope-of-work for the annual report involved completion of the following tasks:

- Analysis of quarterly data from coastal geomorphology/oceanography monitoring and crest protection monitoring.
- Analysis of quarterly data from surface water quality monitoring.
- Analysis of quarterly data from sediment quality monitoring.
- Analysis of eelgrass data collected in July 2008.
- Analysis of benthic invertebrate community data collected in March 2008.
- Analysis of quarterly data from bi-weekly coastal seabird / shorebird composition surveys to monitor brant geese, great blue heron, coastal seabirds, waterfowl, and other birds.
- Summarizing the quarterly monitoring data collected over the year.
- Evaluating the data relative to the objectives of the AMS program. Data evaluation included looking at both temporal and spatial trends in the data observed during the year as well as comparison to data collected from previous years, where applicable.
- Providing recommendations based on the findings to date, for adaptations to the AMS program and/or mitigation measures that may be required if adverse impacts are observed.

A detailed list of monitoring activities completed in 2007 and 2008 is presented in **Table 1**. A chronology of key adaptations to the AMS program implemented during 2007 and 2008 is presented in **Table 2**. A summary of the rationale for the adaptations is presented in **Table 3**.

1.3 FIELD METHODOLOGIES

The detailed field methodologies for the various survey and sampling methods are included in the Detailed Workplan document prepared for the VFPA by Hemmera (2007a) and a summary is also attached in **Appendix A**. The following sections provide some of the basic methodology along with any methodological variations that were necessary for completion of the work.

1.3.1 Coastal Geomorphology

Northwest Hydraulic Consultants (NHC) has responsibility for the Coastal Geomorphology portion of the AMS monitoring program for the area shown in **Figure 2**. This portion of the program included six primary activities:

- Monitoring of the physical conditions in the area around the Crest Protection Structure;
- Automated monitoring of turbidity in the water column on the tidal flats;
- Automated monitoring of erosion and deposition on the tidal flats in the immediate vicinity of the new terminal;
- Collection and analysis of sediment samples for analysis of grain size;
- Interpretation of orthophotographs for the purpose of detecting large-scale geomorphic adjustments to the study area;
- Coastal geomorphology mapping, consisting of hydrographic and topographic surveys; and
- Wave monitoring.

Monitoring began in April 2007 and continued through 2008. The following sub-sections provide a summary of the methodology and timing for each monitoring activity. A detailed description of the methodology is presented in **Appendix A**.

1.3.1.1 Crest Protection Monitoring

Inspections were conducted by NHC during very low tide conditions during Q1 and Q3 and involved the collection of repeat cross-section surveys as well as photographs that were taken during Q3 only at previously established sites. Monitoring of the Crest Protection Structure was initially proposed to be a quarterly activity but following recommendations included in the AMS 2007 Annual Report (Hemmera, 2008d) the monitoring frequency was reduced to twice a year. **Figure 2** shows the locations of the monitoring cross-sections as well as the monitoring points on the Crest Protection Structure and **Table 4** shows the coordinates of the monitoring points. A Real-Time Kinematic Global Positioning System (RTK GPS) was used to navigate to monitoring cross sections for repeat measurements.

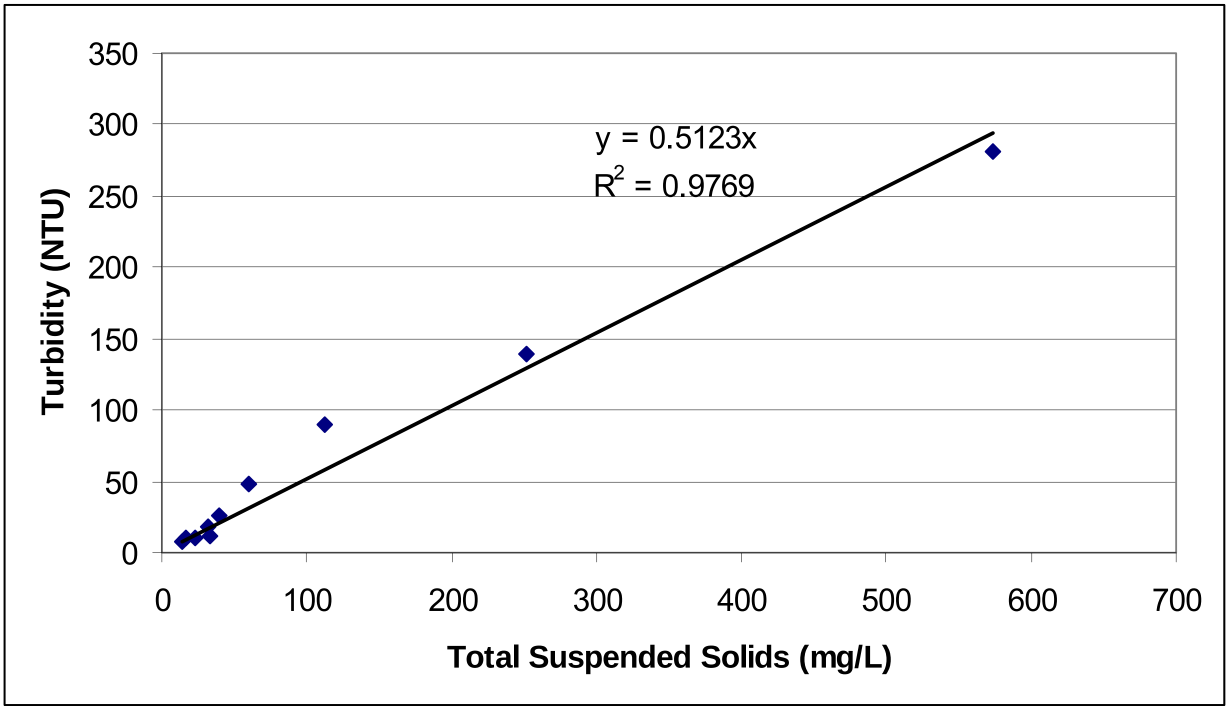
Changes were made to the way that the survey data is processed and plotted into the cross-section graphs in order to eliminate some small inconsistencies that had become apparent. These changes included an updated method to calculate distance along the cross-section from an established mid-point on the Crest Protection Structure as well as a re-calculation of the elevation correction. The previous elevation correction that was being used relied heavily on the real-time kinematic (RTK) correction that is broadcast by a survey support company and did not consider the slight variation that was being measured at a known control point. The re-analyzed cross-sections for both 2008 and 2007 are shown in **Figure 3** and **Figure 4** respectively.

Very low tides occur only at night during the winter months from late September to mid-February each year. Cross section surveys were carried out as part of the monitoring but effective photography of the Crest Protection Structure is not possible at night, and as a result, visual inspection of the structure was not supplemented with a photographic record during the winter monitoring periods.

1.3.1.2 Automated Turbidity Monitoring

Turbidity in the water column was monitored continuously in order to provide a proxy record of sediment transport across the tidal flats. Turbidity is a measure of the passage of light through water and provides only a proxy for sediment concentrations because it is affected by a number of factors such as grain size, material type, and organic content. A location-specific curve was derived based on empirical data in order to relate the measured turbidity to the concentration of total suspended solids (TSS). This requirement was originally addressed in the DP3 Project AMS Detailed Workplan, which is based in part on NHC's project proposal, and included a work task for the periodic collection of water samples during a tidal cycle. Preliminary field data collection showed that this method would not be successful, mainly due to the generally very low turbidity levels in the inter-causeway portion of Roberts Bank. Capturing the relatively rare occurrence of higher turbidity levels would have required extensive field time, and without measuring these higher turbidity levels, extension of the curve would not have been valid. NHC's memo of November 2007 presented a rationale for revising this methodology. The collection of water samples was discontinued in mid-2007 with the development of a TSS-Turbidity relationship using laboratory measurements and sediments collected in the vicinity of the monitoring station. The turbidity monitoring station provided a continuous record of measured turbidity from which TSS was computed using the expression x=y/0.5123 (where x=TSS and y=turbidity) as shown in **Figure 1.3-1**.

Figure 1.3-1 Plot of TSS versus Mean Turbidity (from NHC memo dated November 5, 2007)



Two Analite NEP495 Turbidity Logging Probes were installed and began collecting data on July 12, 2007 (locations shown in **Figure 5**). Due to recurring issues and damage, one of the sensors was removed from the site on April 21, 2008. Details are provided in the Results section. The remaining Sensor 2 was located at a ground elevation of approximately 0.5 m (Chart Datum) and 20 cm above the bed level in order to document near-bed sediment transport characteristics. The turbidity values, expressed in Nephelometric Turbidity Units (NTU), were recorded at 15 minute intervals.

Tidal flow is thought to be one of the most important processes affecting the physical environment at Roberts Bank. A local tide gauge was installed on a caisson at the Deltaport site on June 14, 2007 to provide information to supplement interpretation of the turbidity data. The instrument was placed inside a white plastic pipe and attached to a rope extending to the top of the caisson for retrieval during high tides. Human tampering with the tide gauge occurred on two occasions in 2007. In April 2008 the protective pipe was found to be missing, exposing the levelogger to potential damage from waves and floating debris. A new pipe was installed and the instrument was reset to its approximate original location but similar damage to the setup was again observed on July 3, 2008. The tide gauge was removed from the site during the Q4-2008 monitoring on October 17, 2008.

Corrections were applied to the observed water levels at Point Atkinson to determine the local tide height at Tsawwassen. Local tide height was incorporated into the analysis of turbidity data included in the annual reports and future local tide height data was derived using the Point Atkinson corrections. The tide gauge will not be re-installed until construction activities are largely complete and a new, less exposed location for the gauge can be found.

1.3.1.3 Monitoring of Erosion and Deposition

The pattern of erosion and deposition over the portion of Roberts Bank adjacent to the DP3 terminal was monitored using an array of depth of disturbance (DoD) rods. These consisted of a smooth rod with a washer placed over the rod resting at the sediment surface. The rods were installed by hand in the sediment by pushing to the point of refusal such that on average a 2.4 m length of rod is placed below the sediment surface. Burial or scour of the washer was measured relative to the top of the rod. The bottom of the rod was buried well below the maximum expected depth of disturbance. The rods were inspected on a quarterly basis to record the rate of scour and/or fill and to clear any vegetation built up on the rod.

Twenty-six DoD rods were installed in April 2007 and eight extra rods were added to the array as per recommendations made in the AMS 2007 Annual Report (**Figure 6**). Six of these rods were added on April 9, 2008 to provide increased resolution in the area of new drainage channels and an additional two were added to the pond area on July 3, 2008`. An RTK GPS was used to navigate to the DoD rods during low tides. Monitoring consisted of measuring the depth of scour or burial relative to the top of the rod using a steel tape. At locations where the washer is buried, the surrounding sediment was excavated by hand to expose the washer and then subsequently re-graded to the level of the surrounding surface to reset the washer height. Any significant amount of eelgrass or weed accumulation was noted. A photograph was taken at each installation site to record the general site conditions as well as the specific condition of the DoD rod.

Figure 7 illustrates the sequential measurements that were made to calculate maximum scour and net deposition. The initial condition was established by resetting the washer at the new ground surface following quarterly monitoring. The final condition was measured at the beginning of the subsequent quarterly monitoring. The depth of the washer marks the maximum scour depth, while the elevation of the sediment surface marks the net deposition. (It was not possible to detect if sediment was deposited at a higher elevation and subsequently partially eroded). These elevations were determined by making measurements relative to the top of the rod. After making the measurements, any disturbed sediment around the base of the rod was re-graded and the washer was placed on the new sediment surface.

1.3.1.4 Sediment Samples

Collection of sediment samples was included as part of the AMS geomorphology monitoring to characterize the grain size of near-surface sediments and monitor for potential changes. Samples were collected twice a year at each of the original 26 DoD rod sites, once in the early spring and again in late August to represent conditions during the lower energy, post-Fraser River freshet season. The 2008 sampling was conducted in April and then in October in conjunction with monitoring of the DoD rods. The first set of samples was collected at a distance of 5 m to the west of the DoD rods, while the second sampling took place at a distance of 5 m to the east of each rod. Subsequent sampling will rotate about the rods to avoid re-sampling in the same location. Samples were photographed, stored in containers, and brief sedimentological descriptions were noted. Samples were sent to a commercial lab to be analyzed for particle size as well as organic content.

1.3.1.5 Interpretation of Ortho Photographs

Aerial photographs of the study area were scheduled to be taken on a yearly basis during summer low tides. The 2008 photos were flown on July 2. Aerial photos were evaluated annually to assess trends and patterns of erosion and/or accretion on the tidal flats. The methodology consisted of overlaying successive ortho-rectified photographs using GIS mapping techniques to delineate and identify morphological changes on the tidal flats. A set of systematic mapping protocols was developed to map geomorphic features and allow comparison between photos taken in successive years. Mapping was completed by a geomorphologist who is familiar with the physical environment of Roberts Bank.

1.3.1.6 Coastal Geomorphology Mapping

Coastal geomorphology mapping was included as part of the AMS geomorphology monitoring to assess topographic changes due to long-term erosion or accretion of the inter-causeway tidal flats in the general vicinity of DP3. A combined bathymetric and topographic survey of the tidal flats using RTK GPS positioning was carried out in 2007, and the next survey is scheduled for 2010 or 2011.

1.3.1.7 Wave and Current Monitoring

Wave and tidal currents were initially measured by an upward-looking acoustic wave and current meter (AWAC) that was deployed in the vicinity of DP3 in January, 2007 by ASL Environmental Sciences Inc. Divers recovered the instrument for download on April 20, 2007 but discovered that it had been dragged several hundred meters south of its initial installation location, presumably by construction equipment. The instrument was re-deployed in the ship turning basin to reduce the potential for further interference but was found to have been buried by sediment that had been dredged and placed temporarily over the instrument. The instrument was recovered on September 27, 2007 but it had been damaged beyond repair during burial and recovery and data could not be recovered.

An alternate strategy for monitoring waves and currents was outlined in a memo prepared by NHC dated January 30, 2008 (NHC, 2008). This strategy consists of installing three non-directional wave sensors in the study area and making periodic measurements of ocean currents using a boat-mounted Acoustic Doppler Current Profiler (ADCP) to verify the results of the numerical modeling studies included in the Coastal Geomorphology Study (NHC, 2004).

Three wave sensors were installed at various locations within the study area on April 10, 2008 (**Figure 5**). Sensor 1 was located on the tidal flats opposite the DP3 facility and was quite well protected from most waves that may enter the turning basin. Sensor 2 was fully exposed to waves entering the turning basin but was located on the shoreward side of the Crest Protection Structure so wave energy would be reduced or eliminated depending on tidal stage. Sensor 3 was located on the seaward side of the Crest Protection Structure so is exposed to all waves that enter the turning basin.

The RBR Ltd. TWR-2050 sensor is a tide and wave recorder equipped with both a temperature sensor and a pressure sensor. The sensor measured the pressure of the water above it and by transforming the pressure to depth, tides were seen as the slow changes of depth and waves were seen as higher frequency changes. For the AMS monitoring, the sensors were programmed to record wave height in data bursts for a short period each hour in order to measure the full spectrum of wave conditions while prolonging battery life and data storage capacity to allow for quarterly data downloads. Because the calculation of wave height from changes in water pressure was sensitive to water depth, the initial water depth was carefully determined. If the instrument was moved to deeper or shallower water (as discussed in the Results section below) the results were invalid.

ADCP measurements of tidal currents were originally proposed to be scheduled in the fall of 2008 following completion of the caisson installation to close the DP3 footprint. This work was proposed to be scheduled in the summer of 2009 to coincide with large tides and calmer weather.

1.3.2 Surface Water Quality

Surface water samples were collected by Hemmera at the seven fixed surface water and sediment monitoring stations illustrated on **Figure 8**. In Q1-2008 only, an additional surface water sample was collected at an eighth station (DP08), added to enhance the benthic invertebrate sampling program as per the recommendations from SAC in the AMS 2007 Annual Report. The surface water samples were collected on the following dates:

- Q1-2008: March 3 to 5, 2008;
- Q2-2008: May 29 to 30, 2008;
- Q3-2008: September 20 and 21, 2008; and
- Q4-2008: November 26 and 27, 2008.

A representative surface water sample was collected one metre below the surface at each sampling station using a Van Dorn sampler. At DP05 and DP07, water samples were collected at two depths: the A level (1.0 metres below the water surface) and the B level (2.0 metres above the sediment). At DP01, located in a tidally influenced drainage ditch discharging to the inter-causeway area, samples were collected from 0.5 m below surface from under the dyke bridge (**Figure 9**). Samples were collected as outlined in the methodology presented in **Appendix A**.

The parameters analyzed for each surface water sample included:

- Temperature;
- pH;
- Hardness;
- Salinity;
- Metals;
- Chlorine[1];
- Turbidity and total suspended solids (TSS);
- Nutrients (Phosphate, Phosphorus, Ortho-phosphorus, Total Kjeldahl Nitrogen [TKN], Total Nitrogen, Ammonia, Nitrate, Nitrite and Organic Nitrogen);
- Clarity (via secchi disc); and
- Chlorophyll *α.*

The detailed methodology and the field and laboratory quality assurance and quality control (QA/QC) measures are as outlined in **Appendix A**.

The station nearest the DP3 construction area (DP04), was also monitored continuously for a number of water quality parameters (pH, temperature, conductivity, dissolved oxygen, and turbidity) using a YSI 6600V2 buoy-mounted sonde operated in conjunction with the DP3 construction environmental monitoring program. Sonde data were available until September 2008, at which point the sonde malfunctioned and was removed for repairs.

[1] Chlorine was analyzed only in the sample collected at station DP01. The purpose of this parameter relates to the presence of an immediately up-gradient recreational water park and concerns of discharge to the inter-causeway area.

1.3.3 Sediment Quality

Quarterly sediment sampling was completed by Hemmera at the same time as the surface water sampling at the stations illustrated on **Figure 8**. A representative sediment grab sample was collected from each of the seven stations using a Ponar sampler (and also DP08 in Q1-2008). Sediment samples were analyzed for the following parameters:

- Metals;
- Total nitrogen;
- Ammonia;
- Nutrients;
- Redox (Eh); and
- Hydrogen sulphide (H_2S).

The detailed methodology and the field and laboratory QA/QC measures are as outlined in **Appendix A**.

1.3.4 Eelgrass

1.3.4.1 Distribution and Mapping

The distribution and mapping component of this study, as completed by Precision Identification, was initially based on the maps produced for the 2007 AMS study. The study team ground-truthed the 2007 polygon boundaries using a personal data assistant with GPS capabilities (PDA/GPS). The 2007 orthophotos and maps were downloaded onto the PDA. The Geographical Information System (GIS) software Arcpad was used to record changes in polygon boundaries that have occurred subsequent to September 2007. A mobile Geographic Information System (GIS) mapping program was loaded on the PDA and used to capture and edit changes in polygon boundaries that have occurred subsequent to September 2007.

The digital orthophotos, flown on July 2, 2008, became available in late September. The study team worked with NHC to adjust polygon boundaries to reflect the 2008 eelgrass distribution using the data recorded in the field and the 2008 digital orthophotos. NHC then produced an eelgrass map based on these data.

1.3.4.2 Monitoring Eelgrass Vigour & Health at the Established Stations

Nine stations were sampled; four in the inter-causeway area, two west of the Deltaport Causeway (**Figure 10**), and three reference stations in Boundary Bay (**Figure 11**).

The three reference stations in Boundary Bay were selected in 2003 to represent eelgrass habitat within a range similar to the sites included in the 2003 Roberts Bank study area. Reference site WR1 is located near the upper limit of the eelgrass bed; the *Z. marina* at this location is similar in stature and density to *Z. japonica*. The 2003 Roberts Bank study area included a site west of the Deltaport Causeway that provided habitat similar to WR1 in Boundary Bay; this site was not part of the 2007 or 2008 AMS surveys as there is an absence of this habitat type within the inter-causeway area. The reference site WR1 was surveyed in 2007 and 2008 while waiting for the tide to ebb providing access to WR2 and WR3. reference site WR2 is slightly lower and therefore supports larger plants, while reference site WR3 is the deepest and supports the largest plants of the three reference sites in Boundary Bay.

The methodology for the surveys is included in **Appendix A**, as per the AMS Detailed Workplan (VFPA and Hemmera 2007).

1.3.5 Benthic Community

Hemmera collected and prepared sediment samples for benthic community analysis at seven of the eight sampling stations from March 3 to 5, 2008 (**Figure 8**). Benthic invertebrate sediment samples were not collected from station DP01 (**Figure 9**), a tidally influenced freshwater drainage ditch distinct from the other sampling stations. To capture inherent variability potentially present at the stations, three replicates were collected per station for the benthic community sampling. Benthic invertebrate samples were shipped to Biologica Environmental Services (Biologica) for taxonomic identification. The detailed methodology for the benthic invertebrate sampling is included in **Appendix A**.

1.3.6 Birds

The Fraser River Delta provides habitat that is international in its significance for a wide variety of birds including waterfowl, shorebirds, coastal seabirds, great blue herons, and raptors. Annually, approximately half a million birds depend on this delta with approximately 1.4 million birds utilizing the delta during the peak of migration (Butler and Campbell 1987). The Fraser River Estuary, which includes Roberts Bank and the inter-causeway area between the Deltaport Causeway and the BC Ferries Causeway, provide critical habitat for the largest wintering concentrations of waterbirds and raptors in Canada (BC Waterfowl Society 2006). In addition, the Fraser Delta has been designated part of the Western Hemispheric Shorebird Reserve Network (WHSRN) due to its status as a key stopover point used by shorebirds during migration. The entire worldwide population of western sandpipers (estimated 3.6 million birds) are believed to migrate along the coast of British Columbia. Of these birds, between 500,000 – 1,000,000 stop and stage along the Fraser River Delta during peak spring migration to forage along tidal mudflats where they build up energy reserves needed to reach breeding grounds in the Yukon-Kuskokwim Delta (Butler et al. 2002). Peak spring migration numbers have declined steadily between 1994 (1,125,000) and 2001 (126,000) as indicated by Butler and Lemon (2001). Due to the potential for disturbance to this habitat, Hemmera conducted a detailed study of waterfowl and coastal seabirds as part of the Deltaport Third Berth environmental assessment (Hemmera 2005). This document indicated the following potential impacts to waterfowl and coastal seabirds:

- Approximately 6% of the resting/roosting and/or foraging habitat available to waterfowl and coastal seabirds would be lost under the project footprint. Compensation has been planned for this loss of habitat.
- Temporary displacement of resting/roosting and/or foraging habitat for birds using the inter-causeway area during construction. These impacts were not deemed significant given the availability of alternative habitat throughout the remainder of the study area.
- Dredging operations may cause a reduction in prey items for foraging birds near the dredge areas and increased turbidity associated with dredging could affect visibility for foraging birds.
- No significant auditory impacts from construction were expected to waterfowl and coastal seabirds due to acclimation to existing noise levels and the expectation that noise levels resulting from construction would not exceed those already present at the site resulting from normal activities at the Port.
- No significant impacts from additional lighting were expected as birds have become acclimated to existing lighting at the port facility.

1.3.6.1 Bird Survey Objectives

The main objectives of this bird study are to provide complimentary data towards answering the concern regarding potential marine eutrophication and changes to coastal erosion processes and the distribution and composition of local biota, including shorebirds and coastal seabirds in the inter-causeway area. The bird study data are considered one indicator of ecosystem structure and function on a relatively broad spatial-temporal scale. Ecosystem changes leading to adverse ecosystem effects (e.g., eutrophication and erosion) that may be attributable to DP3 construction activity would likely be first detected through monitoring at a finer scale (e.g., water quality, benthic community, and eelgrass monitoring). However, construction activities can potentially alter bird feeding and/or resting behaviours and bioenergetics, and as such, monitoring bird relative abundance and behaviours in the context of the DP3 construction activity is an important indicator of construction-related effects to a valued ecosystem component.

Due to the possibility that changes to the ecosystem over time can be linked to key species such as great blue heron, brant, western sandpiper, and dunlin, monitoring bird usage within the inter-causeway area is part of the overall strategy to monitor ecosystem structure and function in the inter-causeway area.

To this end, the following study objectives were identified:

1. Determine whether there are impacts to brant geese and great blue heron usage of the inter-causeway area during critical periods of construction and operation.
2. Determine whether there are impacts on coastal seabird and shorebird usage of the inter-causeway area during construction.

A number of changes to the bird program were recommended in the AMS 2007 Annual Report following analyses of data collected during 2007 (**Tables 2** and **3**). A more detailed description of these changes is provided below.

1. Changing distance categories for all point counts to **0 – 250 m**, **250 – 500 m**, **and 500 m – 1 km** as used by the Canadian Wildlife Service during surveys conducted in 2004.
2. Discontinuing point counts along the BC Ferries (BCF) Transect (except as outlined in recommendation #6) as no evidence of impacts from the Deltaport construction work has been documented or is expected.
3. Reducing the number of point counts along the Tsawwassen First Nation (TFN) Transect from five to three by merging PC 113 with PC 115, and merging PC 105 with PC 107. This was implemented after assessing the value of data collection along the TFN Transect to determine whether continued TFN surveys were necessary to achieve the goals outlined in the AMS.
4. Reducing the frequency of survey events from bi-weekly to once every four weeks beginning the week of June 23, 2008 (survey event 31) with the exception of a six-week period during spring western sandpiper migration (April – May).
5. Reducing the frequency of winter surveys to one tidal event per survey for a period of three months (December – February) due to minimal fluctuations between high and low tide levels, during winter surveys.
6. Implementing seasonal species-specific “windshield” surveys in conjunction with regularly scheduled (monthly) survey events to provide absolute abundance counts of brant (i.e., November – May) and great blue heron (i.e., May – August) when these species are most abundant. These surveys would insure that focal species of the AMS (brant and great blue heron), were represented along the BC Ferries Causeway (which had been otherwise removed from the survey scope) and would provide an improved estimate (absolute abundance) of the total number of brant and great blue heron using the study area. No time limit was proposed for these windshield surveys; rather, the objective of the survey would be to count all the brant and great blue heron using the inter-causeway area at a given time. Windshield surveys would be included as part of the existing monthly survey events.

The above recommendations were reviewed and accepted by the Scientific Advisory Committee (SAC) and implemented in June 2008.

To make data comparable between months in 2008, where two survey events were conducted each month from January to March, and between previous years in which bi-monthly surveys were conducted, one event was selected from each month containing more than one survey. Survey events within a month were chosen systematically by selecting the event conducted closest to the 15th day of the month. When surveys were conducted over multiple days, to ensure adequate coverage of the project area, all surveys within that “event” were included in the data analyses. To meet recommendations accepted by SAC associated with western sandpiper both April and the first May survey event were selected for all years.

As a result of the above modifications to the bird program, analyses of changes in abundance, density, and use of the inter-causeway area for all species and functional groups, except great blue heron and brant, were derived from point count data collected from the South Roberts Bank Transect, herein labelled Deltaport Causeway Transect and TFN Transects. For great blue heron and brant, overall abundance estimates were derived from point count data collected from the Deltaport, TFN, BCF Transects (prior to June 2008) and windshield surveys (post May 2008) and analyzed for changes between years. Birds detected flying over points during counts were recorded, but excluded from analyses computing density of birds within sampling polygons.

Hemmera conducted 13 surveys for waterfowl and coastal seabirds between January and December 2008 on the dates listed in **Table 5**. Each survey consisted of point counts (PCs) of 20 minutes in duration along the Deltaport and TFN Transects. The BCF Transect was also surveyed from January through May, and has been included for assessing heron and brant abundance and distribution when possible. In addition, survey data for surveys conducted in 2003-2004 was also included. The survey dates for this time period are listed in **Table 5**. **Figure 12** outlines the study area and PC stations. Both high and low tide surveys were conducted at each PC from February through October 2008. Only one “high” tide survey was conducted in January, November, and December due to the absence of significant daytime low tides. This adaptation is consistent with survey methods used by CWS during 2004 surveys conducted along the Brunswick Marsh Transect, north of the Deltaport Causeway. Surveys were generally conducted over a one to three-day period consistent with the methodology presented in **Appendix A**.

To evaluate potential patterns in bird use of the study area relative to DP3 construction activities, several sources were consulted to develop a Disturbance Severity Rating Scale. Data sources used were: 1) notes taken concerning construction activities and perceived noise levels during surveys while in the vicinity of DP3 construction, 2) environmental monitoring logs (compiled by Hemmera for VFPA), and 3) daily engineer’s reports summarizing daily site activity (compiled by Klohn Crippen Berger for VFPA). Based on analysis of these sources, a rating scheme (**Table 1.3-1**) was developed to categorize and rank disturbance severity from DP3 construction activity.

Table 1.3-1 Disturbance Severity Ratings

Rating	Description
0	No disturbance
1	Low: minimal noise being generated, and/or minimal in water (or near water) activities that would disturb birds
2	Moderate: some construction noise generated and/or activities in project area that may disturb birds
3	High: activities producing loud noises (i.e., pile driving), and/or many activities going on in water.

The severity ratings scale was then used to assess patterns in bird abundance and distribution relative to noise levels and construction activities. Linear regression was also used to evaluate whether a relationship existed between the severity of impacts and great blue heron and brant use of areas closest to DP3 construction.

2.0 RESULTS

The following sections provide a summary of key findings for the AMS quarterly monitoring events during 2008.

2.1 BACKGROUND INFORMATION

2.1.1 Weather, Tides and Fraser River

Winds, waves, tidal currents and Fraser River discharges provide the main driving forces for the physical processes occurring at Roberts Bank. This chapter provides a brief overview of these parameters for the duration of the 2008 monitoring period. Comparisons to historical conditions were made using statistical techniques to provide an assessment of the overall frequency and magnitude of these driving forces. Reference stations for environmental data collected outside of the AMS program were chosen based on proximity to the site, quality of data, and length of historical record. It is recognised that conditions within the AMS Monitoring Area may differ somewhat from those measured at the external stations, both in terms of magnitude as well as timing but an in-depth analysis of these variations is outside the scope of the AMS. The primary purpose of presenting these data is to provide an independent evaluation of the relative wind and wave conditions compared to historical conditions in order to put the data collected for the AMS Monitoring Program into context. The wind and wave analysis based on the external stations provides a useful proxy measurement of the overall energy regime affecting the site.

2.1.2 Winds and Waves

Deltaport Terminal is exposed to waves from the northwest, west, south-west, south and south-east. **Figure 13** shows the fetch lengths measured at 10 degree intervals from a point near the offshore end of the terminal. The offshore (deepwater) wave conditions are governed by the fetch length, wind speed and wind duration. There are no continuous long-term wave or wind measurements at Deltaport. However, hourly wind data for the period from January to December 2008 were obtained from Vancouver International Airport, which has the longest continuous record in the area. Wave heights and wave periods have been recorded at Halibut Bank by Fisheries and Oceans Canada through the Marine Environmental Data Service (MEDS) program. The Halibut Bank station is located in Georgia Strait approximately mid-way between Nanaimo and Sechelt and 45 km northwest of Deltaport. The combination of wind and wave measurements provides a reasonable basis for characterizing the deepwater wave climate near Deltaport in 2008. The wind speed and direction data were used to hindcast the deepwater wave conditions at the site using a standard calculation relating fetch length, wind speed, and wind duration to wave height, while the measurements at Halibut Bank provided an independent check of the predictions. Knowledge of the deepwater wave conditions from the hindcast data provides a useful contextual comparison for evaluating the wave that were collected at the three stations within the study area.

Wind speed and wind direction were tabulated for four periods: January-March (**Table 6**), April-June (**Table 7**), July-September (**Table 8**) and October-December (**Table 9**). The values in these tables represent the number of observations (hourly data) in each speed class and direction range. The time series of wind measurements was also reviewed to identify specific storm events over the monitoring period. In this case, a storm event was defined as having a sustained wind speed greater than 30 km/hour. **Table 10** summarizes each event in terms of the time period, corresponding tide levels, and estimated significant wave height (Hs) and wave period (Tp) and includes an evaluation of the historical probability of occurrence for exceedance of this wind speed.

The strongest wind event that occurred in the January-March period was from the northwest, which was also the strongest wind event of the year. The majority of the strong wind events in this period came from the west, southwest, south and southeast, with nine observations exceeding 40 km/hour (**Table 6**). Of these events, eight are predicted to have generated waves of greater than 1 m (Hs) according to hindcast calculations. During the April-June period there were only two observations with maximum wind speed exceeding 40 km/hour (**Table 10**), which came from the west and northwest. A wind event on April 17th had a maximum wind speed of 44 km/hr from the west and would have generated 1.5 m waves while the event on May 22, with maximum wind speeds of only 41 km/hr but from the northwest would have generated waves exceeding 1.9 m. The strongest winds in the July-September period were also from the west and northwest, with four observations exceeding 40 km/hr. Each of these strong wind events would have generated waves greater than 1 m in height. The strongest winds in the October-December period were from the south and west. Westerly winds exceeded 40 km/hr on six occasions and reached a maximum value of 69 km/hour on November 13th (**Table 10**). Strong winds also occurred from the south, with values exceeding 40 km/hr on two occasions, with the maximum values reaching 43 km/hour on October 4th and on December 30th.

The most severe storm event of the year occurred over the period from early January 14th to early on the 15th with winds rising above 30 km/hr from the east at 6 am and veering steadily throughout the day as they strengthened. Winds rose above 60 km/hr at 4 pm, coming from the west and continued to increase throughout the afternoon and evening, reaching a maximum wind speed of 70 km/hr at 8 pm from the northwest. An average hourly wind of 70 km/hr measured at Vancouver International Airport has a probability of exceedance of 0.01% on the basis of all peak hourly winds for the period 1953 to 2006. During the 22 hour period of this storm, winds exceeded 30 km/hour for 19 hours and exceeded 50 km/hour for nine hours. The highest reported significant wave height (Hs) during this period at Halibut Banks was 2.1 m with a period (Tp) of 5.1 seconds. The hindcast wave height at Deltaport was calculated to be 2.7 m. The storm was associated with a high tide of 4.3 m (Chart Datum) at 16:30 hr on January 14th.

Two other large storm events occurred in 2008 that had maximum wind speeds of over 60 km/hr and average wind speeds of over 50 km/hr. A storm on November 13th had average winds over 40 km/hr for 12 hours and maximum winds of up to 69 km/hr. The station at Halibut Bank recorded relatively small wave heights of 1.2 m during this event, while hindcast wave heights at Roberts Bank were estimated to be 2.2 m. Another strong storm event occurred on December 29th with winds from the west at up to 67 km/hr. The significant wave height (Hs) was estimated to reach 1.9 m during this event.

A frequency analysis was carried out on the wind and wave data to assess the relative magnitude of the 2008 events versus the long-term conditions. Estimates of long-term frequency and duration of wind events and wave conditions were summarized in NHC (2004). **Figure 14** shows cumulative frequency distribution (hours exceedance) plots of wind speed for the four seasons. **Figure 15** shows similar plots for wave heights recorded at Halibut Bank. In 2008, the number of hours with winds below 20 km/hr was higher than average for all four of the quarterly periods, particularly in the April to June, and July to September periods. During October to December, the number of hours with winds in the 20 km/hr to 40 km/r range was approximately average while they were slightly higher than average in the January to March period and slightly below average between April and September. The incidence of stronger winds was about average.

A comparison of the 2008 wave data to the long-term average conditions is more complex. Between January and March there was a slightly higher than average incidence of small waves under 0.3 m (Hs) but for a given wave condition between 0.3 m and 1.2 m, there were fewer times where that condition was exceeded in 2008 than historically. For waves between 1.2 m and 1.5 m in height in this period there were more times when that condition was exceeded than historically. The April to June and July to September periods showed similar trends against the long-term average data. Each of these periods had fewer times when waves between 0.5 m and 1 m in height were exceeded and a slightly higher occurrence of small waves. The most noteworthy departure from average conditions was in the October to December period, which had fewer times where the occurrence of waves between 0.3 m and 1.8 m in height occurred than historically.

Overall, the wind and wave conditions in 2008 were generally less severe than the average conditions. In terms of large storms, it is not possible to make a direct comparison between 2008 and 2007 because the 2007 monitoring period did not span the entire year (April to December only) but the incidence of large storm events that generated significant wave heights during the period of overlapping months was about the same. However, the two big storms in November and December of 2008 were more severe, with higher winds and larger waves, than any of the storms that were measured in 2007.

2.1.3 Tides

Tide levels are predicted by the Canadian Hydrographic Service at Tsawwassen using observed levels at Point Atkinson as a reference station. Tide levels were also measured by NHC at Deltaport from June 14, 2007 using a pressure transducer and data logger. The record from this instrument contains a number of gaps caused by damage, as well as tampering with the installation, and ends on July 3, 2008 when the instrument was permanently removed. **Figure 16** to **Figure 19** show the observed tide levels for 2008 from this gauge superimposed with the recorded tide data from the Point Atkinson gauge. The tides are mixed, semi-diurnal in nature. Consequently, there are differences in elevation between successive high waters and successive low waters. The sequence of the tides typically follows the pattern of Higher High Water, Higher Low Water, Lower High Water and Lower Low Water, although this pattern is reversed approximately 15% of the days in a tide cycle as the tides switch from spring to neap. Lower Low Water occurs in daylight hours between April and August while during the fall and winter season Lower Low Water occurs during the night time. The tide range undergoes a bi-weekly variation due to the influence of the moon. Spring tides, having the largest range, occur 15 days apart, 26 hours after a new or full moon. The maximum tidal ranges occur near the time of the summer and winter solstice. The minimum tidal range occurs around the time of the Spring and Autumn equinoxes.

The highest tide of 2008 occurred on January 10 during a period of moderate winds. The predicted High Water at Tsawwassen was 4.5 m (Chart Datum) at 07:52 hr. **Figure 16** shows the actual observed tide at Deltaport.

2.1.4 Fraser River Discharge and Sediment Inflow

The Fraser River hydrograph has a characteristic nival-regime, with the flow rising in late April, peaking in May and early June, then receding through the late summer and fall. The lowest annual discharge typically occurs in March.

The Fraser River adds approximately 18 million tonnes of sand, silt and clay sediment to the Strait of Georgia each year on average. Suspended sediment concentrations typically rise to between 500 mg/l to 1,000 mg/l during the May-June freshet season, then decline through the late summer and fall to between 100 to 200 mg/l. Sediment concentrations in the low flow winter season typically range between 50 to100 mg/l (McLean and Church, 1986).

Virtually the entire sand load is deposited in the delta front off the main arm jetty near Steveston. Due to the isolated nature of the inter-causeway portion of Roberts Bank and the presence of the Deltaport Causeway, even the fine clay-sized sediment in the Fraser plume is deflected into the deep waters of the Strait of Georgia (**Figure 20**).

Information on conditions during 2008 is based on preliminary data from Water Survey of Canada and is still subject to revision. The 2008 freshet was larger than average, reaching a maximum discharge of 10,540 m3/s at Hope and approximately 11,200 m3/s at Mission at the end of May. This flood had a return period of approximately 7 years. By the first week of July the discharge reduced to 6,000 m3/s and by September the flow reduced further to below 4,000 m3/s. Between October and December the discharge remained between 1,400 to 2,200 m3/s, fluctuating in response to local rainstorms. No sediment measurements were made on the Fraser River in 2008. However, based on a comparison with previous years of observations it is likely that the total load in 2008 was similar to the mean annual load of around 18 million tonnes. Based on previous years observations it is expected the highest sediment concentrations would have reached approximately 1,000 mg/l in early June, declining to a few hundred mg/l by mid-August.

2.1.5 Construction Activities

The majority of construction activities in 2008 (see **Table 1.1-1**) were related to preparation of the caisson trench and placement of the caisson structures. This activity was completed in late December and resulted in the enclosure of the DP3 footprint. Prior to this date, the project footprint was open to tidal exchange through the gap in the caisson wall to the old tug basin. Other activities not directly focused on the caisson trench or caisson wall include caisson recovery from the Mulberry Harbour (the operational name given to the area of the turning basin where the berth caissons were temporarily stored prior to installation) and land-based densification. Some of these activities generated elevated levels of turbidity but most events dissipated to background levels within 30 m to 50 m of the activity. Turbidity levels associated with berm filter placement (Q2, Q3, and Q4) dissipated within 100 m and general fill of the caisson trench from August to December dissipated within 300 m based on the Deltaport Third Berth construction environmental monitoring reports.

2.2 COASTAL GEOMORPHOLOGY

2.2.1 Crest Protection Monitoring

The recommendation included in the AMS 2007 Annual Report (Hemmera, 2008d) to reduce the Crest Protection Monitoring from a quarterly to a bi-annual activity was not implemented until after the Q2 monitoring period. As a result, the 2008 monitoring year includes three repeat Cross-Section surveys as well as two sets of monitoring photos. Surveys were collected during the Q1, Q2, and Q3 monitoring periods and photos were taken during the daylight low tides in Q2 and Q3. The 2008 surveys are shown in **Figure 3** and the 2007 surveys are shown in **Figure 4**. A selection of the monitoring photographs is presented in **Appendix B**.

2.2.2 Automated Turbidity Monitoring

Two Analite NEP495 Turbidity Logging Probes were installed and began collecting data on July 12, 2007 (locations shown in **Figure 5**). Several times during the 2007 monitoring year, Sensor 1 experienced instrument failure as a result of water seepage. Water penetration of Sensor 1 within the Q2-2008 period damaged the instrument again and it was permanently removed from site on April 21, 2008. No data were recorded from Sensor 1 in 2008.

A continuous record of turbidity was measured by Sensor 2 (location shown in **Figure 5**) from the beginning of 2008 until October 17, which was the date of the last data download in 2008. During Q1-2009 monitoring in February, 2009, the instrument was found to have been lost due to disturbance during a large storm event. The installation cage and buoy were dragged a significant distance across the Crest Protection Structure. During this process the plastic housing holding the sensor appears to have become detached and was not located. As a result, any data collected after October 17, 2008 have also been lost. A replacement sensor was installed on March 5, 2009.

Figure 21 shows a time series plot of the raw 2008 turbidity data from Sensor 2 from January 1 to October 17. Periods of low tide below 0.7 m are shown on the plot as well as the timing of monitoring site visits. The timing of large storms that generated significant wave heights of greater than 2 m is also indicated. **Figure 22** shows the same time series but with the large spikes removed and a smoothing function applied to the remaining data. The time series plot shows that a significant number of measurements were made where the recorded turbidity was at the instrument maximum of 400 NTU. The record also shows that on approximately April 10, four days after the instrument was serviced, the turbidity recorded by the instrument shot up to very high levels and did not come down below 180 NTU until May 26, when it suddenly began recording lower turbidity values again. Despite the apparent self-correction of the instrument, turbidity recorded after May 26 continues to show very high values. A more thorough examination of these data is included in the Discussion in Section 3.0 of the report.

2.2.3 Monitoring of Erosion and Deposition

Table 11 to **Table 14** summarizes the bed elevation changes recorded for each monitoring period. No information is available at 'Z' series DoD rod sites prior to Q3-2008, and data from this quarter will serve as a baseline for future comparisons. Many of the DoD rods experience a combination of erosion and deposition during each quarterly monitoring period. A series of figures have been prepared to display the monitoring results graphically. **Figure 23** and **Figure 24** show plots of maximum erosion and net deposition during each monitoring quarter as a series of bar charts for each site. The net change is represented with shaded dots in **Figure 25** to **Figure 28**.

In some instances, erosion computations for DoD sites resulted in a negative value, which indicates that an error was made at some point in the measurement chain. Negative erosion based on the washer position is clearly impossible as it requires either that the washer has risen over time or that the rod has sunk, neither of which are plausible. The values are generally relatively small (under 1 cm) and can be attributed to measurement error. In the 2008 monitoring year, the largest such error was 1.9 cm. In cases where this error appears, the negative erosion value is simply set to zero.

2.2.4 Sediment Samples

Sediment samples were collected on April 9th and October 17th, 2008 at each of the 26 original DoD rod locations. The results of the grain size analysis have been presented within the quarterly monitoring reports in which the samples were analyzed. As the AMS is primarily concerned with changes to the finer portion of the sediment sample, the analysis presented in this report focuses on changes to the percent silt content of the samples between monitoring periods. **Table 15** shows the results of the sediment analysis in terms of percent total organic carbon content by weight for each site in the two sampling periods and **Table 16** shows the percent by weight of silt for each sample. The percent silt content is displayed graphically in **Figure 29** and **Figure 30** for the two monitoring periods. **Figure 31** shows the change in percent silt between April and October at each of the sampling sites.

Sampling depth was limited to the top 10 cm of the sediments, which is a reasonable sampling depth considering the typical depth of disturbance that has been observed in the DoD rod results. The sediments consist primarily of medium to fine sand (median size typically 0.1 to 0.2 mm) with minor amounts of silt. The percentage of silt (less than 0.063 mm) in the samples was used as an indicator of fine sediment inputs to the site. The silt content of the sediment samples is classified into four categories, each with a range of 16 percentage points. The majority of samples contain very low amounts of silt (16% or less) but one of the sites (D02) had a silt content of between 33% and 48% in April. The majority of the samples remained relatively stable in terms of percent silt between April and October but three sites (A03, D02, and E02) showed a decrease of more than 10% in silt content, and one of the sites (A04) showed an increase of more than 10% in silt content.

2.2.5 Interpretation of Ortho Photographs

The study area for this monitoring activity includes the entire area of Roberts Bank within the inter-causeway tidal flats. **Figure 32** shows the results of the orthophotographic interpretation, which was completed using GIS mapping techniques under the direction of the project geomorphologist. Areas of disturbance, shown in light purple, are areas where channel activity or deposition is occurring, but individual bars and/or channels are too small to be mapped individually. Sand bars, either large forms near the low-tide edge of the tidal flats or smaller channel point bars, have been mapped in yellow. Tidal channels are delineated in green – a dark green colour for channels large enough to have its banks mapped with double lines and light green for smaller channels.

The main features of interest shown in **Figure 32** include:

1. New drainage channels that formed at the north-eastern margin of the perimeter dike.
2. Formation of sand bars on the tidal flats on the seaward side of the Crest Protection Structure.
3. The large system of dendritic channels draining into the turning basin.
4. The tidal channels adjacent to the BC Ferries Causeway.

Items 2 through 4 are historic features that pre-date the DP3 project and have been identified and described previously (NHC, 2004).

Figure 33 shows a comparison of the area of new drainage channels from July 2007, shortly after the new channels had formed, to July 2008, a year post-formation. Photo 6 and Photo 7 in **Appendix B** are photographs taken on February 3, 2009 of the new channels. **Figure 34** shows the outline of the large dendritic channels that were digitized from the 2007 and 2008 orthophotos.

2.2.6 Coastal Geomorphology Mapping

The baseline coastal geomorphology mapping survey was completed in 2007 and the results were presented in the AMS 2007 Annual Report. This activity is scheduled for re-survey in year 3 or 4 of the monitoring program, based on the AMS Detailed Workplan (VFPA and Hemmera, 2007). No additional results are presented in this report.

2.2.7 Wave and Current Monitoring

Three wave sensors were installed on the tidal flats on April 10, 2008. The location of the sensors is shown in **Figure 5**. A number of issues have affected the instruments in 2008 since they were deployed. A tug boat operator working for Vancouver Pile and Dredge informed NHC that Sensor #3, which was deployed in the ship turning basin, had been dragged and was later removed from the water on June 19, 2008. NHC retrieved the instrument on June 23, 2008, and inspection revealed that it was undamaged. The data analysis indicated that the instrument was initially dragged on May 4, 2008, so records collected subsequent to this date were invalid. Wave Sensor #3 was again removed by DP3 construction contractors in early September because of construction operations in the area of deployment. It will be re-deployed when dredging operations in the ship turning basin have been completed, likely in the early spring of 2009. Also, Wave Sensor #1 shows a data gap between July 2 and October 17 because a programming error interfered with data collection after it was re-deployed during the Q3 monitoring visit.

Figure 35 shows the 2008 wave record (significant wave height, Hs) for all three sensors. This wave data includes periods of time when Sensor #3 had been dragged, and while still recording, the data is not valid because the pressure changes caused by waves are very sensitive to the initial depth of deployment.

The annual data has been divided into quarterly periods to correspond to the periods of analysis for the wind and wave data from Vancouver Airport and Halibut Bank that has been presented in **Sections 2.1.1** and **2.1.2** above. **Figure 36** shows the wave data between April and June, **Figure 37** shows the data between July and September, and **Figure 38** shows the wave data between October and December.

2.3 SURFACE WATER QUALITY

2.3.1 Quality Assurance / Quality Control

For metals in surface water, the data quality objective (DQO) for precision was to obtain a relative percent difference (RPD) of less than 20% or a difference factor (DF) of less than two. The DQO for completeness was 100%. For the organic parameters the DQO for precision was RPD of less than 50%. As RPDs/DFs for most parameters met the DQOs, it was concluded that the data were, on the whole, reliable and met project requirements for laboratory and field duplicate QA/QC evaluation. Detailed QA/QC evaluations are presented in the quarterly reports. A summary of issues encountered is presented in **Table 17** and discussed below.

In Q1-2008, the RPDs for TSS, lead, molybdenum, nickel, and zinc exceeded the DQO of 20%. The RPDs for lead, molybdenum, and zinc were less than 24%, while the RPDs for nickel and TSS were 33.8% and 36.1% respectively.

In Q2-2008, the RPDs for TSS, aluminum, nickel, and chlorophyll α exceeded the DQO of 20%. While the nickel RPD was only 20.5%, the TSS, aluminum, and chlorophyll α RPDs ranged from 40.9% to 62.3%.

In Q3-2008, the RPDs for TSS, lead, manganese, and silicon exceeded the DQO of 20%. The RPDs for TSS, lead, manganese, and chlorophyll α were 69.0%, 58.5%, and 81.4% respectively, while the silicon RPD was only 22.9%.

In Q4-2008, the RPDs for TSS and arsenic were 38.9% and 32.6% respectively. This is consistent with the QA/QC results from the fourth quarter in 2007, where only TSS and zinc exceeded the DQO (Hemmera 2008).

The TSS RPD was consistently elevated, likely due to unevenly distributed sediment suspended by wave action. Elevated metal RPDs were likely also associated with suspended sediment. The roughest weather (i.e. most windy and wavy) was experienced in Q3-2008, which is the period for which the highest TSS RPD was calculated.

2.3.2 Chemistry

The parameters collected as indicators of potential toxicity to marine organisms were compared against the BC Water Quality Guidelines (WQG) for the Protection of Marine Aquatic Life (MAL) and the Canadian Council of Ministers of the Environment (CCME) MAL WQG presented in **Table 18**.

2.3.2.1 Metals

Total copper exceeded the BC WQG in five surface water samples and zinc in one. Three of the copper exceedances were noted in the drainage ditch DP01 (Q1-2008, Q2-2008, and Q4-2008), and two at reference station DP06 and DP07A in Q2-2008. One zinc concentration in surface water exceeded the BC WQG at DP01 in Q4-2008. The mercury concentration exceeded the CCME MAL and the BC WQG in two samples (SWDP06-6 and SWDP02-7).

Total boron, iron, and vanadium concentrations exceeding the BC WQG were noted in several surface water samples (**Table 18**).

Total boron concentrations measured during 2008 ranged from 65 to 3,800 µg/L. This is compatible with boron concentrations in coastal marine water in Canada (typically ranges from 3,700 to 4,300 µg/L) (Moss and Nagpal, 2003). The only stations where boron concentrations did not consistently exceed the BC WQG were DP01 (a drainage ditch), DP06, and DP07A (but not DP07B). The latter two stations are adjacent to the Fraser River, where there is greater freshwater influence.

The BC WQG apply to total metal concentrations. Dissolved iron was added to the program after total iron concentrations exceeding the BC WQG were measured in Q1-2007. Given that total iron includes iron associated with suspended sediments, dissolved iron is considered more relevant to the assessment of water quality for the AMS. The dissolved iron concentrations were consistently less than the BC WQG. The dissolved iron results suggest that suspended particulate matter was responsible for the elevated total iron concentration measured.

The reported detection limit (RDL) for vanadium was greater than the BC WQG during all four quarterly monitoring events due to the dilution required to avoid sodium interference during analysis. However, all vanadium concentrations were below the RDL. For cadmium, cobalt, copper, iron, lead, manganese, nickel, uranium, and zinc, a chelation procedure was used to remove the sodium; however, this procedure cannot be used for vanadium.

2.3.2.2 Eutrophication-related Parameters

Nitrate concentrations met the CCME MAL of 16 mg/L, except at DP01 in Q4-2008, where a nitrate concentration of 26.6 mg/L was measured. There are no other regulatory criteria applicable to nutrients in seawater. Other parameters will be discussed in the context of potential eutrophication in **Section 3.2.**

2.3.2.3 Sonde

Data from the YSI Sonde, located near DP04 (**Figure 8**) was available from March 19 to August 29, 2008, at which point, the sonde was removed for repairs. A replacement sonde was installed at the site in spring of 2009. It should be noted that the sonde was removed on June 11, 2008 to allow for dredging by the Columbia dredge. It was returned to the water on July 16, 2008, when dredging in the area was completed. The sonde data is included in the AMS 2008 Annual Report as **Appendix C**. Analysis of the data indicated the following trends:

- Dissolved oxygen (DO) and pH variation mirrors the tidal cycle with peaks at low tide and dips at high tide;
- DO decreased from 12-14 mg/L in May & June to below 8% in August; and
- pH remained around 8 throughout the monitoring period.

The low pH values recorded in August and September 2007 (Hemmera 2008), appear to have to been an anomaly linked to calibration issues, as pH values remained around 8 from March through August 2008. The 2008 sonde data supports the conclusion that the decline in DO noted in August and September 2007 was a function of seasonal changes rather than an indication of eutrophication.

Turbidity data were not collected by Hemmera in 2008. Data from NHC's turbidity sondes, installed nearby (**Figure 5**), were presented in **Section 2.2.2**.

2.4 SEDIMENT QUALITY

2.4.1 Quality Assurance / Quality Control

For sediment, the DQOs were a RPD of less than 20% or a DF of less than two. The sediment data set was considered complete and accurate based on the results of the field and laboratory QA/QC. Detailed QA/QC evaluations are presented in the quarterly reports. A summary of issues encountered is presented in **Table 17** and discussed below.

The sulphide RPD exceeded the DQO in Q1-2008, Q2-2008, and Q3-2008. Above-average RPDs for sulphide were not unexpected, as the sediment for sulphide analysis was collected directly from the ponar without homogenization. In Q3-2008, the sodium RPD was 24.6%. No issues were encountered in Q4-2008.

2.4.2 Sediment Chemistry

The sediment toxicity parameters (metals) were compared against the BC Contaminated Sites Regulation (CSR), Schedule 9 Generic Numerical Sediment Criteria for sensitive marine and estuarine sediments ($SedQC_{ss}$) (**Table 19**). No exceedances of the $SedQC_{ss}$ were measured during the four quarterly monitoring events.

There are no regulatory criteria applicable to nutrients in sediment. Nutrient concentrations will be discussed in the context of potential eutrophication in **Section 3.2**.

2.4.3 Grain Size

Grain size samples were collected during the Q1-2008 monitoring event (**Table 20**). The sediment consisted of sand with a trace to some silt and clay, except at DP05 where the sediment was finer grained, consisting of sand and silt with some clay. This is consistent with the grain size results from NHC (**Section 2.2.4**) and with AMS results from 2007.

2.5 EELGRASS

2.5.1 Distribution and Mapping

Field surveys dedicated to mapping the distribution of eelgrass in the inter-causeway area were conducted August 14 through 17, 2008. Additional data were collected for this section while monitoring Eelgrass Vigour and Health between July 29 and August 1, 2008, and while conducting a survey of eelgrass distribution in the vicinity of the sand lobe for VFPA from June 2 through 4, and on July 16, 2008 (Archipelago et al., 2009).

The sand lobe and associated channels have continued to increase in area, smothering *Z. marina*, *Z. japonica*, and transition habitat. The sand lobe has evolved from a series of dendritic channels in the inter-causeway that originally developed during the 1980s. The sand lobe complex is characterized by highly mobile sand surface sediments that are exposed more frequently than the eelgrass beds that previously occupied this area. The habitat in the vicinity of the sand lobe was mapped in detail during the summer of 2008 (Archipelago et al., 2009). The small eelgrass polygons shown on the sand lobe appear to be remnants of the bed that previously occupied this area. These polygons were not visible on the 2007 orthophoto and therefore were not previously mapped.

The weather and water clarity on the date that the air photos were flown were favourable for documenting eelgrass distribution into the shallow subtidal; to a depth lower than in previous years.

The 2008 distribution of eelgrass within the study area is shown in **Figure 39**. The eelgrass distribution mapped in 2003 and 2007 is provided in **Figure 40** for comparison with 2008.

Sediment deposition and drainage channel formation adjacent to the perimeter dyke in the inter-causeway area in 2007 altered the eelgrass distribution in that area. A survey conducted in May 2008 determined that the survival of eelgrass in the area where sediment was deposited and new drainage channels formed far exceeded that indicated on the 2007 orthophoto (AMS 2007 Annual Report Update, May 2008). Areas that appeared devoid of vegetation on the orthophoto supported remnant patches of *Z. marina*. Many of the remnant patches survived and expanded, especially within the new channels during the spring and summer of 2008. The area (m^2) colonized by eelgrass in the vicinity of the area that was altered by sediment deposition from the new drainage channel formation was estimated using GIS and found to be comparable with the area occupied by eelgrass in 2003.

An area along the Deltaport Causeway slightly north east of the site discussed in the paragraph above was classified as unvegetated in 2003. The 2007 survey recorded patchy *Z. japonica* throughout this area. The 2008 field survey documented that the majority of this area was unvegetated.

The area classified as Zostera-mixed represents the transition zone between *Z. marina* and *Z. japonica* habitat where the two species co-exist; it is located above the optimal elevation for *Z. marina*. The width of this zone has varied inter-annually for decades, often reflecting large-scale environmental conditions such as the duration of exposure during summer low tides, climate, and likely the effect of the Pacific Decadal Oscillation which has been shown to affect water temperature and sea level in the region (Thom et al. 2003).

The transition zone west of the main dendritic channel complex had encroached into an area previously classified as *Z. marina* by 2007; the combined cover of the two species was continuous. The transition zone continued to expand over the next year and the distribution became patchy. Vertical rhizome growth of *Z. marina*, indicative of recent sediment accretion, was noted throughout this area.

The distribution of *Z. marina* in the area adjacent to the transition zone has also declined from continuous to patchy.

A large area of unvegetated sand is shown near the head of a channel parallel to the BC Ferries Causeway on the 2007 eelgrass distribution map. The habitat at this location was classified through air photo interpretation using the 2007 photos. A field survey at this location in 2008 revealed that the area currently supports a patchy distribution of *Z. marina* and *Z. japonica*.

The orthophotos from 2007 and 2008 indicate that sediment accretion has been occurring in *Z. marina* habitat near the end of the BC Ferries Causeway.

The subtidal limit of *Z. marina* appears to have increased over the last year, however this may reflect the clarity of the water and the level of the tide at the time the photos were recorded rather than the conditions on site. The maximum depth where eelgrass is visible on an orthophoto is greatest when the water turbidity and tide height are very low.

2.5.2 Monitoring Eelgrass Vigour & Health at the Established Stations

The field survey was conducted from July 29 through August 1, 2008.

Research has shown that eutrophication is one of the factors that may lead to an elevated epiphyte load on eelgrass. Epiphytes are plants growing on the outside of another plant in a non-parasitic relationship (Dunster and Dunster, 1996). The epiphyte load at all stations was ranked as typical. Photographs were taken at each site to document the epiphytic cover for future reference. *Beggiatoa sp.* was not present at any of the sites, nor was it observed when travelling to or from the sites.

The distribution of *Z. marina* was continuous at all sampling stations. *Z. japonica* was absent from all of the sampling stations, except from Site 1 in the inter-causeway area near the Deltaport Causeway where *Z. japonica* was sparse.

The parameters that were quantified at each of the stations included total shoot density, reproductive shoot density, shoot length, and shoot width. Means were calculated from 20 replicate samples at each station.

The relative productivity at each station was calculated using a Leaf Area Index (LAI) formula. The LAI is calculated as follows:

$$\text{LAI} = \text{mean density } (\#/\text{m}^2) \times \text{mean shoot length (m)} \times \text{mean shoot width (m)}$$

T-tests using the Bonferroni correction adjustment were used to test for significant differences between years for each parameter, except in cases where there was no variation within a data set. A standard paired two-sample, 2-tailed t-test was used in cases where the Bonferroni correction adjustment could not be applied.

The data collected in 2008 and in 2007 are summarized in **Table 2.5-1**. The data from 2008 and 2003 are summarized in **Table 2.5-2**. The p-values for each test are provided in **Appendix D**.

Table 2.5-1 Mean Eelgrass Shoot Density (Total and Reproductive), Length, and Width at each Reference Station in 2008 and 2007

Site (#)	Total Density (#/0.25m^2)		Length (cm)		Width (mm)		LAI		Reproductive Shoot Density (#/0.25m^2)	
	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007
Inter-causeway area near Deltaport Causeway										
1	25.4	25.8	**65.0**	**115.8**	**6.0**	**8.2**	**0.40**	**0.99**	*0.0*	*1.4*
2	32.8	26.5	168.9	146.7	7.4	7.8	1.66	1.19	0.6	2.1
Inter-causeway area near BC Ferries Causeway										
5	18.8	17.4	**179.0**	**130.7**	8.6	7.8	**1.15**	**0.71**	0.1	0.4
6	22.6	20.6	135.8	127.3	7.2	7.2	0.90	0.76	0.3	0.8
West of Deltaport Causeway										
3	17.65	16.0	132.15	121.8	7.6	7.9	0.71	0.61	1.0	1.9
4	**21.6**	**14.7**	163.35	164.0	8.5	8.2	**1.2**	**0.79**	1.1	1.1
Boundary Bay										
WR1	73.8	60.6	54.4	48.4	4.6	4.9	0.78	0.56	2.8	0.7
WR2	32.4	29.4	139.0	122.7	7.0	7.3	1.28	1.04	**5.0**	**1.4**
WR3	**32.5**	**19.9**	**201.0**	**167.4**	7.6	7.7	**1.32**	**1.04**	3.6	1.3

Means were calculated from 20 samples at each station, and were reduced to one decimal place. Leaf Area Index values were calculated using two decimal places for each parameter in the equation. Bold values indicate that the difference between years was significant using the Bonferroni correction adjustment. Data sets without variation were assessed using a standard paired two-sample, 2-tailed t-test; comparisons that were significant have been italicized. The p-values for each test are provided in **Appendix D**.

Table 2.5-2 Mean Eelgrass Shoot Density (Total and Reproductive), Length, and Width at each Reference Station in 2008 and 2003

Site (#)	Total Density (#/0.25m^2)		Length (cm)		Width (mm)		LAI		Reproductive Shoot Density (#/0.25m^2)	
	2008	2003	2008	2003	2008	2003	2008	2003	2008	2003
Inter-causeway near Deltaport Causeway										
1	25.4	24	**65.0**	**140.0**	*6.0*	*8.5*	**0.40**	**1.18**	*0.0*	*1.2*
2	**32.8**	**23.9**	**168.9**	**137.6**	*7.4*	*8.5*	**1.66**	**1.12**	0.6	1.2
Inter-causeway area near BC Ferries Causeway										
5	18.8	14.5	179.0	163.5	**8.6**	**9.3**	1.15	0.88	0.1	0.4
6	22.6	16.8	135.8	132.4	7.2	7.5	0.90	0.66	0.3	0.6
West of Deltaport Causeway										
3	17.65	17.3	132.15	141.1	**7.6**	**9.7**	**0.71**	**0.95**	1.0	0.6
4	**21.6**	**15.7**	163.35	188.8	**8.5**	**9.5**	1.2	1.12	1.1	0.8
Boundary Bay										
WR1	**73.8**	33.0	54.4	44.4	4.6	4.5	0.78	0.29	**2.8**	**28.7**
WR2	**32.4**	14.0	139.0	137.4	7.0	7.0	**1.28**	**0.54**	**5.0**	**0.5**
WR3	**32.5**	21.0	201.0	215.2	7.6	7.3	1.32	1.33	3.6	0.8

Means were calculated from 20 samples at each station, and were reduced to one decimal place. Leaf Area Index values were calculated using two decimal places for each parameter in the equation. Bold values indicate that the difference between years was significant using the Bonferroni correction adjustment. Data sets without variation were assessed using a standard paired two-sample, 2-tailed t-test; comparisons that were significant have been italicized.

2.6 BENTHIC COMMUNITY

Due to a limited time window in 2007, the first benthic community sampling event was conducted during a period of high winds and rough seas. The associated wave action complicated Ponar deployment at sampling stations in the intertidal zone. In Q1-2007, recovery volumes for each station were estimated to average 3.0L, with the exception of station DP05 where sample recovery was approximately 8.0L. In Q1-2008, recovery volumes for each station were estimated to average 5.0L, with the exception of station DP05 where sample recovery was approximately 9.0L.

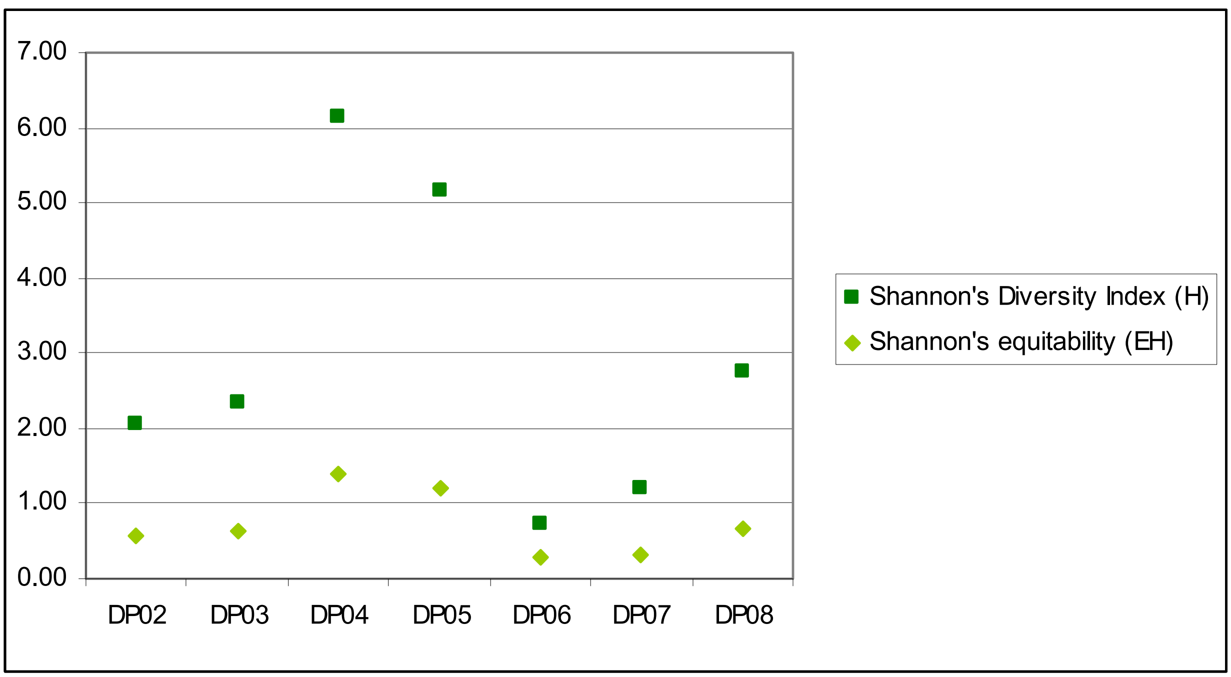
Core indicators used to evaluate the baseline benthic invertebrate community data included total species abundance, taxa richness and diversity. Benthic species abundance and richness were further compared to grain size and sulphide concentration to determine if correlations existed. To evaluate core indicators, sampling stations DP02 to DP07 were assessed as a composite of the replicate numbers (A, B & C).

Intermediate stage and junior stage and only 1.0 mm sieve samples were included in evaluating benthic invertebrate data at each of the stations. As indicated in **Section 1.3.5**, no sample was collected at DP01, a tidally influenced freshwater drainage ditch distinct from the other sampling stations. Benthic invertebrate data evaluated for the baseline sampling program are presented in **Table 21**.

The greatest abundance of benthic invertebrates and taxa richness were observed at station DP04, the site closest to the DP3 construction (**Figure 41**). The lowest abundance of benthic invertebrates and number of taxa was observed at reference stations DP06 and DP07 (**Figure 41**).

The largest proportion of species belonged to the class *Bivalvia* followed by *Polychaeta* (**Figure 41**). *Tanaidacea* were abundant at stations DP04 and DP08. Reference station DP06 showed least diversity, with 90% of species accounted for by the class *Bivalvia*. Stations DP02 and DP03 also showed relatively little diversity with approximately 80% of species accounted for by the *Polychaeta* class. Stations DP04 and DP05 were more species rich as demonstrated by the Shannon's Index of Diversity (H) and Equitability (E_H) calculations (**Figure 2.6-1**). While overall abundance of benthic invertebrates at station DP08 was greater than at stations DP02 and DP03, species diversity and equitability were only marginally greater than at stations DP02 and DP03.

Figure 2.6-1 Shannon's Diversity and Shannon's Equitability (Evenness) Index



The majority of the stations, with the exception of DP05, were composed of over 80% sand (0.063mm – 2.0mm). The sediment collected at station DP05 contained 53% silt and 33% sand. No observable correlations between grain size and species abundance or taxa richness were noted (**Figures 2.6-2 and 2.6-3**). There was a positive correlation observed between sulphide concentrations and species abundance, as well as between sulphide concentrations and taxa richness (**Figures 2.6-4 and 2.6-5**).

Figure 2.6-2 Species Abundance versus Percentage of Grain Size at each Station

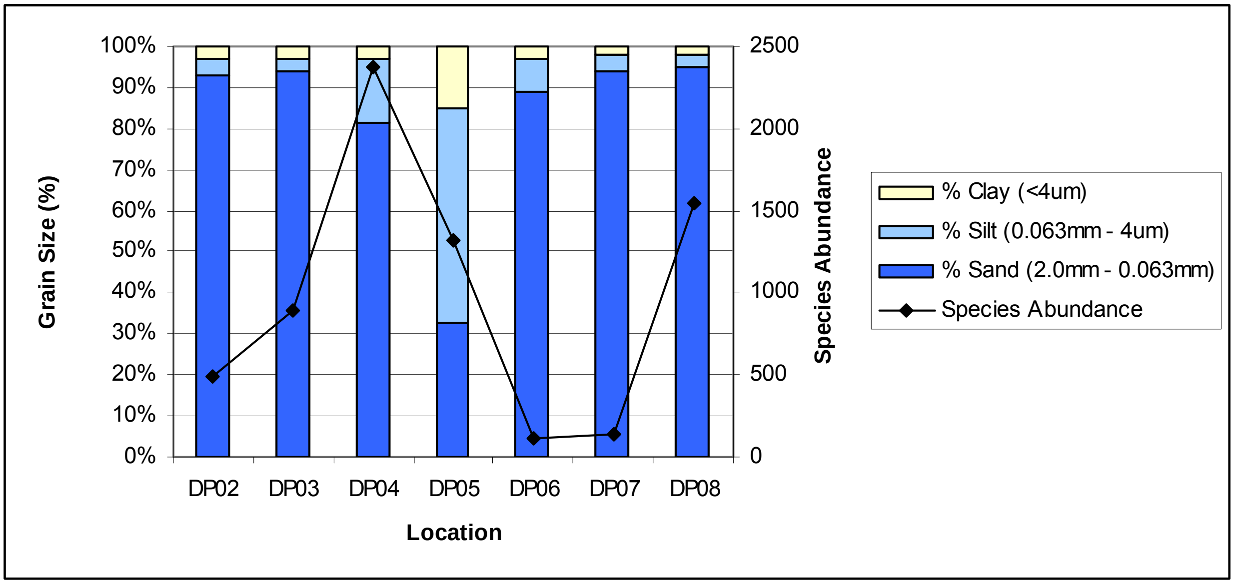


Figure 2.6-3 Total Number of Taxa Observed (Frequency) versus Percentage of Grain Size at each Station

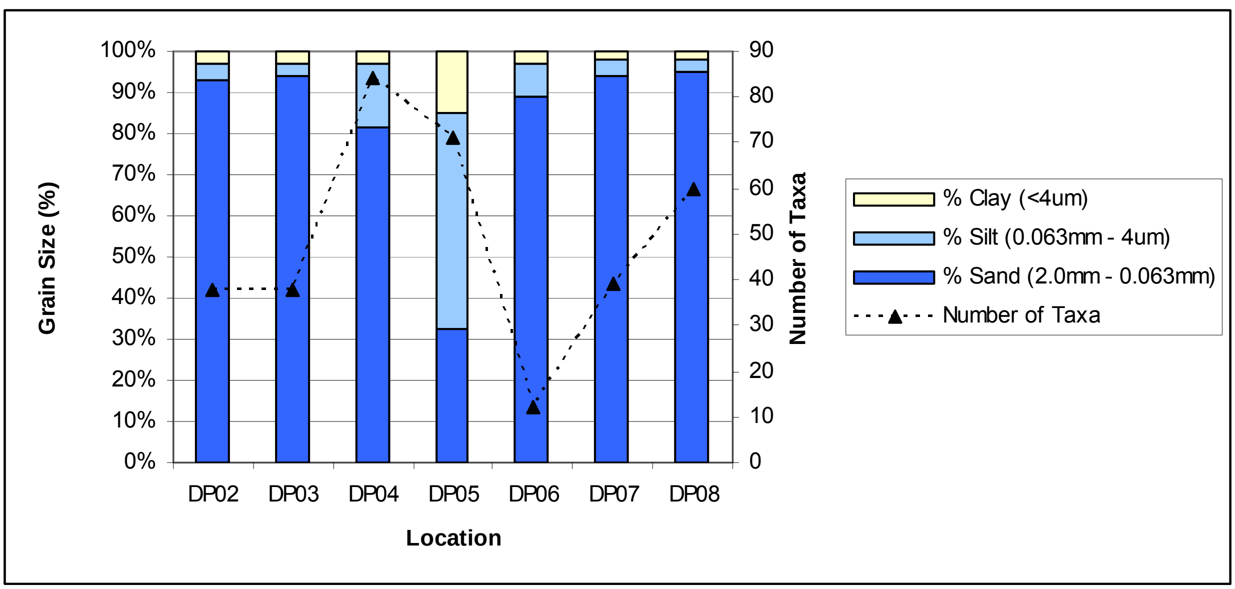


Figure 2.6-4 Species Abundance versus Sulphide Concentration (µg/g) at each Station

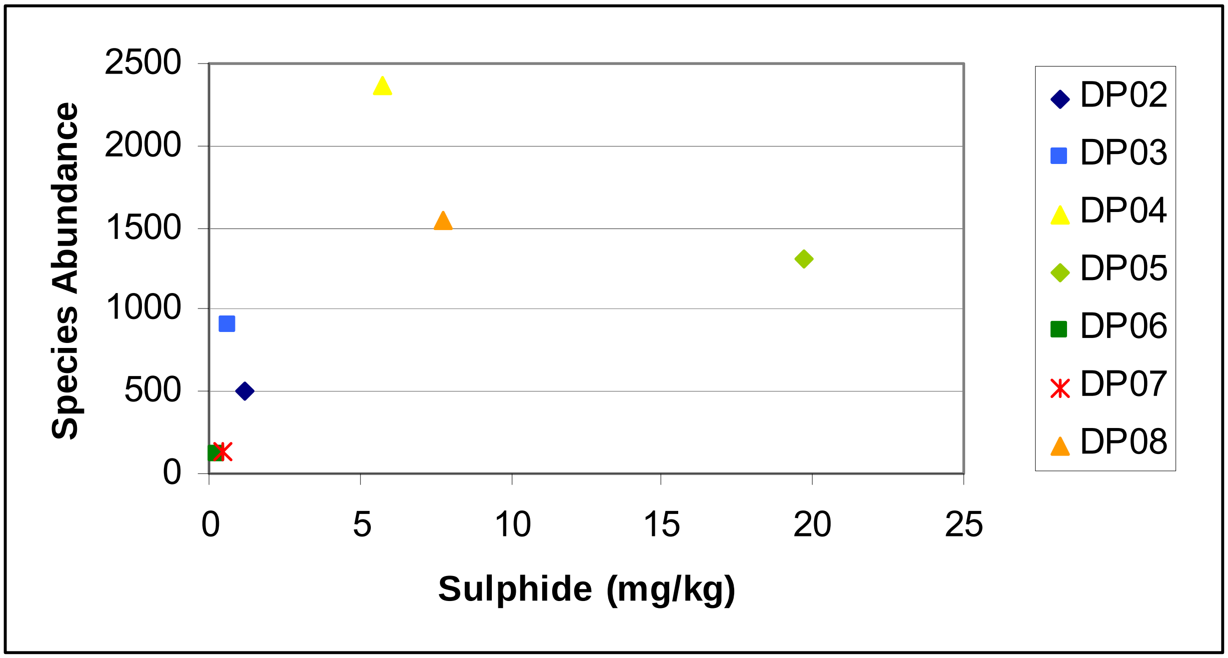
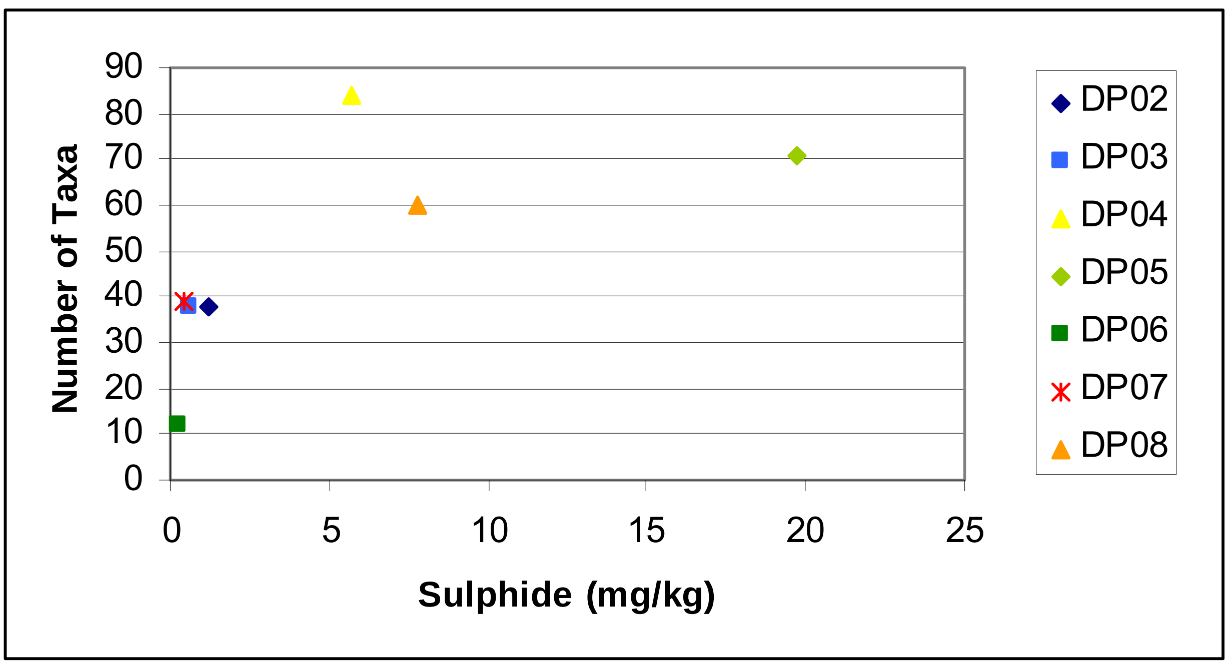


Figure 2.6-5 Total Number of Taxa Observed (Frequency) versus Sulphide Concentration (µg/g) at each Station



2.7 BIRDS

The following data are intended to provide an estimate of the number, composition, and distribution of species using the inter-causeway area during low and high tides on a monthly basis between January and December, 2008. Complete results of the monthly surveys are presented in **Table 22.**

The birds observed at Roberts Bank have been organized into six categories: great blue herons, brant, shorebirds, coastal waterbirds, raptors, and other birds to facilitate a clear presentation of the report's findings and conclusions. Point count survey locations are provided in **Figure 12**.

2.7.1 Great Blue Heron

Assessing and monitoring potential impacts to great blue heron (*Ardea herodius fannini*) was identified as a primary objective of the AMS (Hemmera, 2007). The great blue heron is listed federally by the Committee on the Status of Endangered Wildlife (COSEWIC) under the Species at Risk Act (SARA, Schedule 3) as a species of 'Special Concern', meaning that it is particularly sensitive to human disturbance. Provincially, the coastal *fannini* subspecies is blue-listed due to declining populations attributed primarily to human development and in part to increasing disturbance from eagle populations (Gebauer and Moul, 2001). Blue-listed organisms are indigenous species or subspecies considered to be of Special Concern in British Columbia, but whose populations are not so imperilled as to be considered threatened with, or in danger of, extirpation (i.e., red-listed).

Great blue herons were recorded in the study area in 11 of the 12 months surveyed (January – December 2008) (**Figure 2.7-1**). Heron distribution and abundance changed seasonally within the inter-causeway area with no herons observed during the December survey when weather conditions were unseasonably cold and snow and/or ice covered much of the habitat typically used by herons at this time of year.

Between 11 January and 20 December, 2017 herons were recorded either flying over or using the inter-causeway area for foraging and/or resting. Heron distribution between the Deltaport and TFN Transects was equal, with roughly 50% of birds detected along each (**Figure 2.7-2**). Similar to previous years (Hemmera, 2008) herons were detected in greatest numbers from late spring through summer (April – August), at which time herons exploited long hours of daytime low tides to forage on exposed eelgrass beds primarily along the Deltaport Transect during low tide. Use of the study area by herons decreased dramatically during the fall and winter, with monthly counts averaging only 34 (± 14 SEM) herons from October through March, compared to 317 (± 80 standard error of the mean [SEM]) herons detected from April through August, 2008 (**Figure 2.7-1**).

Figure 2.7-1 Relative Abundance of Great Blue Heron within the Inter-causeway Area during Low and High Tides, Deltaport, 2008

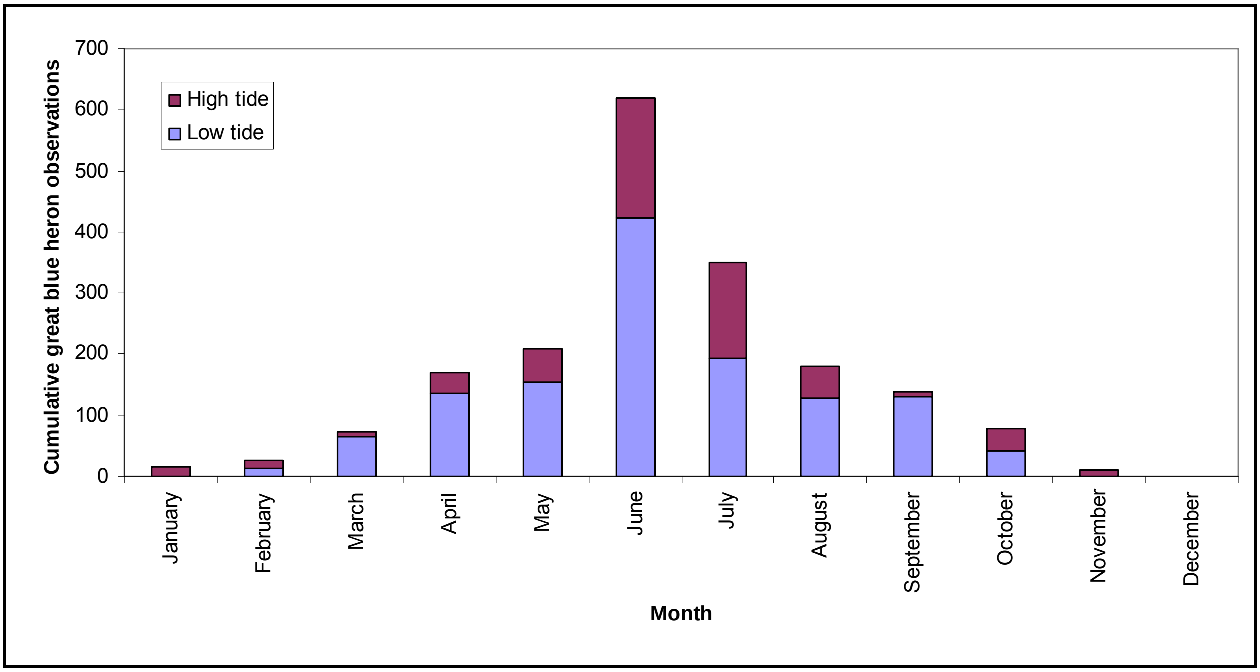
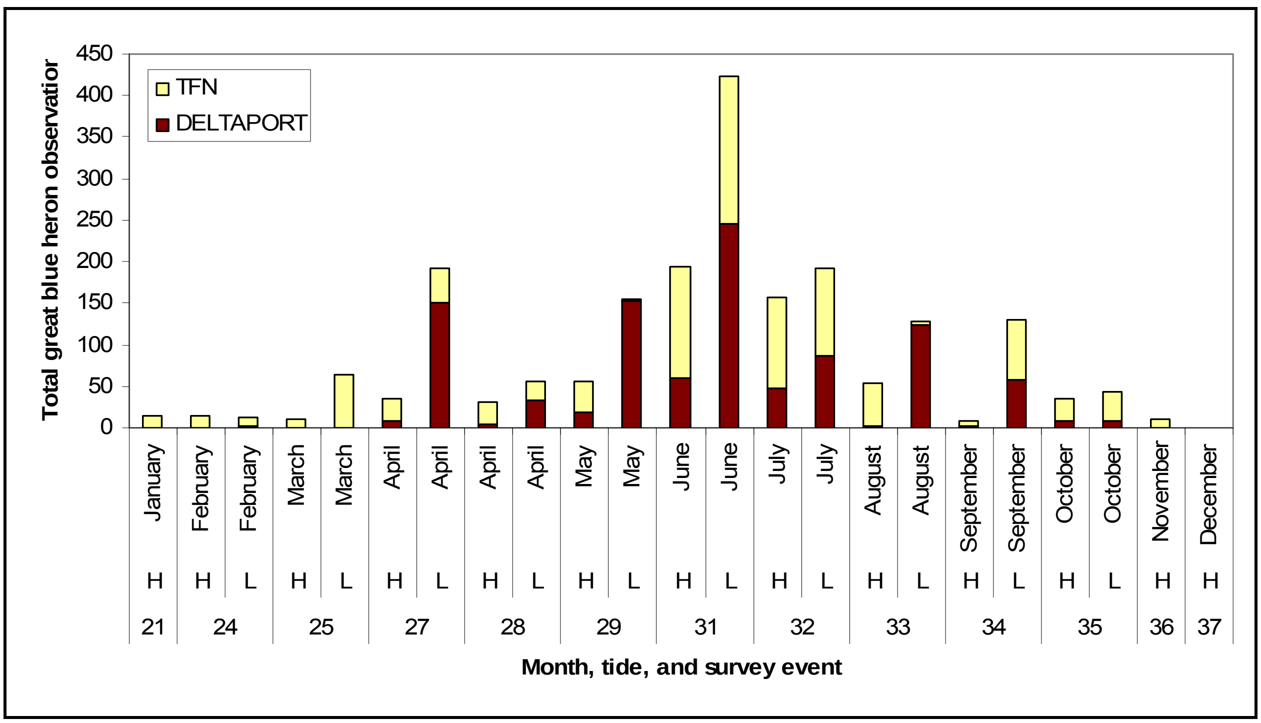


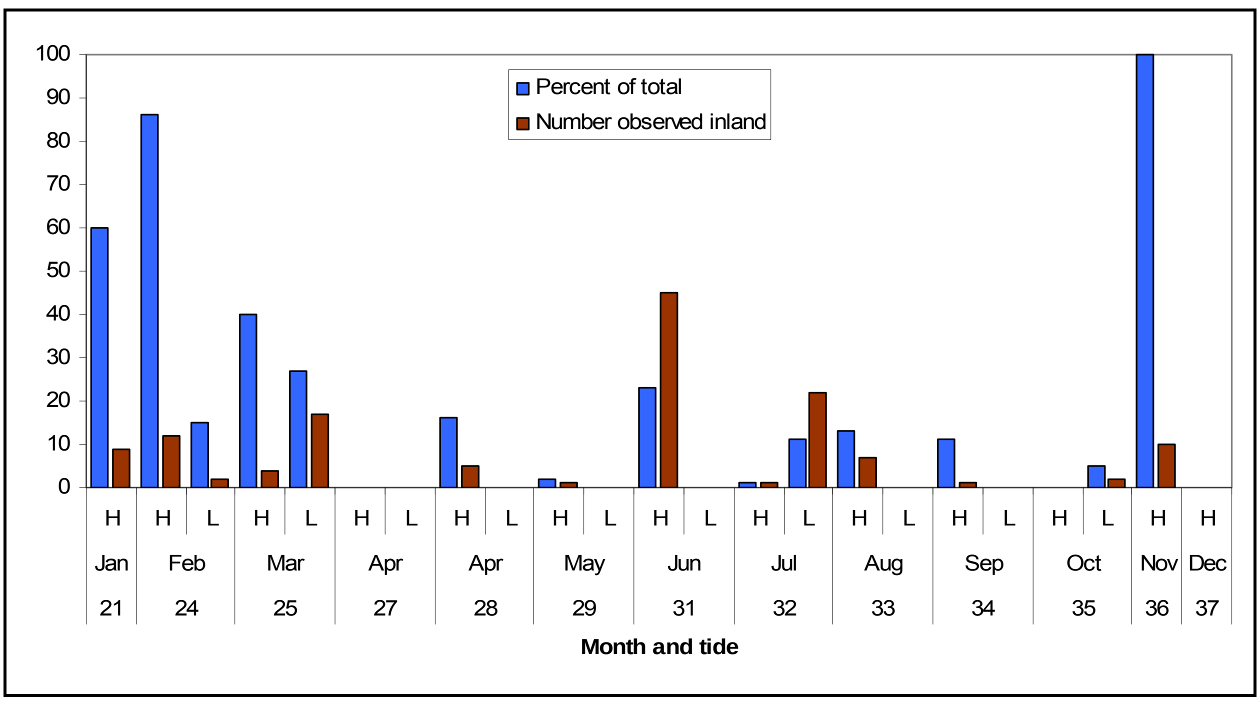
Figure 2.7-2 Abundance of Great Blue Herons Observed Using the Project Area during High (H) and Low (L) Tides along the Deltaport and TFN Transects, Deltaport Inter-causeway Area, 2008



Tide levels influenced heron use of the study area (**Figure 2.7-1 and 2.7-3**). During low tides, herons were found throughout much of the inter-causeway area, following the tide line as eelgrass beds were exposed. The importance of low tides and the subsequent availability/exposure of eelgrass beds are apparent as 69% (1396/2017) of all heron observations were recorded during low tides. Key low tide areas included PCs 14, 15, 17, 109, and 113, accounting for 81% (1128/1396) of heron observations. PCs 109 and 113 were also used frequently by herons during high tides, accounting for 61% (376/621) of high tide observations. The duration and extent of seasonal low daytime tides lessened into late summer and fall at which point daily low tides were short lived and exposed less of the eelgrass beds. This corresponded with a decrease in heron abundance within the study area, and herons shifting their use patterns, spending proportionally more time using the saltmarsh 100 m inland along the TFN Transect during the winter (**Figure 2.7-3**). By November, the majority of heron using the study area were recorded inland as the tidal regime no longer exposed sufficient patches of eelgrass.

Figure 42 provides an overview of great blue heron distribution and relative abundance within the study area.

Figure 2.7-3 Percent of Great Blue Heron Observations and Number of Heron Recorded Inland along the TFN Transect, Deltaport Inter-causeway Area, 2008



2.7.2 Brant Geese

Between January and early-March brant (*Branta bernicla*) numbers within the inter-causeway ranged from 10 to 197 birds per tidal survey event (**Figure 2.7-4**). Brant numbers began to increase in late-March with a maximum number of 3,619 and 2,036 birds (total = 5,655) documented on April 10 along the BC Ferries and Deltaport Transects, respectively. Both of these groups were documented as large flocks, with 72% of the BC Ferries flock documented within 250 m of shore in PC 126, and 89% of brant documented along the Deltaport Transect greater than 500 m off shore in PC 14, in the middle of the inter-causeway area. However, because brant can move between counts the conservative peak brant estimate was 3,619 birds. No brant were documented within the project area between June and October.

Due to a change in survey protocol, as per the recommendation from the AMS 2007 Annual Report, the BC Ferries Transect was not surveyed after June 2008, after which windshield surveys were initiated to assess brant numbers within the entire inter-causeway area. Because point counts along the BC Ferries Transect were not conducted when brant began arriving back onsite in November large differences were apparent between the total number of brant documented using point counts compared to the total recorded from windshield surveys. Abundance estimates from windshield surveys were up to eight times higher than point count estimates for the same survey period (**Figure 2.7-5**, November 2008). Survey estimates derived from point counts and windshield surveys during November and December fluctuated between approximately 500 and 4,500 birds (**Figures 2.7-4** and **2.7-5**). During this period only black-bellied brant were present in the study area. Point count surveys documented flocks of up to several hundred brant offshore along the TFN Transect during November and December 2008. In November, the largest concentration of brant (73%, 372/512) documented using point counts were observed within 250 m of shore in PC 109. Windshield surveys for brant yielded higher numbers of brant using the inter-causeway area. In November, a peak count of 4,500 brant within the inter-causeway area was reported by a Ministry of Environment representative (J. Evans, pers. comm) during the same week as the survey event. In December, the majority of the 2,000 brant documented during windshield surveys were observed from PC 126, greater than one kilometre offshore, along the BC Ferries Transect. Flocks of greater than 200 brant were also observed during point counts within 250 m of shore in PC 109 along the TFN, and PCs 18 and 19 along the Deltaport Transect. The concentration of brant within PCs 18 and 19 was most likely due to inclement weather and brant attempting to take refuge from wind and surf inside of the crest protection.

Figure 43 provides an overview of brant distribution and relative abundance within the study area.

Figure 2.7-4 Abundance of Brant Observed Using the Project Area during High (H) and Low (L) Tides along the Deltaport, TFN, and BC Ferries Transects, Deltaport Inter-causeway Area, 2008

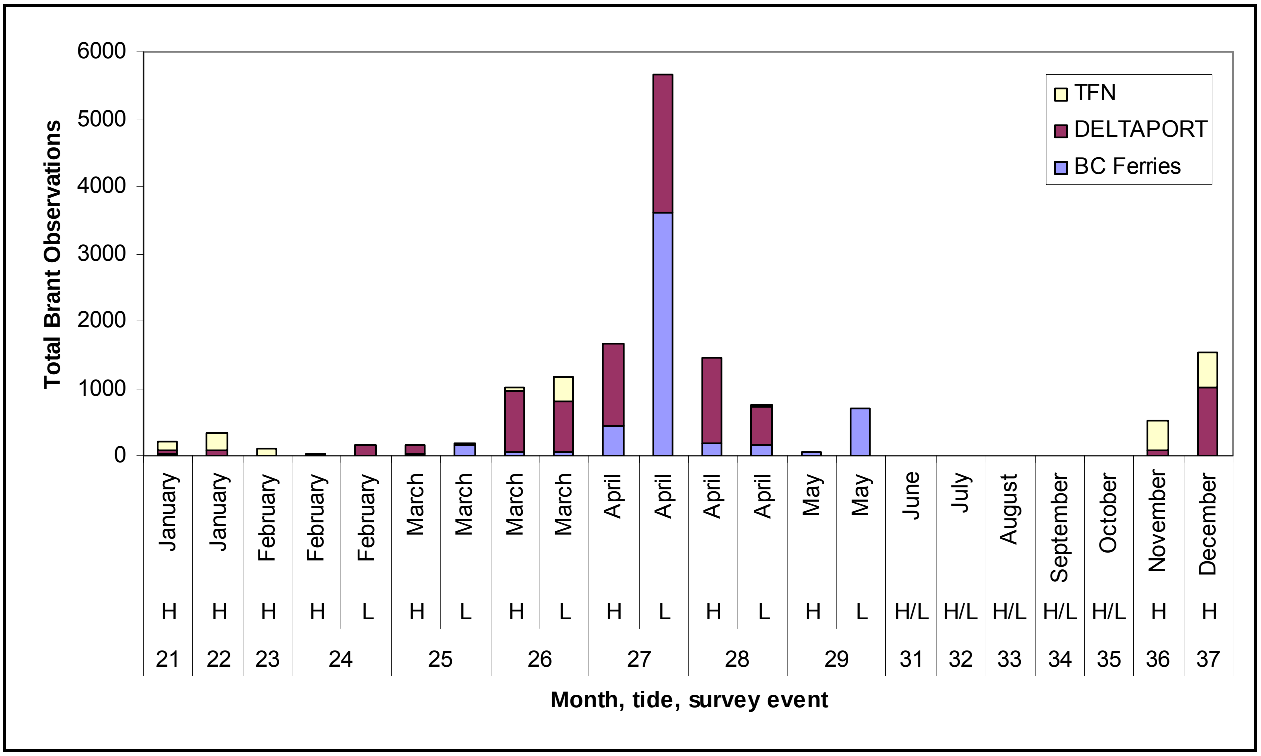
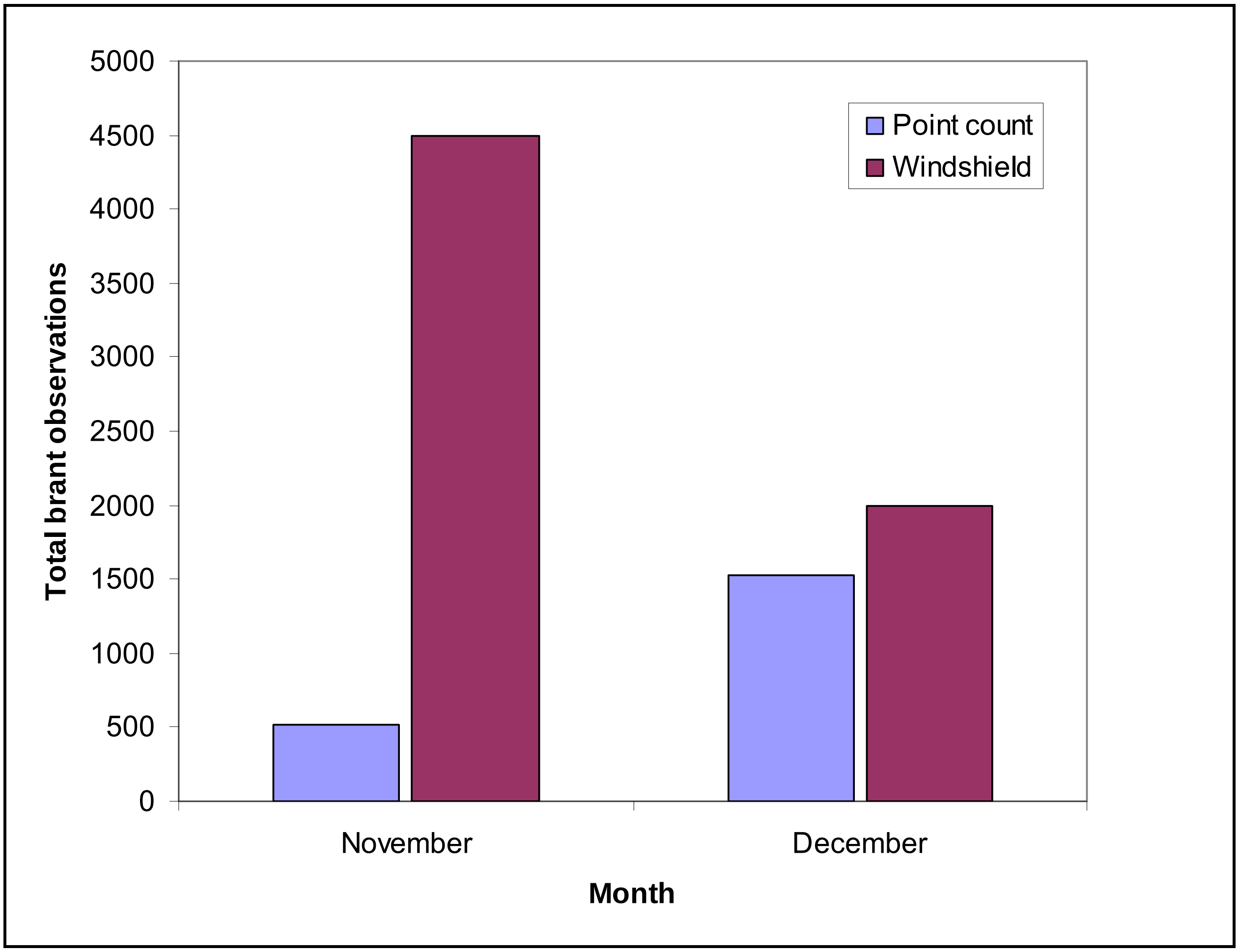


Figure 2.7-5 Number of Brant Observed during High Tide Point Count (Deltaport and TFN Transects) and Windshield Surveys (Deltaport, TFN, and BC Ferries Transects), Deltaport Inter-causeway Area, 2008

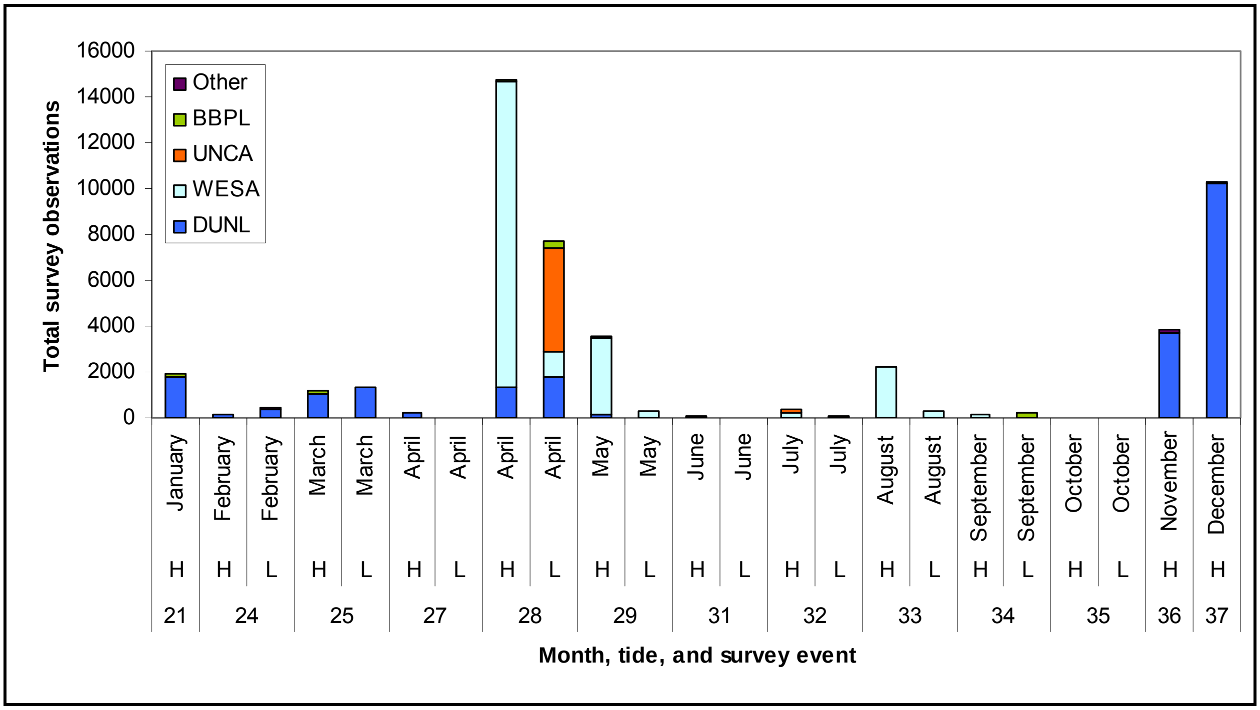


2.7.3 Shorebirds

In 2008, 12 species of shorebirds totalling 49,143 individuals were observed within the project area; however, 90% of detections were one of three species (**Figure 2.7-6**). Dunlin (*Calidris alpina*) and western sandpiper (*Calidris mauri*) numbers were roughly equal, comprising 45% and 43% of all observations, respectively. Black-bellied plover (*Pluvialis squatarola*) comprised an additional 2%, while approximately 9% of observations were recorded as unknown *Calidris* species (UNCA) as conditions did not allow for positive identification to species. All other species comprised less than 1% of observations.

While dunlin and western sandpiper were documented using the site in roughly equal numbers their timing of use varied. Western sandpipers were most abundant during spring (April to early May) and fall (July to early August), comprising the majority of shorebird observations. Maximum daily counts of western sandpiper were 12,333 (April 25) during spring migration and 2,233 in the fall (August 19). Dunlin were detected on site during 8 of 12 months in 2008, and were only absent from June through September. Highest use by dunlin occurred in November and December when 3,700 and 10,249 birds were observed, respectively. A list of all bird codes used in this report is included as **Appendix E**.

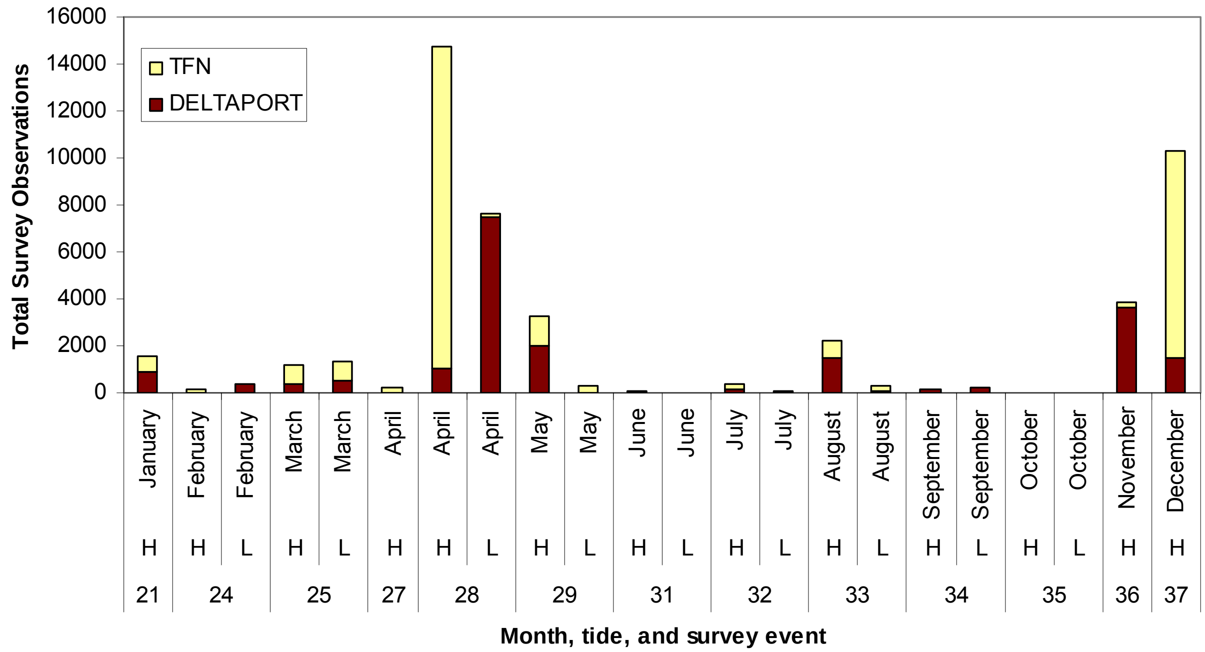
Figure 2.7-6 Cumulative Number and Composition of Shorebird Species Observed at Deltaport Inter-causeway Area, 2008



Note: Species grouped into Other = BLOY, BLTU, GRYE, KILL, MAGO, REKN, SEPL, SESA, and WHIM (H = high tide; L= low tide)

During high tides shorebirds tended to focus their activity along the TFN Transect where there was usually some mudflat exposed (**Figure 2.7-7**). This was particularly true for western sandpiper and dunlin in April and December, respectively. In April, the vast majority of western sandpiper detections (86%) were recorded along the TFN Transect, while in December, 85% of dunlin observations were recorded along exposed TFN mudflats. At low tides, shorebirds distribute themselves along exposed mudflat often following the tide line, and as such, shorebirds were more frequently observed along the Deltaport Transect during low tide events.

Figure 2.7-7 Total Shorebird Observations as Recorded by Transect and Separated by Tidal Level and Survey Event, Deltaport Inter-causeway Area, 2008



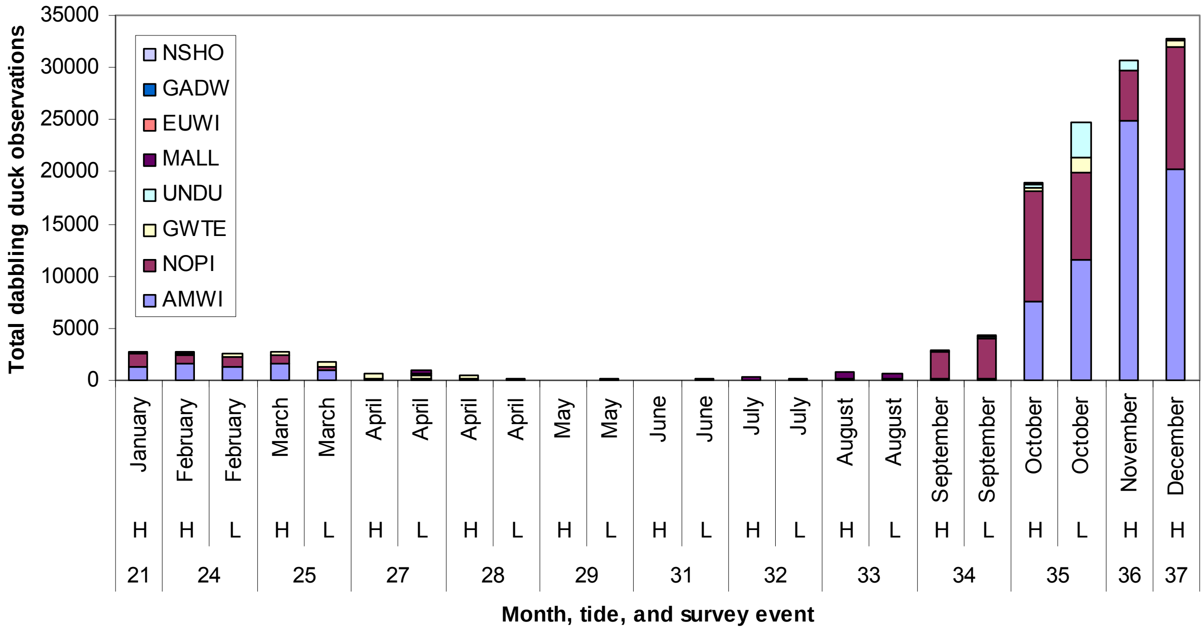
2.7.4 Coastal Waterbirds

The following section provides details of the distribution and relative abundance of dabbling ducks, diving ducks, gulls and terns, and other coastal waterbirds including cormorants, grebes, swans, and geese (other than brant; see **Section 2.7.1.2**). .

2.7.4.1 Dabbling Ducks

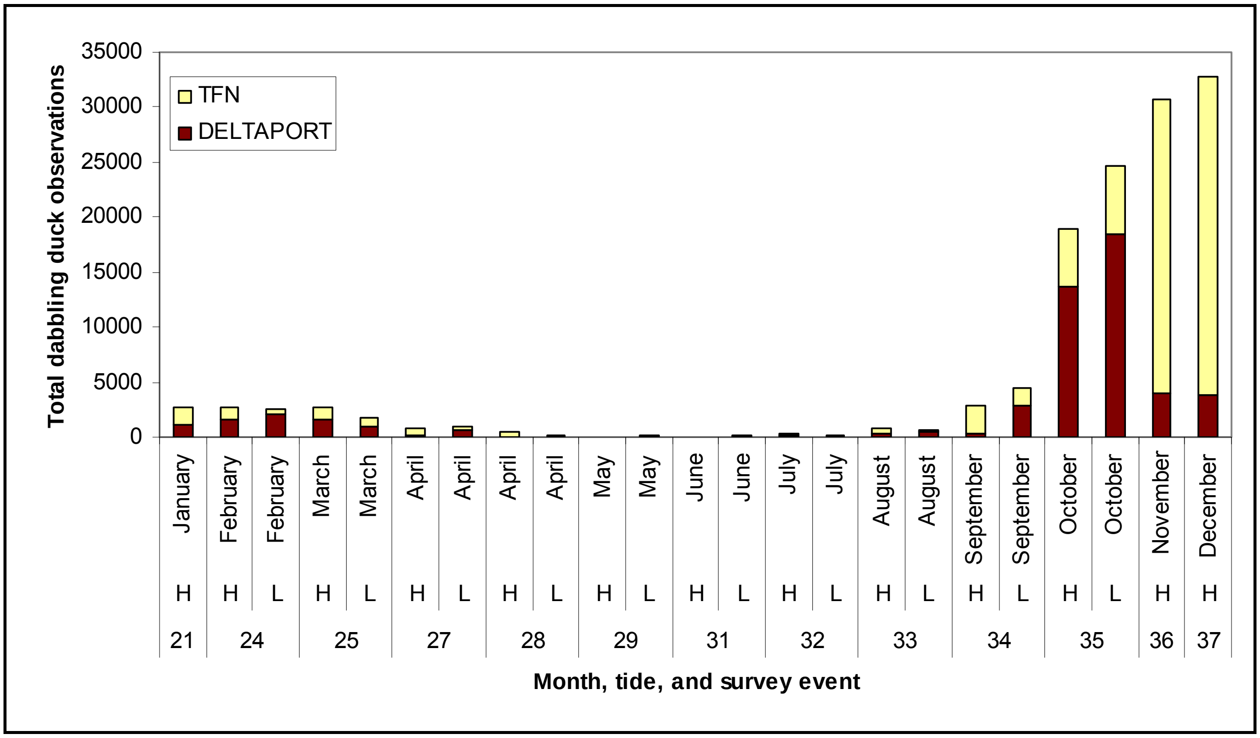
Seven dabbling duck species totalling 131,611 observations were documented during 2008. The dabbling ducks recorded using the inter-causeway area were: American wigeon (*Anas americana*), Eurasian wigeon (*Anas penelope*), gadwall (*Anas strepera*), green-winged teal (*Anas carolinensis*), mallard (*Anas platyrhynchos*), northern pintail (*Anas acuta*), and northern shoveler (*Anas clypeata*) (**Figure 2.7-8)**. American wigeon (71,343) were observed most frequently followed by northern pintail (46,649), green-winged teal (5,103), and mallard (2,817). The remaining three species totalled less than 500 observations each. During the October and November surveys an additional 4,300 dabbling ducks of undetermined species were documented. The birds were observed in large mixed flocks greater than 500 m from shore. The combination of distance and high glare prevented positive identification; however, based on the timing of the survey and the relative abundance of other species detected, the birds were believed to be most likely American wigeon and/or northern pintail.

Figure 2.7-8 Abundance and Composition of Dabbling Ducks Observed at Deltaport Inter-causeway Area, 2008



Dabbling ducks were consistently recorded in mixed flocks throughout the inter-causeway area, with greatest densities occurring between October and December along the TFN and Deltaport Transects (**Figure 2.7-9**). The most abundant species were American wigeon (64,207) and northern pintail (35,414) accounting for 60% and 33% percent of all dabblers recorded, respectively. In October, large numbers of American wigeon and northern pintail were found using habitat within 250 m of shore along the Deltaport Transect, with greatest densities recorded at PCs 15 through18 regardless of the tidal stage. In November and December, the distribution of dabbling ducks within the inter-causeway area shifted, as 91% of all dabblers (n = 63,507) were documented along the coastal shore between PC14 along the TFN Transect northwest to PC19 at the beginning of the Deltaport Transect. The large flocks of ducks documented were dominated by American wigeon (71% of total) and northern pintail (26%).

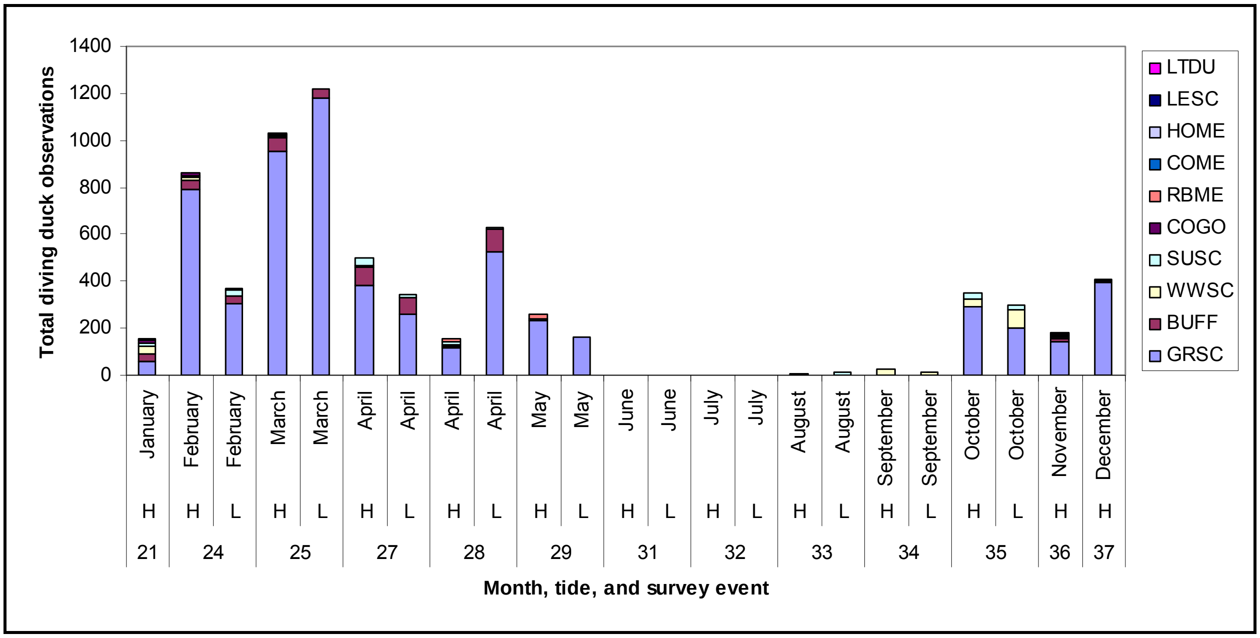
Figure 2.7-9 Total Number of Dabbling Ducks as Recorded by Transect and Separated by Tidal Level and Survey Event, Deltaport Inter-causeway Area, 2008



2.7.4.2 Diving Ducks

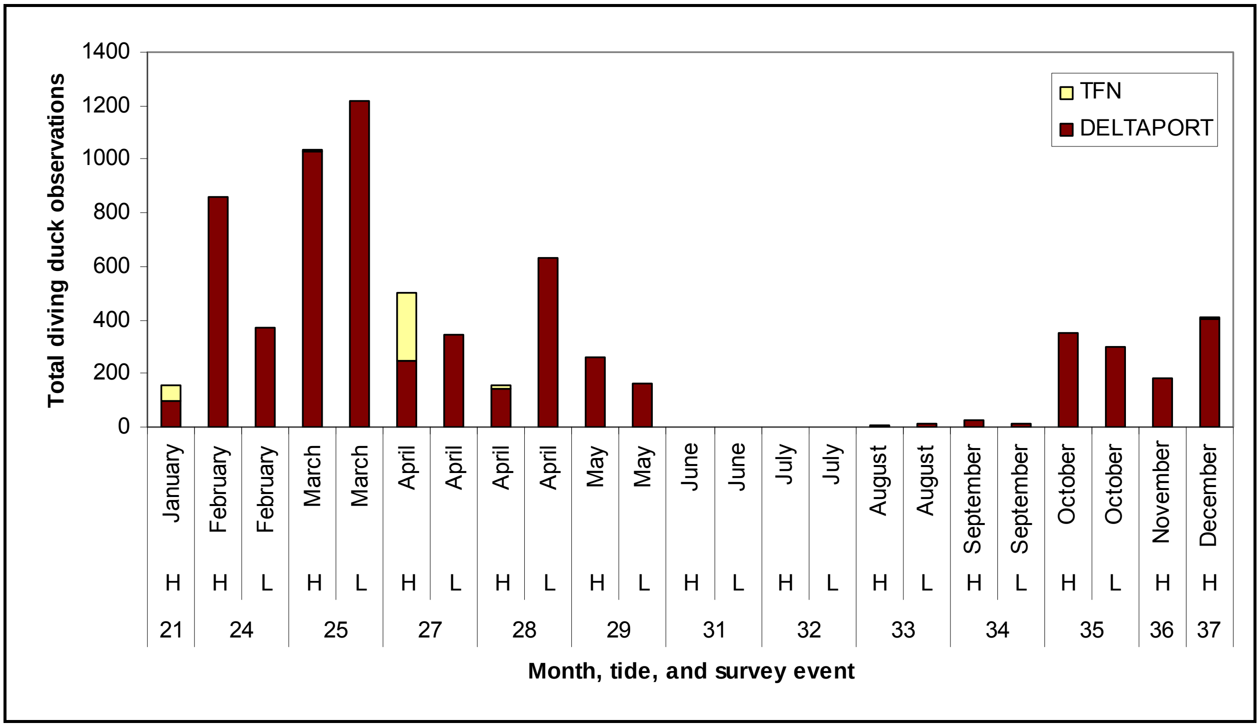
Ten species of diving ducks, totalling 6,990 observations, were recorded during the study period (**Figure 2.7-10**). Of these, 86% were greater scaup (*Aythya marila*), bufflehead (*Bucephala albeola*), white-winged scoter (*Melanitta deglandi*), and surf scoter (*Melanitta perspicillata*) comprised an additional 7%, 3%, and 3%, respectively. All other species individually totalled less than 1% of observations. In general, diving ducks were considerably less abundant than dabblers. The maximum count of diving ducks during a single tidal event was approximately 1,200 birds, compared to almost 33,000 dabblers. With the exception of surf and white-winged scoters, diving ducks were documented within the study area in 8 of 12 months, from January through May and October through December. The only months in which surf scoters were not detected were during June and July. Diving ducks were documented in greatest numbers during February and March, when greater scaup abundance was highest.

Figure 2.7-10 Abundance and Composition of Diving Ducks Observed at Deltaport Inter-causeway Area, 2008



The vast majority (95%) of diving ducks were recorded offshore along the Deltaport Transect (**Figure 2.7-11**). Diving ducks were documented in approximately equal numbers within the 0–250 m (2,476), 250-500 m (2,342), and > 500 m (2,154) distance categories along the Deltaport Transect, with 69% of observations occurring within PCs 13, 14, 15, and 17.

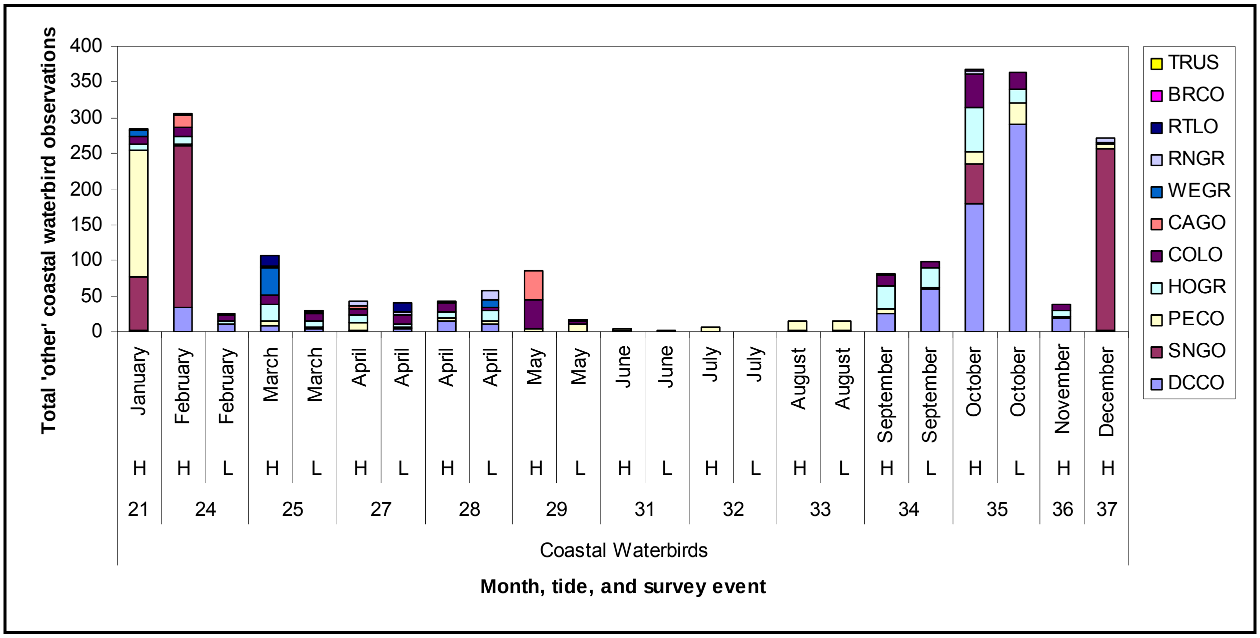
Figure 2.7-11 Total Number of Diving Ducks as Recorded by Transect and Separated by Tidal Level and Survey Event, Deltaport Inter-causeway Area, 2008



2.7.4.3 'Other' Coastal Waterbirds

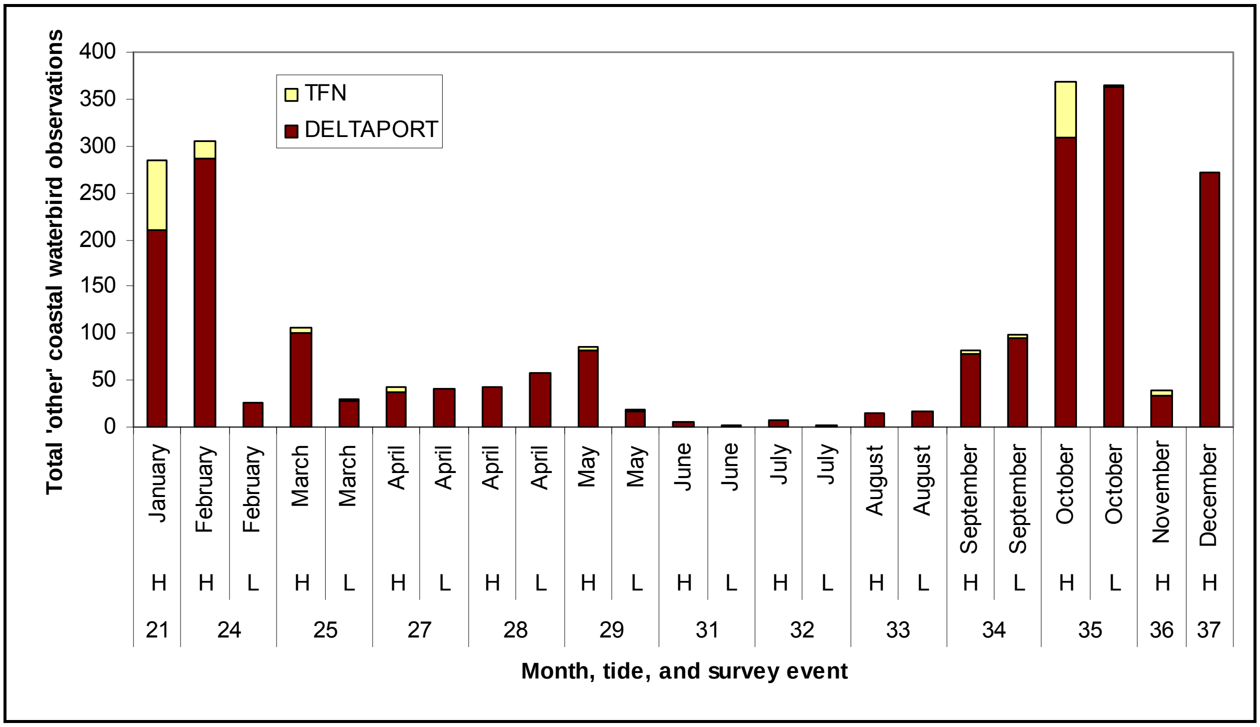
Other relatively common coastal waterbirds were double-crested (*Phalacrocorax auritus*) and pelagic cormorant (*Phalacrocorax pelagicus*), horned grebe (*Podiceps auritus*), common loon (*Gavia immer*), and snow goose (*Chen caerulescens*) (**Figure 2.7-12**). These birds comprised approximately 91% of all 'other' coastal waterbird observations: double-crested cormorant (29%), snow goose (27%), pelagic cormorant (14%), horned grebe (11%), and common loon (10%). Less common species included Canada goose (*Branta canadensis*), red-necked grebe (*Podiceps grisegena*), western grebe (*Aechmophorus occidentalis*), red-throated loon (*Gavia stellata*), Brandt's cormorant (*Phalacrocorax penicillatus*), and trumpeter swan (*Cygnus buccinator*).

Figure 2.7-12 Abundance and Composition of 'Other' Coastal Waterbird Species Observed at Deltaport Inter-causeway Area, 2008



Similar to diving ducks, the majority of waterbird observations were recorded offshore along the Deltaport Transect with infrequent observations along the TFN Transect (**Figure 2.7-13**).

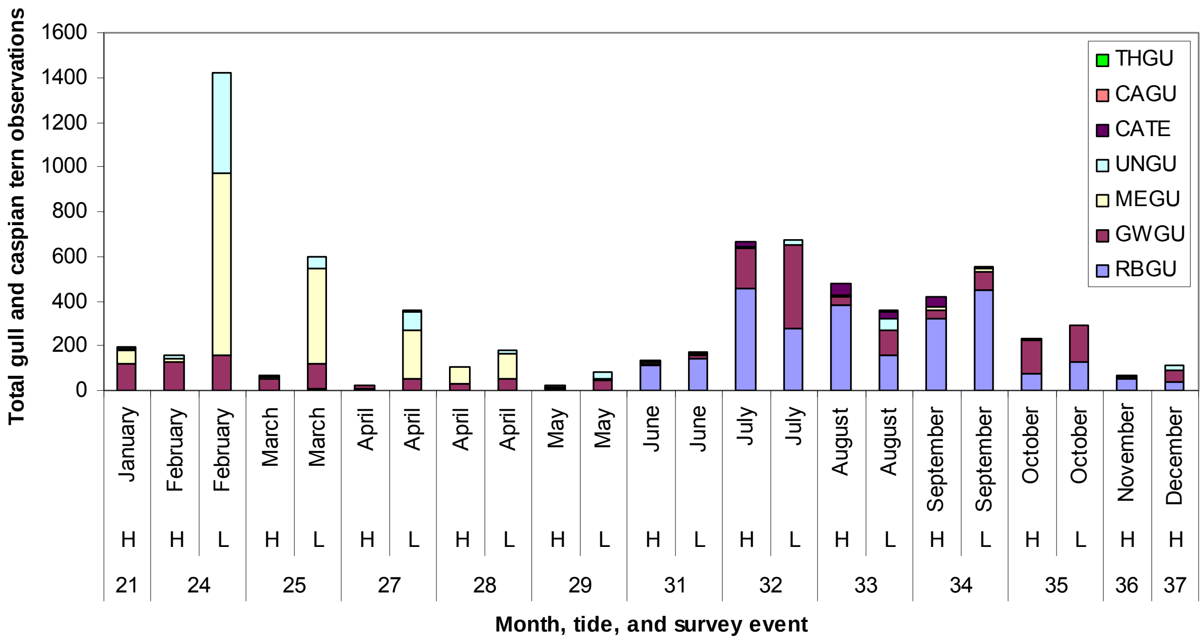
Figure 2.7-13 Total Number of 'Other' Coastal Waterbird Species as Recorded by Transect and Separated by Tidal Level and Survey Event, Deltaport Inter-causeway Area, 2008



2.7.4.4 Gulls and Caspian Tern

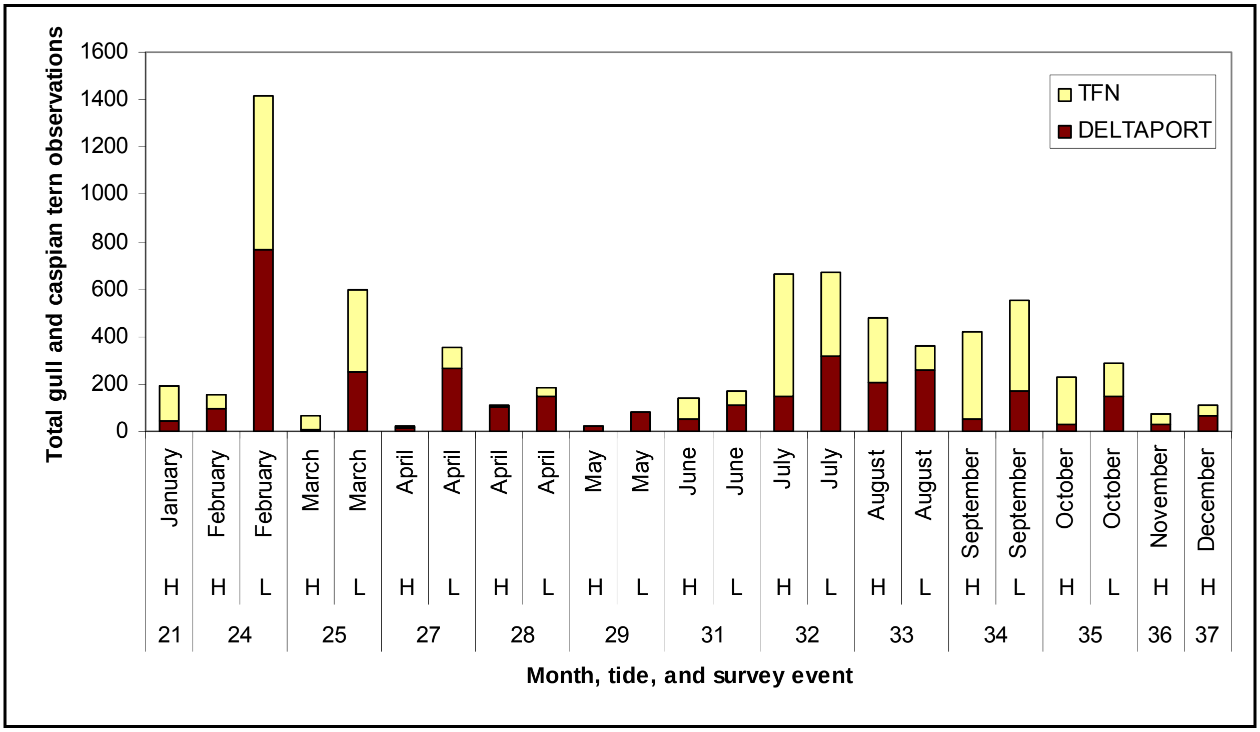
Five gull and one tern species were documented within the study area in 2008 (**Figure 2.7-14**). Eighty-six percent of gull observations were comprised of ring-billed (*Larus delawarensis*) (35%), glaucous-winged (*Larus glaucescens*) (27%), and mew gull (*Larus canus*) (24%), with California (*Larus californicus*) and Thayer's gull (*Larus thayeri*) comprising less than 1% of observations. Eleven percent of observations were recorded as "undetermined" gull species. Attempts were made to distinguish hybrid gulls (mixed species gulls assumed to contain part glaucous-winged gull), but accurate classification was often not possible in the field. Potential hybrid gulls were classified during the study as glaucous-winged and potential hybridization was noted. One hundred eighty-one Caspian tern (*Hydroprogne caspia*) were observed in 2008; comprising 2% of all gull/tern observations, with most observations occurring between June and September.

Figure 2.7-14 Abundance and Composition of Gull and Tern Species Observed at Deltaport Inter-causeway Area, 2008



Gulls were distributed throughout the inter-causeway area, and were regularly documented along both the Deltaport and TFN Transects (**Figure 2.7-15**).

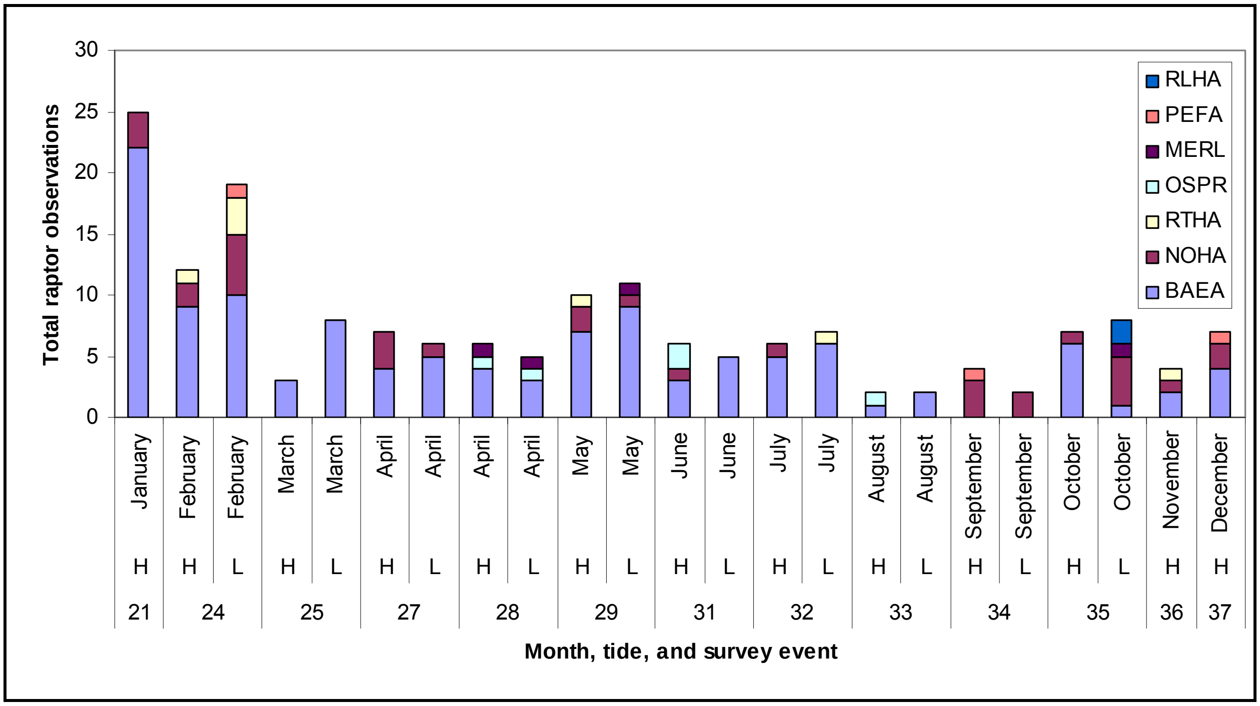
Figure 2.7-15 Total Number of Gull and Tern Species as Recorded by Transect and Separated by Tidal Level and Survey Event, Deltaport Inter-causeway Area, 2008



2.7.5 Raptors

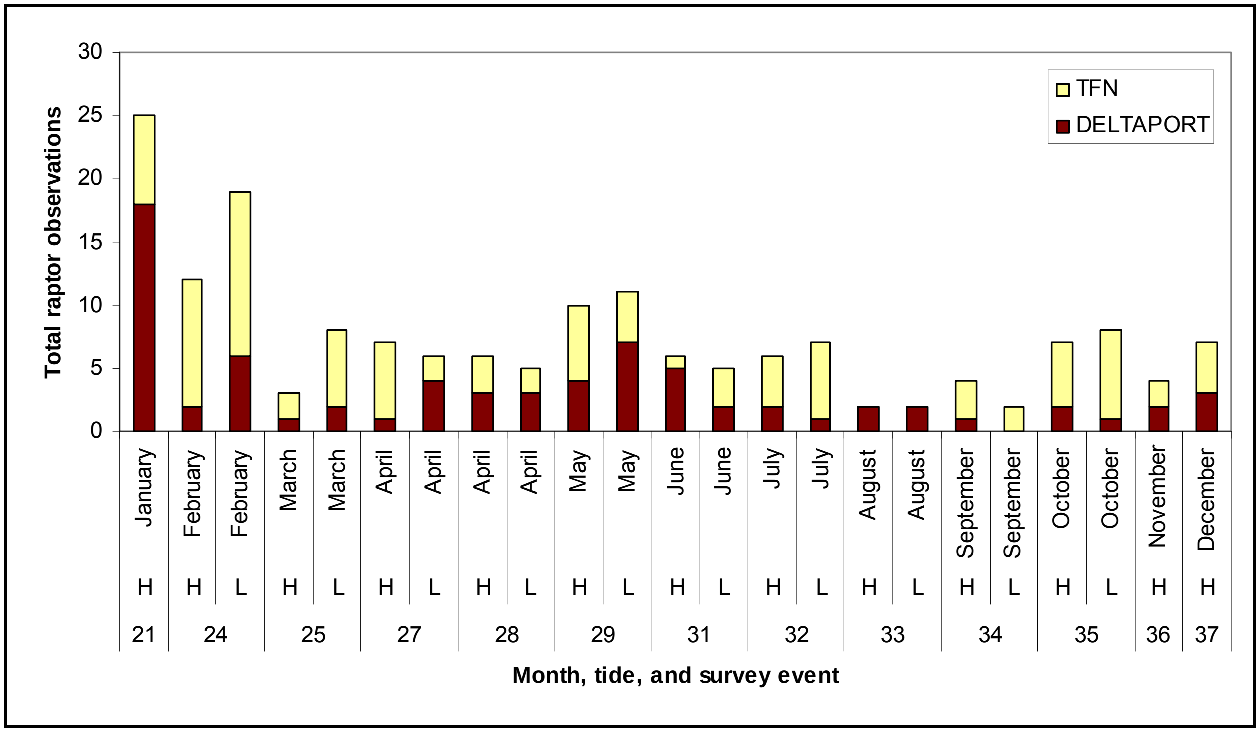
Seven species of raptors were identified in and around the inter-causeway area (**Figure 2.7-16**). Bald eagles (*Haliaeetus leucocephalus*) were the most frequently documented, comprising 69% of 172 total observations, followed by northern harrier (*Circus cyaneus*) (19%). Other less frequently observed raptors were red-tailed hawk (*Buteo jamaicensis*) (4%), osprey (Pandion haliaetus) (3%), merlin (*Falco columbarius*) (2%), peregrine falcon (*Falco peregrinus*) (2%), and rough-legged hawk (*Buteo lagopus*) (1%).

Figure 2.7-16 Abundance and Composition of Raptors Observed at Deltaport Inter-causeway Area, 2008



Eagles were observed as flyovers throughout much of the survey area and were the major cause of disturbance to resting and feeding duck species. Bald eagle were most frequently observed in the study area during January and February. Use of the inter-causeway by eagles was roughly split equally between Transects, as 55% (65/119) of observations were recorded along the Deltaport transect, compared to 45% (54/119) along the TFN Ttansect. Northern harrier were most commonly (94% of harrier observations) documented foraging within the TFN marshlands. Peregrine falcons were observed on several occasions along the BCF and the TFN Transects. All red-tailed hawk observations were recorded along the TFN Transect. All other species were documented in roughly equal numbers between the two Transects (**Figure 2.7-17**).

Figure 2.7-17 Total Raptor Observations as Recorded by Transect and Separated by Tidal Level and Survey Event, Deltaport Inter-causeway Area, 2008

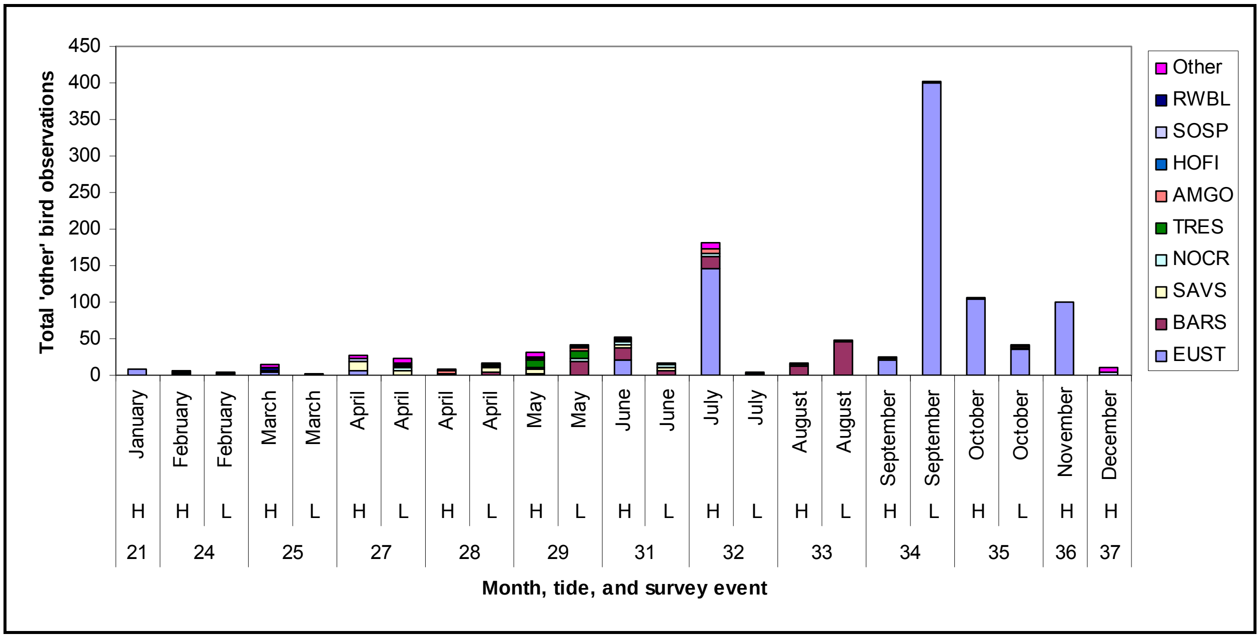


In 2008, osprey were observed along the Deltaport, Tsawwassen and BCF Transects in April, June, and August. Osprey were typically observed flying over survey plots or perched on man-made structures along the port facility. Only one osprey was typically observed at a time, although two osprey were observed together on several occasions. No juvenile ospreys were observed during the survey period. No osprey nest building or breeding activity was observed in 2008.

2.7.6 Other Birds

Twenty-four additional bird species, totalling 1,189 individuals, were documented within the study area in 2008. Of these, European starling (*Sturnus vulgaris*) (71%) and barn swallow (*Hirundo rustica*) (11%) were most commonly observed, followed by savannah sparrow (*Passerculus sandwichensis*) (4%), northwestern crow (*Corvus caurinus*) (2%), tree swallow (*Tachycineta bicolor*) (2%), American goldfinch (*Carduelis tristis*) (2%), house finch (*Carpodacus mexicanus*) (1%), song sparrow (*Melospiza melodia*) (1%), and red-winged blackbird (*Agelaius phoeniceus*) (1%). All other species detected total less than ten individuals (**Figure 2.7-18**).

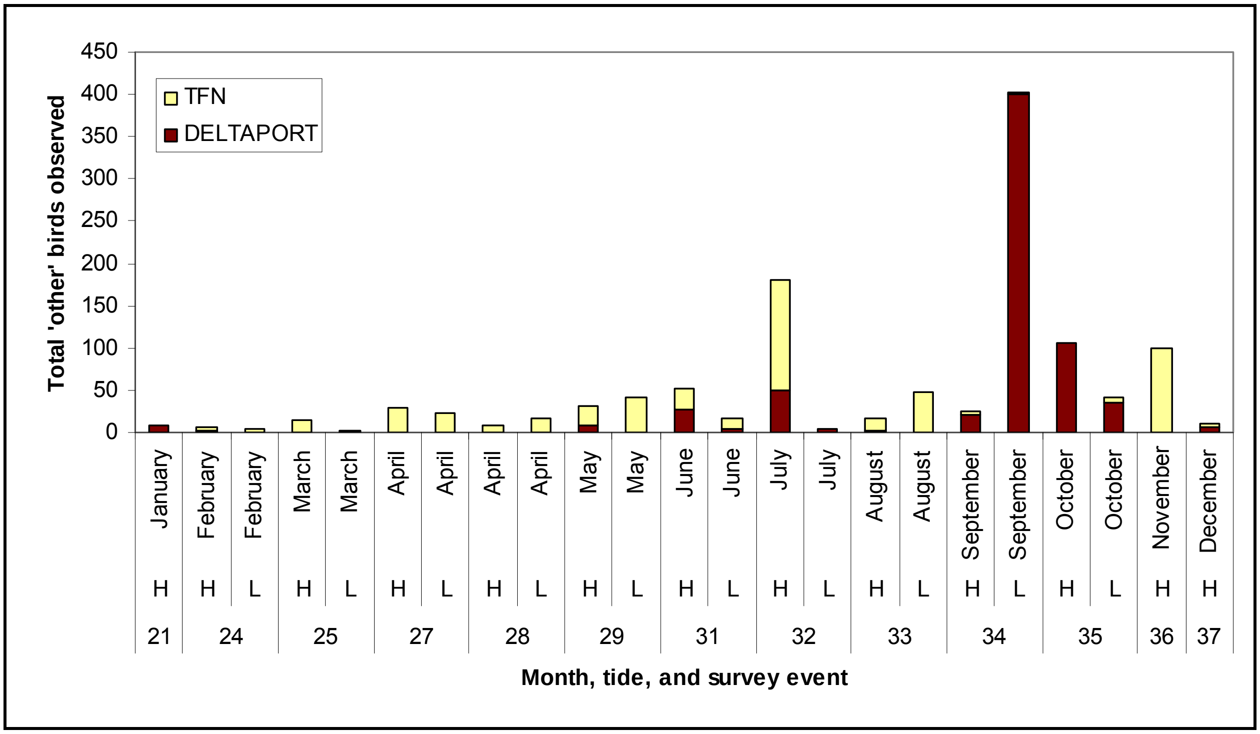
Figure 2.7-18 Abundance and Composition of "Other" Species Observed at Deltaport Inter-causeway Area, 2008



Note: Species grouped into the Other category are: AMRO, BEKI, CORA, COYE, DEJU, GCSP, MAWR, NOFL, ROPI, RUHU, SPTO, VGSW, WCSP, WEME, and YRWA.

These birds were typically observed along the perimeter of the study area, as flyovers or heard singing/calling. In general, all birds, with the exception of European starling, were documented along the TFN Transect, often perched in surrounding trees and shrubs along the TFN Transect (**Figure 2.7-19**). Although starlings were documented using this area, they were detected in greatest numbers in large flocks from September through November along the Deltaport Causeway.

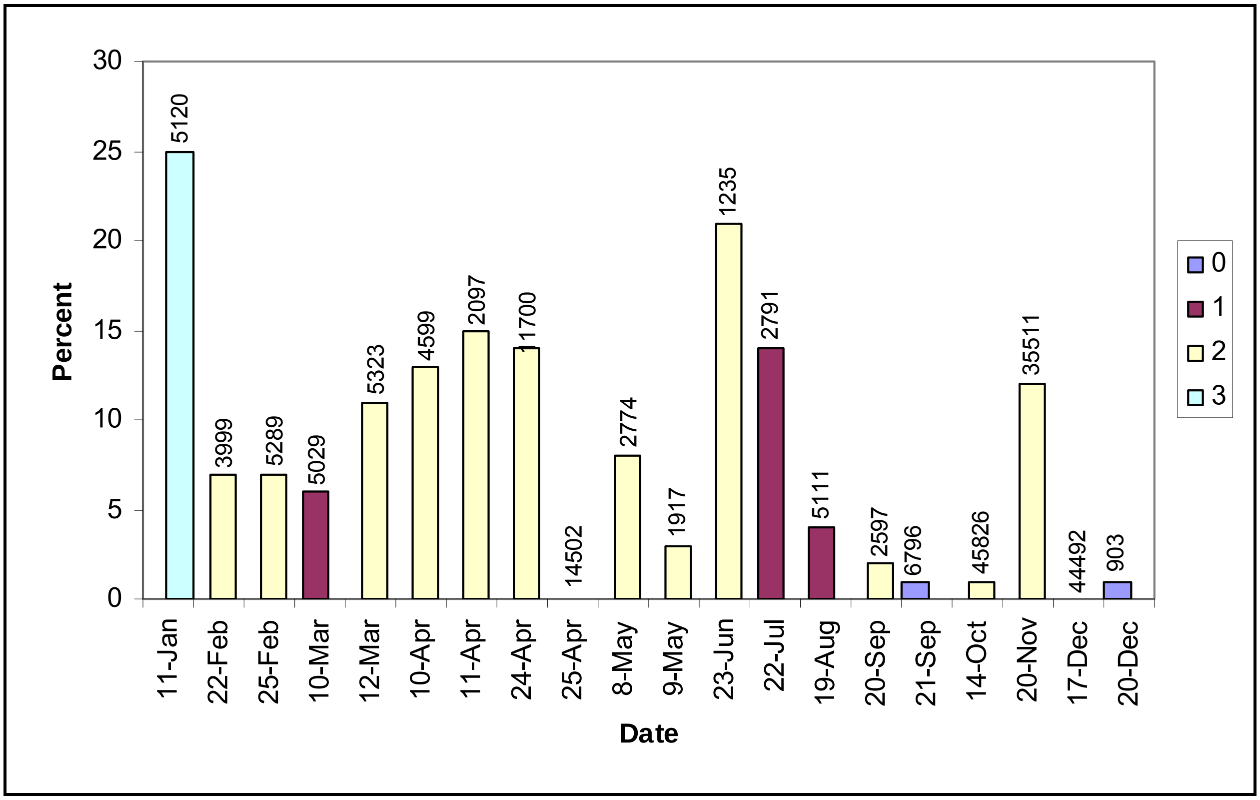
Figure 2.7-19 Abundance of "Other' Birds as Recorded by Transect and Separated by Tidal Level and Survey Event, Deltaport Transect, 2008



2.8 Construction Impacts on Birds

If construction activities are impacting bird use of the inter-causeway it should be reflected to the greatest degree in abundance and distribution data collected from stations closest to the construction area (i.e., PCs 12 and 13). **Figure 2.8-1** plots disturbance severity against the total bird observations recorded daily in PCs 12 and 13 as a percentage of total bird observations recorded throughout the entire study area on the survey date. This method was selected as it is thought that if disturbance from construction was affecting bird distribution, overall bird abundance would be negatively correlated with construction impacts levels, with a smaller percentage of birds using PC12 and 13 when impacts were greatest. No obvious trends in overall bird distribution with construction noise or activities were apparent, as use of PC12 and 13 fluctuated independently of the disturbance severity rating (**Figure 2.8-1**). For example, the highest percentage of bird use of PC12 and 13 was documented on the day (i.e., January 11) with the highest construction severity rating, while the two days having the lowest rating (September 21 and December 20) had the smallest portion of use.

Figure 2.8-1 Percent of Birds Documented in PC12 and 13 by Date and Construction Severity Rating, Deltaport, 2008



Note: Coloured columns indicate disturbance severity as rated using the criteria in **Table 2.8-1** – numbers above bars are the total number of birds detected along the Deltaport and TFN Transects.

Results from the linear regression analysis showed no relationship between the level of construction noise and/or construction activity and great blue heron or brant use of sites closest to DP3 construction (i.e., PC12 and PC13) (**Table 2.8-1**). Potential factors influencing great blue heron, brant, and coastal seabirds and shorebirds use of and distribution within the inter-causeway area are discussed in **Section 3.6.**

Table 2.8-1 Results of Linear Regression Testing for a Relationship between the Use of PC12 and 13 by Great Blue Heron and Brant and the Severity of Impacts from Construction Activities

Factor	SS[1]	df[2]	MS[3]	*F*[4]	*P*[5]
Great blue heron (r^2 = 0.003)					
Disturbance	6.1	1	6.1	0.04	0.84
Error	2425.1	16	151.6		
Brant (r^2 = 0.02)					
Disturbance	151.2	1	151.2	0.13	0.72
Residual	9030.9	8	1128.9		

Notes: [1] SS = Sum of squares [2] df = Degrees of freedom [3] MS = Mean square
[4] F = F-statistic [5] P = P-value

2.9 BIRD ABUNDANCE AND DISTRIBUTION IN THE DELTAPORT INTER-CAUSEWAY AREA, 2003 – 2008

Data on bird use of the Deltaport inter-causeway area from October 2003 through August 2004 were obtained from Envirowest and VFPA to investigate possible differences in abundance and distribution within the study area since the initiation of the Deltaport Third Berth expansion project. Consistent and complete data from the 2003-2004 study period is limited to surveys of the Deltaport Transect. Consequently, direct comparisons between 2003-2004, 2007, and 2008 do not include the TFN Transect and are therefore limited in scope.

2.9.1 Great Blue Heron

For most months of the year, great blue heron abundance along the Deltaport Transect between 2003-2008 were comparable and followed the same trend, with most heron observations occurring from May through July (**Figure 2.9-1**). Documented heron numbers between 2007 and 2008 were most similar. Fluctuations between months were evident, but the overall trend was the same, with peak use of the study area occurring in June. Maximum low tide heron counts were almost identical with 433 herons documented in June 2007, compared to 424 in 2008 (**Figure 2.9-2**). The average number of herons documented during this period did not differ statistically between 2007 and 2008 (**Table 2.9-1**).

Approximately 400 more herons in June and 350 more observations in July were recorded during low tide surveys along the Deltaport Transect in 2003 compared to 2007 or 2008. This difference may partly be explained by daily variability in heron use of habitat within the inter-causeway area, as an additional 160 and 180 herons were detected along the TFN Transect in June 2007 and 2008, respectively, which was not surveyed in 2003 (**Figure 2.9-1**). Overall, the average number of herons using the inter-causeway area during months associated with peak heron use (i.e., May – July) did not differ statistically between years when data from the Deltaport Transect was analyzed separately (P = 0.13) or when combined with TFN heron estimates (P = 0.82) (**Table 2.9-1**).

Figure 2.9-1 Relative Abundance of Great Blue Heron during Low Tide, Deltaport Transect, 2003-2008

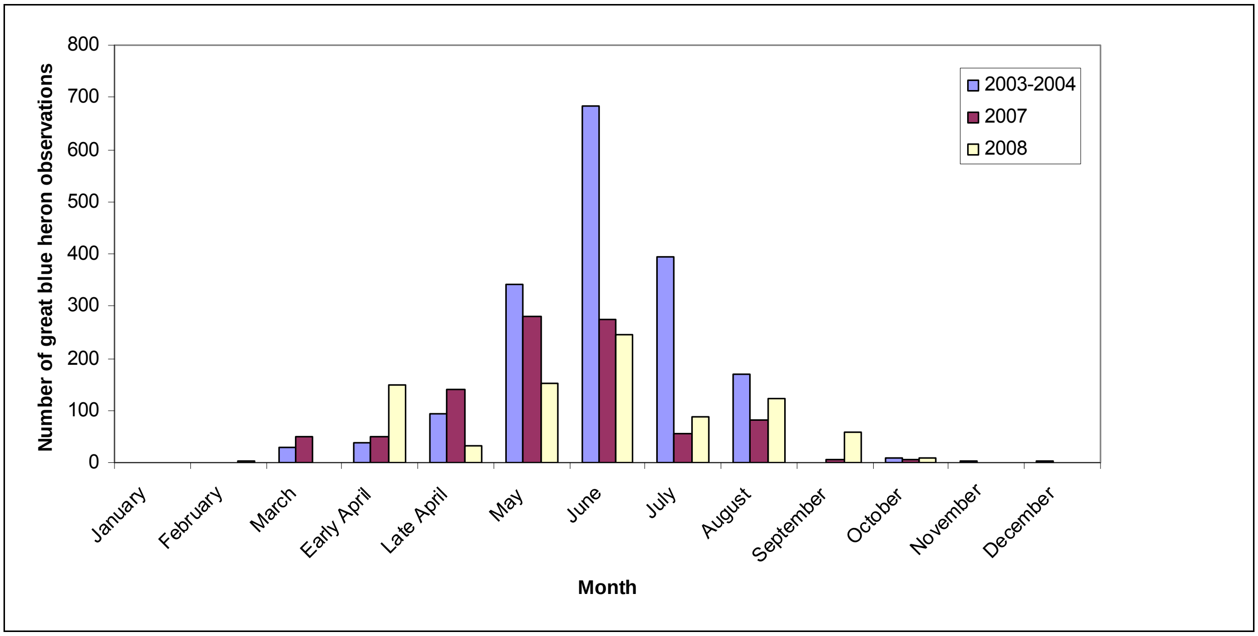
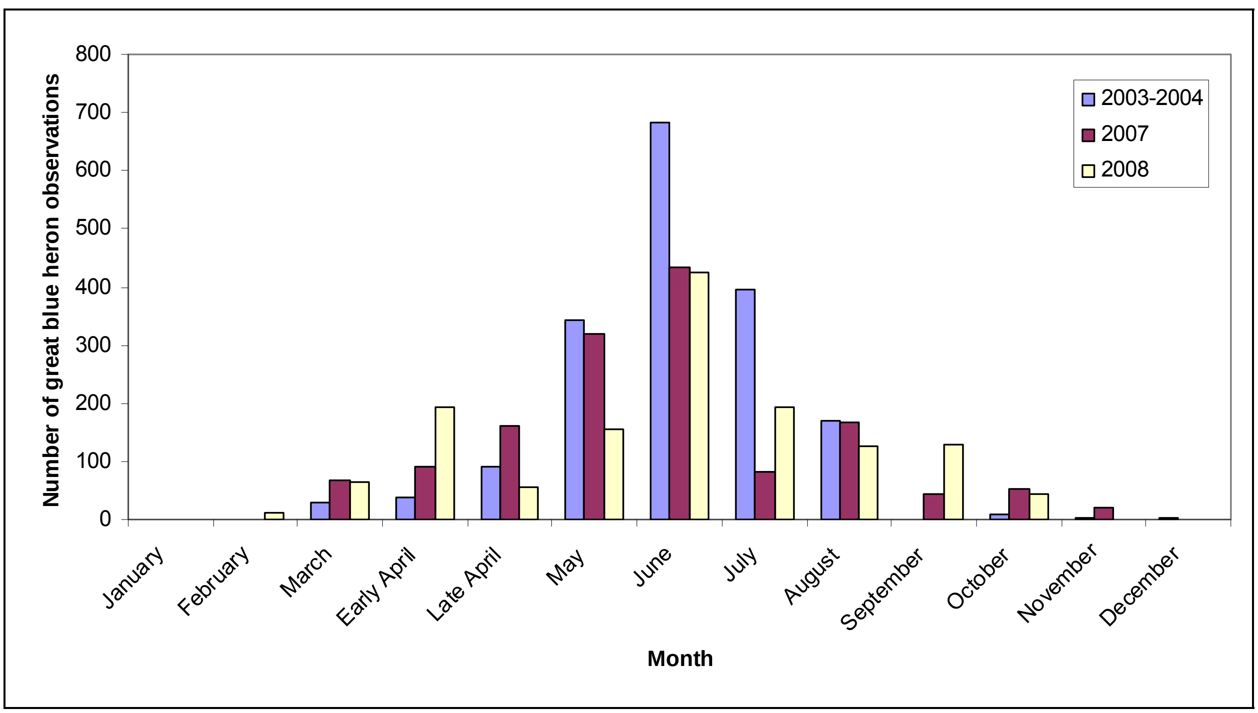


Figure 2.9-2 Relative Abundance of Great Blue Heron during Low Tide, Deltaport and TFN Transects, 2003-2008



Notes: 1) The TFN Transect was not surveyed in 2003-2004.
2) No surveys were conducted in January or February 2007 within the study site.

Table 2.9-1 Analysis of Variance (ANOVA) Results Comparing the Number of Great Blue Heron Observations Recorded during Peak Heron Use (May through July) on: (A) the Deltaport Transect, and (B) the Deltaport and TFN Transects from 2003 – 2008

Factor	SS	df	MS	*F*	*P*
(A) Deltaport Transect					
Year	132273	2	66136	2.97	0.13
Error	133543	6	22257		
(B) Deltaport and TFN Combined					
Year	16843	2	8421	0.21	0.82
Error	240217	6	40036		

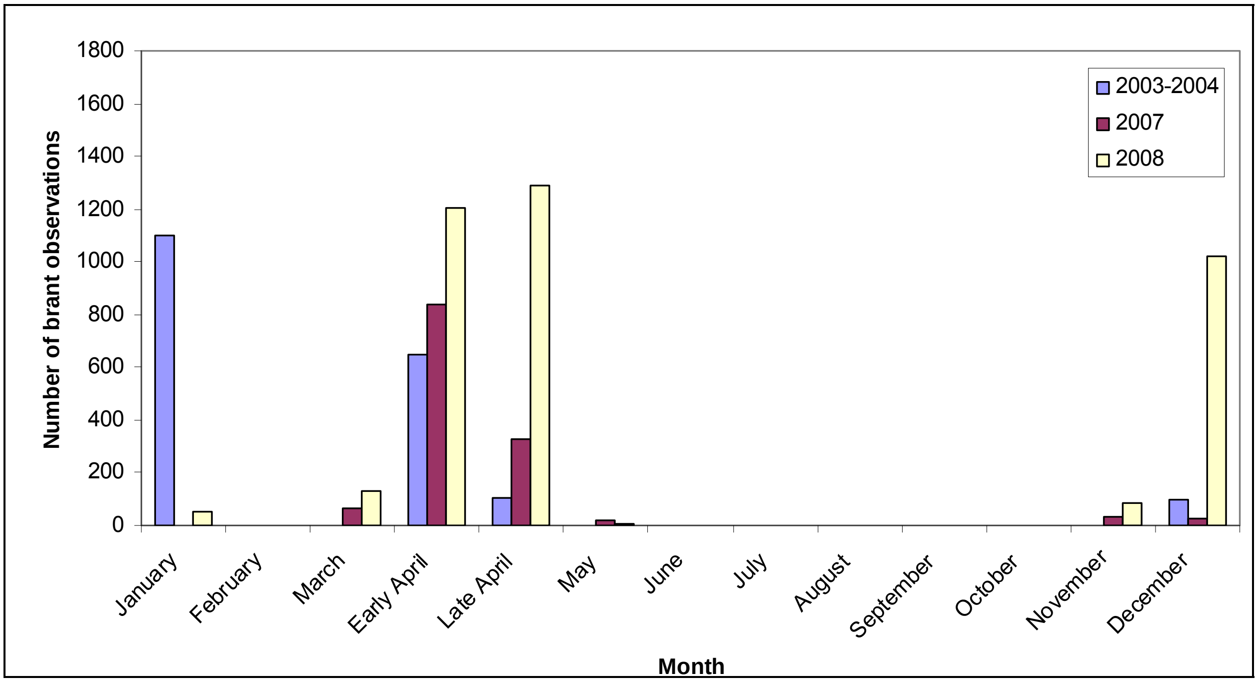
Note: Bonferroni test was used to correct for multiple comparisons.

Heron use of the inter-causeway area has shifted since 2003-2004, as fewer heron observations have been recorded at point count stations closest to Deltaport construction activities (i.e., PC12, PC13, and PC14) (**Figures 42**, **44**, and **45**). In 2003, 73% (1365/1858) of all heron observations along the Deltaport Transect were recorded in PC12, PC13 and PC14. In 2007, this number was reduced to 53% (687/1302), and in 2008 only 30% (300/1012) of all heron observations along the Deltaport Transect were recorded within PC12, PC13, and PC14. While herons have apparently shifted their use of habitat away from points adjacent to construction activities the proportion of great blue heron using the TFN Transect has only increased slightly. In 2007, 43% (976/2275) of all heron observations were recorded along the TFN Transect compared to 50% (1005/2017) of observations in 2008. Heron distribution and abundance along the TFN Transect in 2003-2004 is unknown, as the Transect was not surveyed. Other possible factors affecting heron distribution and use of the inter-causeway area will be discussed in **Section 3.6**.

2.9.2 Brant

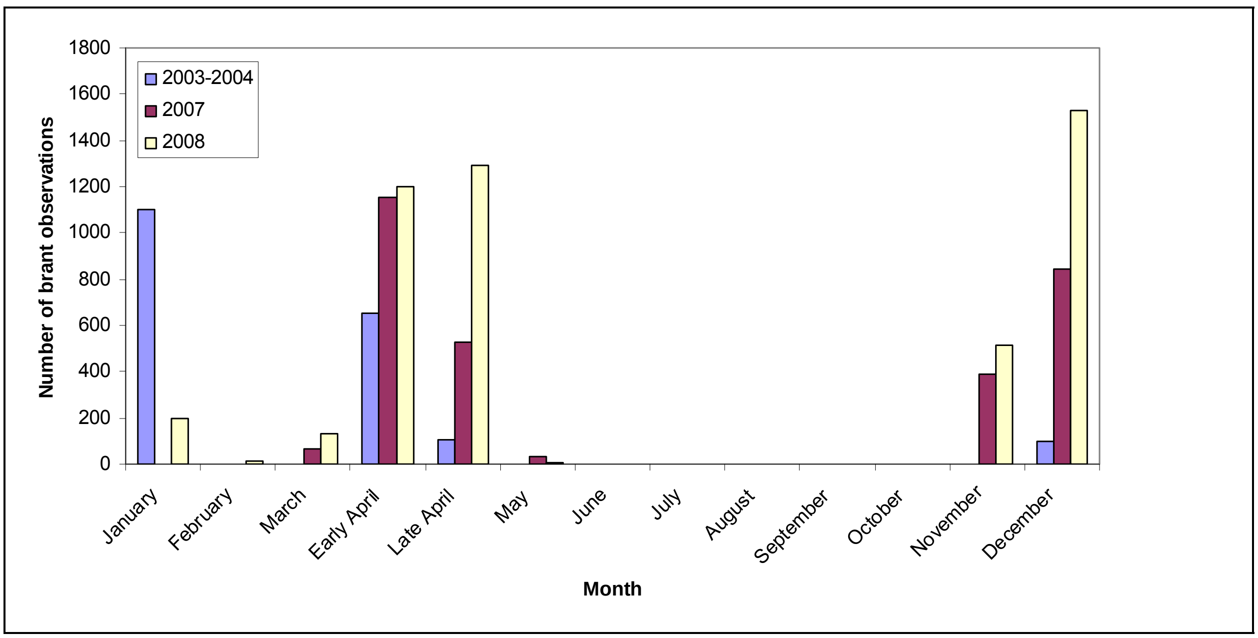
Brant distribution within and timing of use of the study area along the Deltaport Transect between 2003-2008 (**Figure 2.9-3**) were comparable and followed the same trend, with most observations occurring in the winter months from November through January and again in April. Typically, the majority of brant were documented along the Deltaport Transect; however, one exception to this occurred in December 2008 when heavy wind, snow, and ice forming within the inter-causeway area forced brant to cluster in large numbers on the landward side of the crest protection along the TFN Transect (**Figure 2.9-4**). Brant numbers were highest in 2008 in all seasons compared to previously documented abundance estimates in 2003-2004 or 2007 (**Figure 2.9-4**). In all years, brant use of the inter-causeway area was greatest during high tide events compared to low tide events. Brant are not represented in figures for January 2007 because surveys were not initiated until March 2007.

Figure 2.9-3 Relative Abundance of Brant during High Tide, Deltaport Transect, 2003-2008.



Note: No surveys were conducted in January or February 2007 within the study site.

Figure 2.9-4 Relative Abundance of Brant during High Tide, Deltaport and TFN Transects, 2003-2008



Notes: 1) The TFN Transect was not surveyed in 2003-2004.
2) No surveys were conducted in January or February 2007 within the study site.

Brant use of the inter-causeway area appears to have not been affected by activities associated with Deltaport Third Berth construction as the distribution of brant along the Deltaport and TFN Transects has not changed (**Figures 43**, **46**, and **47**). In all years, brant have been documented along the length of the Deltaport Transect, and in 2007 and 2008 large flocks have been recorded along TFN. Areas of frequent use have been PC18, PC19, and PC105 at the intersection of the Deltaport and TFN Transects, and greater than 250 m offshore within PC 13, PC14, and PC15.

2.9.3 Shorebirds

2.9.3.1 Western Sandpiper

Annual western sandpiper abundance and distribution has been known to fluctuate greatly on an international scale. From 2003 to 2008 sandpiper use of the Deltaport Transect has been limited, with peak counts recorded in May 2008 of 1,911 birds (**Figure 2.9-5**). This estimate is approximately threefold greater than previous counts along the Deltaport Transect. Peak estimates of sandpiper abundance in 2003-2004 were extremely low, with only 394 sandpipers documented in May 2004, and 663 sandpipers recorded in July 2007. In contrast, much greater numbers have been traditionally recorded along the TFN Transect where large exposed mudflats provide abundant habitat for foraging birds (**Figure 2.9-6**). Annual peak estimates of sandpiper abundance along TFN have occurred in Late April in 2007 (6,055 birds) and 2008 (12,492 birds). No estimate of sandpiper use of the TFN Transect in 2003-2004 is available.

Figure 2.9-5 Relative Abundance of Western Sandpiper during High and Low Tide Combined, Deltaport Transect, 2003-2008

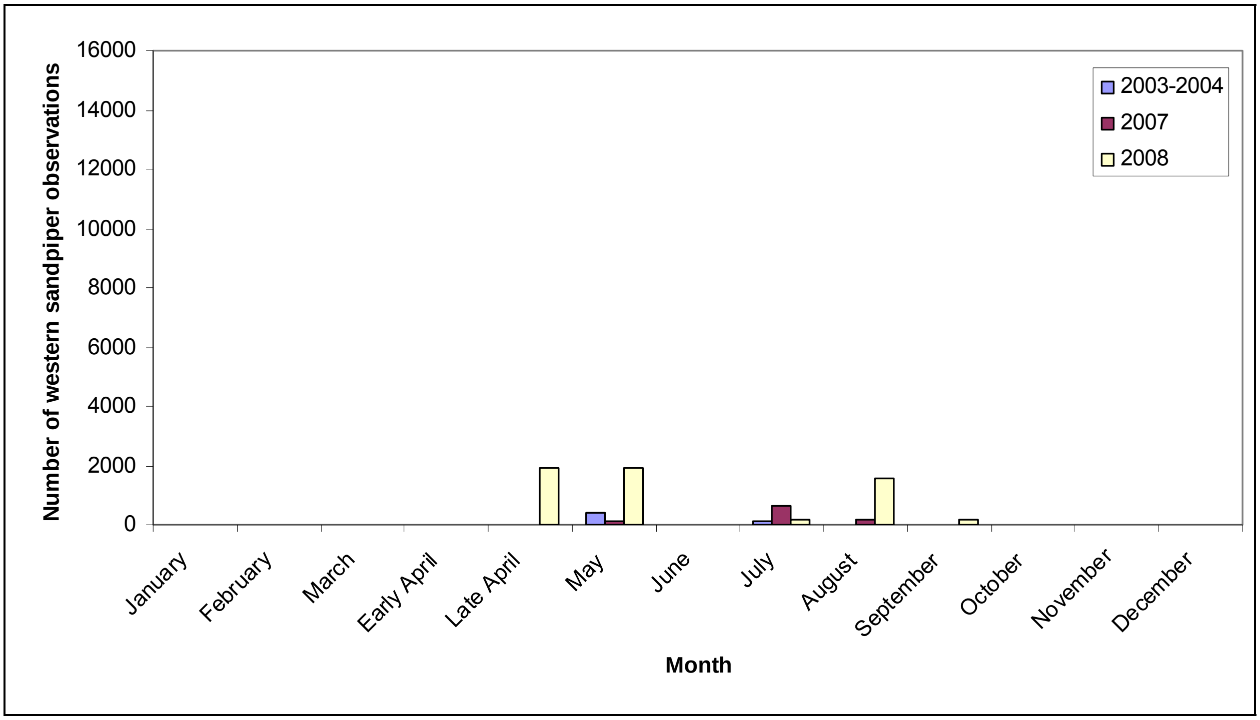
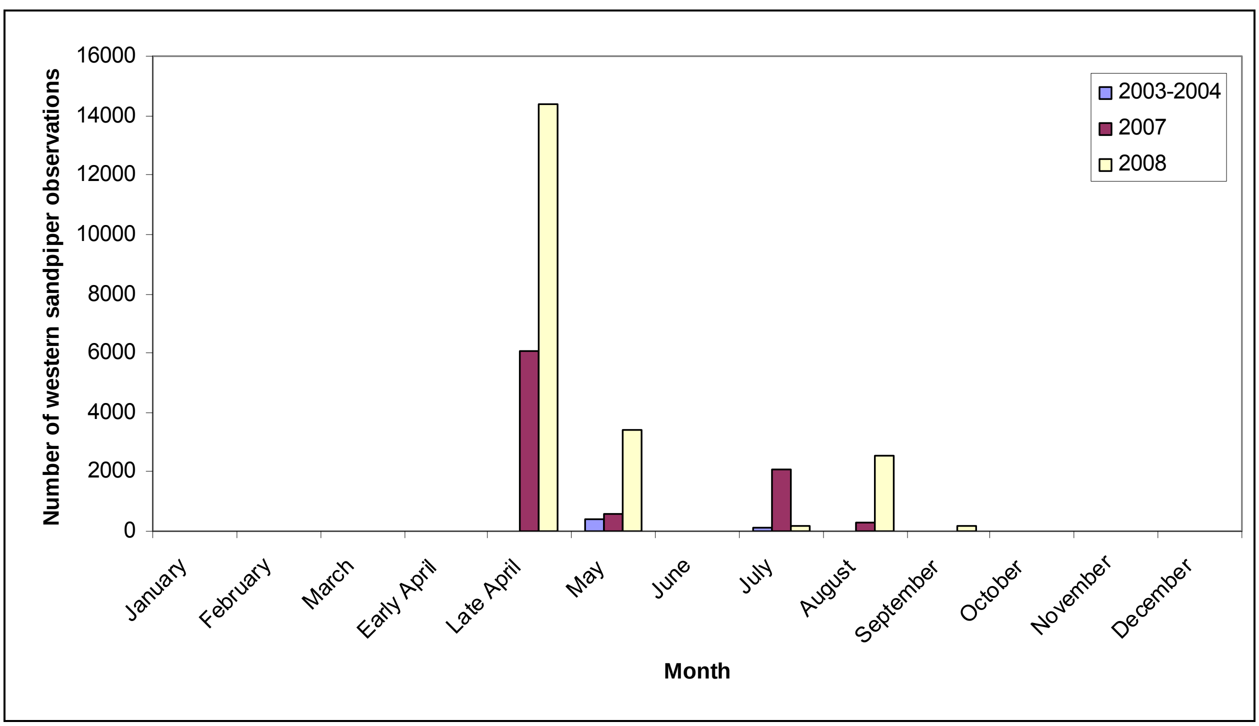


Figure 2.9-6 Relative Abundance of Western Sandpiper during High and Low Tide Combined, Deltaport and TFN Transects, 2003-2008

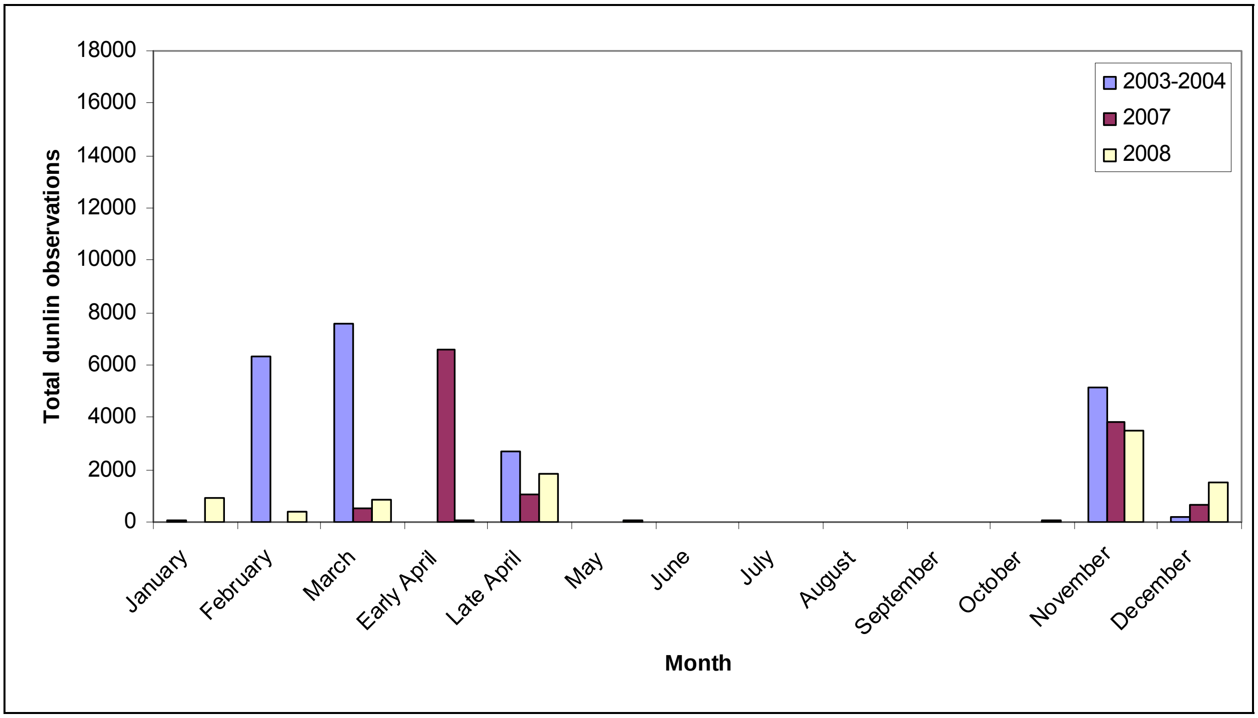


2.9.3.2 Dunlin

Dunlin abundance within and timing of use of the study area varied from 2003-2008. Cumulative dunlin counts ranged from approximately 22,000 birds in 2003-2004 and 2008 to 35,161 in 2007. Although dunlin have been consistently documented along the Deltaport and TFN Transects (**Figure 2.9-7 and Figure 2.9-8**), more dunlin have been regularly documented along TFN (**Figure 2.9-8**); most likely due to the availability of extensive mudflats during low tide events, compared to the limited habitat available on the Deltaport Transect. Areas of consistently high use were PC105 and PC109 along the TFN Transect (cumulative abundance > 4,000 in 2007 and 2008), and PC13 and PC16 along the Deltaport Transect (cumulative abundance > 2,000 birds in all years). In contrast, fewer dunlin have been documented within PC17 and PC18 from 2003-2004 to 2008. In 2003-2004, 7,925 and 2,521 birds were documented in PC17 and PC18, respectively, while from 2007 to 2008 fewer than 600 have been documented at these points annually. The cause of the change in use away from PC17 and PC18 is unknown as it is approximately 2 km away from Deltaport construction activities and the extent of foraging habitat appears unchanged.

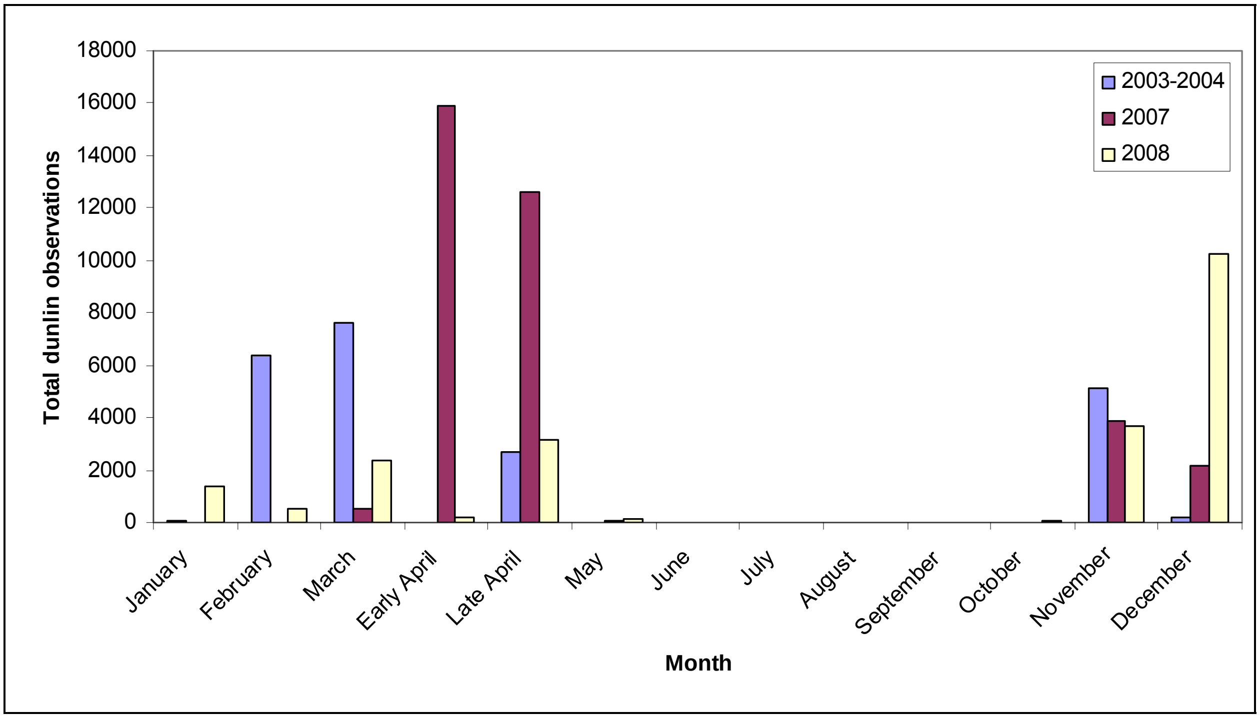
One further difference in dunlin use of the inter-causeway area was in the timing of annual maximum counts. In 2003-2004, peak dunlin counts occurred in February (6,349 birds) and March (7,600), while maximum numbers of birds were not documented until April (15,875) in 2007, and December (10,249) in 2008.

Figure 2.9-7 Relative Abundance of Dunlin during High and Low Tide Combined, Deltaport Transect, 2003-2008



Note: No surveys were conducted in January or February 2007 within the study site.

Figure 2.9-8 Relative Abundance of Dunlin during High and Low Tide Combined, Deltaport and TFN Transects, 2003-2008



Notes: 1) The TFN Transect was not surveyed in 2003-2004.
2) No surveys were conducted in January or February 2007 within the study site.

2.9.4 Coastal Waterbirds

2.9.4.1 Dabbling Ducks

Dabbling duck abundance and distribution along the Deltaport (**Figure 2.9-9**) and TFN (**Figure 2.9-10**) Transects from 2003-2008 were generally comparable following the same seasonal trends. Peak annual high tide counts, encompassing both the Deltaport and TFN Transects, ranged from 26,734 ducks in November 2007 to 32,780 ducks in December 2008. Dabbling ducks were most common within the inter-causeway area from October through December along the TFN Transect, where flocks of greater than 1,000 birds were frequently documented. Annual peak counts along the Deltaport Transect varied more. Maximum high tide abundance estimates along the Deltaport Transect in 2007 (15,757 birds) and 2008 (13,645 birds) were more than double maximum counts recorded in 2003-2004 (6,177 birds). Overall, large flocks of dabbling ducks annually used habitats contained within the inter-causeway area during late fall through early winter.

Figure 2.9-9 Relative Abundance of Dabbling Ducks during High Tide, Deltaport Transect, 2003-2008

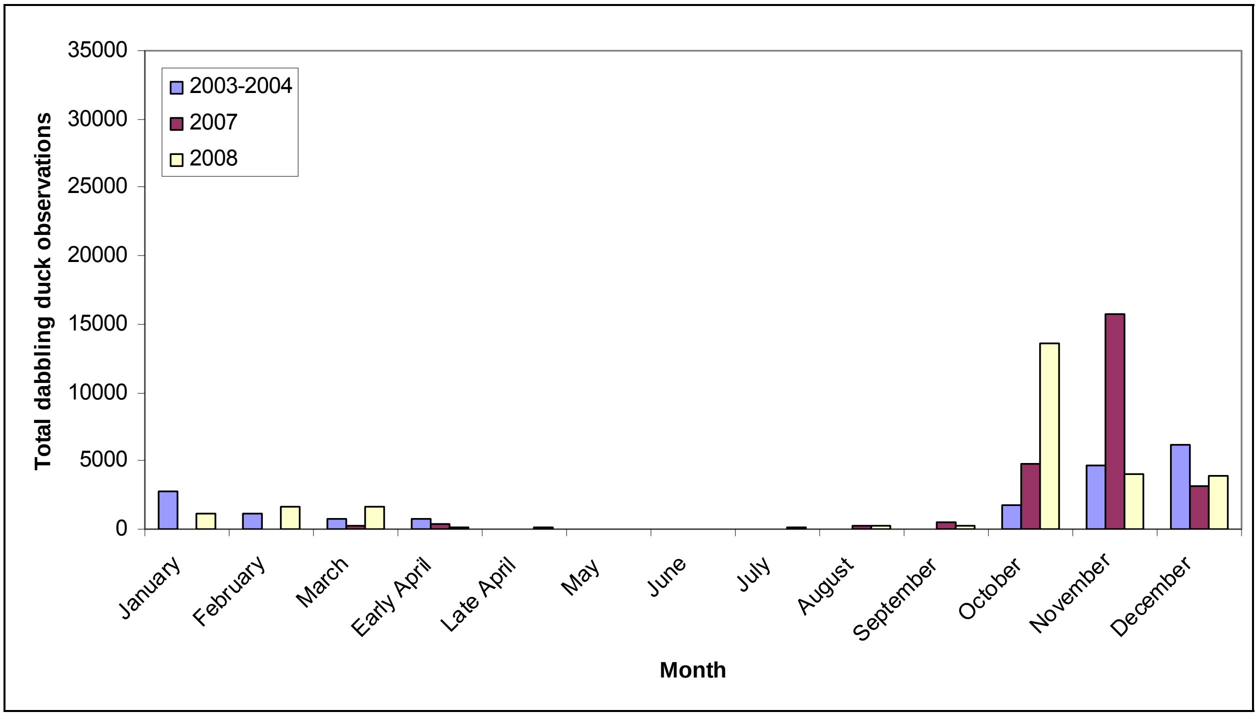
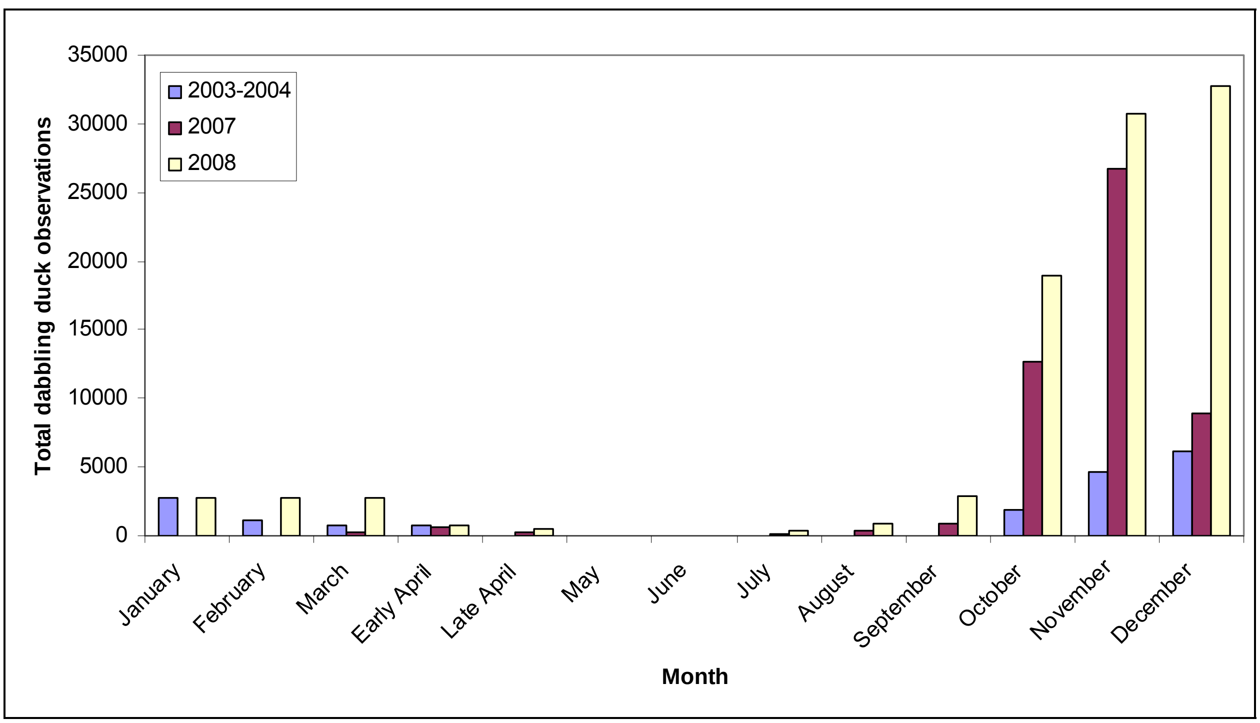


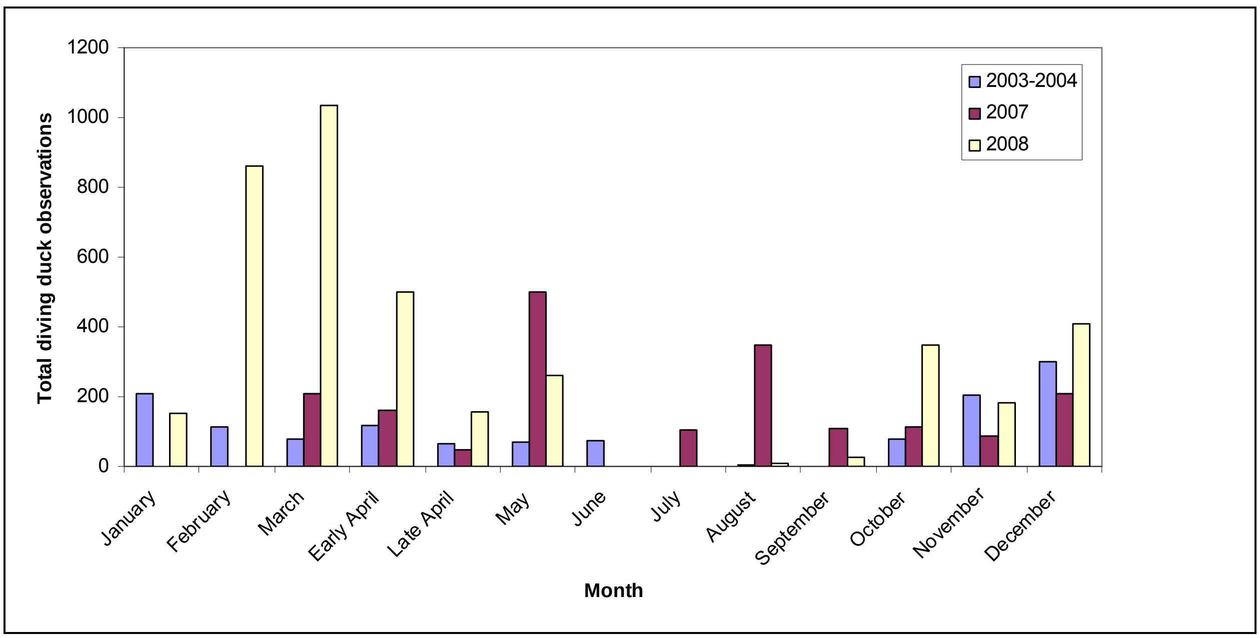
Figure 2.9-10 Relative Abundance of Dabbling Ducks during High Tide, Deltaport and TFN Transects, 2003-2008



2.9.4.2 Diving Ducks

Diving duck abundance varied annually, but distribution within the inter-causeway area and annual timing of use by divers varied little. The vast majority of diving ducks were documented along the Deltaport Transect as only two percent (42 ducks) and eight (335 ducks) percent of ducks were recorded along the TFN Transect in 2007 and 2008, respectively (**Figures 2.9-11**). General abundance estimates were comparable between years with a few exceptions. Diving ducks tended to remain in higher numbers longer throughout the year in 2007 compared to either 2003-2004 or 2008, as they were detected in July and August when few divers were detected in other years. Ducks documented at this time were surf scoter and greater scaup. Second, large flocks (> 500 birds) of greater scaup were recorded from February through early April in 2008. In 2003-2004 and 2007 peak monthly counts at this time of year ranged from 28 to 47 birds. Overall, diving duck abundance and habitat use within the inter-causeway area did not differ significantly between 2003-2004, 2007, and 2008.

Figure 2.9-11 Relative Abundance of Diving Ducks during High Tide, Deltaport and TFN Transects, 2003-2008



Notes: 1) The TFN Transect was not surveyed in 2003-2004.
2) No surveys were conducted in January or February 2007 within the study site.

2.9.4.3 'Other' Coastal Waterbirds

General trends in abundance, use, and distribution of 'other' coastal waterbirds did not differ between years (**Figure 2.9-12**). Similar to trends documented by diving ducks, the vast majority of birds were observed using habitats along the Deltaport Transect, as 84% (794/942) and 90% (1,481/1,652) of all 'other' coastal waterbirds were documented along the Deltaport Transect in 2007 and 2008, respectively.

Large spikes in monthly abundance estimates were almost always driven by the detection of a large single species flock. Often these detections were of birds that flew over or through a point count station. Species commonly documented as “fly-overs” were: snow goose and double crested cormorant, with flock sizes ranging from 97 to 254 and 87 to 179 birds, respectively. When fly-overs were removed variability in monthly survey results between years was greatly reduced (**Figure 2.9-13**). Overall, ‘other’ coastal waterbird abundance and habitat use within the inter-causeway area did not differ significantly between 2003-2004, 2007, and 2008.

Figure 2.9-12 Relative Abundance of ‘Other’ Coastal Waterbirds during High Tide, Deltaport and TFN Transects, 2003-2008

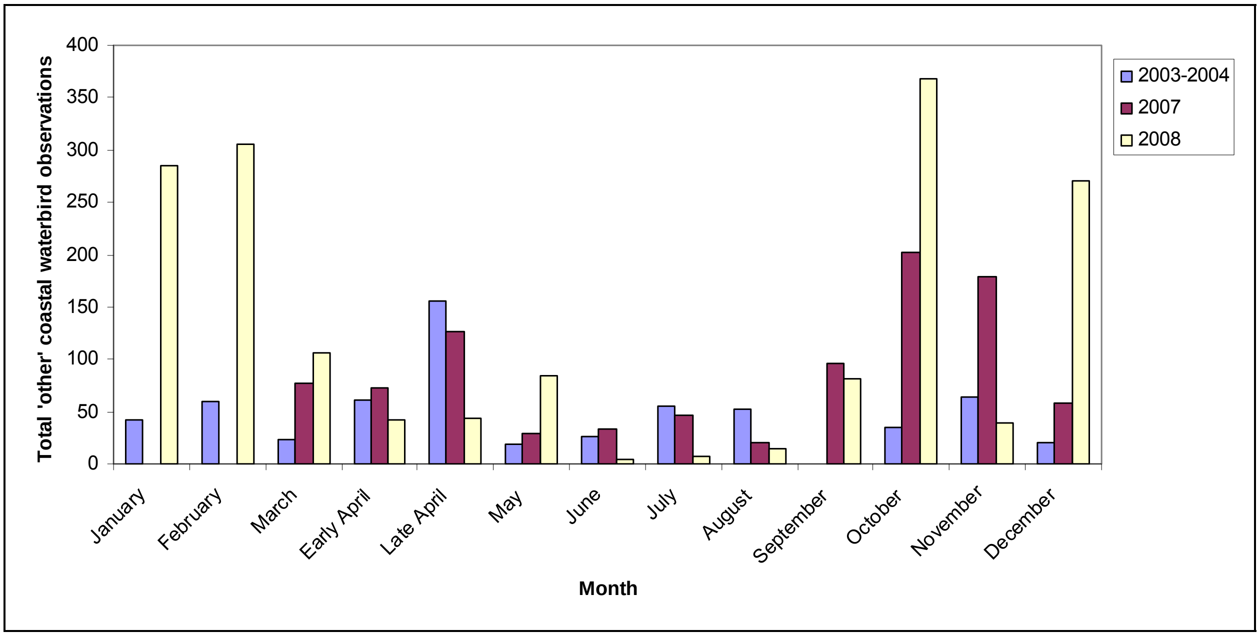
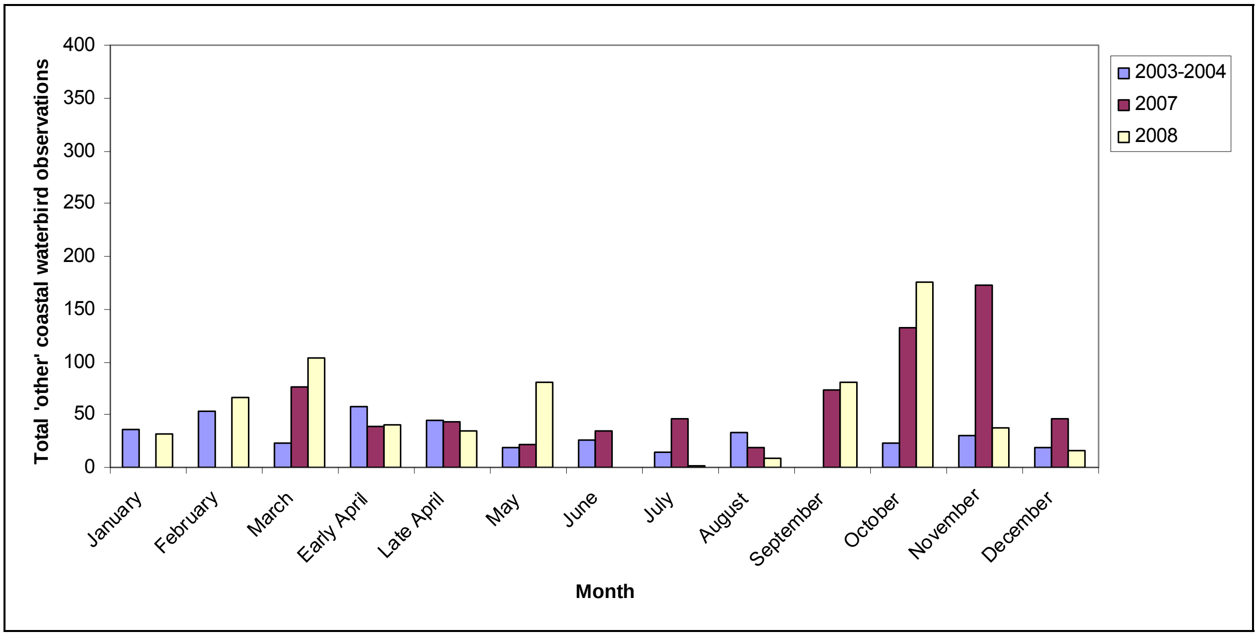


Figure 2.9-13 Relative Abundance of 'Other' Coastal Waterbirds during High Tide after Birds Detected 'Fly-over' Count Stations Were Removed, Deltaport and TFN Transects, 2003-2008



3.0 DISCUSSION

3.1 COASTAL GEOMORPHOLOGY

One of the primary objectives of the AMS monitoring program is to make an assessment of the possible effects of the DP3 project on the surrounding physical environment of the Roberts Bank tidal flats, specifically, the inter-causeway area. Data collection for the AMS program was initiated in April 2007, after construction operations for the DP3 project had already begun, albeit in the early stages of construction. As a result, except for aerial photographs and some limited hydrographic surveys, there is no baseline data for which a comparison of the pre- and post-project conditions can be made. However, the rate of change of the processes affecting the physical environment in the vicinity of Deltaport is not rapid, and it is reasonable to expect that the parameters that are being monitored would have represented near-baseline conditions at the onset of the project. Analysis of the present data set therefore involves discussion of the existing conditions and attempting to place these existing conditions in the context of observations made in the AMS 2007 Annual Report (Hemmera 2008d).

3.1.1 Crest Protection Monitoring

The Crest Protection Structure was installed on the tidal flats as an anti-erosion measure between 1982 and 1984 in conjunction with expansion of the turning basin. As drainage channels had formed around the perimeter of the initial excavated sediment borrow pit, the turning basin was installed in part to mitigate the formation of new channels. Since 1984, an extensive and complex system of channels has formed on the tidal flats, which are driven by tidal flow. Although these tidal channels continue to evolve, it is not thought likely that the new DP3 berth will have any significant effect on the existing tidal channels.

The primary purpose for monitoring of the Crest Protection Structure, as outlined in the DP3 Project AMS Detailed Workplan (VPA & Hemmera, 2007) is to “detect channel incision, headcutting or dendritic channel formation around perimeter crest protection.” Tidal flows interact with the Crest Protection Structure at a range of tidal stages during both the flood and the ebb tide. Water flows over the structure during high tidal stages and is diverted laterally by the structure during lower tidal stages. The result is a complex, dynamic system resulting in channels and flow paths of various sizes at different orientations relative to the Crest Protection Structure. Some of these flow paths may have been altered somewhat by the construction of the temporary barge berth facility adjacent to the new tug basin as casual observations have indicated that there appears to be additional ponding of water due to the temporary fill placed on the tidal flats. The effect would likely be that the volume of water draining over the crest protection structure in the vicinity of CRST-04 (**Figure 2**) would be increased somewhat, particularly during large tidal swings.

The Crest Protection Structure is not perfectly level. Therefore, water flowing over the structure at higher tide stages is concentrated into the areas where the crest is lower. Channels running perpendicular to the structure on both the seaward and landward sides are found in these areas. At tide stages near to the elevation of the crest, tidal flow is diverted laterally along the structure, and this has created significantly-sized channels running parallel to the structure. The main data collection tools used in the crest protection monitoring program are: visual inspection, and repeat topographic surveys of established cross-sections. Repeat photography from established photo points during daytime low tides supplements the visual inspection. Additional information about the physical processes affecting the area in the vicinity of the Crest Protection Structure is provided from the other monitoring activities such as interpretation of orthophotos and monitoring of the DoD rods, which are discussed in the following sections.

Figure 3 shows the plotted cross-section data from January, April and July, 2008. This survey data has been re-calculated and is slightly different from the data that has been presented in the quarterly reports to date. The reasons for this re-calculation and the methods are outlined in **Section 1.3.1.1**. These surveys show very minor elevation changes at all cross-sections that are related to slight variations in the accuracy of the survey. Instrument inaccuracy is reduced as much as possible by re-surveying a known monument during each survey but variations during the course of data collection occur that cannot be evaluated. These variations can be as high as 5 cm. Other sources of random error include slight variation in the position of the collected points from one survey period to the next, which show up as apparent changes in the plotted cross sections. For the points collected on the Crest Protection Structure, this variation could be as high as 10 cm because of the irregular elevation of the ground between boulders. Due to these random variations, elevation differences of less than 15 cm are difficult to resolve.

Monitoring of the Crest Protection Structure has demonstrated that the structure itself remains stable, with no detectable change over the 2008 monitoring period except where construction activities in the vicinity of the new tug basin and barge ramp have resulted in alterations to the structure shown in Cross-Section 1 (XS 1). The area of tidal flats and tidal channels in the immediate vicinity of the structure is generally stable but minor changes in elevation in the tidal channels near the structure have been measured. The top of the Crest Protection Structure at XS 2 appears to have increased in height by up to 30 cm in the July, 2008 surveys. This elevation increase was not measured in the most recent Q1-2009 surveys and there have been no reports of material added to the structure. We have concluded that this apparent increase must be related to survey error.

The surveys at Cross-Section 5 (XS 5) have shown a steady increase in the ground elevation on the seaward side of the Crest Protection Structure between January and July, 2008. This elevation change is on the order of 0.4 m to 0.6 m and appears to be related to migration of sand on the exposed tidal flats facing the ship turning basin. The deposition may also account for the apparent increase in the height of the Crest Protection Structure as the Q1-2009 surveys show a similar elevation in this area to the Q3-2008 surveys. In 2007 this area showed a similar pattern of elevation change between July and October.

There are also slight changes to the elevation on the shoreward side of the Crest Protection Structure in XS 5. The maximum change is on the order of 0.2 m so is only slightly outside the precision of the surveys. It is possible that tidal flow over, and along, the structure causes periodic scour and fill in this area.

The area on the shoreward side of the Crest Protection Structure also appears to be fairly dynamic at Cross-Section (XS 3). Although the vertical differences appear to be fairly large (up to 0.4 m), these vertical differences are partly caused by the difference in the horizontal location of the surveyed point. There are, however, some changes that may be related to scour and fill in the tidal channel that parallels the structure.

A brief examination of orthophotos collected in 2002, 2006, 2007, and 2008 shows that the small channels on the seaward side of the Crest Protection Structure appear to be stable. Any apparent change in the location of the channels over time is within the error limits of the photos, particularly introduced by slight changes in tide levels. The elevation changes shown in cross-sections 3 and 5 are relatively small and appear to indicate cyclical variation, possibly related to winter storms. The two years of monitoring data show no clear trend towards either infilling or erosion and therefore no concerns about the long-term stability of the Crest Protection Structure, or the area immediately adjacent.

The AMS Detailed Workplan (VFPA & Hemmera, 2007) includes a methodology for evaluating change within the study area. For those monitoring parameters that do not have national, provincial or regional objectives or standards, a 20% effect level or percent change over background has been selected as the AMS threshold. The 20% effect level is derived from standard toxicity testing and as a result, does not necessarily have wide application to monitoring of geomorphic parameters. Many natural physical processes vary within a very large range of values. For example, the mean discharge in the Fraser River at Hope for the period March 1 to March 14, 2008 was approximately 820 m^3/s while the peak discharge during the spring freshet of 2007 was over 10,000 m^3/s (Water Survey of Canada), representing a change of over 1,100%. A further complication to applying this method for evaluating change at the Crest Protection Structure is that the survey data are not in an absolute scale and there is no record of typical background variation at the site. At this time it is necessary to rely on qualitative interpretation of the monitoring data to evaluate acceptable thresholds for change.

3.1.2 Automated Turbidity Monitoring

As noted in the Results Section 2.0 above, the time series plot of raw turbidity values shown in **Figure 21** and **Figure 22** shows three distinct periods of values. The general range of values recorded between January 1 and April 10, 2008 is similar to that recorded in previous quarters in 2007. From April 10 to May 26 the instrument was recording very high values but suddenly returned to what initially appeared to be normal operating conditions on May 26. The record from May 26 to October 17, 2008 shows elevated turbidity values with occasional corrections down to more typical values.

The measurements recorded between April 10 and May 26, 2008 are not reliable and were possibly caused by marine organisms or other debris that may have been lodged inside the tube housing the instrument. (In the past a starfish was found on the end of the instrument inside this plastic tube). This would explain the sudden drop in the average turbidity on May 26 (**Figure 22**). From May 26 to July 2, measured turbidity values display an upward drift, which is likely caused by failure of the wiper mechanism. The instrument was serviced on July 2 and turbidity values dropped immediately afterwards. A similar period of upward drift was observed between August 15 and August 22, 2008 but the return to background levels does not correspond to a field visit for wiper replacement. Turbidity measurements between May 26 and October 17, 2008 are noticeably higher than in previous quarters. Based on the erratic behaviour of the instrument during this period it is difficult to place any confidence on the accuracy of this data.

The turbidity sensor essentially measures the ability of light to pass through the water column in the immediate vicinity of the optical sensor. Possible sources of turbidity include dead plant material and other organic debris, live organisms, and mineral sediments. This material may originate immediately around the sensor or it may be transported within the water column for some distance. The main physical processes that could influence turbidity on the tidal flats are waves and the tides. Conceptually, the tides would affect conditions at the turbidity sensor both in terms of the strength and direction of tidal flow, but also in terms of the potential for waves to interact with the surface of the tidal flats. At very low tides, waves would break on the Crest Protection Structure or on the beach in front of it, while at higher tide stages, the depth of water over the instrument would dampen the force of the wave motion over the sediments. Only at medium tide stages would conditions be appropriate for waves to pass over the Crest Protection Structure and still be able to disturb surface sediments.

Given the complex relationship between tide stage, tidal flow direction, waves and turbidity, it is not possible to draw simple conclusions from the turbidity data. In order to analyze the data, the available time series was broken into shorter segments of approximately 15 days and the turbidity data were converted to sediment concentrations using the derived relationship outlined in the Field Methodologies Section 1.3 above. An examination of these data shows that superimposed on the longer-term trends in the data, spanning several days for instance, are very short-term spikes in the turbidity values. These spikes are typically a single, anomalously high value amidst a series of reasonably similar values. The spikes, whether they represent erroneous values or not, create too much visual distraction. In order to further simplify the data analysis process, all values over 150 NTU were removed from the raw data set and the maximum vertical scale on the graphs was set at 100 mg/l. Tide height from the local gauge at Deltaport was superimposed on the secondary axis of the graph to provide a graphical relation between turbidity events and tide stage. **Figure 48** shows a series of these plots for the period between January 1 and April 15, 2008 at approximately 15-day intervals.

Figure 48a shows the modified time series for the period January 1 to 15, 2008. The most significant period of increased sediment concentrations occurs over the period from January 3 to 5. This period corresponds to a series of storms that generated winds in excess of 30 km/hr (measured at Vancouver International Airport) at various times during these three days. Local waves within the ship turning basin were large enough to cause turbulence at the tide gauge, which is also shown in the graph. Within this storm cycle, periods of higher sediment concentration appear to be related to times of lowest tide. There are nine other smaller increases in sediment concentrations that are roughly related to low tides. The rise in sediment concentration around January 14 corresponds to the most severe storm of the year. This storm had winds as high as 70 km/hr and would have generated waves up to 2.7 m at Deltaport but they would have been coming from the northwest and they occurred during a period when the tide height did not go below 2 m. As a result, the sediment concentrations in the water column were quite low and the overall effect of this storm was quite minor as compared to the series of much smaller storms that occurred near the beginning of the month.

Figure 48b shows the period from January 16 to January 31, 2008 in which there were no significant storm events. In general, sediment concentrations rise above background levels for short periods of time during very low tides, but not during every low tide. Also, sediment concentrations occasionally rise for very short periods during higher tides. The higher sediment concentrations on January 27 and again on January 30 correspond to two minor wind events with maximum wind speeds that barely exceeded 30 km/hr yet produced sediment concentrations in excess of the largest wind event of the year.

Analysis of the remaining plots (**Figure 48c** to **Figure 48g**) shows that in general this pattern is repeated. The magnitude of the rise in sediment concentration is generally related directly to the magnitude in the drop from the high tide to the low tide, as well as the minimum elevation of the low tide. It would be possible to deconstruct each significant wind event or each major rise in sediment concentration in order to relate the processes. However, there is very little value in this exercise as it relates to the objectives of the AMS. Sediment concentrations are generally very low and the larger events do not even usually approach the concentrations found in the Fraser River during the low-flow periods of the year. Given the challenges presented by the unreliable data record, it is not possible to detect a long-term trend in sediment concentrations throughout the year. The downloaded quarterly turbidity data will continue to be examined to ensure that negative trends are detected as early as possible.

3.1.3 Monitoring of Erosion and Deposition

The rates of erosion and deposition on the tidal flats in the vicinity of the DP3 project as well as the area of tidal flats on the seaward side of the Crest Protection Structure are monitored by an array of 26 DoD rods that were installed at the inception of the monitoring program and an additional eight DoD rods that were installed during Q2 and Q3 of 2008 (**Figure 6**). The DoD rod array covers an area approximately

750 m by 600 m, not including the DoD rods that extend southward along the perimeter of the turning basin. The rods measure maximum erosion at and net deposition (see Field Methodologies Section 1.3 for discussion). Although the rods are installed as an array, they measure changes at point locations. Extrapolation of the values to the area surrounding the rod must be done with extreme caution. Observations made during the 2007 monitoring year indicated that the magnitude of changes to the pattern of erosion and deposition over relatively small distances may outweigh the conclusions that can be made about changes over larger distances.

The magnitude of erosion and deposition measured at the DoD rod sites during each quarter is displayed graphically in **Figure 23** and **Figure 24** using bar charts. The bar charts represent the magnitude of change only and are not intended to show cumulative change in the elevation of the sediment surface. Measurements that may have been affected by the presence of significant accumulations of weed on the rod are marked on the figure. **Figure 25** to **Figure 28** show the net change (erosion and deposition) between each quarter in 2008 using colour-coded circles to denote various ranges in the magnitude of net change.

The effect that temporary vegetation accumulation may have on the DoD rod measurements has been raised as a possibly significant impact on the validity of the results. Eelgrass fronds are typically found loosely wrapped around or against the rods but occasionally more significant amounts of weed have been found on some of the rods during the annual spring and summer monitoring visits (Q2-2007 and Q3-2008). A fairly common sight at rods located at the western edge of the DoD rod array shoreward of the Crest Protection Structure (specifically the X01 and X02 series rods and Z series rods) are large cones of filamentous green algae on the DoD rod. The species *Enteromorpha* has regularly bloomed on the tidal flats each summer and represents a local source for this material. These cones can measure up to 80 cm across and up to 20 cm high. It is impossible to determine how long the cones remain on the rods but it is likely that the majority of the material floats away with the rising tide. As the weed is removed, we have observed that some of the material at the base of the cone is sometimes partially buried in the sediments. There does not appear to be a trend with rods which have cones around them towards greater or lesser erosion or deposition but the presence of these cones are noted in the field observations and the incidence of the cone is marked on the summary figures.

For the AMS 2007 Annual Report (Hemmera, 2008d) the DoD rods were considered in three separate populations: DoD rods located on the seaward side of the Crest Protection Structure, DoD rods located in the area of new drainage channels, and DoD rods located elsewhere on the tidal flats. Although the new drainage channels appear to have largely stabilized, this division of the rods into populations remains useful for comparison purposes.

The rods on the seaward side of the Crest Protection Structure continue to show the greatest amount of overall erosion and deposition as well as net change. These rods are affected by sand bars that migrate along the perimeter of the ship turning basin due to wave action at lower tide stages as well as tidal flow draining from the upper tidal flats. It is not possible to determine if the sandy sediments are simply being redistributed from the material already present on this part of the tidal flats or if new sediment is introduced from the erosion of the upper tidal flats and transport by the large dendritic channels. At the more exposed of these rods, F06 and G06, there is predominantly net erosion recorded, with a value as high as 12.4 cm that was measured at G06 for Q4-2008. Although these changes are nearly four times less than the high values recorded in 2007, the variation is attributed to the naturally dynamic nature of the sediments in this area.

The DoD rods in the vicinity of the new drainage channels had initially shown very high levels of erosion and deposition in early 2007 that was related to the formation of the channels and leakage of supernatant from the perimeter dike. Some of the rods in this area occasionally show slightly higher rates of erosion or deposition but there is no overall spatial or temporal trend. Q1 and Q2 monitoring show that all rods measured less than 2 cm of net change, except for the rod at C01 which measured over 4 cm of total erosion, as well as deposition. This trend continued through the Q3 and Q4 monitoring periods with the exception that E02 had a net deposition of 2.8 cm in Q3 and Z06 had a net erosion of 2.3 cm. Overall the magnitude of erosion and deposition is generally very low except for at C01, which had erosion and deposition of 3.6 and 3.8 cm, respectively in Q2. This is possibly related to localized sediment transport in one of the small drainage channels.

The remaining DoD rods on the tidal flats show net change (erosion +/- deposition) that is less than 2 cm for all quarters. Some of the DoD rods measured fairly high values of erosion and deposition but there is no strong spatial or temporal trend. C05 measured almost no activity during the Q1 to Q3 periods but in Q4 it measured erosion and deposition of 6.1 cm and 4.6 cm, respectively, but this appears to be an isolated occurrence. C06 showed low rates of erosion and deposition for all quarters except Q3 when the rates were 3.1 cm and 4.0 cm, respectively, and D06 showed rates of 4.7 cm and 6.1 cm, respectively, in Q2. As was mentioned in the AMS 2007 Annual Report (Hemmera, 2008d), these patterns tend to be highly localized and temporally unrelated. Because the effects of waves on the tidal flats is sensitive to tide height and wave direction, waves could be affecting one area of the tidal flats at a certain tide stage and then die down as the tide rises or falls so that they do not affect other areas during the same event. Also, small drainage channels can have a short-lived but significant localized effect.

As discussed above in **Section 3.1.1**, the DP3 Project AMS Detailed Workplan (Hemmera, 2007) stipulates that changes in the monitoring parameters in the study be evaluated based on a 20% exceedance threshold. Similar to the elevation data collected during Crest Protection Structure monitoring, it is not possible to make a simple percentage calculation for a threshold of change because the values collected refer to relative, not absolute, change. Also, as described above, the magnitude of change to geomorphic parameters in a natural system can exceed one or more orders of magnitude. On the shoreward side of the Crest Protection Structure, the typical observed bedform height on the tidal flats is in the order of 5 cm to 10 cm. Any changes within this magnitude therefore are within natural variability due to bedform migration. Changes that are greater than 10 cm are likely to be caused by other processes such as channel formation or localized scour and may be indicative of larger-scale morphologic changes.

A methodology was developed to evaluate the DoD rod data objectively, meeting the commitments of the AMS Workplan, which was used in the analysis of DoD rod data in the AMS 2007 Annual Monitoring Report. The methodology change is a necessary departure from the original AMS document and was developed following discussions with members of the SAC (i.e. R. Atkins, pers. comm. March, 2008). As it is not possible to directly calculate a percentage change on individual measurements made using a relative scale, this methodology uses the existing population of DoD rod data as a basis for evaluating the typical range of values for erosion and deposition because pre-project, or baseline, data are not available. Consideration of the distribution of values around the mean allows the calculation of confidence limits to set a reasonable threshold for change.

For the purposes of the analysis, the DoD rods are separated into three areas having similar geomorphic characteristics: rods outside the Crest Protection Structure (n=5), rods within the area of new drainage channels (n=3 + 4), and the remaining rods on the tidal flats behind the Crest Protection Structure (n=18 + 4). The ‘Z’ series rods that were installed on the tidal flats in mid-2008 provide additional sample points. Most DoD rods were sampled four times during 2008, resulting in four measurements of relative change. Six of the ‘Z’ series rods were measured three times, and two of them were measured twice for an additional two and one measurements each, respectively. The quarterly measurements for each subset of rods were lumped together to provide a grouping of measurements describing change in elevation on the tidal flats throughout one year. The rods were assigned to the three groups as follows:

- Group 1 (area seaward of the Crest Protection Structure): D04, D05, E06, F06, G06;
- Group 2 (area of new drainage channels): D01, E01, E02, with the addition of Z03, Z04, Z05, and Z06;
- Group 3 (remainder of tidal flats): A03, A04, A05, A06, B02, B03, B04, B05, B06, C01, C02, C03, C04, C05, C06, D02, D03, and D06, with the addition of Z01, Z02, Z07 and Z08.

Table 23 shows the summary statistics for each geomorphic area (group) by quarter and for the year, as well as the summary statistics for the combined erosion and deposition data for each group. Because the 2007 values were combined with the 2008 values, the summary statistics are different than those reported in the AMS 2007 Annual Report. Group 3 shows almost zero net change in elevation for the year, while Group 1 and Group 2 show net change of less than 0.5 cm. Not surprisingly, Group 1 showed the greatest range in erosion and deposition with a standard deviation of 5.13 cm but this was reduced slightly from the 2007 calculation of 6.57 cm. Group 2 and Group 3 experienced a much smaller range in erosion and deposition with a standard deviation of 2.23 cm and 1.74 cm, respectively. These values are generally consistent with the magnitude of change from migration of bedforms as outlined above. The standard deviation of erosion and deposition for all groups declined from the 2007 values.

The summary statistics provide a measure of variability and from these it is possible to set a reasonable threshold of change for consideration under the AMS. For normally distributed data, one standard deviation (1s) on either side of the mean accounts for 68.3% of the variance, while two standard deviations (2s) account for 95.5% of the variance. Given that there is a considerable amount of natural variability in most geomorphic systems, 1s seems too low of a threshold but 2s captures too much of the variability and does not provide enough conservatism for monitoring a sensitive environment such as the Roberts Bank tidal flats. A reasonable limit therefore, would be to consider that 80% of the variability is acceptable and that values falling outside of the 1.282s bear further investigation. The remaining variability falling outside of the 1.282s includes the 10% of values that are above the mean (net deposition) and the 10% that are below the mean (net erosion) for a total of 20%, a value that is in keeping with the orginal spirit of the AMS. **Table 23** provides a calculation of the 1.282s threshold.

For Group 1 all DoD rods were within the thresholds for erosion and deposition for all quarterly monitoring periods except for G06, which exceeded the threshold for erosion during both Q3 and Q4. The values of erosion at this DoD rod were also noted above as being particularly high. These values are most likely associated with natural cycles of erosion and deposition of sand bars along the exposed beach face.

There were several rods in Group 2 that exceeded the thresholds for deposition and erosion in Q3 and Q4 but none in Q1 or Q2. The threshold for deposition was exceeded at E02, Z05, and Z06 and the threshold for erosion was exceeded at Z03, Z05, and Z06. We know from observations, that following the initial disturbance of erosion and deposition that occurred when water and sediment were leaking from the perimeter dyke, that leakage ceased and the site has begun to stabilize. These rods exceeded the thresholds by less than 1 cm, which is not of concern in terms of immediate action.

In Group 3, the threshold for erosion and deposition was exceeded at a number of DoD rods during each of the four quarterly periods. None of the DoD rods has exceeded the thresholds in more than one quarter. High values for C05 and for C06 have been discussed above. For the remainder of the instances of exceedence, the values are generally one-off during a single quarterly monitoring period and are not repeated and therefore do not point to a negative or positive trend.

The accuracy of the DoD rod data could be affected by a number of potential factors, including measurement error, settling of the washer into the soft surface sediments, the uneven sediment surface, settling or sinking of the rod, and subsidence of the sediments. Measurement error is minimised as much as possible by consistently taking measurements at the southwest edge of the rod. However, the rod is often not level and accuracy is likely only within several millimetres. The initial stability of the washer at the sediment surface is occasionally affected by the need to regrade the sediments to the surrounding surface elevation following excavation of the washer. Fine sediments within shallow standing water may be loose such that the washer will sink slightly after it is re-deployed.

The potential for the rod to settle into the sediments has been minimised by installing the rod to the point of refusal at an average depth of 2.4 m. It is assumed that the rod is co-responsive to any potential subsidence of the sediments but it is not possible to evaluate this because of the limitations of the accuracy of survey instruments that can be deployed on the tidal flats. Hill, et al (2006) provide an evaluation of the estimated subsidence rates for Roberts Bank at up to 3 mm/year but it is not known to what depth this subsidence occurs. The elevation of the top of each rod was surveyed using an RTK GPS at the time of installation but it is unlikely that repeat measurements would detect change outside of the vertical accuracy of the instrument, which can vary between 1 cm and 5 cm.

3.1.4 Sediment Samples

The silt content (particles less than 0.063 mm) of the surface sediments is monitored as an indicator of potential effects to the physical environment in the area adjacent to DP3. Results from the DoD rod monitoring indicate that in most areas of the tidal flats, only the near-surface portion of the sediments are eroded and deposition is typically less than 4 cm. Only in the area on the seaward side of the Crest Protection Structure are these rates exceeded. **Table 15** and **Table 16** provide a summary by sampling period for carbon content and silt content, respectively. **Figure 29** and **Figure 30** show the silt content by site for April and October, and **Figure 31** shows the change in silt content between these two periods.

Organic carbon content was included as part of the sediment analysis in order to remove this material so that it did not skew the results of the grain size analysis. The organic carbon content presented in (**Table 15**) demonstrates that it is very low in the samples. Percent carbon for samples collected in April is between 0.1% and 1.1% but most samples are in the 0.1% to 0.4% range. For the October samples the range is from 0.2% to 0.9% but most samples are in the 0.2% to 0.5% range. Noticeably higher carbon content is observed in the sample at A03 and at D02, which also had much higher silt content, as well as the samples collected in the vicinity of the new drainage channels, at E01 and E02.

The percent silt content of the samples presented in **Table 16**, and graphically in **Figure 29** and **Figure 30**, show clear differences in the silt content over different areas of the tidal flats. The most obvious difference is that the samples collected on the seaward side of the Crest Protection Structure have very low silt content, generally less than 10%. This area is subject to frequent wave action and higher tidal currents and the surface sediments are typically characterized as rippled sands. Two of the samples collected within the area of new drainage channels, E01 and E02, are quite high (between 18% and 28%) but the third sample at D01 is fairly low at 14%. This is possibly because finer material was eroded from upslope, or was released through the perimeter dike during pre-load, and was deposited lower down on the tidal flats near E01 and E02. The samples collected on the remainder of the tidal flats are all generally low, in the range from 10% to 16%. The samples collected on the upper tidal flats at A03, A04, and B03 have silt contents between 21% and 37%. These sites, particularly A03, were also high in 2007 so it is likely that this area generally exhibits finer sediments. The sample collected at D02 was very high (53%) in April but was only 11% in October. This same pattern was observed in 2007 and could be related to seasonal processes but could also be related to a heterogeneous sediment surface. If fine sediments were deposited in patches, random sampling could easily show disparate silt content depending on where the sample was collected.

No overall increasing or decreasing trend in percent silt content is apparent in sediment sample data collected since monitoring began. The percent silt content of most samples collected in Q4-2008 does not differ greatly from Q2-2008 (**Figure 31**) or previous quarters (Q1 and Q3 in 2007). The most obvious exceptions are samples taken from sites at A03, A04, D02 and E02.

The area of new drainage channels has been closely monitored since the inception of the monitoring program. Percent silt values reported in Q1-2007 at E01 and E02 averaged 12%. Samples collected in Q3-2007at these sites had 36% and 39% silt content respectively, which was attributed to fine sediments having leaked out of the porous perimeter dike. With no additional inputs of sediment in 2008, the silt content appears to have stabilized at approximately 25%. This supports the conclusion that the system of new drainage channels has stabilized now that water is no longer draining from the perimeter dike.

Results of the carbon content analysis (**Table 15**) demonstrate that the values overall are very low in the samples. There is a correlation between organic carbon content and percent silt content as higher than average percent carbon values are observed in samples collected at A03, D02, E01 and E02. For instance, it is likely that the large amounts of fine sediments in the vicinity of the new drainage channels have also slightly increased the percent carbon in these samples. Also, this parameter is sensitive to the presence or absence of pieces of eelgrass within the sample because root fragments or blades of eelgrass can have a marked effect on the results of the carbon analysis. Also, unlike changes in the grain size that occur in only the near-surface sediments, carbon content would be expected to change at greater depths in the sediment due to bioturbation and other natural processes. Local variation in the samples due to micro site sampling selection appears to have a greater influence on the returned value than any expected temporal or geographic trend.

3.1.5 Interpretation of Orthophotographs

The study area for this monitoring activity, as outlined in the Detailed AMS Workplan (Hemmera, 2007), includes the area of Roberts Bank within the inter-causeway portion of the tidal flats. Important changes to the physical environment have been ongoing since the initiation of construction activities for the BC Ferries Causeway and terminal in 1958. These changes have been extensively documented in the Coastal Geomorphology Study (NHC, 2004) and include formation of large systems of dendritic channels, lateral expansion of eelgrass beds, and dredging for expansion of the ship turning basin.

Four main areas of geomorphic change have been identified from the interpretation and mapping of the orthophotos:

1. New drainage channels that formed at the north-eastern margin of the perimeter dike in 2007,
2. Formation of sand bars on the tidal flats on the seaward side of the Crest Protection Structure,
3. The large system of dendritic channels draining into the turning basin, and
4. The tidal channels adjacent to the BC Ferries Causeway.

These features are shown in **Figure 32**. **Figure 33** shows a detailed view of the area of new drainage channels.

3.1.5.1 New Drainage Channels

The new drainage channels visible in the 2007 orthophoto (**Figure 33**) were initially formed by seawater leaking from the perimeter dike enclosing the DP3 footprint. The south side of the perimeter dike was sealed with sand in July 2007 and flow was observed to have decreased from the perimeter dike the next day. Some leakage of sediment-laden waters was reported within this period but the precise quantity is not known. By the time the 2008 monitoring began, the area within the DP3 footprint had been filled with sediment from dredging activities and water drainage from the dike had ceased.

The channels affected an area of approximately 3.4 hectares, roughly divided between a zone of erosion and a zone of deposition. The channels on the upper mud flats (above approximately 1.5 m (Chart Datum) elevation), which were mostly free of vegetation, initially incised into the soft sediments and carried a significant amount of material into the lower tidal flats immediately shoreward of the Crest Protection Structure. The deposition zone resembles that of an alluvial fan and coincides with an area of medium to dense eelgrass beds. Areas within the eelgrass were observed to be buried under the soft sediments within the deposition zone.

Sediment redistribution along the area of new drainage channels has continued over the last year. Much less sediment is apparent within the zone of erosion in the 2008 orthophotos as compared to those flown in 2007 (**Figure 33**). Field observations have shown that tidal drainage during the ebb tide transports very small amounts of sediment towards the zone of deposition. **Figure 33** also gives the impression that topographic relief of the sediment lobes has diminished since 2007. It is primarily the channel banks that have evolved from sharp-sided to gently-sloping over the period between photos. In fact, DoD rods located in the area have shown very little change in 2008. Rods at E01 and E02, for instance, on average experienced net erosion or net deposition of 0.5 cm or less.

In addition to stable bed level, the channels have not undergone appreciable lateral migration since 2007. The footprint of the active channel zone is also largely the same. Whereas the expansion of eelgrass beds in the upper mud flats has reduced the area of this zone, it has also increased the stability of the sediments. The new drainage channels were inspected during a site visit on February 3, 2009. The channels appear to be no longer active, though small amounts of tidal water still drain via the channels.

3.1.5.2 Sand Bars Seaward of the Crest Protection Structure

The portion of the tidal flats on the seaward side of the Crest Protection Structure has a much higher level of exposure to waves than the areas behind the structure. Breaking waves have often been observed in this area but never on the landward side of the structure. Large bar forms are visible in the orthophotos flown in 2008 and have generally similar extents as compared to those seen in the 2007 orthophotos.

Natural modification of the sand bars in this area is expected to continue, with wave action and tidal flow moving the existing sediment along the edge of the turning basin, and some new sediment coming from the existing tidal channels. The DoD rods in this area have measured some of the largest amounts of erosion and deposition, which is discussed above, and the crest protection monitoring cross-sections have captured some of the elevation changes.

Future monitoring activities will continue to make note of changes to this area.

3.1.5.3 Large System of Dendritic Channels

The large system of dendritic channels shown in **Figure 32** was the focus of detailed geomorphic and hydrodynamic analysis as part of the Coastal Geomorphology Study (NHC, 2004). Historic orthophotos show that these channels evolved gradually since the ship turning basin was originally dredged in 1969 and developed further, following expansion of the turning basin and construction of the Crest Protection Structure in 1982. The system of channels and sand bars presently extends over a large area of the tidal flats. The sand bars alone covered an area of over 30 hectares in 2002. The results of previous analysis

(Coastal Geomorphology Study, NHC, 2004) concluded that the formation of these large channels is related to historic dredging of the ship turning basin. Given that they are relatively removed from the assumed area of influence of the new DP3, it is unlikely that they are being influenced by, or have influence on the present project.

The main features of interest in the large dendritic channels include the main trunk channel, a very large sand deposit at the shoreward end of the trunk channel, referred to as the ‘sand lobe’, and a system of smaller ‘tributary’ channels extending from the trunk channel shoreward across the tidal flats. **Figure 34** shows the outline of the channels that were digitized from the 2007 and 2008 orthophotos. The trunk channel has remained relatively stable, but the orthophoto comparison shows small changes to the rest of the system since July 2007. Shoreward extension of the tributary channels has continued to occur over the last year with some additional widening of these channels. The lateral migration of some of the larger tributary channels is accompanied by an evolution towards a more meandering planform. In some instances, flow appears to have split to form additional small tributaries.

3.1.5.4 Channel Development along the BC Ferries Causeway

The tidal channel and its tributaries that have formed adjacent to the BC Ferries Terminal do not appear to be related to any of the activities of Deltaport but the channels fall within the study area for the AMS monitoring program. These channels appear to have formed initially in response to expansion of the ferry terminal and have continued to headcut as a result of tidal drainage. In the period between 2007 and 2008 orthophotos, the channels have further extended shoreward.

A much smaller channel has developed on the upper tidal flats from overland drainage from the agricultural lands inside the dikes. The creek and its active channel zone have been extending seaward. It is expected that at some point in the future these channels may join, and it is possible that the larger connected channel will expand more rapidly once this has occurred.

3.1.6 Coastal Geomorphology Mapping

As outlined in the Results Section 2.0, there was no new data collected under this activity. Resurvey of the inter-causeway portion of the study area is scheduled for year 3 or 4 of the monitoring program. At present, as there have been no major issues identified in the AMS monitorin program that would be captured by these surveys, there is no imminent requirement to conduct the follow-up surveys.

3.1.7 Wave and Current Monitoring

The wave climate at Deltaport is affected both by waves generated in deep water in the Georgia Strait as well as waves generated locally from within the inter-causeway area. **Figure 13** shows the fetch lengths for waves at Deltaport. This figure was developed to illustrate fetch length used in the hindcast wave calculations so does not accurately reflect the fetch length of waves that would be measured by the wave sensors that were installed in the study area but does provide a generalized picture. Waves generated by winds from the southeast to the northwest would be generated in open water and would enter the ship turning basin with some degree of deflection for waves that interact with Deltaport or the BC Ferries terminal. Winds from the northwest, clockwise through to the east southeast, have very short fetch length because of the proximity of the site to shore and its location relative to the two causeways and the terminals. Any open water waves would be almost completely blocked and only local waves would be generated by these winds.

The locations of the three wave sensors in the study area were chosen to reflect a range of wave environments to be representative of overall conditions on the tidal flats (**Figure 5**). Sensor #3 is located within the ship turning basin and is exposed to open water waves from all directions that are not physically blocked by Deltaport or large ships berthed at the terminal. The instrument is deployed at a height of approximately -3 m (Chart Datum), so with the ground sloping gradually shoreward, most waves at most tide heights would not be significantly affected by interaction with the bottom. Sensor #2 is located immediately behind the Crest Protection Structure at an elevation of 0.7 m but the elevation of the Crest Protection Structure in this area is approximately 1.2 m. Sensor #2 is therefore in the same general wave path as Sensor #1 but waves at most tides are completely blocked or partially transformed by interaction with the Crest Protection Structure. Sensor #1 is located on the middle tidal flats, within eelgrass beds at an elevation of approximately 1.2 m. The wave climate measured by Sensor #1 has been influenced by the Crest Protection Structure, DP3 construction activity, and the shallow tidal flats surrounding the instrument. In general the wave climate is expected to be most energetic at Sensor #3 and least energetic at Sensor #1. This general trend may not apply for locally generated waves but these waves would typically be smaller than the open water waves.

The maximum significant wave height measured in the inter-causeway area in 2008 was 0.69 m on December 24 at 1:00 pm. This large wave event does not correspond to a large wind event recorded at Vancouver Airport. The largest hindcast wave coming from open water was calculated at 2.7 m for a wind storm that occurred on January 14, 2008 but the wave sensors were not installed at this time. The second largest hindcast wave at Deltaport was predicted to be 2.23 m on November 13, 2008 from a windstorm coming from the west. The largest wave measured by Sensor #2 for this date was 0.12 m (Hs). In general, wave heights measured at Sensor #1 are less than 0.05 m and at Sensor #2 and #3 they are generally less than 0.2 m.

Although there are significant data gaps, the 2008 wave heights shown in **Figure 35** for 2008 indicate that the expected general trend of highest wave energy at Sensor #3 and lowest energy at Sensor #1 is supported by the data but the waves measured at Sensor #2 are very similar in height to Sensor #3. April 10 to June 4 has the longest period of coincident measurements at all three sensors (**Figure 36**). The maximum significant wave heights during this period are listed below in **Table 3.1-1**. The largest wave measured in this period was 0.28 m at Sensor #2. However, there is an incomplete record for Sensor #3, which would otherwise be expected to measure the largest waves.

Table 3.1-1 Maximum Significant Wave Heights for the Three Wave Sensors for the Period between April 10 and May 4

	Sensor 1	Sensor 2	Sensor 3
Max. wave height (m)	0.18	0.28	0.22

For the period from July 3 to September 2 there was no data collected at Sensor #1 but Sensors #2 and #3 were active (**Figure 37**). The maximum significant wave height measured at Sensor #3 during this period was more than twice as high as at Sensor #2 (0.43 m versus 0.20 m).

For the smaller wave heights (under 0.3 m) that were measured in the earlier part of the year, it is possible that the effects of the Crest Protection Structure are not as important as expected. During the April 10 to May 4 period, the incidence of low tides was such that the Crest Protection Structure was exposed for approximately 5% of the time while during the July 3 to September 2 period the structure was exposed for 2% of the time, a similar amount. The generally smaller waves that were measured in the April to May period would have been less affected by interaction with the structure than the slightly larger waves that were measured during the July 3 to September 2 period. A longer wave record with more periods of overlap would be required to make more detailed observations.

The period of largest overall wave heights measured at Sensor #2 is from October to December (**Figure 38**). Several large storms during this period generated waves in excess of 0.4 m in height, particularly towards the end of December when a storm with gusts of 67 km hour occurred on December 29, 2008. The waves recorded at Sensor #1 do not appear to be significantly larger than those measured during the April to June period. The most notable difference between these two periods were the waves measured at Sensor #1 around April 22 that exceeded 0.15 m while waves at Sensors #2 and #3 did not exceed 0.3 m. This is compared to the numerous wave events in October, November and December that exceeded 0.4 m at Sensor #2 but only once exceeded 0.1 m at Sensor #1. This illustrates that wind direction and timing of wind events with respect to tide height can play an important role.

3.2 SURFACE WATER QUALITY

The discussion of surface water quality monitoring results considered both spatial and temporal trends.

Results from stations DP02, DP03, and DP04, intertidal stations in the inter-causeway area, were compared to results from DP06, the intertidal reference station (**Figure 8**). The results from station DP05, the subtidal station in the inter-causeway area were compared to those from the subtidal reference station (DP07). The A level and B level subtidal results were considered separately. As noted in **Section 1.3.2**, the A level samples at DP05 and DP07 were collected one metre below the surface of the water and B level samples were collected 2.0 metres above the sediment. Station DP01 was not included in this comparison as it has no associated reference station. Station DP08 was not included in the temporal trend analysis since it was only sampled in Q1-2008, as part of the benthic invertebrate monitoring program. A few general comments precede the discussion of spatial and temporal trends.

3.2.1 Metals

Although boron, iron, and vanadium exceedances were measured, these exceedances were not considered significant for the reasons discussed in **Section 2.3**. Copper and zinc were the only two metals that exceeded the BC WQG. As indicated in **Section 2.2**, the copper exceedances (**Table 18**) were identified at DP01 (in Q1-2008, Q2-2008, and Q4-2008), DP06 (in Q2-2008), and DP07A (in Q2-2008). The zinc exceedance was identified at DP01 (in Q4-2008).

In Q1-2008, surface water was collected at station DP01 during seasonal daytime low tides when the ditch was filled with freshwater, as evidenced by lower sodium and chloride concentrations (**Table 18**). Ideally, all surface water samples from DP01 would have been at low tide, to best capture upland inputs to the inter-causeway area. In Q2-2008, an attempt was made to collect surface water from DP01 at low tide; however, there was too little water in the channel to collect a sample following the standard methodology. Given that the program had to be timed around the highest possible tides to access the intertidal stations, the tide was relatively elevated during the next available opportunity to sample DP01. In Q3-2008 and Q4-2008, surface water was sampled at station DP01 during the day, as low tides occurred only at night. The surface water samples collected from DP01 in Q2-2008, Q3-2008, and Q4-2008, therefore, had greater seawater influence than the sample collected in Q1-2008. As such, they did not provide as accurate a measure of upland inputs.

3.2.2 Eutrophication-related Parameters

Phosphorus and nitrogen are two key nutrients associated with plant growth. Increasing concentrations of either may signal an increased risk of algal blooms or eutrophication. Orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, is the form taken up by plants.

For nitrogen, nitrate is the primary source for aquatic plants; however, both nitrite and ammonia have the potential to undergo nitrification to nitrate. TKN is the sum of organic nitrogen and ammonia. Elevated TKN concentrations are usually the result of sewage and manure discharges to water bodies. Nitrate accounted for the bulk of total nitrogen in the water samples (**Table 18**) and the highest concentrations were observed at DP01. TKN concentrations were also greatest at DP01, reflecting potential upland input to the inter-causeway area from adjacent agricultural land. Nitrite concentrations were in a similar range across all stations.

Other parameters that may act as warning indicators for eutrophication include chlorophyll *α,* dissolved oxygen, and TSS. Chlorophyll *α* concentrations provide a direct measure for an increase in algal biomass. Algal blooms associated with eutrophication may initially be linked to a diurnal increase in dissolved oxygen concentrations; however, as eutrophication progresses, an increase in bacterial populations feeding on the algae would be expected to increase biological oxygen demand and decrease dissolved oxygen concentrations. An increase in TSS can signal an increase in phytoplankton or detritus associated with eutrophication although inorganic particulate matter may account for a significant portion of TSS and confound any trends.

3.2.3 Spatial Trends between Inter-causeway and Reference Stations

The data collected within the inter-causeway area were compared with the results from the reference stations in **Figures 49** and **50**. A 20% difference between the measured parameter inter-causeway and reference station results was initially proposed to gauge the potential for impacts; however, AMS results from 2007 suggested that baseline conditions at the inter-causeway and reference stations differed by more than 20%. As such, an alternate approach to evaluating the data was adopted in 2008.

The minimum and maximum concentrations recorded during each quarterly sampling event in 2008 for each parameter of interest were noted and three categories of approximately equal range were created. The average concentration for the parameter over the four quarters was then calculated at each station and the value categorized as low, intermediate, or high, with low average values represented by small dots and high average values represented by large dots. This method facilitated the identification of spatial trends in metal and nutrient concentrations and the comparison of spatial trends in sediment and surface water data. Note that the average values presented in **Figures 49** and **50** include only data from the four quarters in 2008. Similar figures, using the data from the four quarters in 2007, were prepared for an addendum to the AMS 2007 Annual Report. **Figures 49** and **50** are intended to capture spatial trends in 2008. Temporal trends (2007 and 2008) are captured in **Figures 51** and **52**.

3.2.3.1 Metals

Figure 49 compares average metal concentrations at the eight monitoring stations over the four quarters in 2008. In addition to copper and zinc (which exceeded the BC WQG), the figure also includes arsenic, barium, lead and cadmium, as these are metals with regulatory guidelines with detected concentrations generally greater than the RDL. Other regulated metals parameters, including beryllium, chromium, mercury, selenium and silver, were not included as most values were less than the RDL. Uranium was not included as concentrations were typically less than 2% of the BC WQG.

The highest metal concentrations in surface water were measured at DP01, while the lowest were measured at DP05A and DP05B, with the exception of arsenic which was relatively elevated at DP05A. Metal concentrations at the A and B levels at DP05 were more similar than metal concentrations at the A and B levels at DP07. Metal concentrations measured at DP07A were more similar to those at DP06 than to those at DP07B. Lead and zinc concentrations were in the lowest range at the inter-causeway stations, except at DP02, where the lead concentration was in the intermediate range. The copper and zinc exceedances noted at DP01 suggest potential upland inputs of metals. This input appears to be limited, as copper and zinc concentrations at the next nearest station, DP02, met the BC WQG. The copper exceedances noted at DP06 and DP07A are likely linked to inputs from the Fraser River as the two stations are located at its point of discharge into the Georgia Strait.

3.2.3.2 Eutrophication-related Parameters

Figure 50 shows spatial trends in eutrophication-related parameters. The highest nutrient concentrations in surface water were measured at DP01, with the exception of nitrite which was greater at DP02 and DP03. Noting the distinct nutrient profile at DP01, results from this station were not further considered in the discussion of spatial trends. The elevated concentrations at DP01 are attributed to upland agricultural inputs as the ditch conveys water from an area east of the inter-causeway area used for agriculture.

The DO concentrations fell in the lowest range at DP05A, DP05B, and DP07B, and in the intermediate range at the inter-causeway stations. Relatively low DO was expected at DP05B and DP07B, as DO typically decreases with depth. The chlorophyll α fell in the lowest range at all stations except DP02 and DP03, where it fell in the intermediate range. The nitrate and phosphate concentrations fell in the lowest range at DP06 and DP07A, but in the intermediate range at DP02, DP03, DP04, and DP05A. The nitrate concentration was higher at the B level at both DP05 and DP07. With the exception of nitrate, nitrite and total nitrogen, the nutrient concentrations were in the same range in samples from DP05A and DP05B. The relationship between nutrient concentrations in samples from DP07A and DP07B was more variable, with only ammonia and total nitrogen falling in the same range. The ammonia concentrations were greater at DP06 and DP07A than in the inter-causeway area.

The key spatial trends were the elevated nutrient concentrations at DP01, elevated DO and ammonia at the reference stations, and elevated phosphate and nitrate at the intertidal inter-causeway stations. The remaining parameters were variable. The elevated nutrient concentrations at DP01 are considered to be a function of agricultural inputs. However, they do not appear to be linked to DP3 construction or to be affecting nutrient concentrations at other stations in the inter-causeway area. The higher ammonia concentrations measured at the reference stations are considered to likely be due to inputs from the Fraser River as there is significant agricultural activity upstream. The higher phosphate and nitrate concentrations may be a function of greater biological activity in the sheltered inter-causeway area. The spatial analysis did not suggest a trend towards eutrophication.

3.2.4 Temporal Trends between Quarters

Metal concentrations in surface water did not show an increasing or decreasing temporal trends between quarters or consistent seasonal patterns (**Figure 51**), with the exception of the barium concentration at stations DP06 and DP07, which was higher in Q2 in both 2007 and 2008. Both the highest metal concentrations and the greatest variability were observed at DP01. Temporal trends at DP02 resembled those at DP03, but not those at DP01 or DP04. Metal concentrations at DP06 and DP07A showed similar temporal trends, likely as a function of influence from the Fraser River. In contrast, temporal trends at DP07B showed greatest resemblance to trends at DP05A and DP05B, suggesting a greater influence from the waters of the Georgia Strait.

Dissolved oxygen concentrations did not show major fluctuations over time or distinct seasonal patterns (**Figure 52**). This is in general agreement with the sonde data (**Section 2.3.2**), located in the subtidal portion of the inter-causeway area.

With the exception of a rise in Q2-2008 at DP01, chlorophyll *α* concentrations were similar to those measured in 2007, showing neither a distinct seasonal trend, nor a distinct increase or decrease over time (**Figure 52**).

Total nitrogen and nitrate concentrations measured at DP05A and DP05B in 2008 were generally higher than those measured in the first three quarters of 2007; however, this pattern was not reflected at other monitoring stations. The nitrite, TKN, phosphorus and ammonia concentrations did not exhibit a clear temporal trend (**Figure 52**). The temporal analysis did not suggest a trend towards eutrophication.

3.3 Sediment Quality

Similar to surface water, the discussion of sediment quality results considered both spatial and temporal trends, with particular attention given to parameters associated with eutrophication.

A lithium geonormalizing technique was applied to distinguish between metals inputs from anthropogenic sources and natural variations in background metal concentrations. Lithium occurs predominantly in several common silicate minerals where it substitutes for potassium, sodium, and magnesium and has been shown to be an effective means to normalize metals concentrations to background (Sutherland et. al. 2007).

Figure 53 shows sediment metals parameters normalized to lithium in 2007 and 2008. For most parameters, the normalized metal parameters for 2008 lay close to the regression line suggesting natural background concentrations. Outliers representing potential external enrichment for aluminum, barium, copper, chromium, manganese and zinc were noted in 2007 at DP01 and DP02, suggesting potential upland inputs from the ditch located at DP01 (**Figures 9 and 10**). Outliers were also noted at DP06 (the intertidal reference station) for mercury during Q4-2007 and manganese during Q3-2008.

The lithium normalization plots suggest that elevated metal concentrations measured at DP05 are reflective of background conditions, rather than inputs from DP3 construction.

3.3.1 Spatial Trends between Inter-causeway and Reference Stations

Figures 54 and **55** show a comparison of the relative variation of sediment metals and eutrophication-related parameters between the intertidal inter-causeway stations (DP02 to DP04) and their associated reference samples (DP06) and the subtidal inter-causeway station (DP06) and its associated reference samples DP07).

3.3.1.1 Metals

Figure 54 shows spatial trends in metals concentrations for the CSR Schedule 9 sediment metals parameters (arsenic, chromium, copper, mercury and zinc)[2]. It should be noted that there were no exceedances of the CSR standards. The lowest metal concentrations in sediment were measured at DP01, while the highest metal concentrations were measured at DP05. Arsenic concentrations did not show a clear spatial trend between the inter-causeway and reference stations, falling in the lowest category at DP01, DP02, DP08, DP06, and DP07, and in the intermediate range at DP03 and DP04. Chromium concentrations also did not show a clear spatial trend between the inter-causeway and reference stations, with chromium concentrations falling in the intermediate range at DP04, DP06, and DP08, but in the upper range at DP02, DP03, and DP07. The copper, mercury, and zinc concentrations were generally lower in the inter-causeway area, falling in the lowest range at DP01, DP02, DP04, and DP08, and in the intermediate range at DP06 and DP07, with the exception of copper which fell in the low category at DP06.

[2] Cadmium and lead were not included in the spatial trend graphs as concentrations were less than the RDL for all samples. CSR Schedule 9 sediment criteria are generally adopted by federal regulators in BC due to the extensive federal input into their development.

3.3.1.2 Eutrophication-related Parameters

As with surface water, phosphorus and nitrogen in sediment are two key nutrients associated with plant growth. Increasing concentrations of either may signal an increased risk of eutrophication. For nitrogen, as indicated above, nitrate is the primary source for aquatic plants; however, both nitrite and ammonia have the potential to undergo nitrification to nitrate. Elevated TKN concentrations are usually the result of sewage and manure discharges to water bodies.

Concentrations of eutrophication-related parameters at the inter-causeway stations were generally greater than those at the reference stations (**Figure 55**), with nutrient concentrations consistently falling in the lowest range at DP06 and DP07. The highest nutrient concentrations were measured at DP05, where all five nutrients considered fell in the upper range. Nutrient concentrations consistently fell in the intermediate range at DP01. There was otherwise no clear spatial trend in nutrient concentrations at the inter-causeway stations. Ammonia fell in the intermediate range at DP02, DP03, and DP04, and in the lowest range at DP08. TKN fell in the low range at DP02 and DP08, and in the intermediate range at DP03 and DP04, while total nitrogen fell in the low range at DP03 and DP08, and in the intermediate range at DP02 and DP04. Phosphate concentrations fell in the lowest range at DP04 and DP08, and in the intermediate range at DP02 and DP03. Sulphide concentrations were in the upper range at DP04, in the intermediate range at DP08, and in the low range at DP02 and DP03.

Redox values were generally between –100 mV and –300 mV. Exceptions to this included redox values measured at DP01 in Q1-2008 (60 mV), DP02 in Q4-2008 (-60 mV) and DP06 in Q1-2008 (70 mV), and an anomalous redox value of +50 mV measured at DP01 in Q2. As in 2007, there was no clear spatial trend in redox values (**Table 19**). If a consistent decrease in redox values were observed, it might suggest a trend towards eutrophication.

3.3.2 Temporal Trends between Quarters

3.3.2.1 Metals

Temporal variation in metal concentrations in the intertidal sediments is shown in **Figure 56**.

Copper, chromium, and zinc concentrations showed the greatest variability at DP01, but remained within the same range as those measured in 2007. No net increase or decrease in copper, chromium, or zinc concentrations was observed.

Arsenic concentrations were relatively stable at DP01, DP02, and DP04 through the first three quarters of 2008, but increased by 40 to 60% in Q4-2008. DP05 was the only station to show a clear trend in arsenic concentrations, with concentrations increasing from less than 5 mg/kg in Q1-2007 to 8.6 mg/kg in Q4-2008. The arsenic concentrations at DP06 increased from less than 5 mg/kg in Q1-2008 to 7.6 mg/kg in

Q4-2008; however, these values are within a similar range to those measured in 2007. With the exception of Q1-2008, arsenic concentrations measured at DP07 in 2008 were greater than those measured in 2007. It should be noted that despite the apparent increases at DP05, DP06, and DP07, arsenic concentrations were still considered low, as they were less than two times the detection limit of 5 mg/kg and well below the $SedQC_{SS}$ of 26 mg/kg.

In 2008, mercury concentrations were stable at DP01, DP02, and DP04, with values generally falling between 0.020 and 0.030 mg/kg. Mercury concentrations were also stable at DP05, but ranged from 0.057 to 0.080 mg/kg. At DP06, mercury concentrations were similar to those measured in 2007, ranging from 0.0251 to 0.0513 mg/kg. Mercury concentrations at DP03 and DP07 were in the same range as at DP06.

3.3.2.2 Eutrophication-related Parameters

Of the five eutrophication parameters considered in sediment, sulphide has shown the greatest variability over the course of the two years of monitoring (**Figure 57**). As in 2007, sulphide concentrations at DP02, DP06, and DP07 remained relatively stable, while those at DP01 varied by up to three orders of magnitude. Sulphide concentrations at DP03, DP04, and DP05 ranged over two orders of magnitude. There were no clear temporal trends in sulphide concentrations.

Ammonia concentrations were relatively stable over time, with lower concentrations consistently observed at reference stations DP06 and DP07.

As anticipated, DP01 showed the greatest variability in phosphate, TKN, and total nitrogen concentrations. There was no evidence of an overall increase or decrease in concentrations. A rise in total phosphate was observed in Q4-2008, but this is unlikely to be related to DP3 construction. At DP02, DP03, and DP04, phosphate, TKN, and total nitrogen concentrations have remained stable over the course of the two years of monitoring. The TKN and total nitrogen concentrations were, however, generally greater at DP04 than at DP02 and DP03. The TKN and total nitrogen concentrations showed a slight increase over 2008, but remained within the range measured in 2007. As previously noted, the highest nutrient concentrations were observed at DP05. The TKN and total nitrogen concentrations were variable, but consistently fell between 0.14 and 0.19 mg/kg. The phosphate concentration at DP05 has, increased from 610 mg/kg in Q1-2007 to 955 mg/kg in Q4-2008. At DP06 and DP07, the TKN and total nitrogen concentrations were similar to those at DP02 and DP03. At DP06, as at DP04, a slight increase in TKN was observed over the course of 2008, but the values remained in the same range as those measured in 2007.

3.4 EELGRASS

The eelgrass habitat in the area that was affected by sediment deposition and new drainage channel formation adjacent to the perimeter dyke in the inter-causeway area in 2007 has recovered. The distribution has changed, however the net area occupied by *Z. marina* at this location is comparable to the area mapped in 2003. It is possible that the eelgrass habitat at this location will expand to cover substrate that is currently unvegetated.

A reduction in *Z. japonica* habitat was noted relative to 2007 in an area that was unvegetated in 2003. *Z. japonica* is an annual species that develops from seed each spring and therefore its density and distribution may be highly variable between years and is strongly influenced by climate. The reduction in *Z. japonica* habitat may have been caused by the cooler than average spring in 2008.

The changes that have occurred in the transition (mixed) zone and the adjacent *Z. marina* zone were likely caused by sediment deposition, as indicated by vertical rhizome growth. A comparison of the eelgrass distribution maps (**Figures 39** and **40**) indicates that the sediment deposition is likely caused by the evolution of the sand lobe and associated dendritic channels since the area of diminished eelgrass productivity extends to the sand lobe. Sand accretion in the vicinity of the channels has been studied in detail by NHC (Section 3.1.5.3 – AMS 2007 Annual Report). NHC concluded, “it is considered unlikely that these large channels, which are removed from the assumed area of influence of the new DP3, are being influenced by, or have influence on the present project.” It is likely that reduction in *Z. marina* habitat and expansion of transition habitat are the result of sediment movement and accretion caused by the continued evolution of the dendritic channels and sand lobe, and not related to the development of DP3.

The area near the head of the channel parallel to the BC Ferries Causeway supports a patchy distribution of *Z. marina* and *Z. japonica*; this area was classified as unvegetated sand in 2007. It is possible that both species were present in 2007 but at a density too low to provide a signal on the orthophoto. The unvegetated sand polygons near the end of the BC Ferries Terminal will be ground truthed in 2009 to determine whether these areas are also vegetated.

The lower edge of *Z. marina* distribution appears to have expanded over the last year; however this may simply reflect the environmental conditions at the time the photos were recorded. A subtidal imaging survey (SIMS) survey, using a georeferenced remotely operated video camera, will map the lower distribution of *Z. marina* in 2009.

3.4.1 Eelgrass Vigour & Health

Research has shown that eutrophication is one of the factors that may lead to an elevated epiphyte load on eelgrass. The epiphyte load on the eelgrass at all stations on Roberts Bank and at the reference stations at Boundary Bay in 2008 was comparable to previous years at the time these beds were surveyed.

Beggiatoa sp. is often used as an indicator species to identify degraded marine habitats. The filamentous preteobacteria forms visible whitish mats in many polluted marine environments, especially those with sediments rich in hydrogen sulphide. *Beggiatoa* sp. was not noted at either Roberts Bank or Boundary Bay during the 2008 eelgrass surveys.

The distribution of *Zostera marina* and the absence of *Z. japonica* at all sampling stations except Site 1 was consistent with records from previous years. Site 1 is located in the area that has changed from continuous *Z. marina* to transition zone (**Section 2.5.1** and **3.4.1**). The *Z. marina* in this area exhibited vertical rhizome growth which is indicative of recent sediment deposition. The colonization of this area by *Z. japonica*, a species that is usually located above *Z. marina* in the intertidal zone, is further indication that the elevation has increased.

The eelgrass density, shoot morphology, and relative productivity are compared between sampling dates in **Sections 3.4.2** through **3.4.4**.

3.4.1.1 2008 vs. 2007

The density of shoots was similar or greater at all stations in 2008 relative to 2007. The difference was significant at Site 4 west of the Deltaport Causeway and at the deepest station (WR3) in Boundary Bay.

The mean shoot length tended to be greater in 2008 relative to 2007, with the exception of Site 1 at Roberts Bank where mean shoot length had decreased by 44%; the difference was significant. The increase in length was significant at Site 5 and WR3.

The mean shoot width was similar at all stations except Site 1 where it had decreased; the difference was significant.

The LAI (relative productivity) at Site 1 had decreased by approximately 60% over the last year; the difference was significant. There were increases in LAI at all of the other sites however it was only significant for those sites where density and/or shoot length was significantly different.

There was an absence of flowering shoots at Site 1 in 2008; therefore the t-tests using the Bonferroni correction adjustment returned the result of 'insufficient data'. A standard paired two-sample, 2-tailed t-test found a significant difference in reproductive density at Site 1 between 2008 and 2007. The reproductive density at the other Roberts Bank sites at Roberts Bank tended to be slightly lower in 2008; however these differences were not significant. The reproductive density at the Boundary Bay sites was greater in 2008 than in 2007; the difference was significant at Sites WR1 and WR2.

3.4.1.2 2008 vs. 2003

A comparison of the 2008 and 2003 data sets for Site 1 found trends that were consistent with those described for 2008 relative to 2007 above. The overall trends at the other stations were also similar to those described for 2008 vs. 2007, although the sites where the differences were significant were not always the same (**Table 3.4-1**).

Table 3.4-1 A summary of the comparisons when significant differences that were observed when each parameter measured in 2008 was compared with the data from 2003 and 2007

Site #	Total Density	Length	Width	LAI	Reproductive Density
Inter-causeway near Deltaport Causeway					
1	-	2003/2007	2003/2007	2003/2007	2003/2007
2	2003	2003	2003	2003	-
Inter-causeway area near BC Ferries Causeway					
5	-	2007	2003	2007	-
6	-	-	-	-	-
West of Deltaport Causeway					
3	-	-	2003	2003	-
4	2003/2007	-	2003	2007	-
Boundary Bay					
WR1	2003	-	-	-	2003
WR2	2003	-	-	2003	2003/2007
WR3	2003/2007	2007	-	2007	-

3.4.2 Summary

The eelgrass productivity in 2008 was greater at all sites except Site 1 relative to the 2003 and 2007 data sets. The reduction in productivity at Site 1 appears to be the result of sediment deposition by the sand lobe and expansion of the dendritic channels, and therefore not related to development of DP3.

Site 1 was originally selected as a reference station due to its proximity and similarity to Site 2, the site closest to DP3. The 2009 survey should include an additional site that is within the same polygon as Site 2 and may be used to assess eelgrass habitat changes near DP3.

Eelgrass shoot density, length, and relative productivity tended to be greater than usual at many sites along the south coast in 2008 (C. Durance, pers. obs.). The size, morphology, and distribution of eelgrass vary in response to chemical and physical forcing factors (Thom et al. 2003, Thom et al. 1998, Phillips 1984). One of the physical factors that has recently been recognized for its influence on eelgrass productivity is the Pacific Decadal Oscillation (PDO).

The PDO was first described in 1996 by Steven Hare while researching correlations between Alaska salmon production and Pacific climate. 'The PDO Index is defined as the leading principal component of North Pacific monthly sea surface temperature variability. Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and inhibited productivity off the west coast of the contiguous United States, while cold PDO eras have seen the opposite north-south pattern of marine ecosystem productivity' (http://jisao.washington.edu/pdo/).

A study in Willapa Bay, Washington reported an annual increase in total eelgrass biomass during a PDO phase shift from warm to cold between the years 1998 and 2001 (Thom et al. 2003). The total above ground eelgrass biomass increased from 1.2 x 10^6kg in 1998 to 7.8 x 10^6kg in 2001. A similar phase shift started in 2007 and continued through 2008 (http://jisao.washington.edu/pdo/).

The PDO may be a significant factor contributing to the increased productivity of eelgrass that has been observed in this study. A subsequent reduction in productivity may be observed during periods of time when the PDO shifts from cold to warm.

3.5 BENTHIC COMMUNITY

The rough weather conditions experienced during the Q1-2007 baseline sampling event had a significant effect on sediment grab recovery. Only at station DP05, where an estimated 8 litres of sediment were recovered, was the sample considered optimal. At the remaining sample locations, sample recovery ranged from 2 to 3 litres. In 2008, approximately 5 litres were recovered at each station, with the exception of DP05, where approximately 8 litres of sediment were recovered. The increase in species abundance observed at DP03 and DP04 in 2008 is likely linked to increased sediment recovery, as opposed to an increase in the benthic invertebrate population.

Adult, intermediate, and juvenile benthic invertebrates were observed at all stations. The diversity in taxa observed in the samples suggests that benthic invertebrate populations in both the inter-causeway area and the reference area were healthy after the second year of Third Berth construction activity. This is substantiated further by Shannon's Index, which shows that the stations in the inter-causeway area are relatively diverse and individual species are also distributed fairly evenly among the stations.

There were no observable correlations between either grain size or sulphide concentrations and species abundance or taxa richness, confirming results from 2007.

The classes observed in 2008 were similar to those observed in 2007, but there was some variation in the species observed and the percentage accounted for by the different classes at the six stations. The following classes were observed in 2007, but not in 2008: *Hydrozoa, Tubellaria, Hirudinoidea,* and *Echinoidea*. Less than three organisms in each of these classes were observed in 2007, except for *Hydrozoa*, of which ten were observed. *Enteropneusta* was the only class observed in 2008 that was not observed in 2007. The most notable shifts in taxa from 2007 to 2008, were increases in the number of *Ophiuroidae* at DP04 and *Polychaeta Sedentaria* and *Amphipoda*at DP03, and a decrease in the number of *Amphipoda* at DP02 and DP04. These changes are likely a function of natural variability.

The benthic invertebrate community at DP08 resembled that observed at DP02 and DP03 in terms of diversity and equitability. Species abundance and the number of taxa at DP08 were closer to those observed at DP04. These

Species ratios can be used to evaluate trends towards eutrophication. As such, the polychaete-amphipod ratio was calculated for each station (**Table 3.5-1**). Polychaetes are considered a tolerant species, able to proliferate after an increase in organic matter. They are widely used as indicators of anthropogenic or natural disturbance. Amphipods, in contrast, are relatively sensitive to environmental changes.

Table 3.5-1 The Polychaete-amphipod Ratio in 2007 and 2008

	DP02	DP03	DP04	DP05	DP06	DP07	DP08
2007	7.8	5.8	0.9	282.0	8.0	11.7	-
2008	22.5	5.8	15.2	92.7	1.2	3.4	1.6

The increase in the polychaete-amphipod ratio at DP02 and DP04 resulted from a decrease in the number of amphipods collected, rather than a significant increase in the number of polychaetes. Given that the sediment chemistry results did not shown a significant change in metal or nutrient concentrations at these stations, the decrease in the amphipod count is more likely to be a function of sediment recovery and natural variability, perhaps linked to the timing of the sampling. The decreases noted at DP05 and DP06 are a result of a slight increase in the number of amphipods; however, the numbers of polychaetes and amphipods at these stations were very consistent in 2007 and 2008. At DP07, the amphipod total showed almost no variation between 2007 and 2008, but the polychaete count dropped from 210 to 57. The number of amphipods present at DP08 was similar to that recorded at DP03, but the number of polychaetes was approximately 3.5 times lower than at DP03. In general, the data does not suggest a trend towards eutrophication.

Nematodes are very close in size to the 1 mm mesh. Since a number of nematodes may have passed through the screen, Biologica did not consider the number of nematodes counted to be sufficiently accurate to present them in the report. The nematode-harpaticoid ratio was therefore not calculated.

3.6 BIRDS

3.6.1 Great Blue Heron

Similar to previous years herons were detected in greatest numbers from late spring through summer (April – August) (Hemmera, 2008). Increases in heron numbers within the study area in spring corresponded with territory establishment and nest initiation at the end of March/early April, while the large increase in heron numbers documented in June/July are most likely a result of the successful fledging of juvenile herons from nearby nests that subsequently forage within the inter-causeway area. Heron foraging in the inter-causeway area is tidally influenced because daylight low tides expose the extensive eelgrass beds, which provide shelter for a variety of prey during the summer months. During the spring and summer, great blue heron use the eelgrass beds within the inter-causeway area for foraging. Food resources available to herons within the inter-causeway area include sculpins, sticklebacks, herring, tube snout, starry flounder, gunnels, and surf perch. Through the winter months, the reduction or absence of daylight low tides reduces heron access to the eelgrass beds. In addition, fish are known to remain in the eelgrass beds during this time; however, they tend to be larger and harder for the herons to catch (Butler 1997). Butler (1997) provides an excellent overview of the seasonal behaviour of coastal great blue herons, and patterns elucidated in his work are consistent with the observations collected during the survey period addressed in this report.

The large number of herons (n=684) documented in 2003 is comparable to the maximum count documented in 2007 (n=433) and 2008 (n=424). This apparent decrease in heron use of the Deltaport Transect may or may not be a real phenomenon, as fluctuations such as these can result from a number of factors. Firstly, more great blue herons could have been distributed along the TFN Transect than the Deltaport Transect on the day surveyed. This partly accounts for the difference, as the gap between 2003-2004 and 2007-2008 is reduced to approximately 250 observations when data from the TFN Transect for 2007 and 2008 are incorporated (**Figure 2.7-22**). Secondly, survey results are known to fluctuate daily depending on a number of biotic and abiotic conditions (such as weather, predator abundance, and prey abundance) that can influence bird distribution and abundance within an area. It is possible that on the day surveys were conducted heron use of the study area was atypically low. This phenomena was illustrated in May 2007, from survey data collected in the second half of May that was not included in this report as a result of one survey per month being systematically selected for inclusion (see Methods Section 1.3.6). On May 23, 2008 605 great blue heron were observed along the Deltaport Transect compared to only 280 on May 7 and 8, 2008 further reducing the difference between 2003-2004 and 2007 to approximately 75 birds. At this time it is believed that overall heron use of, and abundance within, the study area has not been affected, as herons were detected in roughly equal numbers during 2007 and 2008.

The Deltaport Third Berth Environmental Assessment (VPA, 2005) predicted potential impacts to coastal seabirds and waterfowl would result from direct habitat loss associated with the DP3 footprint. Based on comparisons between distribution and abundance data collected in 2003-2004 along the Deltaport Transect, it is possible that great blue heron have shifted their use away from habitats immediately adjacent to construction activities (i.e. PCs 12-14), as anticipated. In 2003-2004, key low tide foraging areas included PCs 12 – 15. In comparison, key low tide (eelgrass) foraging areas in 2007 included PCs 14 (DP) and 15 (DP3) inside of the crest protection, and key low tide foraging areas in 2008 included PCs 15 (DP=398 herons), 113 (TFN=232), and 109 (TFN=221) (**Figures 12** and **43)**. Habitat loss associated with the DP3 footprint has precluded heron usage of approximately 6% of the total resting/roosting and foraging habitat available in the study area associated with infilling a portion of PC13 for DP3 construction.There appears to have been a possible shift by herons away from habitats adjacent to construction activities to other habitats within the study area (such as the TFN Transect) as the size of the DP3 footprint have increased. Based on the availability of alternative habitat and the extensive confirmed use of this alternative habitat by great blue herons during surveys conducted in 2007 and 2008, it is concluded that construction impacts have not had a detrimental effect on heron foraging in the inter-causeway area.

Observations recorded during the survey period also indicate that herons can be quite opportunistic and acclimatize to certain types of disturbance. For example, herons were frequently observed foraging along the riprap perimeter dyke during active construction. Additionally, herons appear habituated to traffic from both the Deltaport Causeway and the BC Ferries Causeway; however, less common, “acute disturbances” such as surveyors or recreational walkers and cyclists sometimes caused herons to abandon a resting or hunting locations if they were approached too closely.

Eagles appear to pose the greatest threat to herons nesting at the base of Tsatsu Bluffs, and in one instance, an eagle reportedly attacked and killed a full-grown heron (Westshore Terminals employee pers. comm. 2007).

3.6.2 Brant

The abundance of black-bellied brant in the study area fluctuated between approximately 500 and 4,500 birds during November and December 2008 (**Figure 2.7-4**). During this period only black-bellied brant are present in the study area. The number of observations differed depending on which type of survey was conducted. Estimates derived from point count data tended to underestimate the number of brant using the inter-causeway compared to estimates derived from "windshield" surveys. Abundance estimates from windshield surveys were up to eight times higher than point count estimates for the same period, (**Figure 2.7-5**, November 2008). The discrepancy between the estimates is believed to result from the fixed nature of the point counts, where birds can potentially move between points and avoid being counted, compared to the rapid assessment methodology employed using windshield surveys, which result in the entire inter-causeway area being sampled in a relatively short period of time ensuring that all brant are counted. As a result, Hemmera considers windshield surveys an effective and accurate method of determining the number of brant using the inter-causeway area.

Increasing numbers of brant observed during late April are attributed to migrants staging in the inter-causeway area on their way to summer breeding grounds in Alaska. This is evidenced by an influx of grey-bellied brant that do not over-winter in the Lower Mainland, as well as the presence of black-bellied brant. During this period, brant were observed to use the inter-causeway area to feed on eelgrass, obtain gravel (generally along exposed shoreline along the TFN Transect), and loaf, rest, or preen. A conservative peak estimate of 3,619 brant observed in April 2008, and 3,710 brant observed during late April 2007 are consistent with previous estimates of 3,560 brant documented using Roberts Bank as spring staging habitat (unpublished data cited in Moore *et al*., 2004). Additionally, estimates of 1,000 over-wintering brant in the inter-causeway area reported in Butler and Cannings (1989) are consistent with typical over-wintering brant numbers observed during both 2007 and 2008.

With respect to diet, brant are adaptable to changes in the composition of eelgrass beds from the native Z. *marina* to the introduced *Z. japonica*. Dietary studies conducted on brant feeding in nearby Boundary Bay indicate consumption of both *Z. japonica* (57% dry mass) and *Z. marina* (41% dry mass) based on examination of esophageal contents (Baldwin and Lovvorn, 1994). As expected, general comparisons of brant and eelgrass distributions within the inter-causeway area indicate that brant primarily forage in areas of abundant eelgrass. However, it is important to note that the bird survey methodology is not conducive to examining detailed spatial relationships between brant and eelgrass. Brant use of the inter-causeway area appears to have not been affected by activities associated with Deltaport Third Berth construction as the distribution of brant along the Deltaport and TFN Transects has not changed (**Figures 12** and **44).**

As described in the AMS 2007 Annual Report (Hemmera, 2008), recent studies have found that both Boundary Bay (peak estimate of 1,660 brant during spring migration) and Roberts Bank (peak estimate of 3,170 during spring migration) received lower usage than expected by spring staging brant along the Pacific Flyway based on the amount of eelgrass habitat available and the site's degree of isolation from other staging locations (Moore et al. 2004). These studies found that there is sufficient eelgrass habitat to support more brant in both the inter-causeway area and at Boundary Bay, than are currently supported. Additionally, both of these staging areas were among the least isolated of the sites examined. In this same study, isolation from other staging areas was shown to influence brant usage, as isolated eelgrass habitats are implied to be more critical for staging brant than those in close proximity to other staging areas. The reason(s) for lower than expected usage of the inter-causeway and Boundary Bay habitats are not known.

During the survey period, observations of acute disturbances resulting in brant displacement were limited to bald eagles flying over, surveyors, cyclists, and walkers (sometimes with dogs), disturbing resting and feeding birds near the shoreline. In all instances, brant and other waterfowl took off and circled for a short period of time before settling down on or close to the same location. It is likely that birds using the inter-causeway area are habituated to a degree to disturbance as a result of fairly constant ship, truck, and rail traffic, as well as recreational users including people walking along the TFN dyke, and cars and trucks pulling off along the Deltaport Causeway. Brant were typically observed offshore (**Figure 44** and **Appendix E**) and did not react to regular traffic such as vehicles moving along the Deltaport Causeway or the BC Ferries Causeway or surveyors, cyclists, and walkers using the edges of the study area.

No negative impacts to brant from the DP3 construction were observed during the survey period. It is assumed that the main impact to brant is exclusion from the portion of the perimeter dike lost to the DP3 footprint. This was a known resting site and a location where loose eelgrass fronds would wash up providing an easy foraging opportunity for brant.

3.6.3 Shorebirds

In 2008, 12 species of shorebirds totalling 49,143 individuals were observed within the project area. Western sandpiper and dunlin made up the vast majority of these observations, with western sandpipers most abundant during spring (April to early May) and fall (July to early August), while dunlin were observed during most of the year, absent only during mid summer and most abundant in winter. Most observations were recorded along the TFN Transect where large exposed mudflats provide abundant habitat for foraging birds.

Annual western sandpiper abundance and distribution has been known to fluctuate greatly on an international scale. This trend was mirrored between 2003-2004, 2007, and 2008 within the inter-causeway as annual peak counts ranged from lows of 394 and 663 in 2004 and 2007, respectively, to greater than 1900 birds in 2008. Dunlin followed a similar trend with peak annual counts and the timing of use of the study area fluctuating between years. The cause of these changes in use are unknown as the primary foraging area, where most dunlin and western sandpiper were documented, is along the TFN Transect more than 2.5 km away from Deltaport construction activities and appears unchanged.

No direct impacts to shorebirds have been observed. However, continued monitoring of sedimentation and eelgrass distribution as part of this AMS is recommended, as potential alterations to the mudflats resulting from changes to the inter-causeway topography, water elevations, and the distribution of eelgrass could negatively impact shorebirds. *Z. japonica* is able to grow in slightly more exposed locations than the native *Z. marina* and consequently, there is a potential for loss of critical mudflat feeding habitat if these changes were to occur.

3.6.4 Coastal Waterbirds

General trends in abundance, use, and distribution of coastal waterbirds did not differ between years, with the vast majority of birds observed using habitats along the Deltaport Transect in all study years, except for dabbling ducks, which primarily use the TFN Transect. Numbers of over-wintering waterfowl were consistent with peak numbers of dabbling ducks (approximately 25,000 in December 1988) using the inter-causeway area as reported in Butler and Cannings (1989). Overall, coastal waterbird abundance and habitat use within the inter-causeway area did not differ significantly between 2003-2004, 2007, and 2008.

Coastal waterbirds observed in PC 12 and PC 13 appeared habituated to disturbance from DP3 construction activities, likely due to the extent of disturbance that already occurs in this area from operation of the existing two berths at Deltaport and the Seaspan tug facilities located in the embayment area. Diving birds including cormorants, grebes, loons, mergansers, and other diving ducks were regularly seen swimming, diving, and feeding in close proximity to active work.

Dabbling ducks, primarily American wigeon and mallard, were frequently observed resting/roosting along the perimeter dyke, likely due to the protection from wind and wave action that it provides. Based on observed foraging patterns for dabbling ducks, DP3 related construction impacts are considered negligible. However, non-routine disturbance, such as observers, walkers, and cyclists using the dyke or walkway often caused birds closest to the shoreline to take flight. Disturbed birds would settle either slightly further out within the same PC, or move further along the Transect staying at approximately the same tidal line.

Based on the observations of bird activity in the inter-causeway area, it is concluded that coastal waterbird species using the study area have not been significantly impacted by DP3 related construction activities to date. Rather, it is habitat loss (estimated at 6% of total resting/roosting and foraging habitat available) that appears to have the greater impact. Based on the availability of alternative habitat within the study area, and the observed usage of alternative habitat by bird species in the inter-causeway area, this habitat loss does not appear to be significant and is consistent with the predicted impacts assessed in the EA.

3.6.5 Raptors

During studies in 2003-2004, a pair of osprey was observed nesting in a navigational aid situated within the DP3 footprint (ECL Envirowest, 2004). Hemmera and VFPA relocated this nest on March 12 and 13, 2007, under BC Ministry of Environment (MOE) permit SU07-31495 granted under provisions of the *Wildlife Act*, prior to the arrival of the osprey pair to the inter-causeway area in the spring of 2007. While the navigation marker and the remnant nest structure were successfully relocated and a pair of osprey returned to the inter-causeway area in 2007 and 2008, no nesting activity was observed either on the relocated platform or elsewhere in the vicinity of the study.

3.6.6 Ecosystem Health and Function

The main objectives of the bird study are to provide complimentary data towards addressing the concerns regarding potential marine eutrophication and changes to coastal erosion processes that could potentially result in changes in the distribution and composition of local biota, including shorebirds and coastal seabirds, in the inter-causeway area. To this end, the bird study data are considered one indicator of ecosystem structure and function. Due to the possibility that changes to the ecosystem over time can be linked to key species such as great blue heron, brant, western sandpiper, and dunlin, monitoring bird usage within the inter-causeway area is part of the overall strategy to monitor ecosystem structure and function in the inter-causeway area.

Comparisons of 2007 and 2008 AMS data and baseline data collected by Envirowest and CWS in 2003-2004 for the Deltaport Transect suggest few changes and high natural annual variability in bird abundance and usage of the inter-causeway area. To date, construction impacts on shorebirds and coastal seabirds appear to be minimal. The continued use of the study area seems driven by the availability of productive foraging habitat. As such, the maintenance of existing eelgrass beds and mudflats are believed to be the most important factor in ensuring the Inter-causeway remains an area of continued importance to shorebirds and coastal seabird populations within the Lower Mainland.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 COASTAL GEOMORPHOLOGY

The AMS monitoring program has been on-going for almost 20 months since its inception in April 2007 to the end of 2008. For most of the monitoring activities, the data analysed in this report represents a full year of quarterly monitoring in addition to the eight months of data collected in 2007. However, for some of the activities, such as wave monitoring and some of the newer DoD rods, the period of record is shorter. For some of the monitoring activities, such as the monitoring of the Crest Protection Structure, portions of the interpretation of orthophotographs and portions of the coastal geomorphology mapping activities, this data can reasonably be considered to provide baseline data for the pre-project condition. In other cases, such as with wave monitoring, erosion/deposition monitoring, and monitoring of turbidity, the data will be considered to represent conditions with the new DP3 project in place. The distinction lies mainly with the proximity to the new project as well as the amount of time that would be expected to pass before effects would be detected.

Construction-related activities in 2007 at the DP3 perimeter dike generated a series of new drainage channels in the vicinity of the dike. The area of new drainage channels has stabilised. The expansion of the channels ceased once the supply of water draining from the DP3 perimeter dike was stopped when the area was infilled by pumping dredgeate into the footprint area in June of 2007. Since that time the steep-sided cross-section shape of the channels has evolved into a gently-sloping rounded cross-section shape. Observations in the field indicate that only very small amounts of sediment are transported within the channels. Mapping from the orthophotos shows that the position of the channels has not changed between the time that the 2007 and 2008 photos were taken, and the DoD rod data indicates a much lower level of erosion and deposition in this area.

No other long-term physical changes have occurred on the tidal flats that could be attributed to the construction of DP3.

The AMS monitoring program has collected a significant amount of data that describes the ongoing physical processes at Roberts Bank. One of the most important conclusions that can be drawn from this data is that the magnitude of change on the tidal flats is not large. As expected, sedimentation and erosion rates are small (generally less than 10 cm) and turbidity levels are generally very low. These findings are consistent with the predictions that were made in the coastal geomorphology studies.

Based on the observations made over the last year we recommend that the monitoring program be implemented in 2009 without substantial modifications.

As noted in Section 3.1.6, there have been no major issues identified in the AMS monitoring program that would be captured by the topographic and hydrographic surveys that were first carried out at the inception of the monitoring program. Follow-up surveys were scheduled to be completed after three or four years, as per the DP3 Project AMS Detailed Workplan (VPA & Hemmera, 2007). Based on the above findings, we recommend that the surveys be conducted in 2010.

It was originally planned that tidal currents in the vicinity of DP3 would be measured in 2008 using an Acoustic Doppler Current Profiler (ADCP) to verify the results of the numeric modeling that was carried out as part of the Coastal Geomorphology Study. However, the DP3 footprint was not completed until late fall 2008, at which time tide and wave conditions were not suitable. We recommend that these measurements be made during a large tidal exchange during the summer of 2009.

4.2 SURFACE WATER QUALITY

In 2008, there was no evidence of metals loading as a result of the construction activities at Deltaport. Elevated metal concentrations in surface water at DP01 do not appear to be having an effect on surface water chemistry at stations DP02 or DP03. Mercury exceedances identified at DP02 in Q3-2008 and at DP06 in Q2-2008 are anomalous, as mercury concentrations have otherwise been less than detection limits over the two years of monitoring. Continued monitoring of the metals concentrations in surface water is recommended for 2008. However, if the observed pattern of metal concentrations persists in 2009, we recommend deleting metals parameters from the monitoring program in 2010.

The key spatial trends identified for nutrients in surface water were the elevated nutrient concentrations at DP01 and the higher phosphate and nitrate at the intertidal inter-causeway stations. The elevated nutrient concentrations at DP01 likely result from inputs from adjacent agricultural land. They do not appear to be affecting overall nutrient concentrations in the inter-causeway area. The elevated phosphate and nitrate concentrations measured in the inter-causeway area are likely a function of greater biological activity in the sheltered environment. There were no clear temporal trends for nutrients in surface water. Continued monitoring of the nutrient concentrations in surface water is recommended for 2009.

There is no evidence of adverse effects to the valued ecosystem components (e.g., eelgrass density and distribution, benthic invertebrate community, bird usage) in the second year of the AMS program or of a trend towards increased levels of nutrients suggesting eutrophication.

4.3 SEDIMENT QUALITY

Metal concentrations complied with the BC CSR sediment quality standards.

Lithium geonormalization was used to distinguish between natural background concentrations and anthropogenic metal inputs. Outliers to the lithium normalized regression line represent potential external enrichment for aluminum, barium, copper, and manganese in 2007; however, no such outliers were observed in 2008. While metal concentrations measured at DP05 in 2008 were greater than average, lithium geonormalization did not suggest an anthropogenic source.

The lowest metal concentrations were measured at DP01 and the highest at DP05. Metal concentrations were in a similar range at DP05 in 2007. Metal concentrations did not exhibit a clear temporal trend, with the exception of arsenic, which has shown an increasing trend at station DP05. There is no known source of arsenic associated with construction at DP3. Metal concentrations in sediment at the remaining stations in the inter-causeway area were generally lower than those measured at the reference stations. These results suggest that the DP3 construction activities were not contributing to metals loading at the site.

As in surface water, nutrient concentrations were relatively elevated in the inter-causeway sediments. This is likely a function of the high level of biological activity in the sheltered environment created by the two causeways. There is no evidence, at this time, of eutrophication occurring as a result of the construction activities at Deltaport. Continued monitoring of the nutrient and metals concentrations in sediments is recommended for 2009. However, if the observed pattern of metals concentrations persists in 2009, we recommend deleting metals parameters for 2010 and continuing only with nutrients.

4.4 EELGRASS

The assessment of epiphyte load and the absence of *Beggiatoa* sp. indicate that the eelgrass habitat was in good condition.

The *Z. marina* distribution in the new drainage channel area adjacent to the DP3 footprint has increased and is similar in area (m^2) to that documented in 2003.

There is evidence of recent sediment deposition and reduced eelgrass productivity in the vicinity of Site 1, and through the transition (mixed) zone that extends between Site 1 and the sand lobe. It is likely that the changes observed at these locations have resulted from the evolution of the sand lobe and associated dendritic channels and are not related to the development of DP3. It is recommended that the survey in 2009 includes Site 1 and adds an additional station between Sites 1 and 2 that is representative of dense, continuous *Z. marina* habitat and provides the data that was originally supplied by Site 1.

The relative productivity (LAI) at all the inter-causeway sites, with the exception of Site 1, was greater in 2008 than in 2007 or 2003.

Comparison of the 2008 and 2007 eelgrass habitat maps revealed that eelgrass habitat loss has occurred near the dendritic channels; this is likely due to the evolution of these systems and not caused by the development of DP3.

There are no indications that the development of DP3 has negatively affected the inter-causeway eelgrass habitat.

With the exception of an additional station between Sites 1 and 2, no changes to the eelgrass survey program are recommended.

4.5 Benthic Community

The results indicate that the benthic invertebrate populations in both the inter-causeway area and the reference area appeared diverse, healthy and well established. Variations in total abundance and the number of taxa were not directly influenced by substrate type or sulphide concentrations. Nematode – harpaticoid copepod ratios could not be assessed as nematode counts were not considered reliable. Polychaete amphipod ratios increased at some stations and decreased at others between 2007 and 2008 but the data did not suggest a trend towards eutrophication or direct DP3 construction impacts.

At the request of the SAC, an eighth benthic community sampling station in the intertidal zone (DP08) was added in 2008 (**see Section 4.2**). The SAC has recommended adding an additional benthic community sampling location (DP09) in the vicinity of the new drainage channels for the 2009 monitoring program.

4.6 Birds

Overall, bird abundance and habitat use within the inter-causeway area did not differ significantly between 2003-2004, 2007, and 2008. The Deltaport Third Berth Environmental Assessment (Hemmera 2005) predicted potential impacts to coastal seabirds and waterfowl would be limited to direct habitat loss associated with the DP3 footprint. Based on the availability of alternative habitat and the extensive confirmed use of this alternative habitat by birds during the surveys conducted in 2007 and 2008, it is concluded that construction impacts have not had a detrimental effect on bird habitat use in the inter-causeway area.

The second year of the AMS implementation has incorporated several adaptations to the original bird monitoring program with marked success, and Hemmera recommends that this current monitoring program be continued for 2009.

4.7 Summary

In conclusion, to date, the AMS monitoring program has not shown compelling evidence to suggest that the DP3 construction activities are contributing to significant widespread adverse effects within the inter-causeway area.

Based on the findings to date, the following adaptations to the AMS program have been recommended:

- Measure tidal currents with an Acoustic Doppler Current Profiler (ADCP) in the summer of 2009
- Add an extra benthic community sampling station (DP09) in the vicinity of the new drainage channels.
- Add an extra eelgrass survey station between Sites 1 and 2, representing dense *M.marina* habitat.

No changes are recommended to the bird monitoring program.

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6.0 STATEMENT OF LIMITATIONS

This report was prepared by Hemmera Envirochem Inc. (Hemmera), based on work conducted by the project team of Hemmera, Northwest Hydraulic Consultants (NHC) and Precision Identification (the Project Team) for the sole benefit and exclusive use of the Vancouver Fraser Port Authority. The material in it reflects the Project Team's best judgment in light of the information available to it at the time of preparing this Report. Any use that a third party makes of this Report, or any reliance on or decision made based on it, is the responsibility of such third parties. The members of the Project Team accept no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this Report.

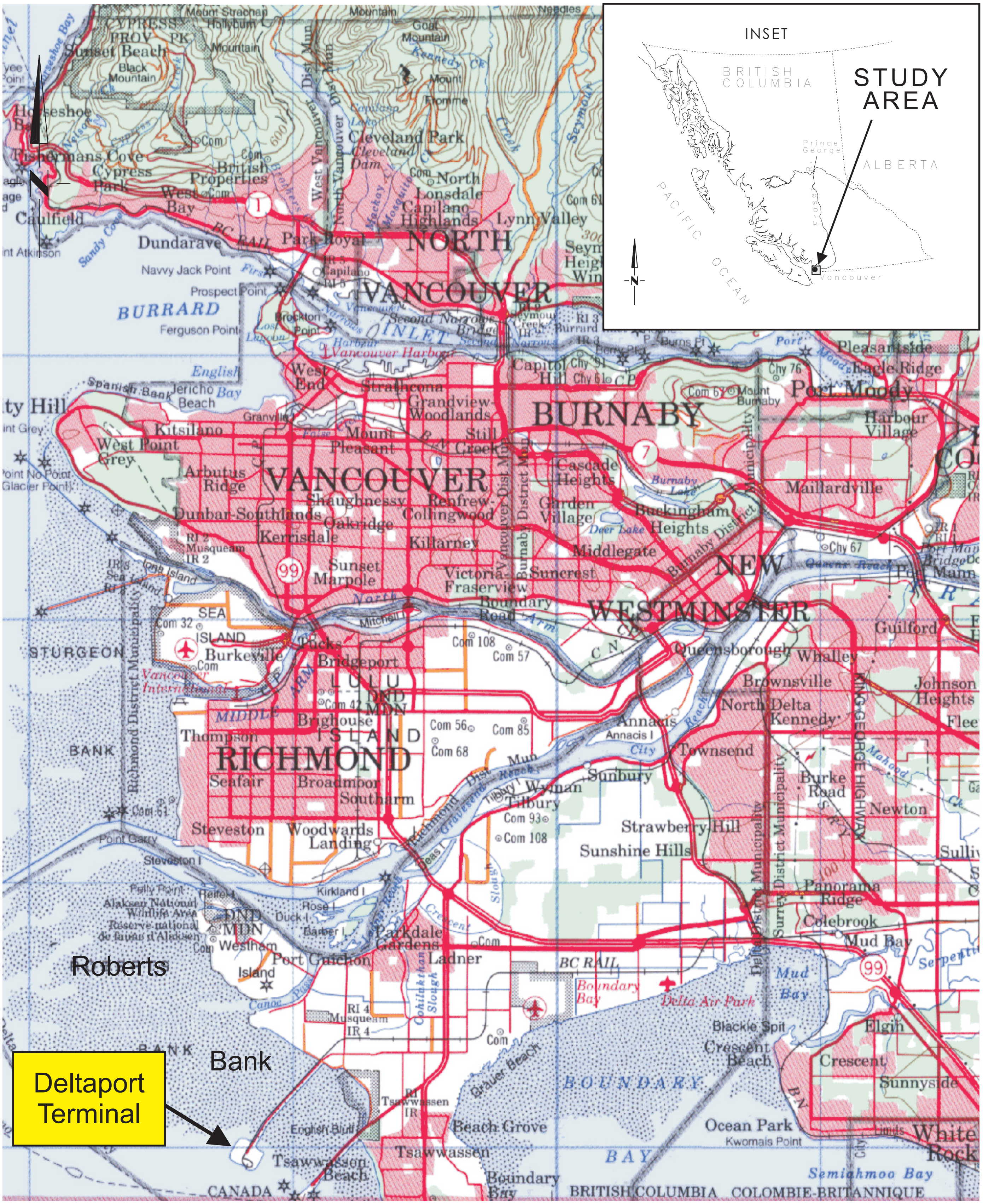
The Project Team has performed the work as described above and made the findings and conclusions set out in this Report in a manner consistent with the level of care and skill normally exercised by members of the environmental science profession practicing under similar conditions at the time the work was performed.

This Report represents a reasonable review of the information available to the Project Team within the established Scope, work schedule and budgetary constraints. It is possible that the levels of contamination or hazardous materials may vary across the Site, and hence currently unrecognised contamination or potentially hazardous materials may exist at the Site. No warranty, expressed or implied, is given concerning the presence or level of contamination on the Site, except as specifically noted in this Report. The conclusions and recommendations contained in this Report are based upon applicable legislation existing at the time the Report was drafted. Any changes in the legislation may alter the conclusions and/or recommendations contained in the Report. Regulatory implications discussed in this Report were based on the applicable legislation existing at the time this Report was written.

In preparing this Report, the Project Team have relied in good faith on information provided by others as noted in this Report, and has assumed that the information provided by those individuals is both factual and accurate. The members of the Project Team accept no responsibility for any deficiency, mis-statement or inaccuracy in this Report resulting from the information provided by those individuals.

The liability of the members of the Project Team to the Vancouver Fraser Port Authority shall be limited to injury or loss caused by the negligent acts of the Project Team. The total aggregate liability of Hemmera and the members of the Project Team related to this agreement shall not exceed the lesser of the actual damages incurred, or the total fee of the members of the Project Team for services rendered on this project.

FIGURES



HEMMERA

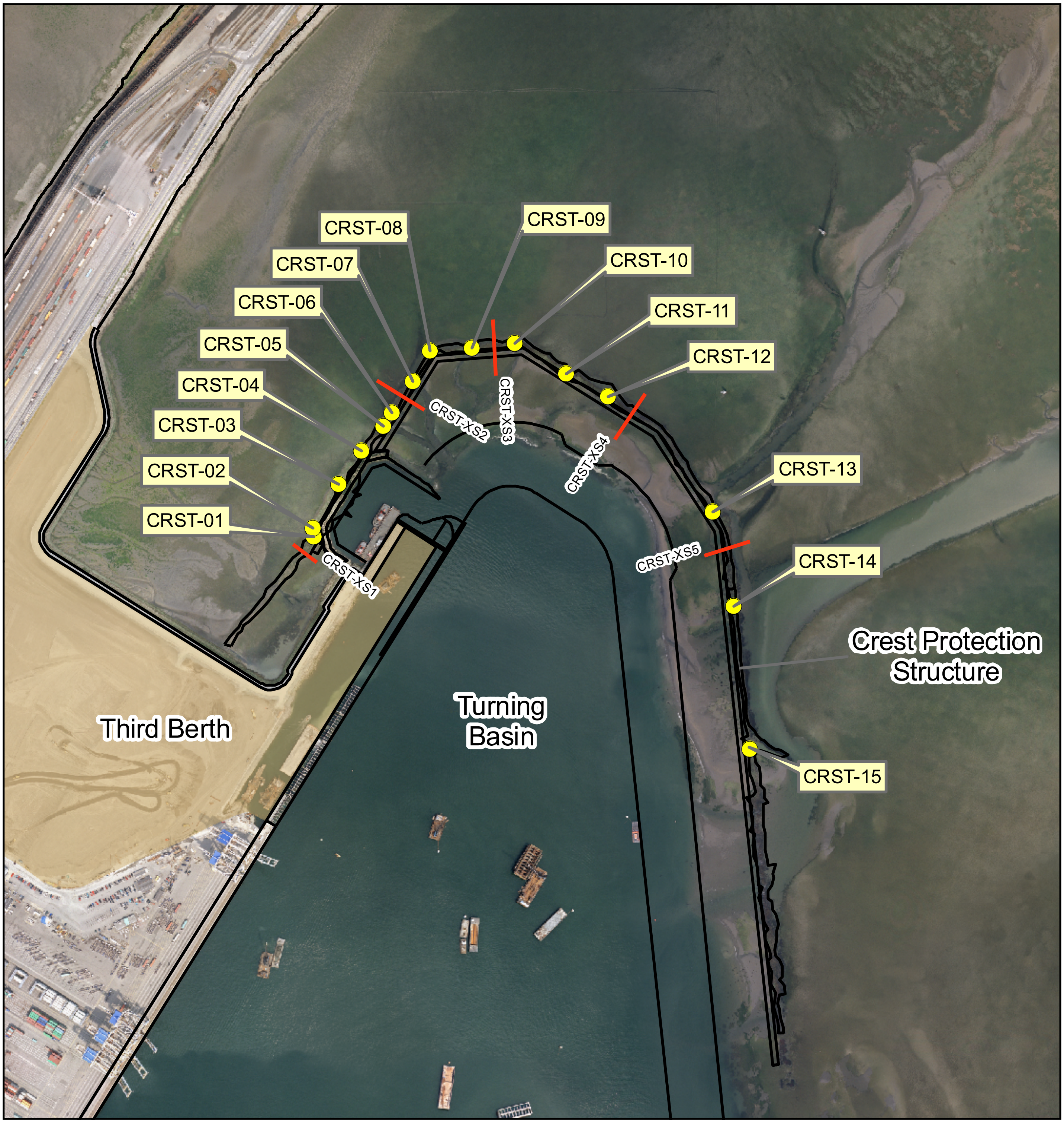
CLIENT:

PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2008 ANNUAL REPORT

SITE LOCATION

PROJECT No.		
499-002.11	SEPTEMBER 2009	FIGURE 1

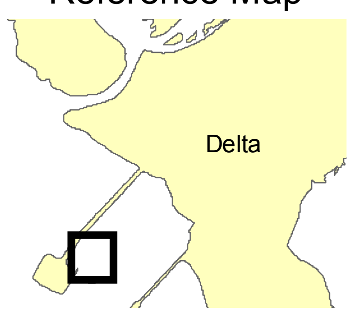


Legend

- Monitoring Sites
- Topographic Sections

Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Crest Protection Structure
Monitoring Site Location Map

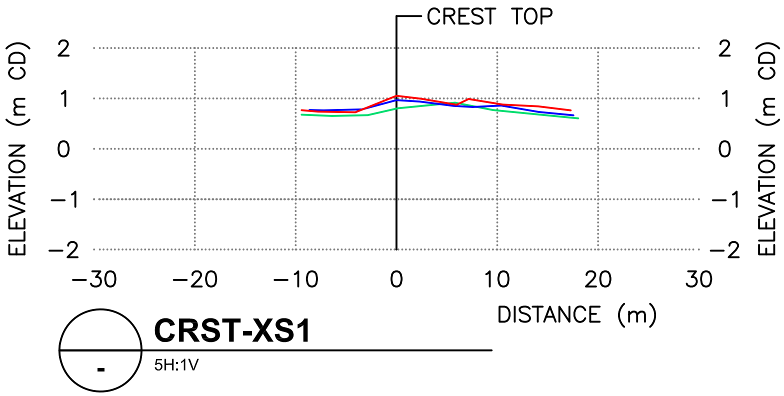
Scale - 1:7,500

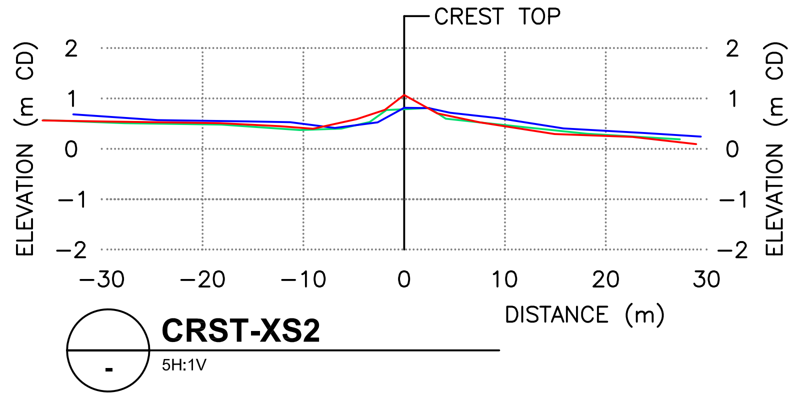
100 50 0 100 200 Metres

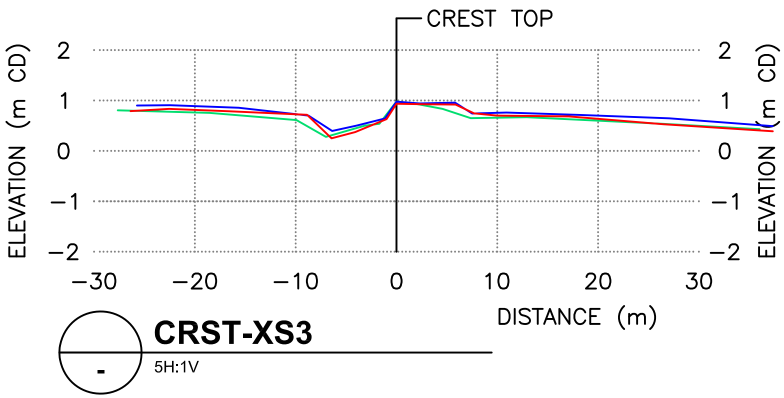
coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

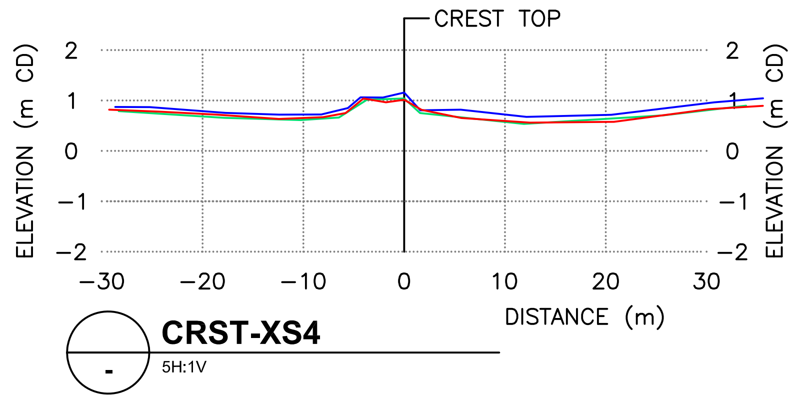
MSN, 34648 Deltaport Monitoring\GIS\Fig_CrestProtectionSites.mxd

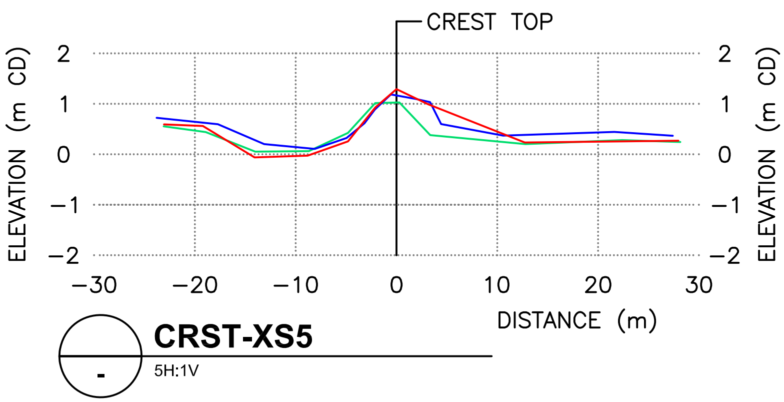
Figure 2











Note: sections drawn from shoreward (negative distance) to seaward (positive distance)

Jan 2008 survey
April 2008 survey
July 2008 survey

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM

2008 ANNUAL REPORT

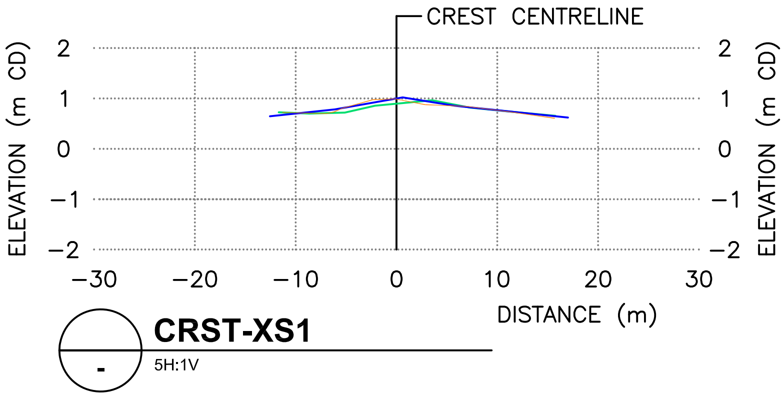
Crest Protection Structure
Monitoring Cross Sections

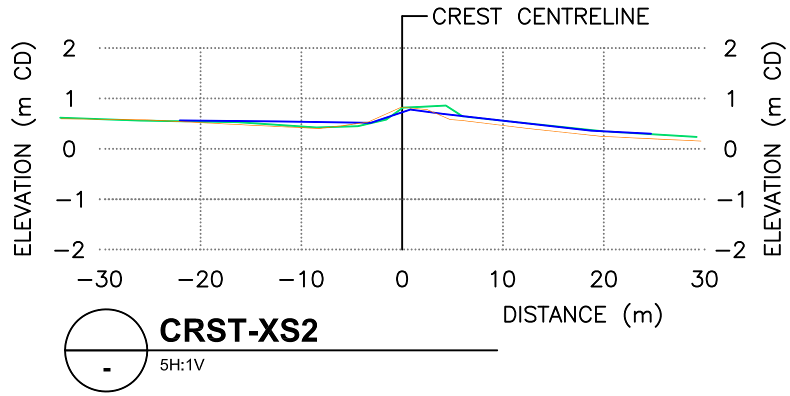
DWG. NO.	REV. NO.	DATE
crstpro−2008	00	September 2009

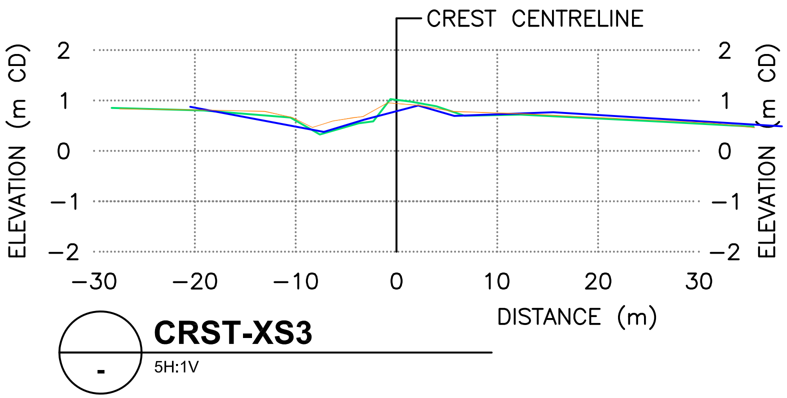
northwest hydraulic consultants

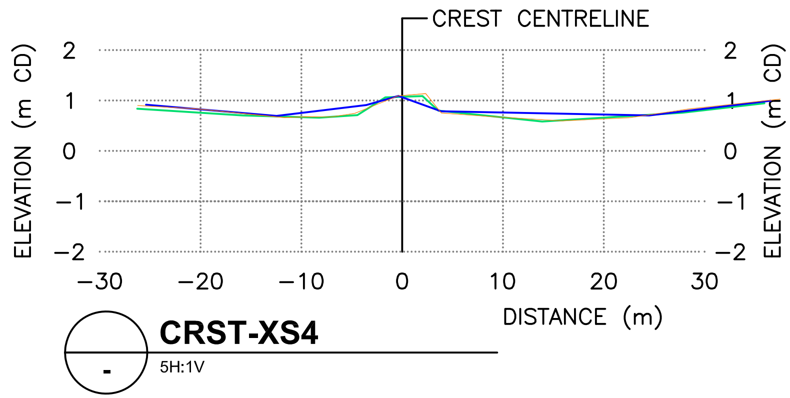
FIGURE 3

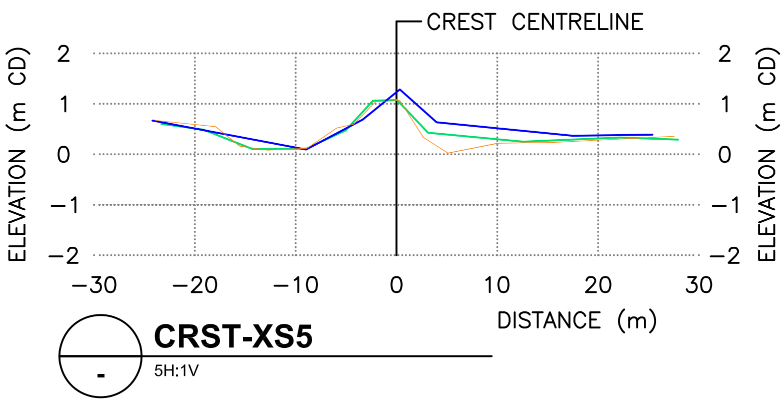
FIGURE 4











Note: sections drawn from shoreward (negative distance) to seaward (positive distance)

- Jul 2007 survey
- Oct 2007 survey
- Jan 2008 survey

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM

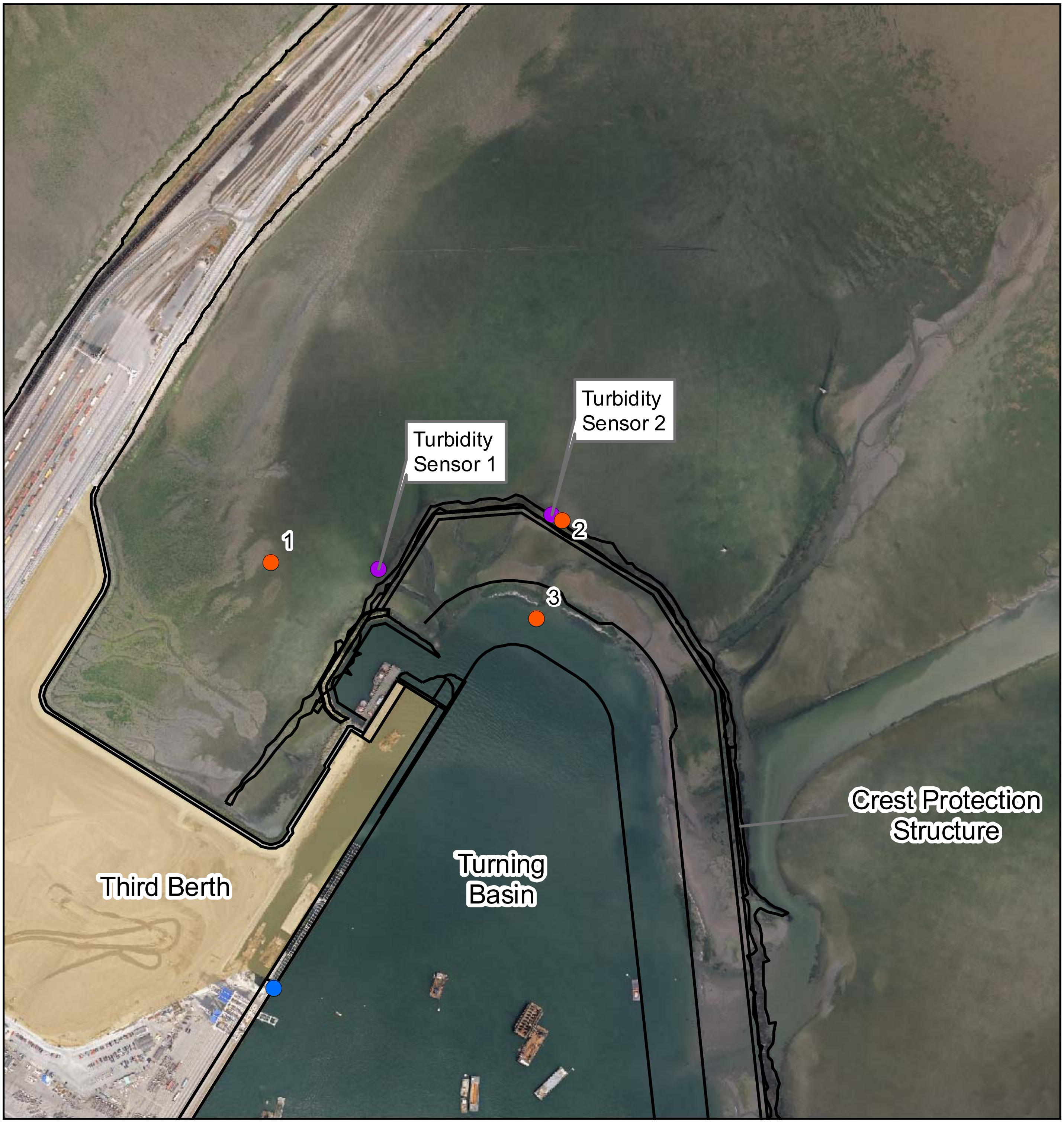
2008 ANNUAL REPORT

Crest Protection Structure

2007 Monitoring Cross Sections

DWG. NO.	REV. NO.	DATE
crstpro–2008	00	September 2009

northwest hydraulic consultants

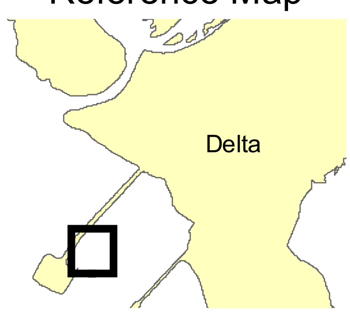


Legend

- Wave Sensor
- Tide Gauge
- Turbidity Sensor

Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Instrumentation
Site Location Map

Scale - 1:7,500

100 50 0 100 200 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

CM, 34648 Deltaport Monitoring\GIS\Fig_AllInstrumentSites.mxd

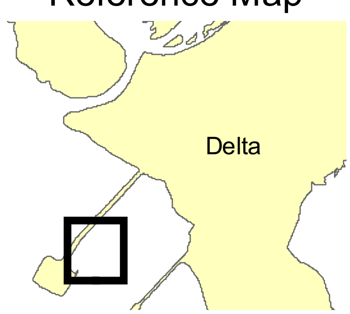
Figure 5

Legend

● Existing DOD Rod

Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Depth of Disturbance Rods Location Map

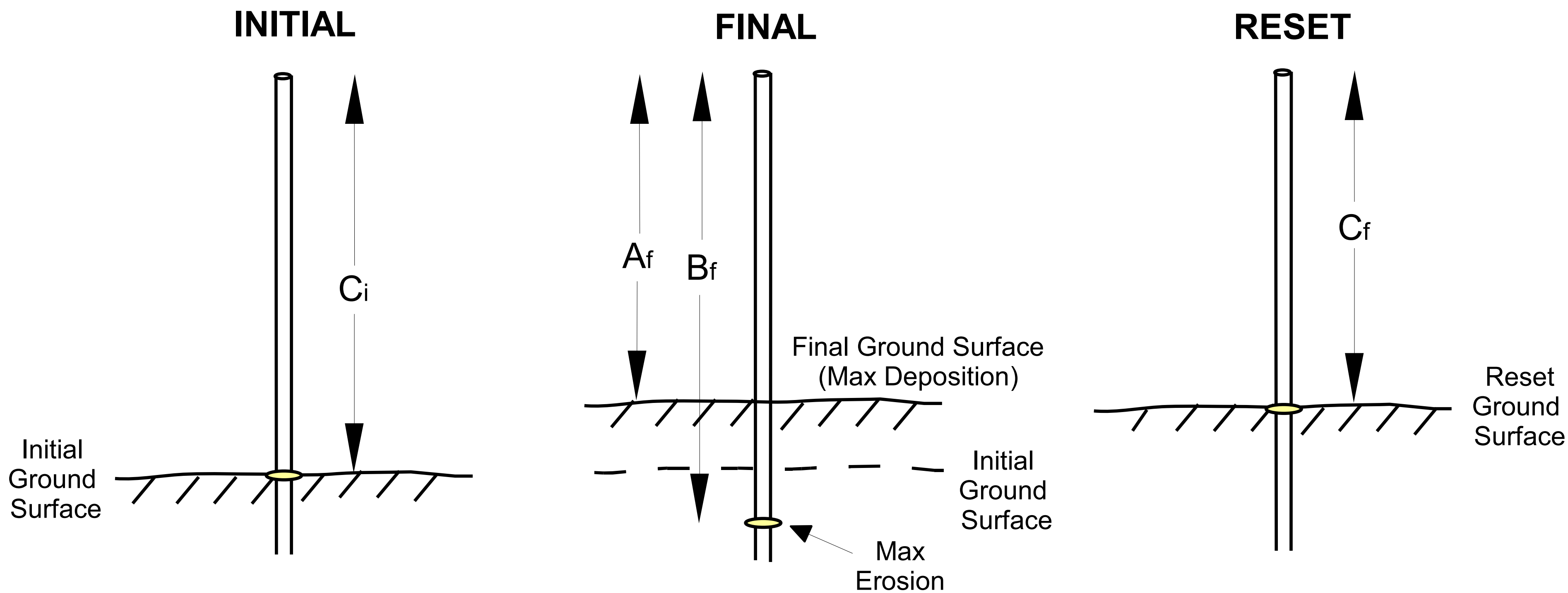
Scale - 1:10,000

100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

MSN, 34648 Deltaport Monitoring\GIS\Fig5DepthOfDisturbanceSites.mxd

Figure 6



A = Height Above Ground
B = Height Above Washer
C = Reset: Height Above Ground/Washer

Deposition = $B_f - A_f$
Erosion = $B_f - C_i$ (if $B_f - C_i < 0$, then $B_f - C_i$ set to 0 to remove error)
Net Change = Deposition – Erosion

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT		
Bed Level Change Computations at Depth of Disturbance Rods		
northwest hydraulic consultants	project no. 3-4648	September 2009

Figure 7

UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203
DP08	490760.801	5430036.675

LEGEND

- Water
- Tidal Mud & Sand
- Water Quality Sampling Station
- Initial AWAC Location

HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

SURFACE WATER, SEDIMENT & BENTHIC INVERTEBRATE SAMPLING STATIONS

PROJECT No. 499-002.11	September 2009	FIGURE 8

LEGEND

✳ Water Quality and Sediment Sampling Station

SCALE 1:5,000 (metres)
0 100 200

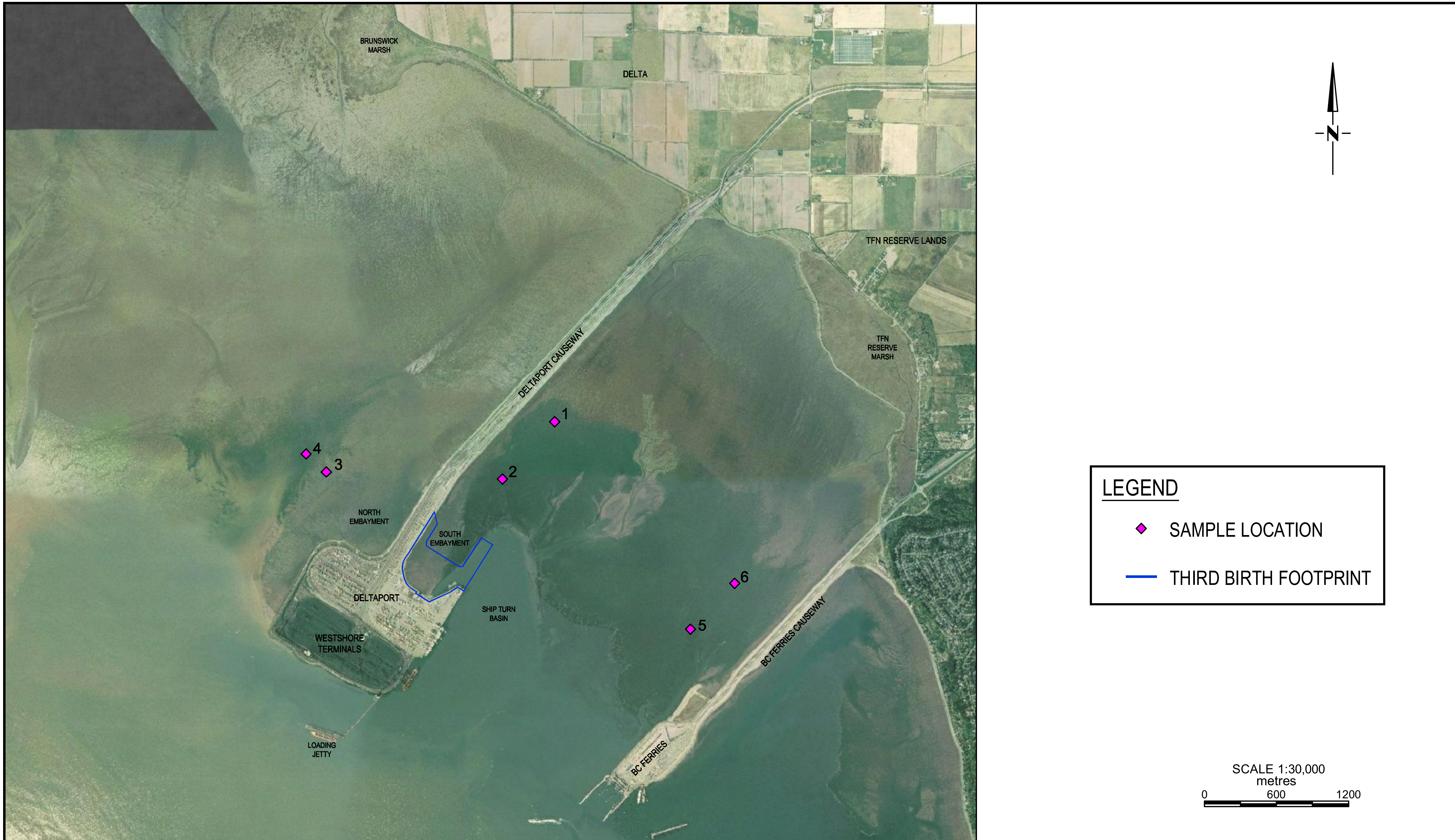
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2008 ANNUAL REPORT

DETAILED LOCATION OF SAMPLE DP01

PROJECT No.		
499-002.11	September 2009	FIGURE 9



REFERENCE DRAWINGS

- Base Map Information Provided by Triton Consultants Ltd., dated Sept 2004.
- Envirowest Environmental Consultants Figure 'Appendix A', dated Nov. 1, 2004.

HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2008 ANNUAL REPORT

EELGRASS STATION REFERENCE LOCATIONS (DELTAPORT AREA)

PROJECT No. 499-002.11	September 2009	FIGURE 10

LEGEND

◆ Eelgrass Sampling Station (UTM Coordinates Shown)

Note: The shallow and deep station are each approximately 10 metres away from the mid station.

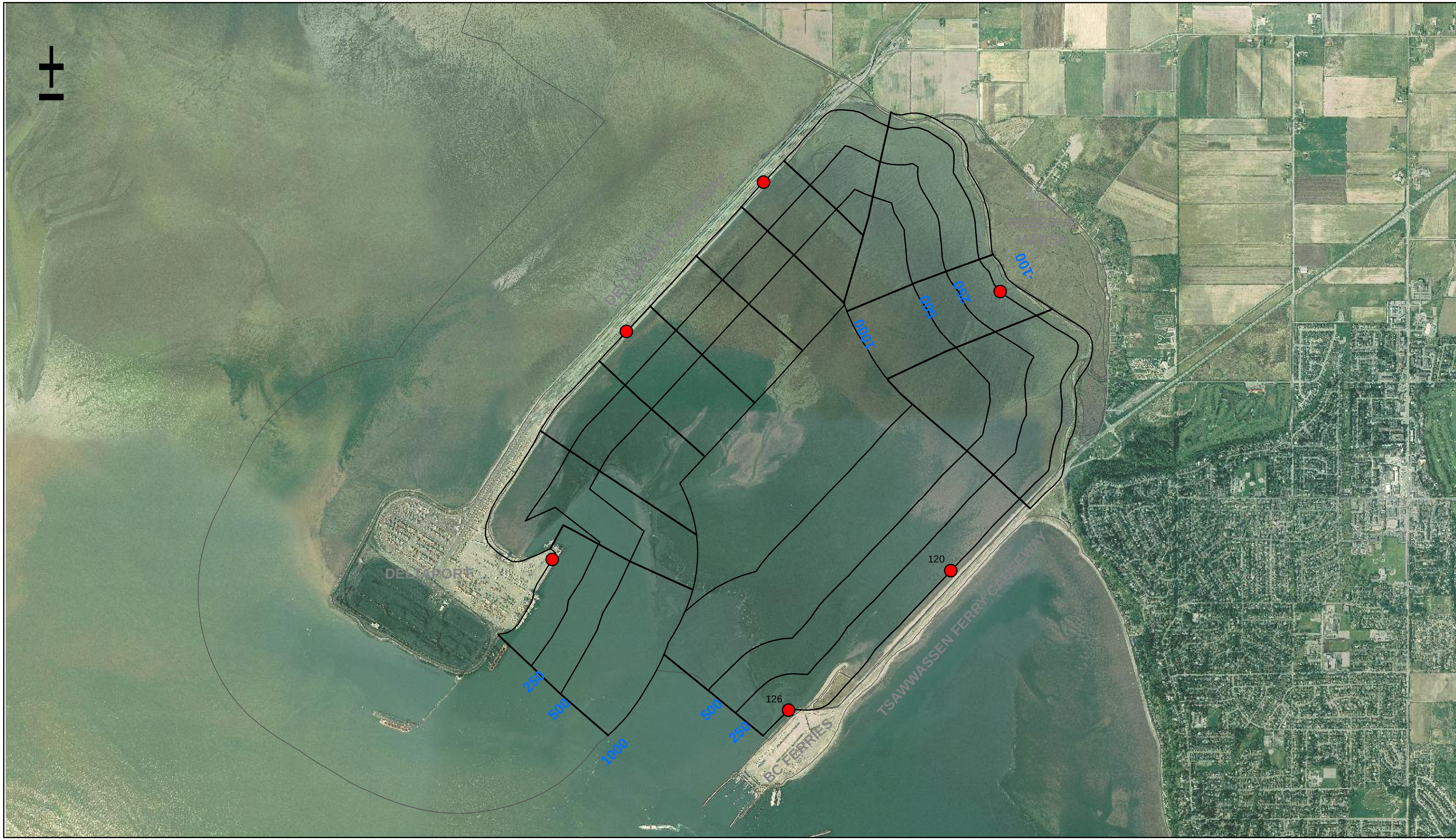
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2008 ANNUAL REPORT

EELGRASS REFERENCE STATION LOCATION (BOUNDARY BAY AREA)

PROJECT No.		
499-002.11	September 2009	FIGURE 11



Legend

100	Contour Line Label	
●	Species Specific (GBHE & BRAN) "windshield" survey locations	

American Ornithological Union Code
Common Name
GBHE
Great Blue Heron
BRAN
Brant

1:25,000
800 400 0 800 Meters

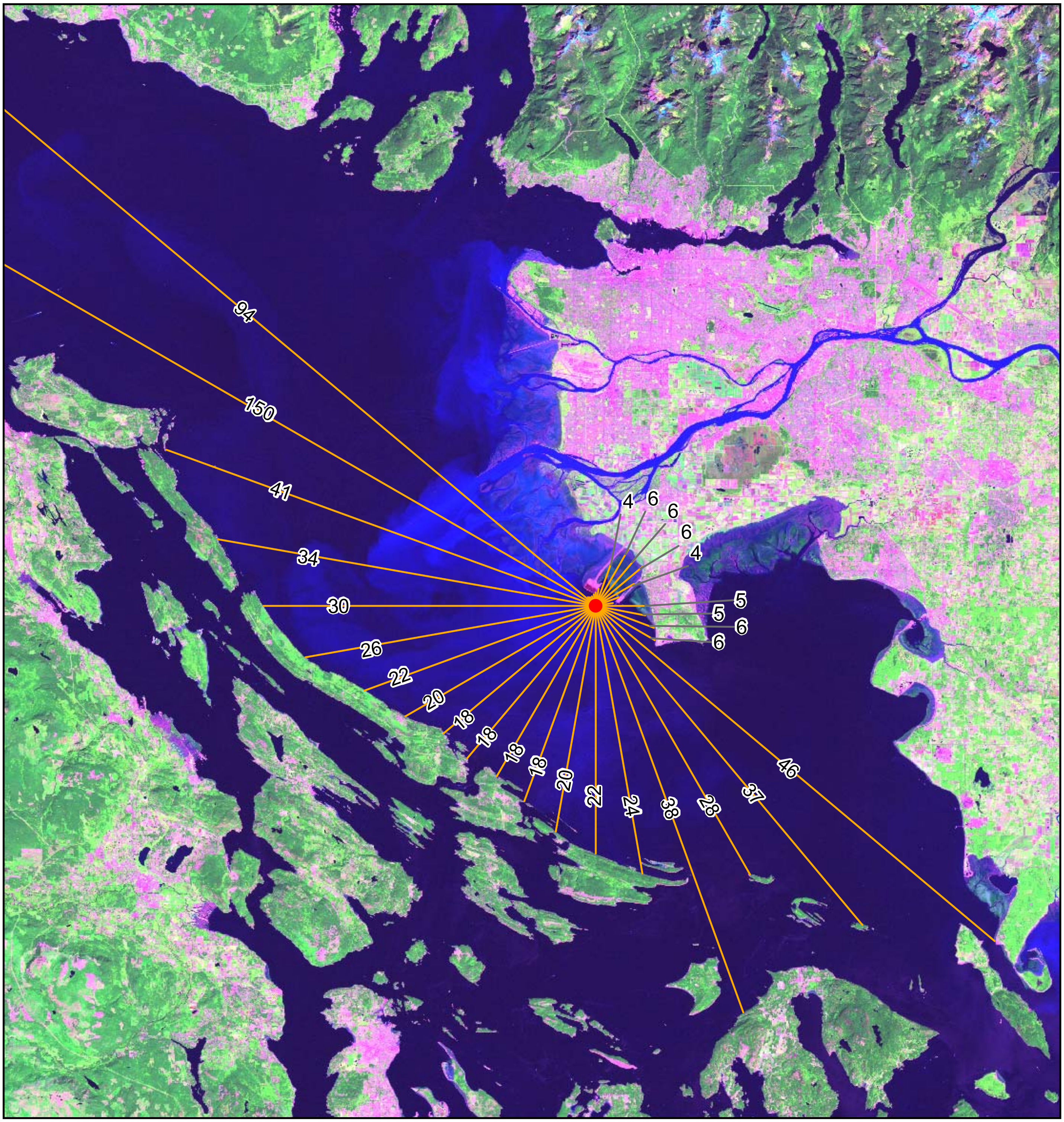
HEMMERA

PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

BIRD SURVEY TRANSECT LOCATIONS

PROJECT NO: 499-002.11	SEPTEMBER 2009	FIGURE 12



Legend

● Reference Point

—— Fetch Lengths at 10˚ intervals (km)

Note:
- July 30, 2000 Landsat composite image courtesy of Geogratis.

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Fetch Lengths at Deltaport

Scale - 1:500,000

10 5 0 10 Kilometres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648S	September 2009

CXM/MSN, 34648 Deltaport Monitoring\GIS\Fig_FetchLength.mxd

Figure 13

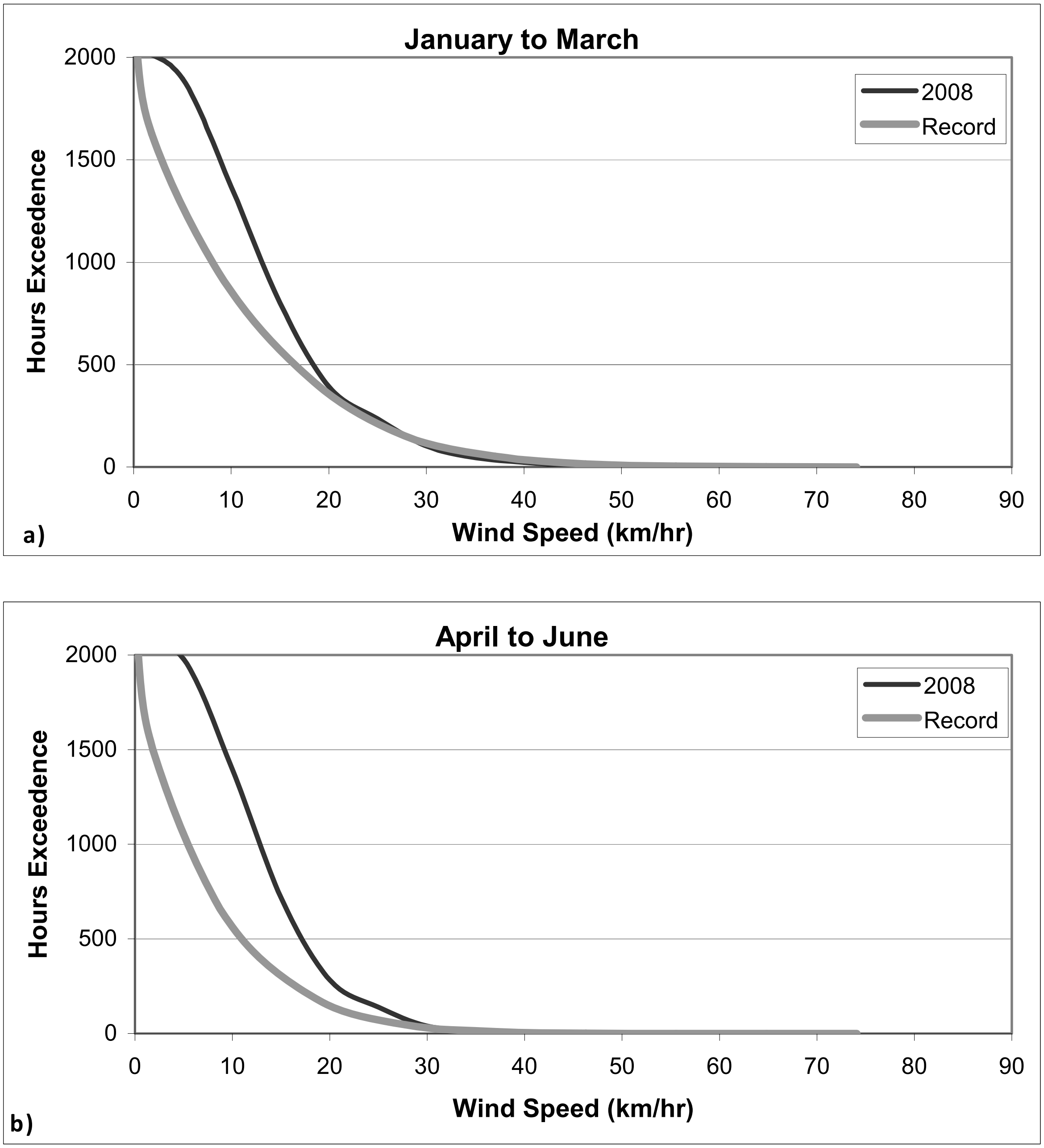
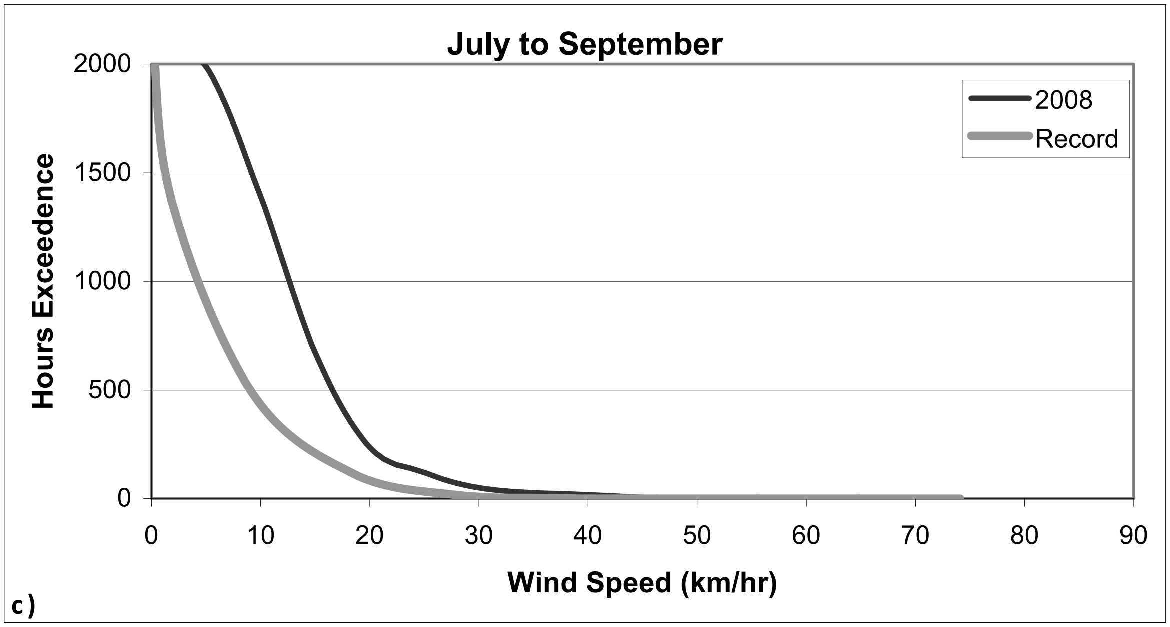


Figure 14 **Summary of hourly wind speed measured at Vancouver International Airport for the period a) January to March, and b) April to June**



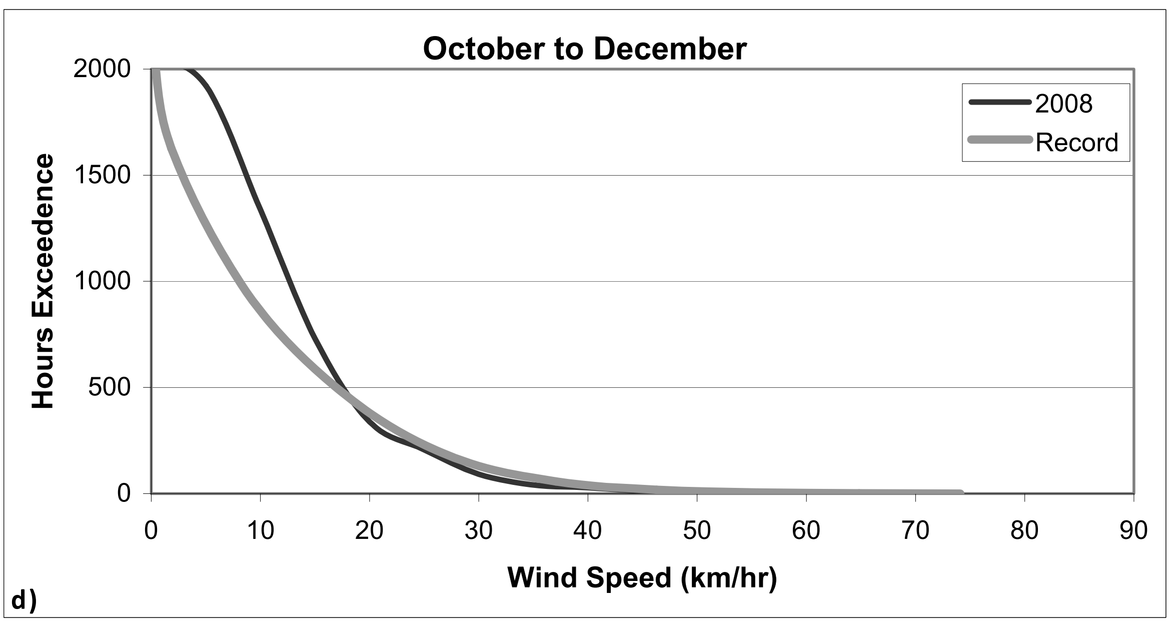


Figure 14 **Summary of hourly wind speed measured at Vancouver International Airport for the period c) July to September and d) October to December**

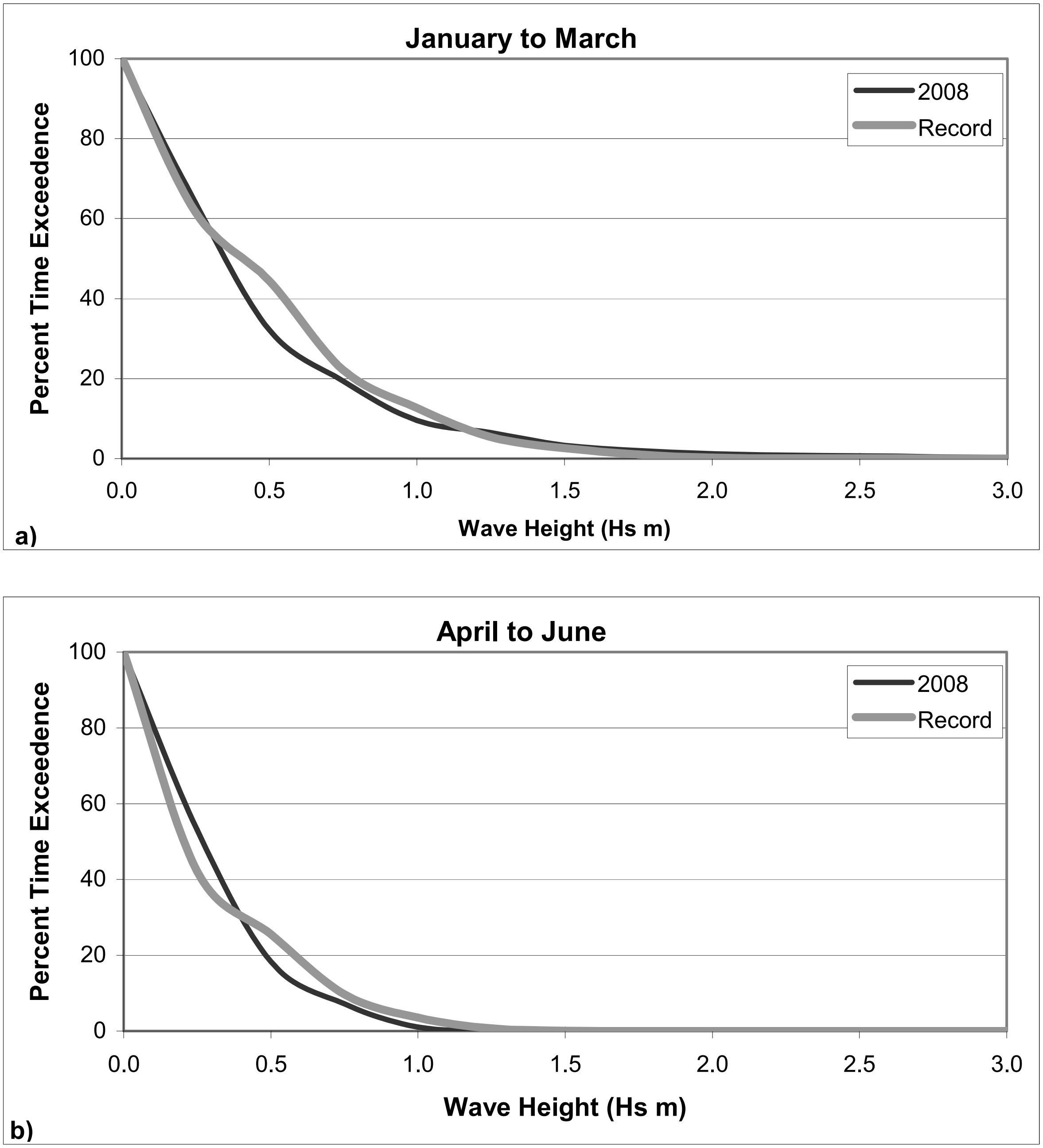
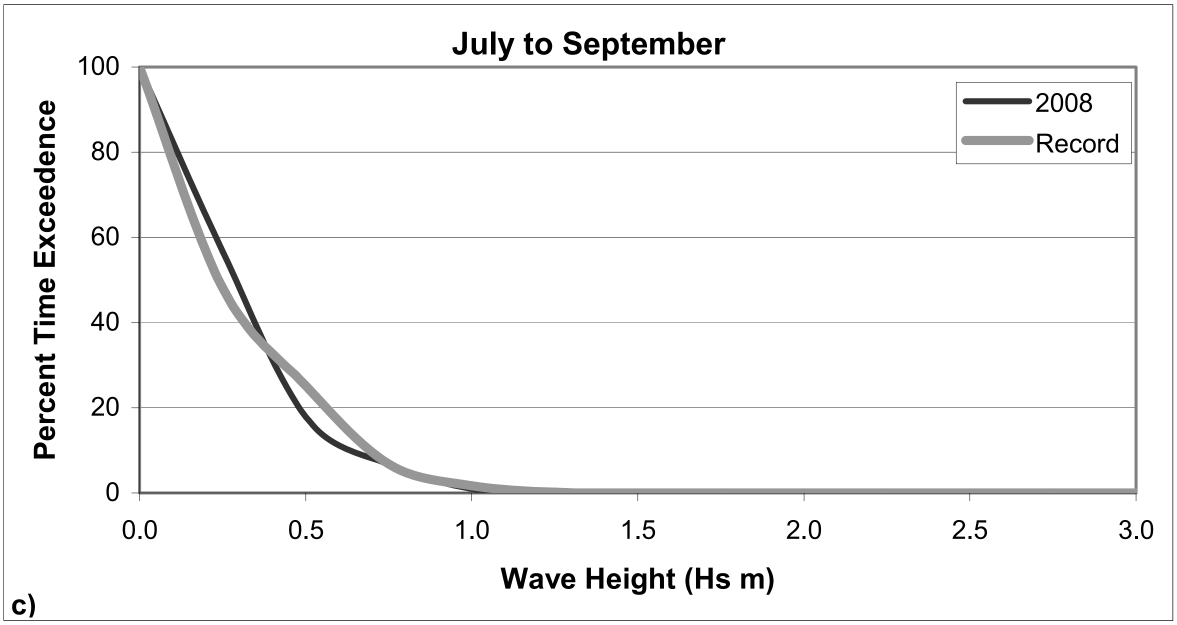


Figure 15 **Summary of wave data from Station #46146 (Halibut Bank) for the period a) January to March, and b) April to June**



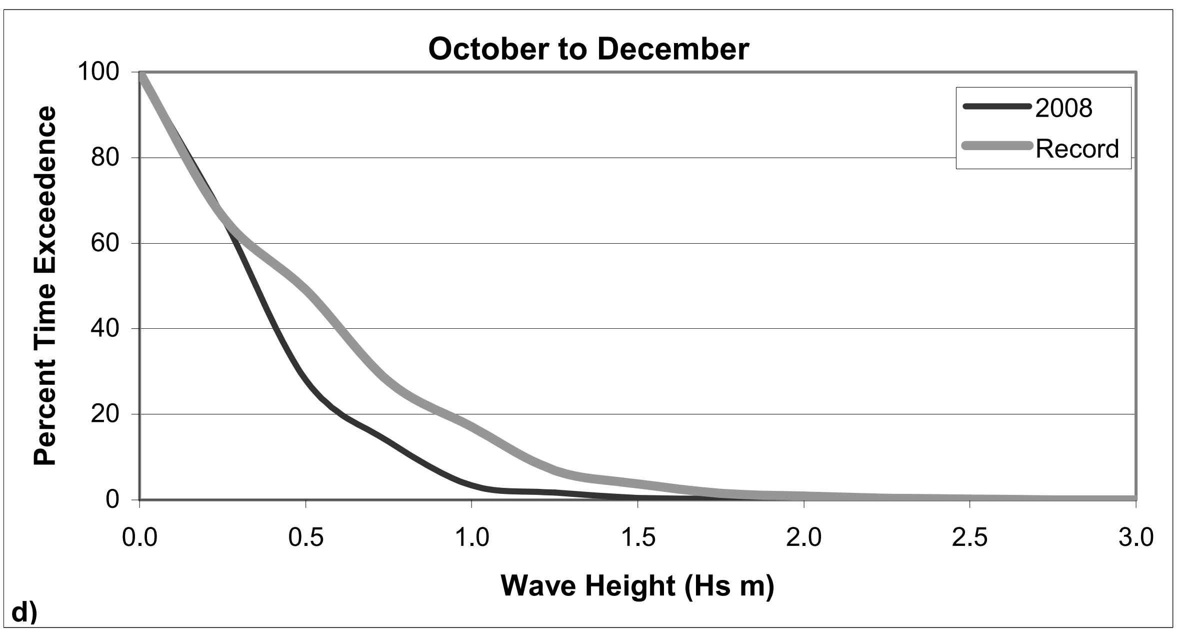


Figure 15 **Summary of wave data from Station #46146 (Halibut Bank) for the period c) July to September, and b) October to December**

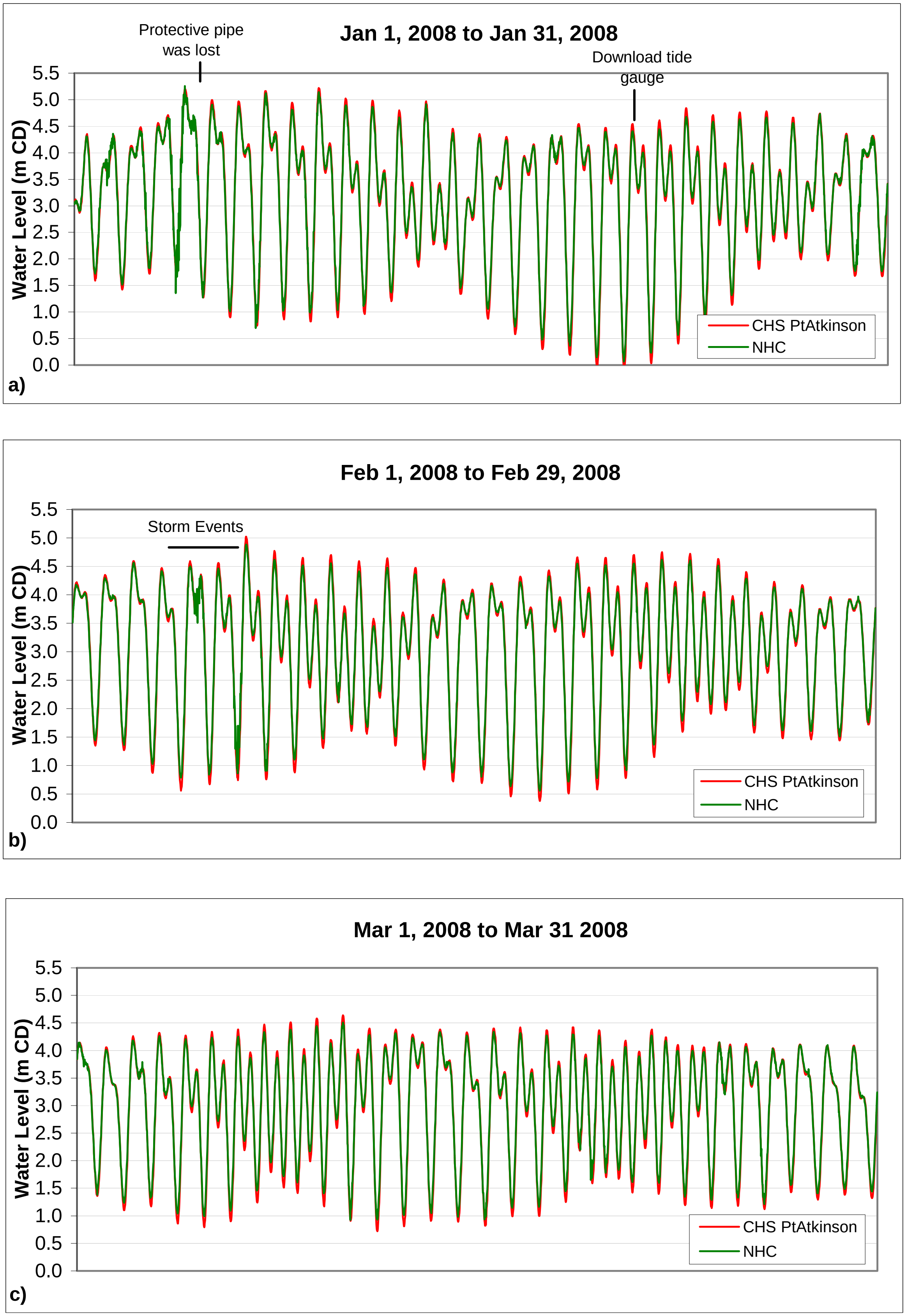


Figure 16 Observed Tide Levels at Deltaport and Point Atkinson, January to March

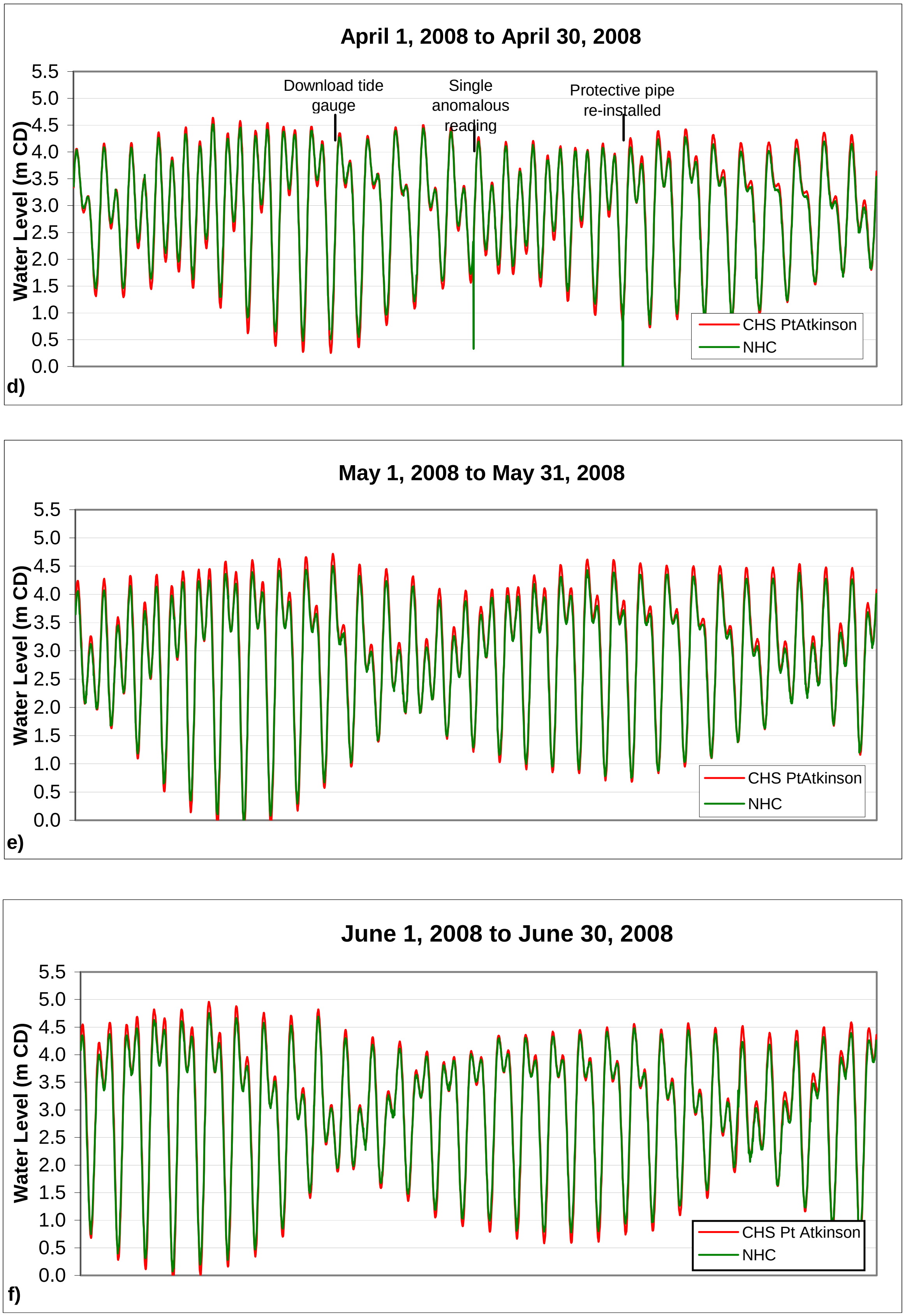


Figure 17 **Observed Tide Levels at Deltaport and Point Atkinson, April to June**

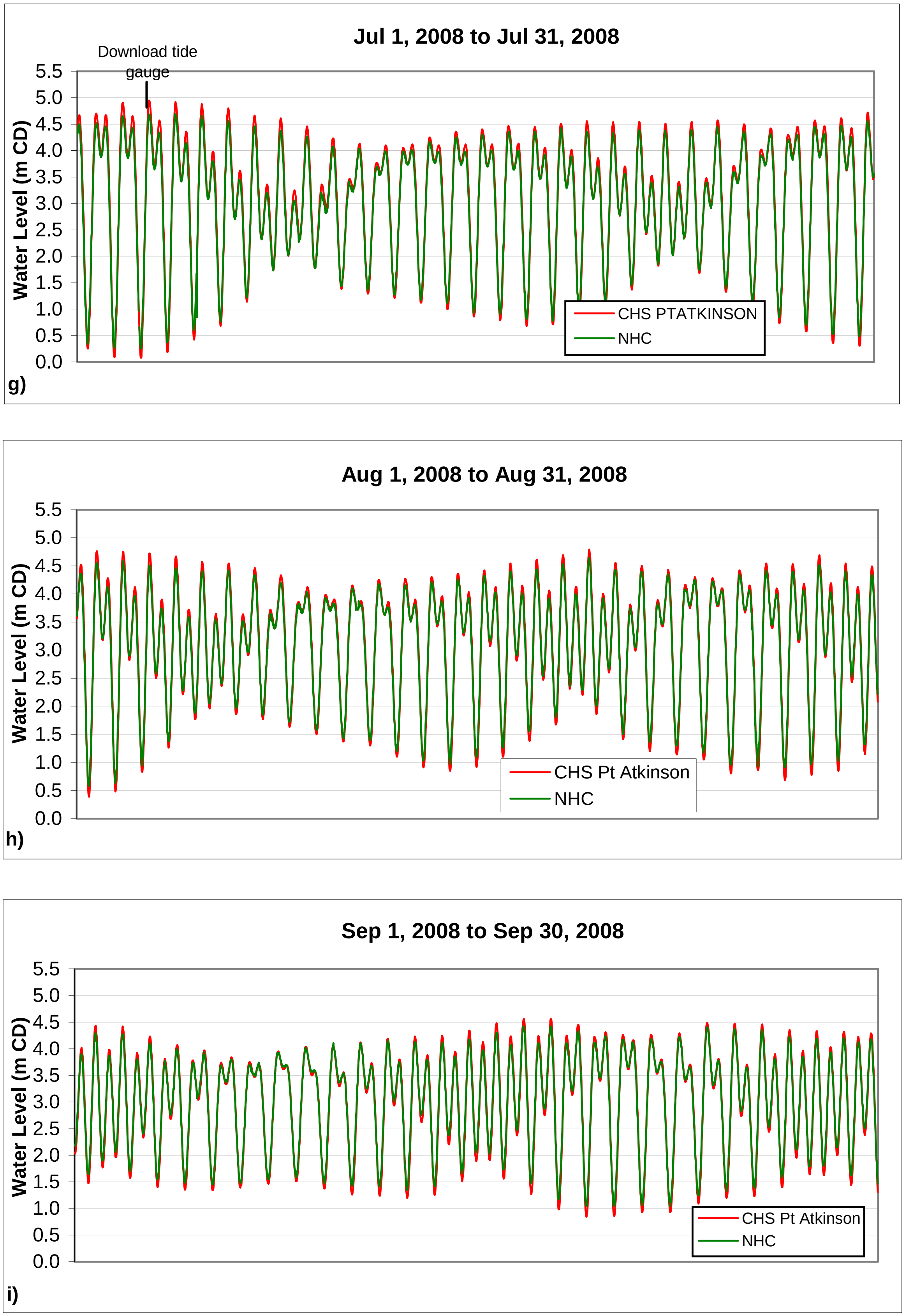
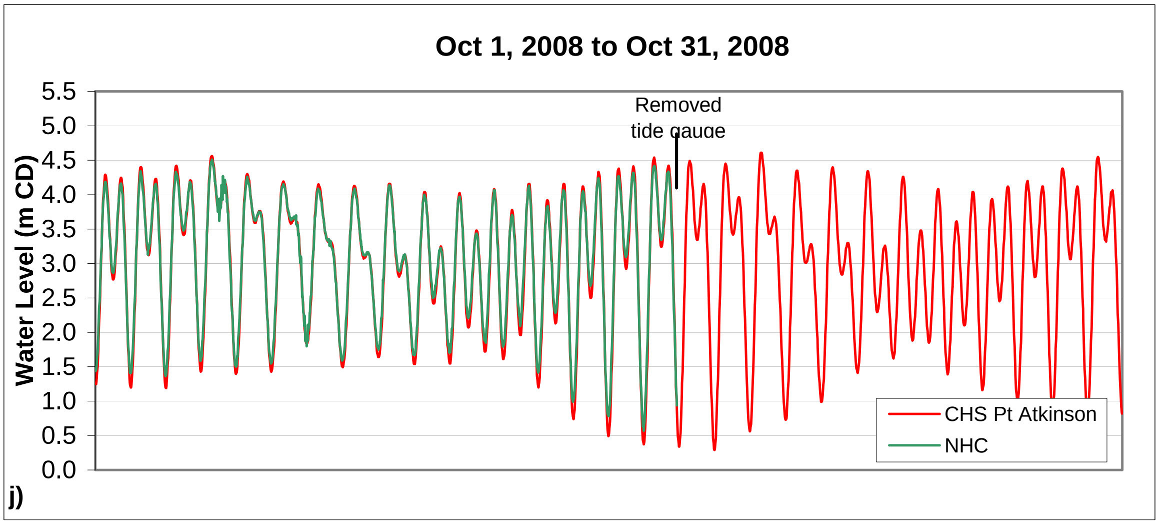
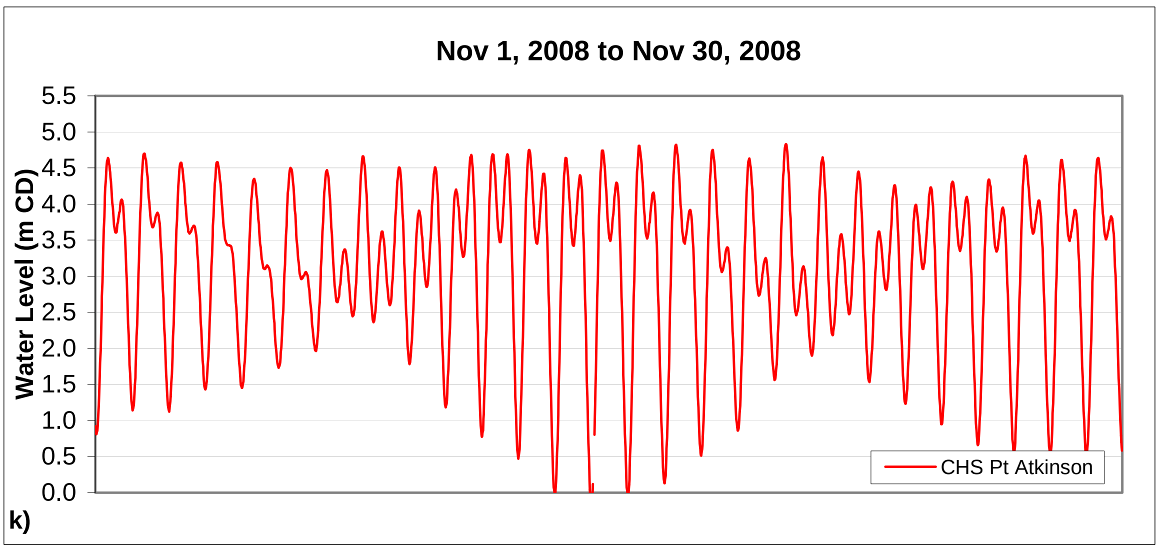


Figure 18 **Observed Tide Levels at Deltaport and Point Atkinson, July to September**





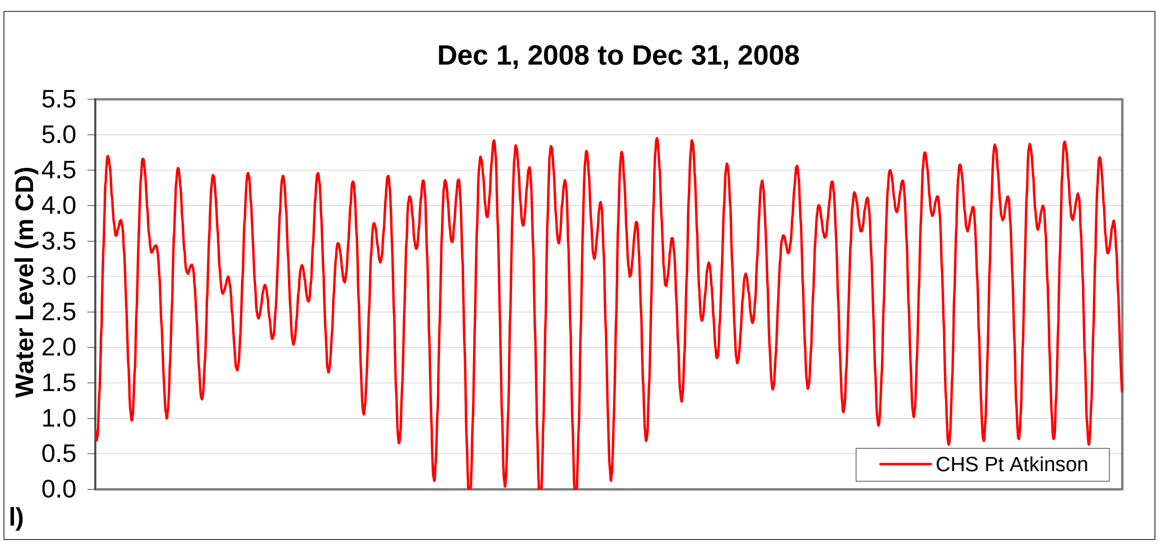


Figure 19 Observed Tide Levels at Deltaport and Point Atkinson, October to December

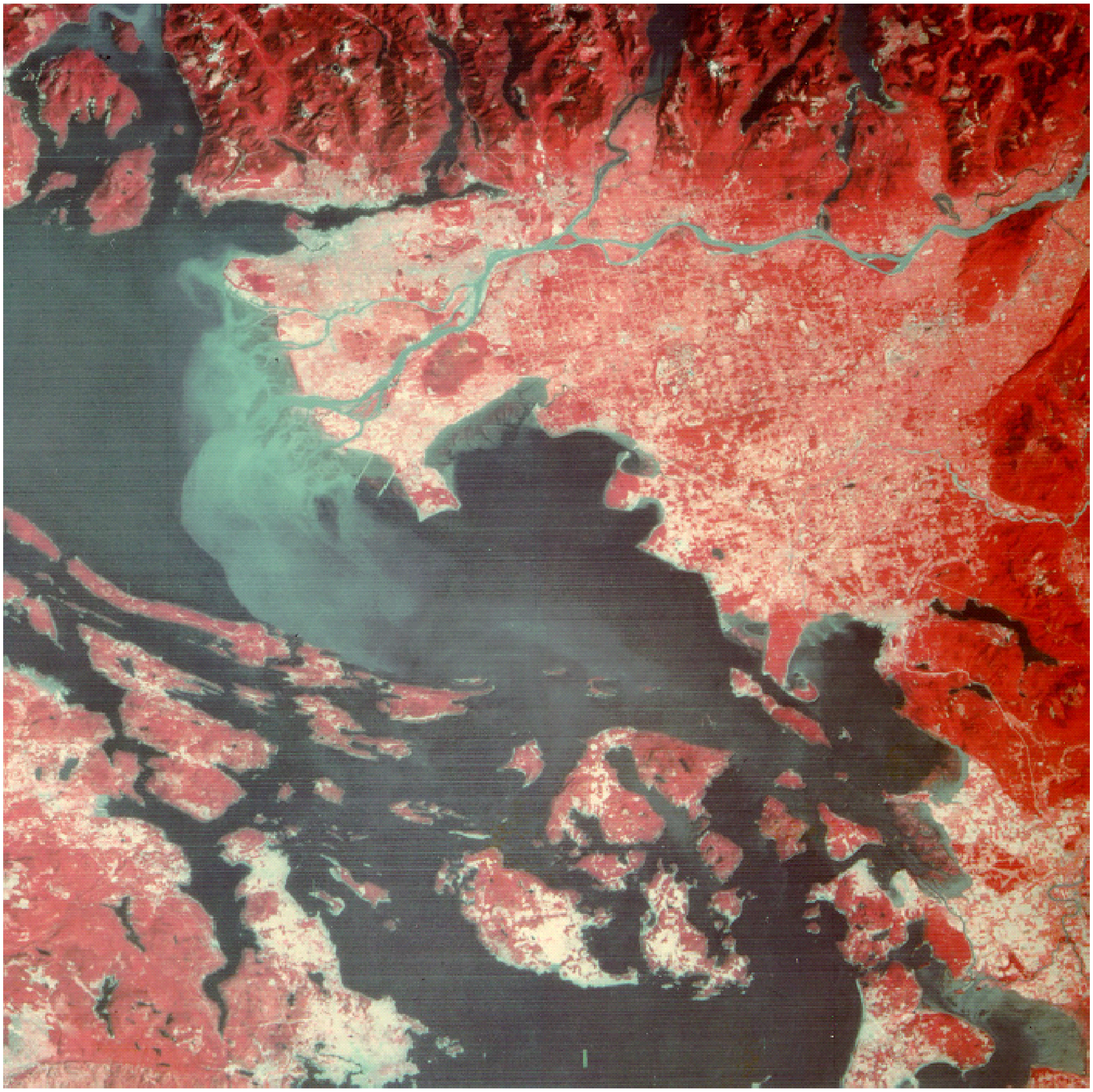


Figure 20 **Fraser River Plume Deflected By Deltaport Causeway During Ebb Tide (1982 Colour IR Photograph).**

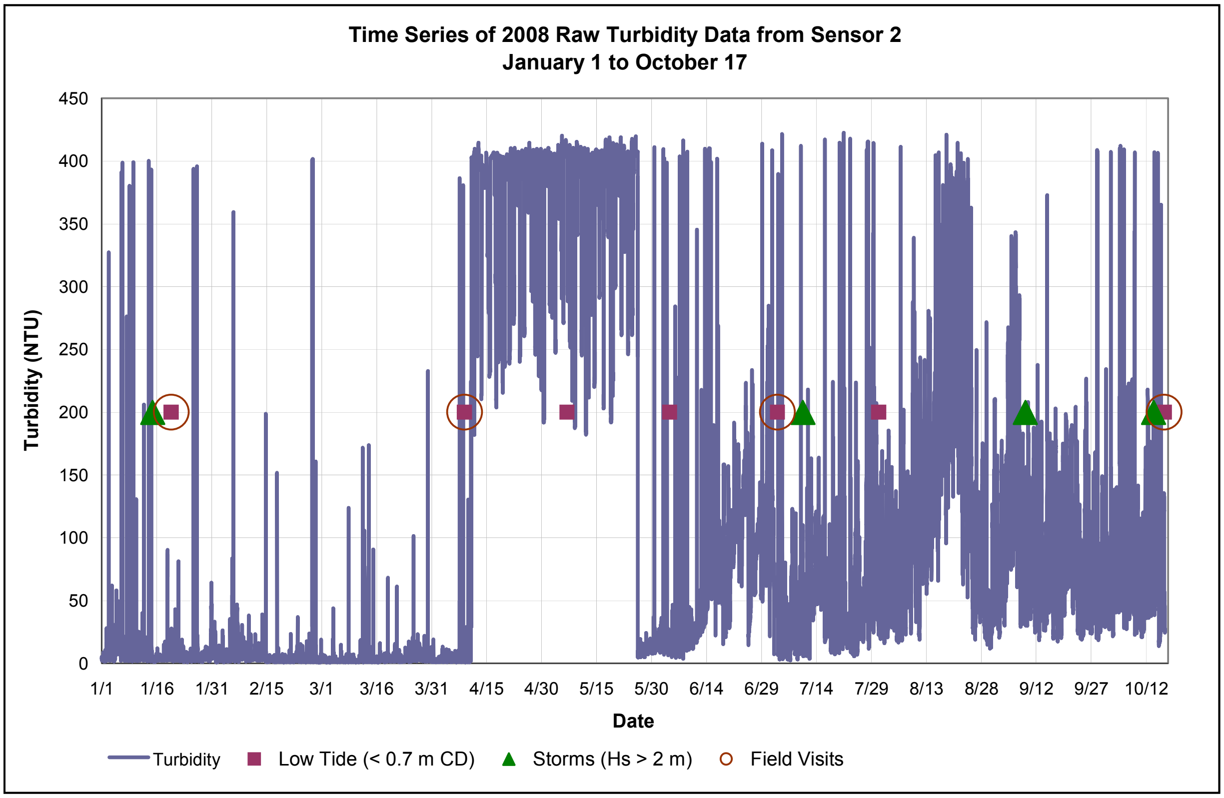


Figure 21. Time series of 2008 raw turbidity data from Sensor 2 - January 1 to October 17

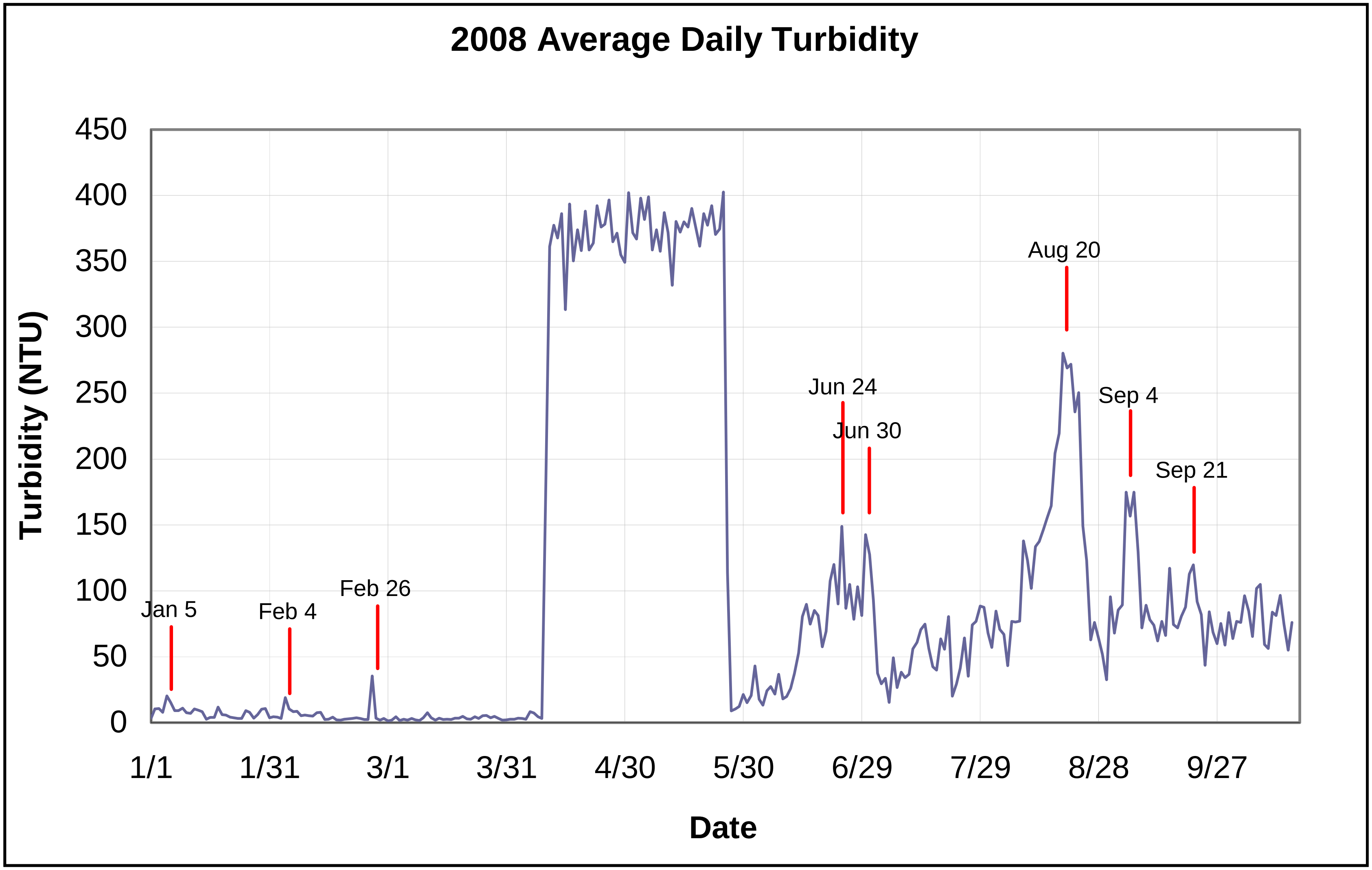
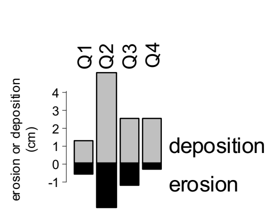


Figure 22 **Time series of 2008 average daily turbidity data from Sensor 2 – January 1 to October 17**

DoD Rod Locations

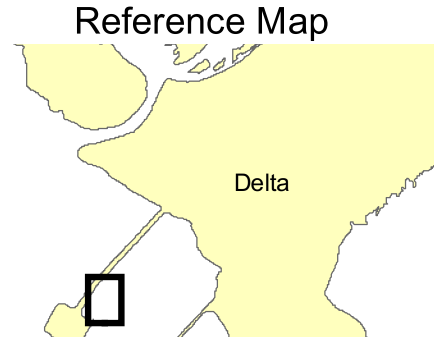
Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

Bar chart shows quarterly erosion and deposition at each DoD rod location



* indicates that measurement may be affected by cone of vegetation

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Bar Charts of 2008 Quarterly Erosion and Deposition at Original DoD Rods

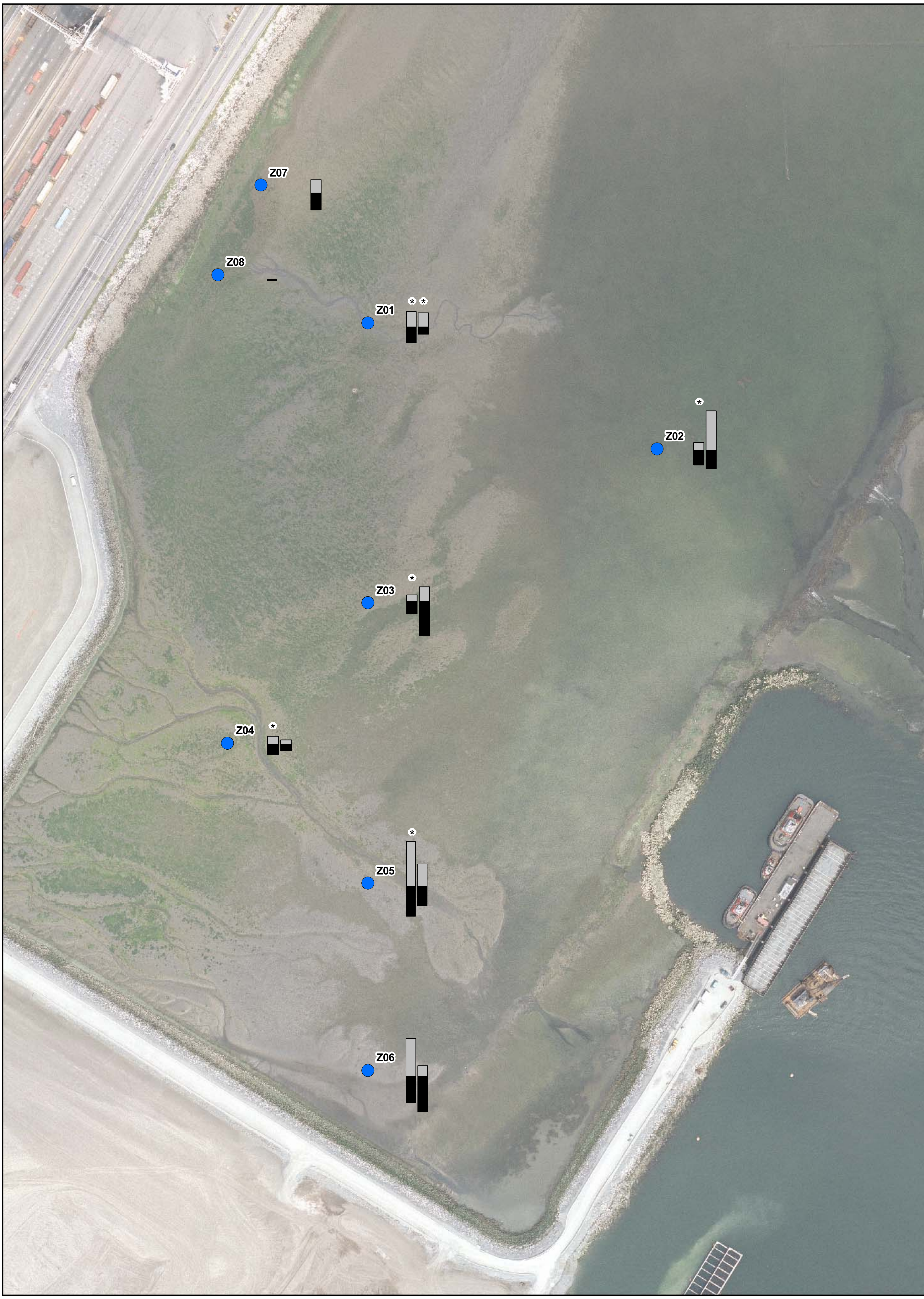
Scale - 1:4,000

100 50 0 100 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

Figure 23

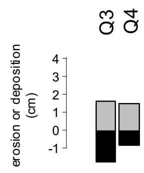
JXD, 34648 Deltaport Monitoring\GIS\Fig_DoDErosionDepositionCharts_2008_AtoG.mxd



● DoD Rod Locations

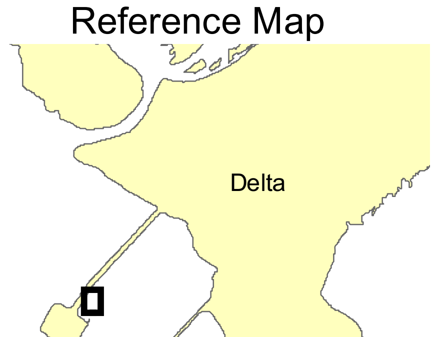
Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

Bar chart shows quarterly erosion and deposition at each DoD rod location



* indicates that measurement may be affected by cone of vegetation

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Bar Charts of 2008 Quarterly Erosion and Deposition at Z series DoD Rods

Scale - 1:2,000

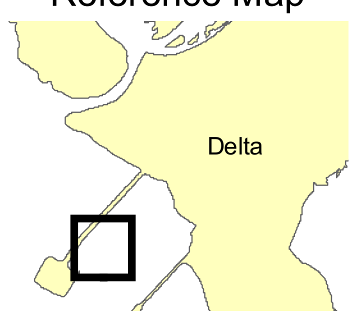
100 50 0 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

Figure 24

JXD, 34648 Deltaport Monitoring\GIS\Fig_DoDErosionDepositionCharts_2008_Z.mxd

Reference Map



Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Net Change in Erosion/Deposition at DoD Rods Q1-2008

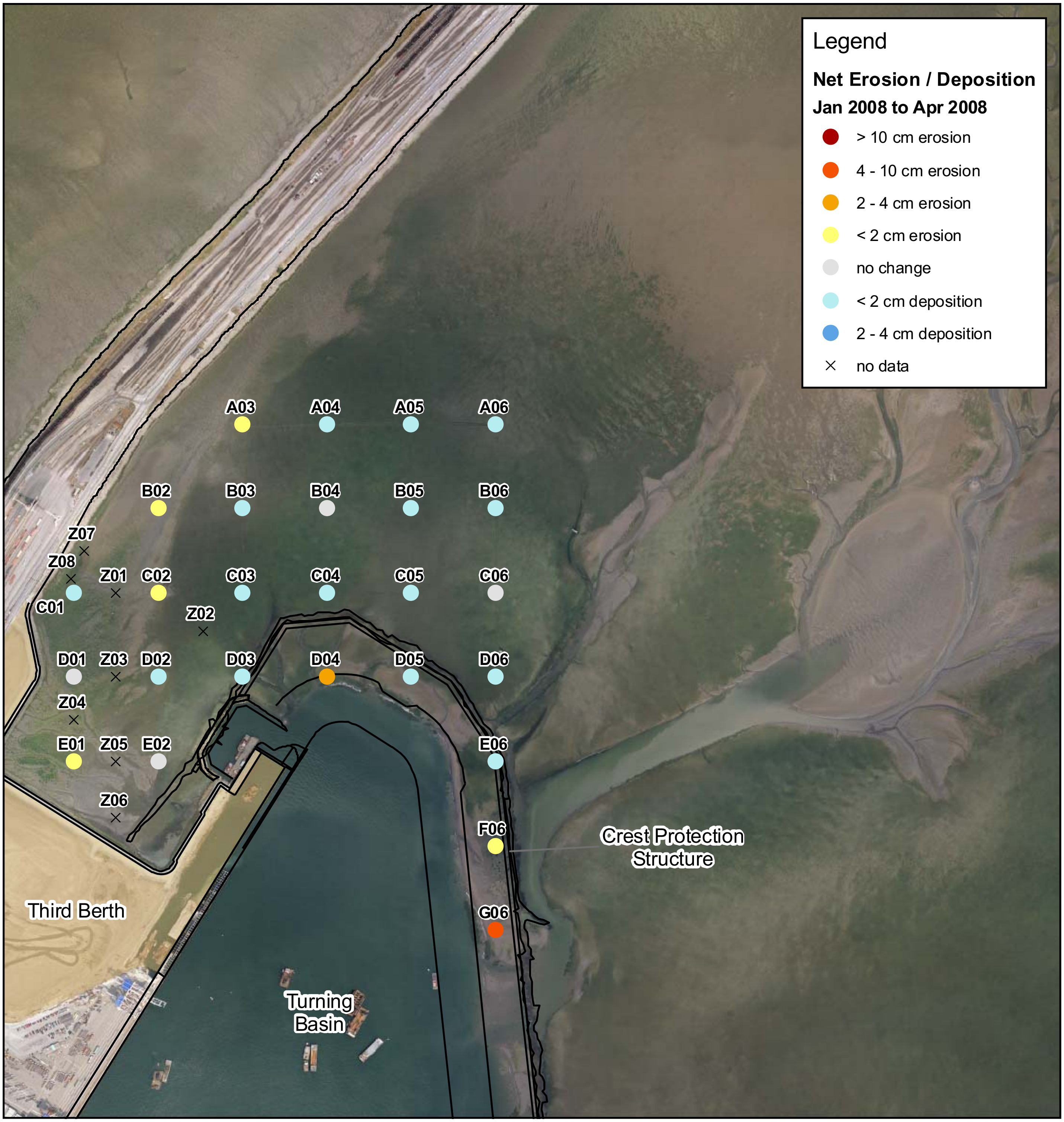
Scale - 1:10,000

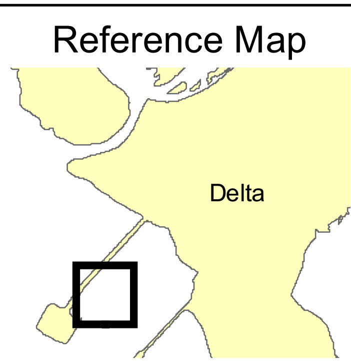
100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

JXD, 34648 DP3 AMS\GIS\Fig_DoDResultsNetR1.mxd

Figure 25





Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Net Change in Erosion/Deposition at DoD Rods Q2-2008

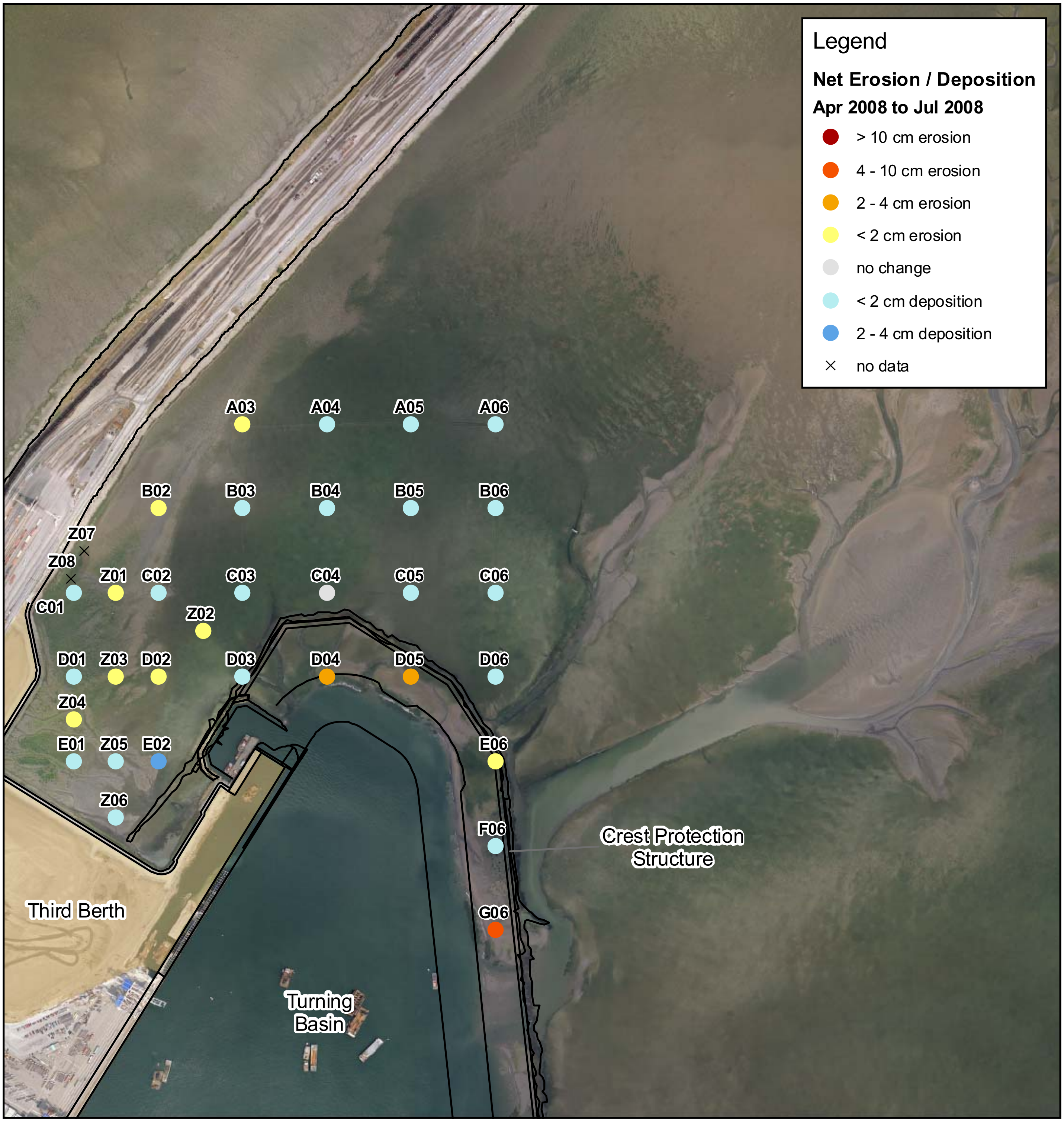
Scale - 1:10,000

100 50 0 100 200 300 Metres

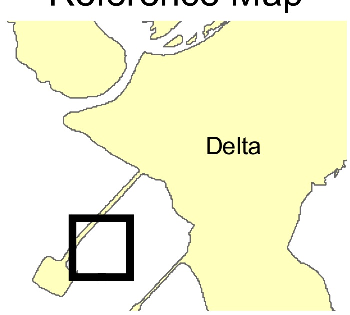
coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

JXD, 34648 DP3 AMS\GIS\Fig_DoDResultsNetR1.mxd

Figure 26



Note:
- July 2, 2008 orthophoto image courtesy of VFPA.



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Net Change in Erosion/Deposition at DoD Rods Q3-2008

Scale - 1:10,000

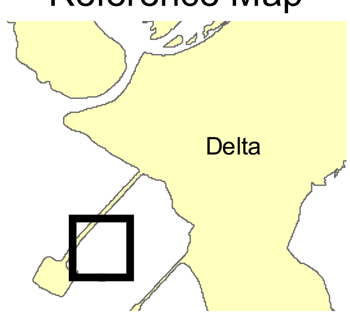
100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

JXD, 34648 DP3 AMS\GIS\Fig_DoDResultsNetR1.mxd

Figure 27

Reference Map



Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Net Change in Erosion/Deposition at DoD Rods Q4-2008

Scale - 1:10,000

100 50 0 100 200 300 Metres

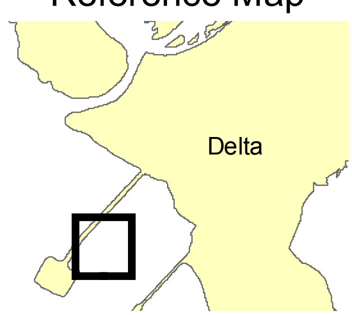
coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648S	September 2009

JXD, 34648 DP3 AMS\GIS\Fig_DoDResultsNetR1.mxd

Figure 28

Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Percent Silt Content (< 0.063 mm) at DoD Rod Locations Apr 2008

Scale - 1:10,000

100 50 0 100 200 300 Metres

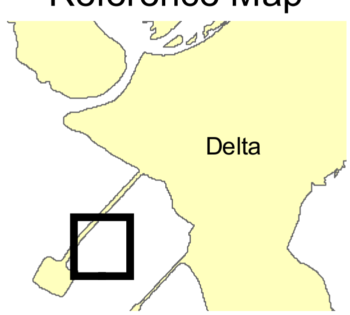
coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

JXD, 34648 Deltaport Monitoring\GIS\Fig_SiltContent.mxd

Figure 29

Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Percent Silt Content (<0.063 mm) at DoD Rod Locations Oct 2008

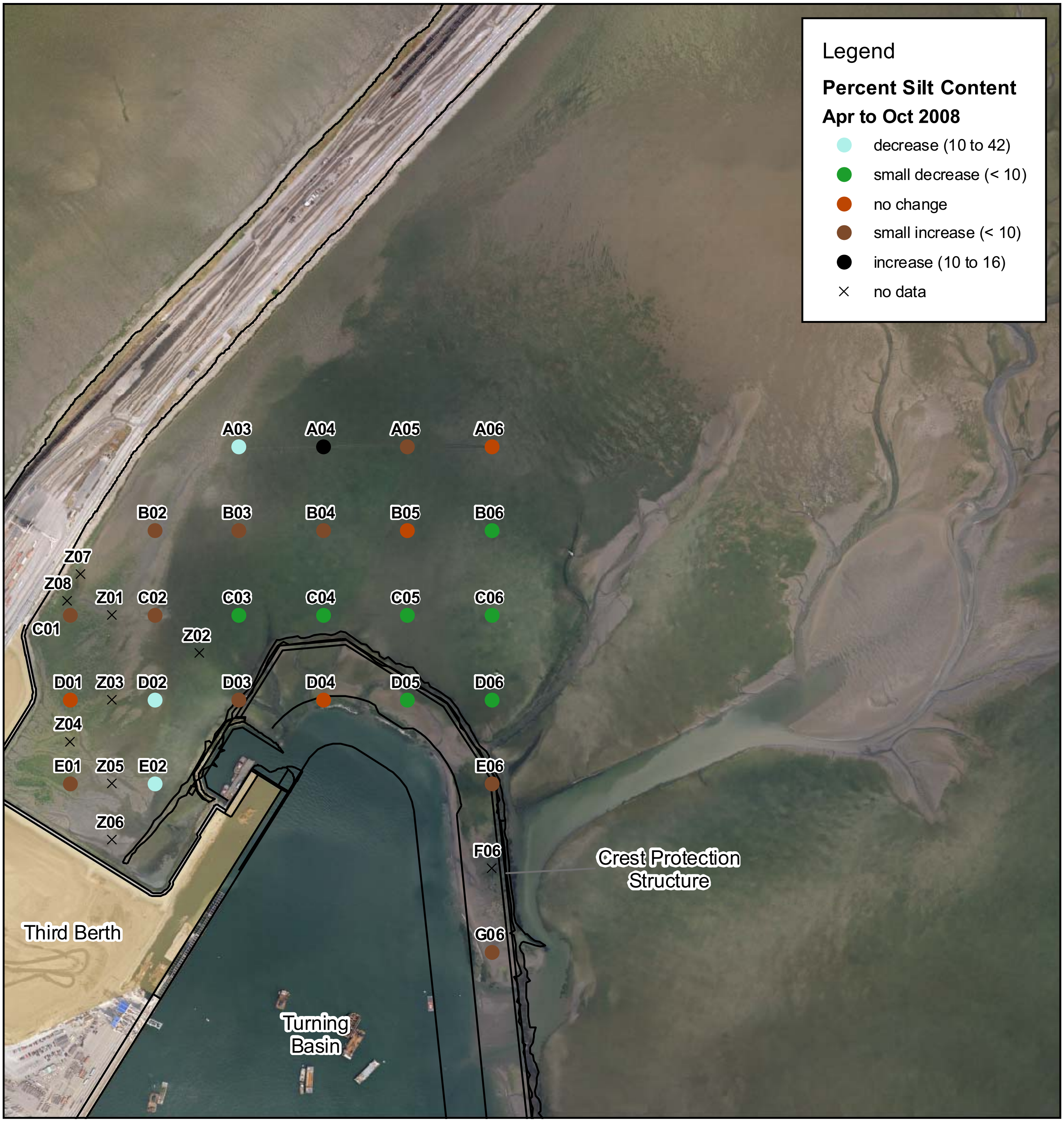
Scale - 1:10,000

100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

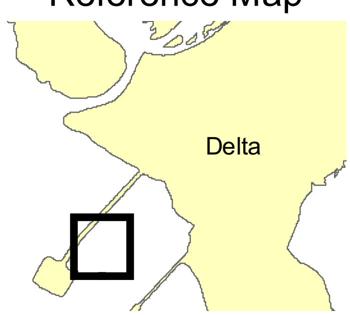
JXD, 34648 Deltaport Monitoring\GIS\Fig_SiltContent.mxd

Figure 30



Note:
- July 2, 2008 orthophoto image courtesy of VFPA.

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Percent Silt Content Change
Apr to Oct 2008

Scale - 1:10,000

100 50 0 100 200 300 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

JXD, 34648 Deltaport Monitoring\GIS\Fig_SiltContent.mxd

Figure 31

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

2008 Orthophoto Interpretation

Scale - 1:15,000

200 100 0 200 400 600 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

Legend

2008 Channel Mapping

- ACTIVE CHANNEL ZONE
- BAR
- CHANNEL-DOUBLE LINE
- CHANNEL-SINGLE LINE
- ACTIVE CHANNEL ZONE
- BAR
- CHANNEL

Note:
- July 2, 2008 orthophoto supplied by Vancouver Fraser Port Authority.

CM, linuxprojects\34648 DP3 AMS\GIS\Fig_Mapping2008.shp

Figure 32

DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

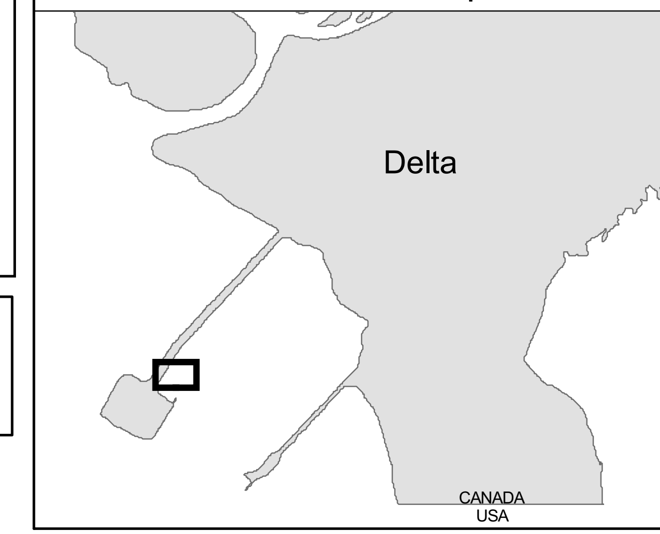
Drainage Channel Detailed Comparison, 2007 and 2008 Orthophotos

Scale - 1:4,000

100 50 0 100 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

Reference Map



Legend

2007 Channel Mapping

- ACTIVE CHANNEL ZONE
- CHANNEL - DOUBLE LINE
- CHANNEL - SINGLE LINE

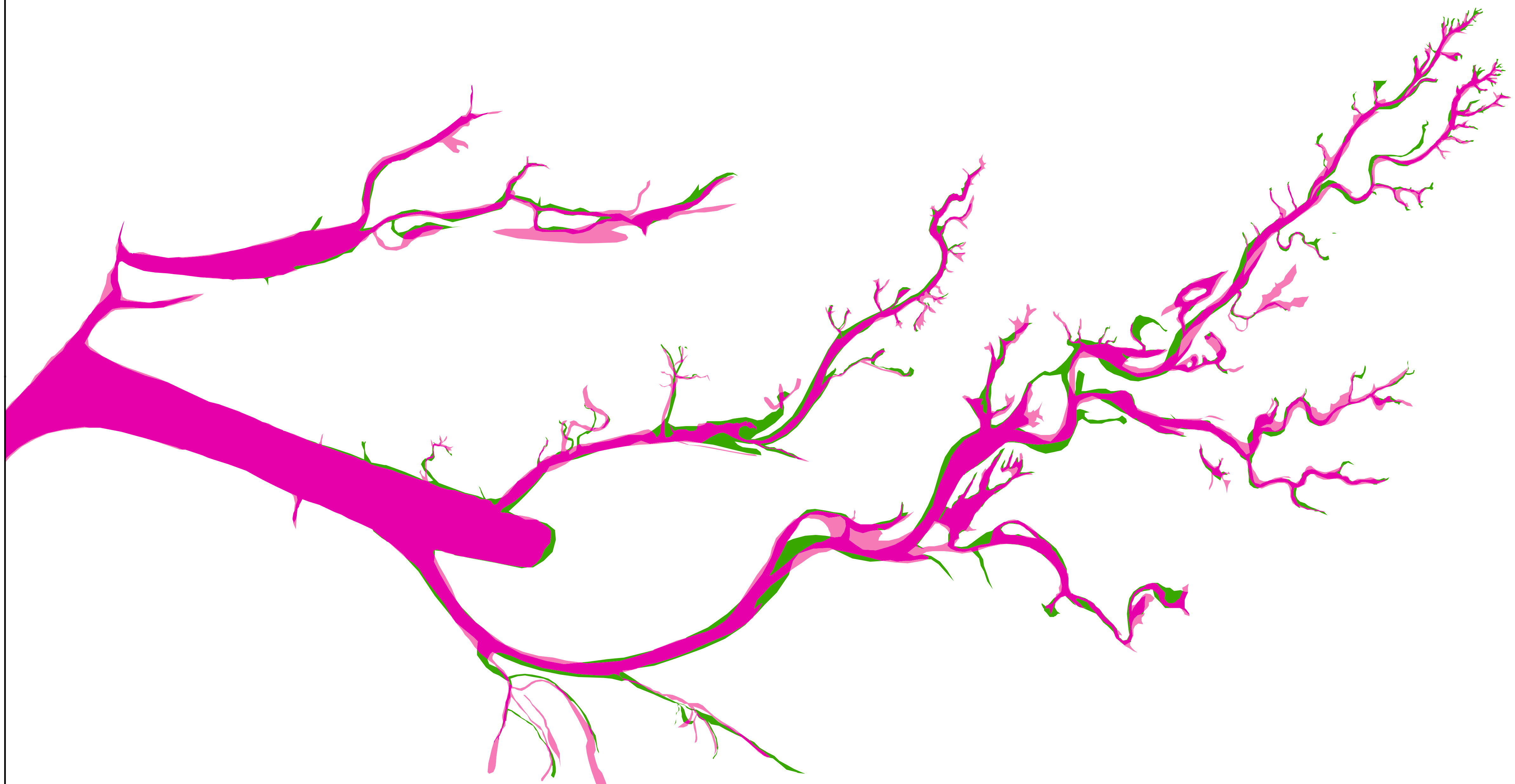
2008 Channel Mapping

- ACTIVE CHANNEL ZONE
- CHANNEL

Note:
- 2007 and 2008 orthophotos supplied by Vancouver Fraser Port Authority.

MSN_34648 Deltaport Monitoring\GIS\Fig_New2008Channels.mxd

Figure 33



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

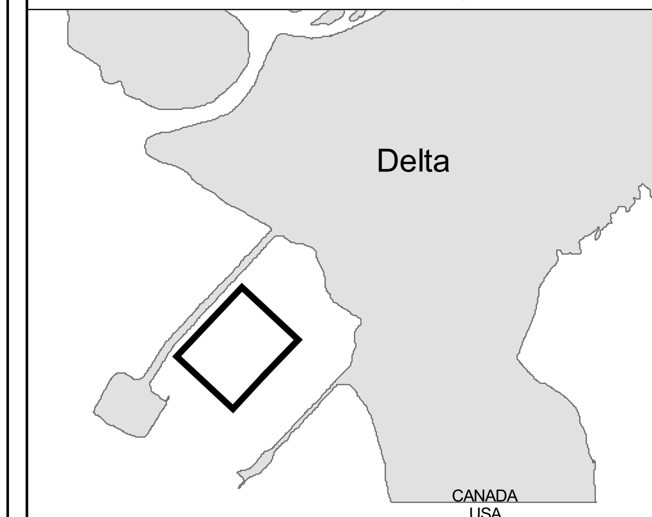
Mapped Channel Changes Based on 2007 and 2008 Orthophotos

Scale - 1:6,000

100 50 0 100 200 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4648	September 2009

Reference Map



Legend

ChannelChanges07to08

2007 to 2008

- channel in 2007 (not in 2008)
- channel in 2007 and 2008 (no change)
- channel in 2008 (not in 2007)

Note:
- Variation in conditions such as tide level, vegetation growth and water clarity may influence the accuracy of change mapping between 2007 and 2008.

JXD,34648 Deltaport Monitoring\GIS\Fig_Mapping2008Comp2007.mxd

Figure 34

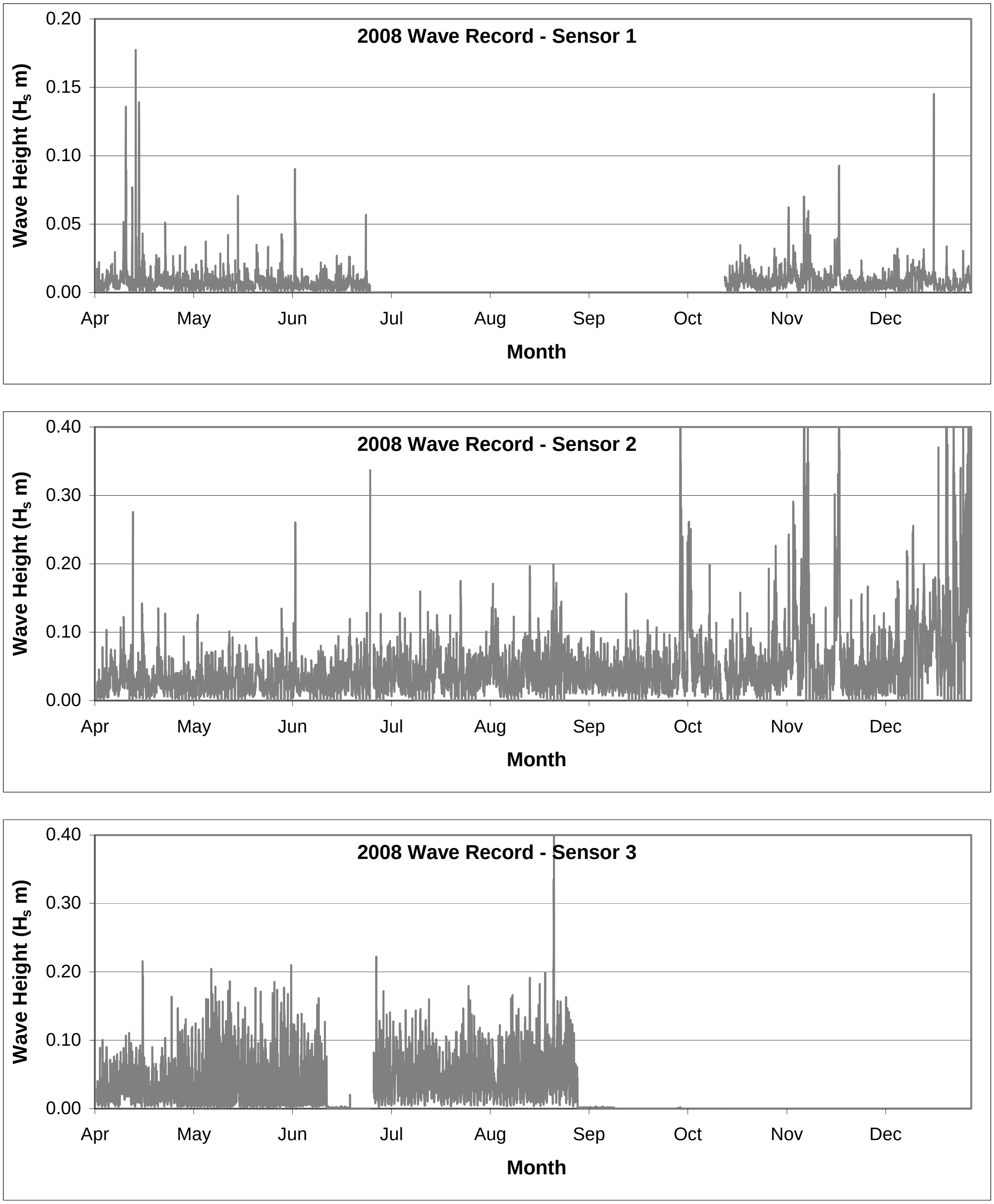


Figure 35 **Time-series record of significant wave heights (H_s) measured at the three wave sensors in the study area**

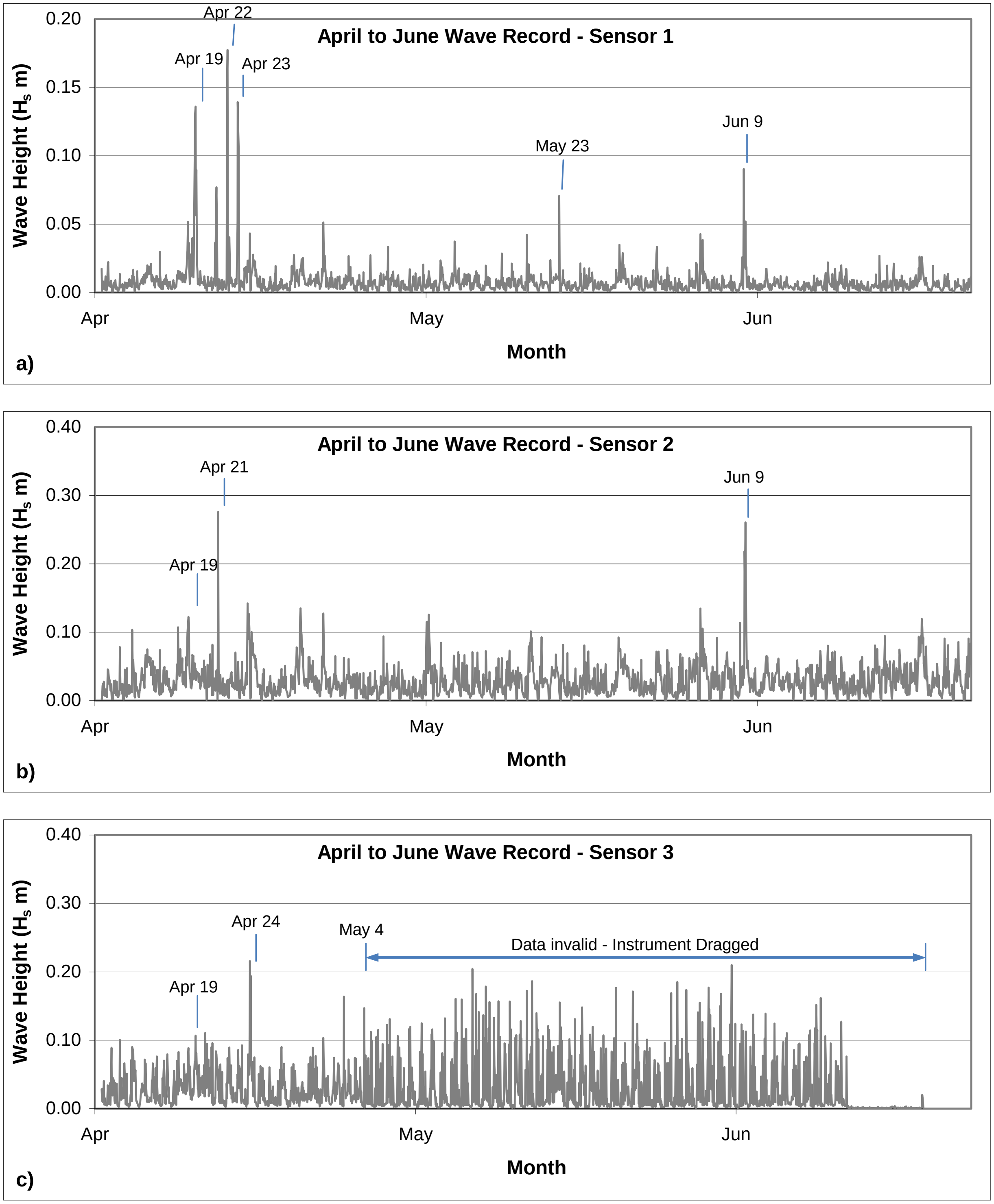


Figure 36 **Time-series record of significant wave heights (Hs) measured at the three wave sensors in the study area for the period April to June, 2008**

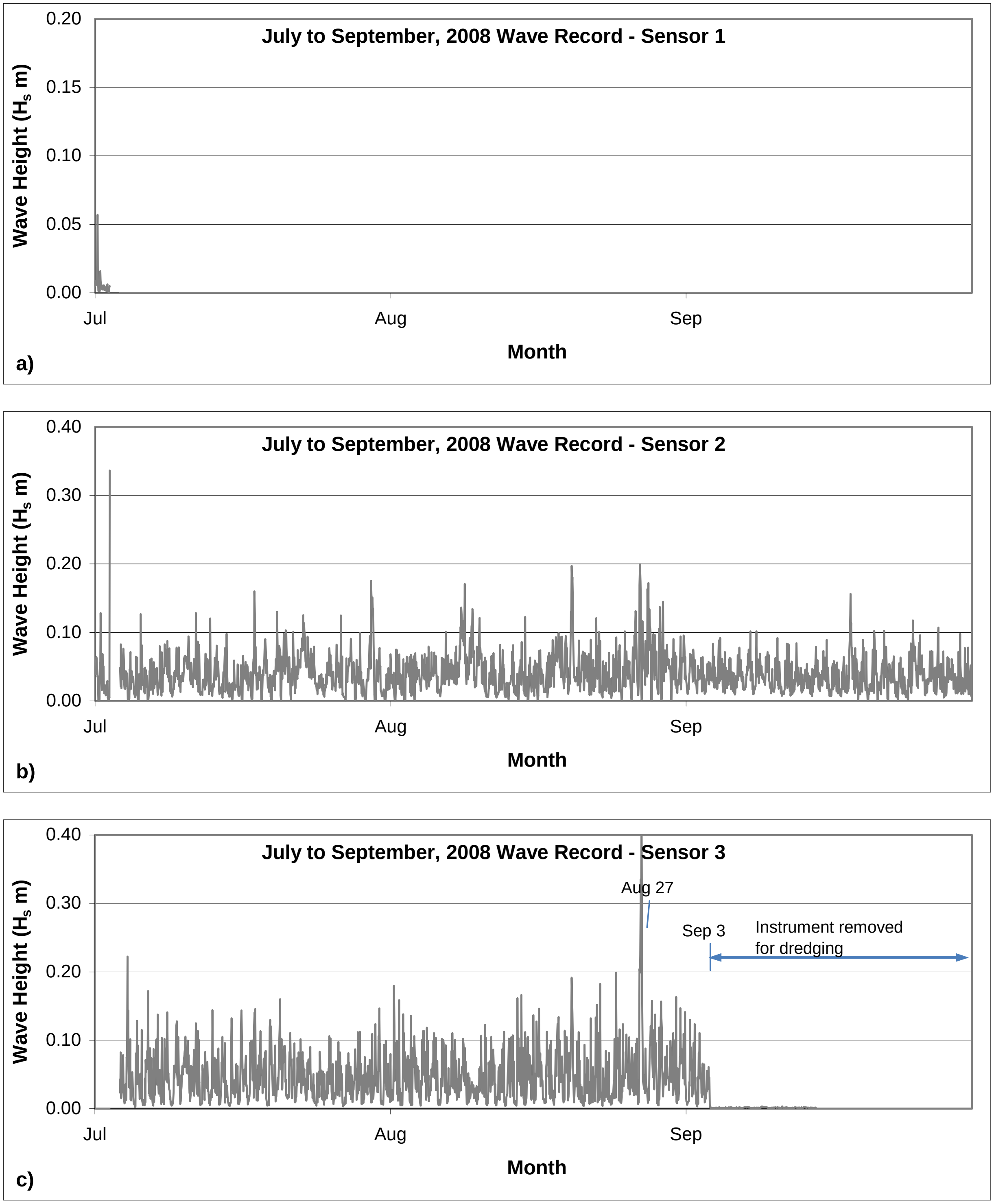


Figure 37 **Time-series record of significant wave heights (Hs) measured at the three wave sensors in the study area for the period July to September, 2008**

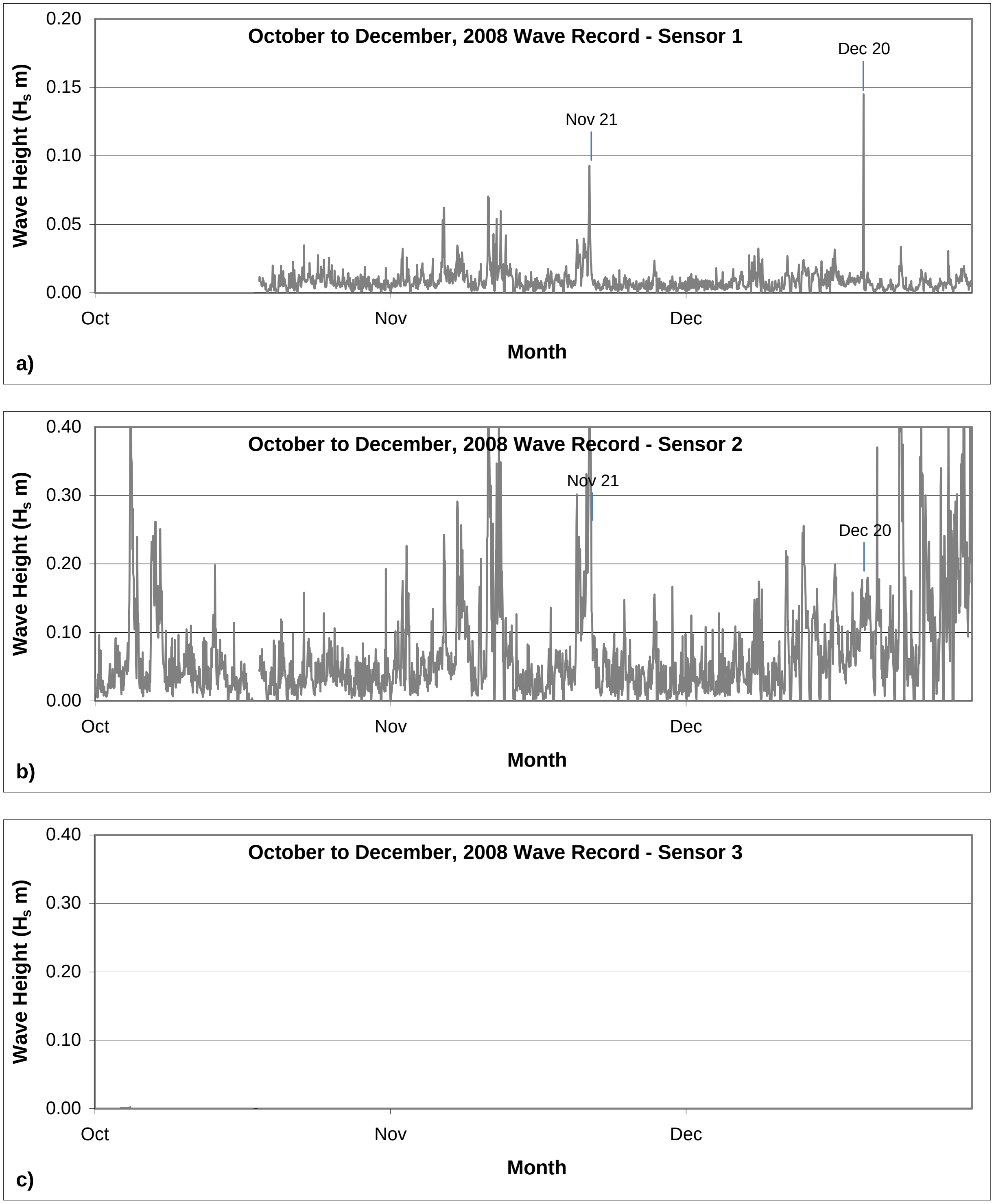


Figure 38 **Time-series record of significant wave heights (Hs) measured at the three wave sensors in the study area for the period October to December, 2008**

DP3 AMS PROGRAM 2008 ANNUAL REPORT

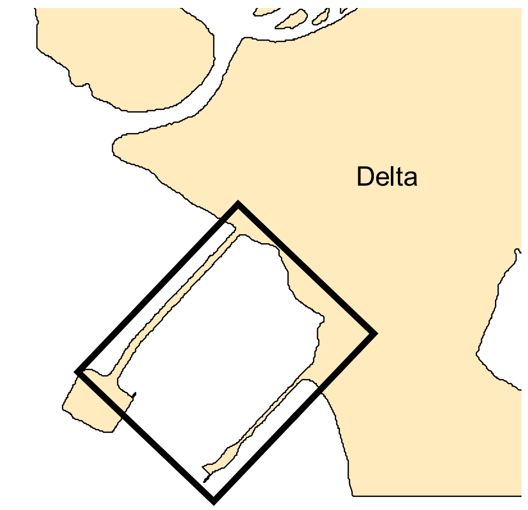
2008 Eelgrass Classification

Scale - 1:15,000

400 200 0 400 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-5074	September 2009

Reference Map



Legend

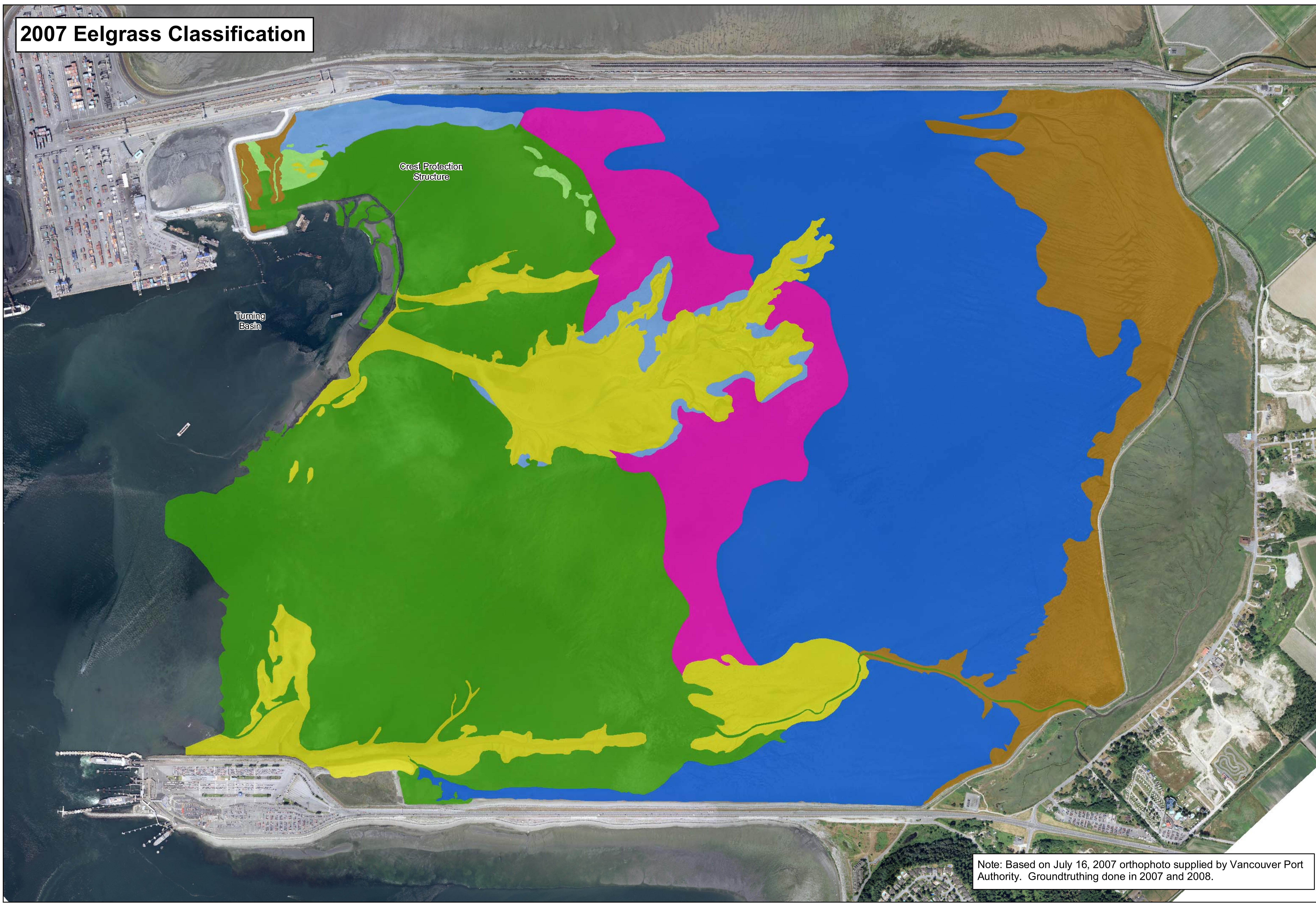
- Mud
- Sand
- Z. japonica
- Z. japonica - patchy
- Z. marina
- Z. marina - patchy
- Zostera mixed*
- Zostera mixed - patchy*

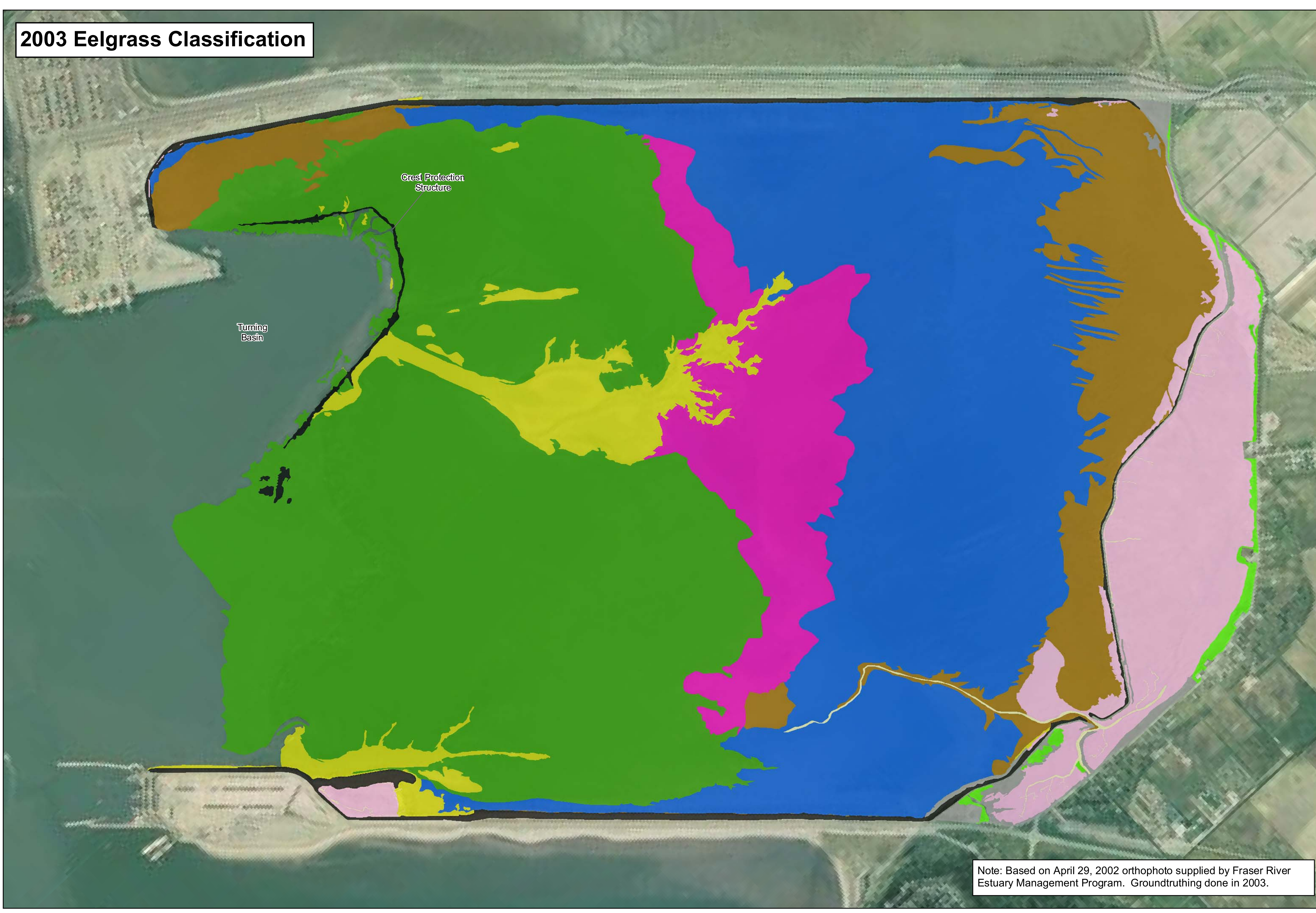
Note:
- July 2, 2008 orthophoto supplied by Vancouver Fraser Port Authority.
- Groundtruthing done from August 14 to 17, 2008.

* Transition Zone

CM, linuxprojects\34789_RobertsBankEelgrass2007\GIS\CM_FigEelgrass2008_AMS.mxd

Figure 39





2007 Eelgrass Classification

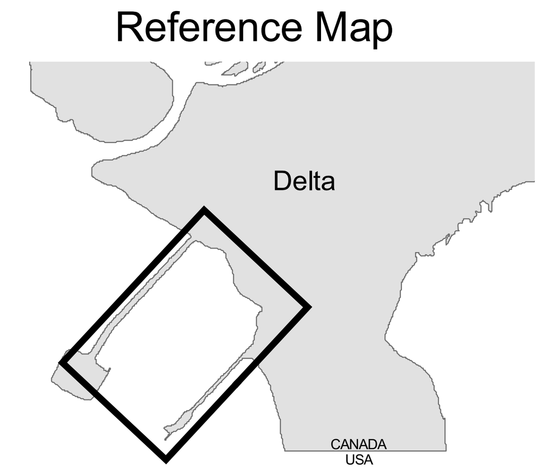
- Z. japonica
- Z. japonica - patchy
- Z. marina
- Z. marina - patchy
- Zostera - mixed*
- Mud
- Sand

* Transition Zone

2003 Eelgrass Classification

- Z. japonica
- Z. marina
- Zostera - mixed*
- Channel
- Grass
- Marsh
- Mud
- Sand
- Shrubs
- Rocky Habitat

Reference Map



DELTAPORT THIRD BERTH ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

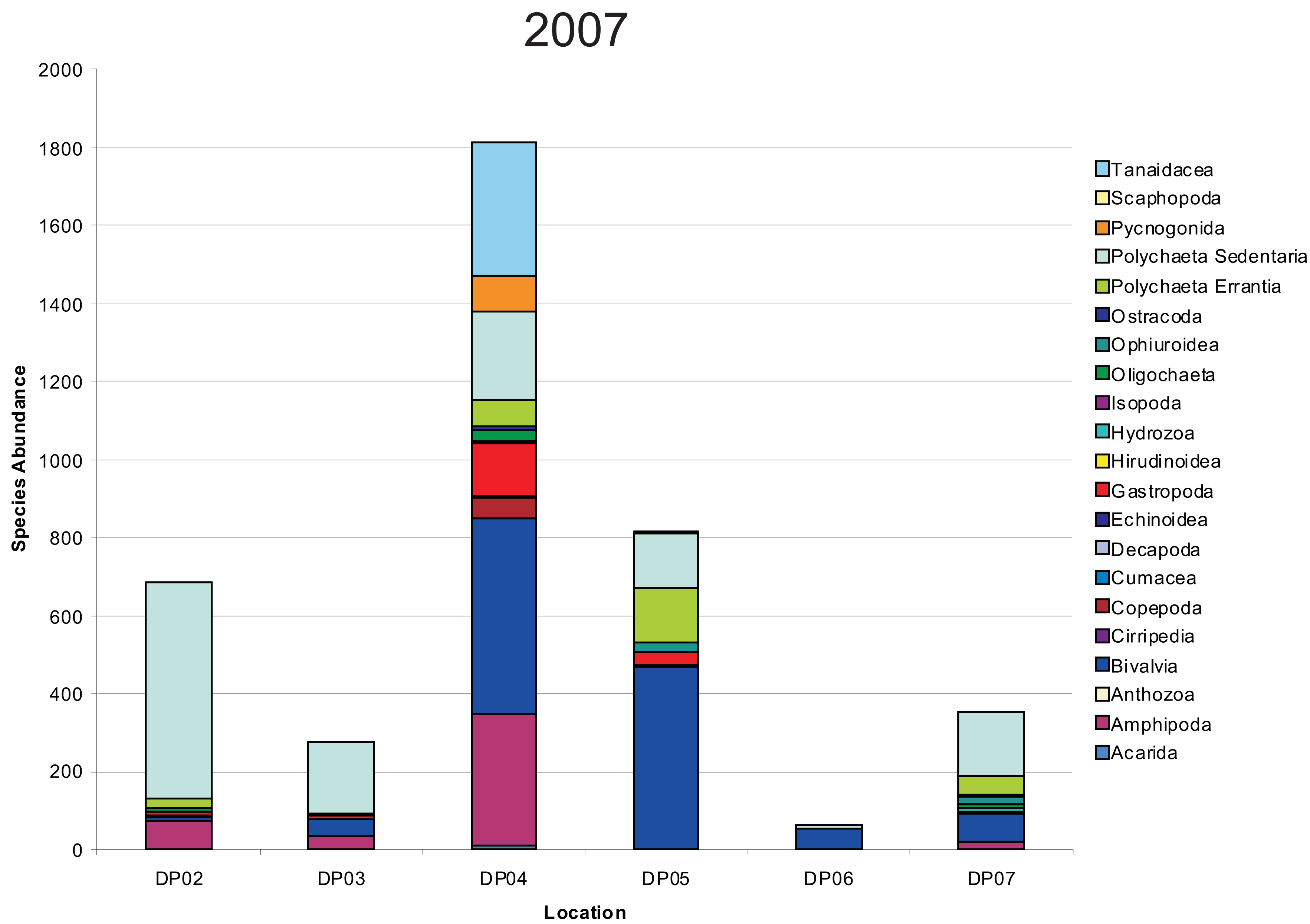
Eelgrass Classification
2003 and 2007

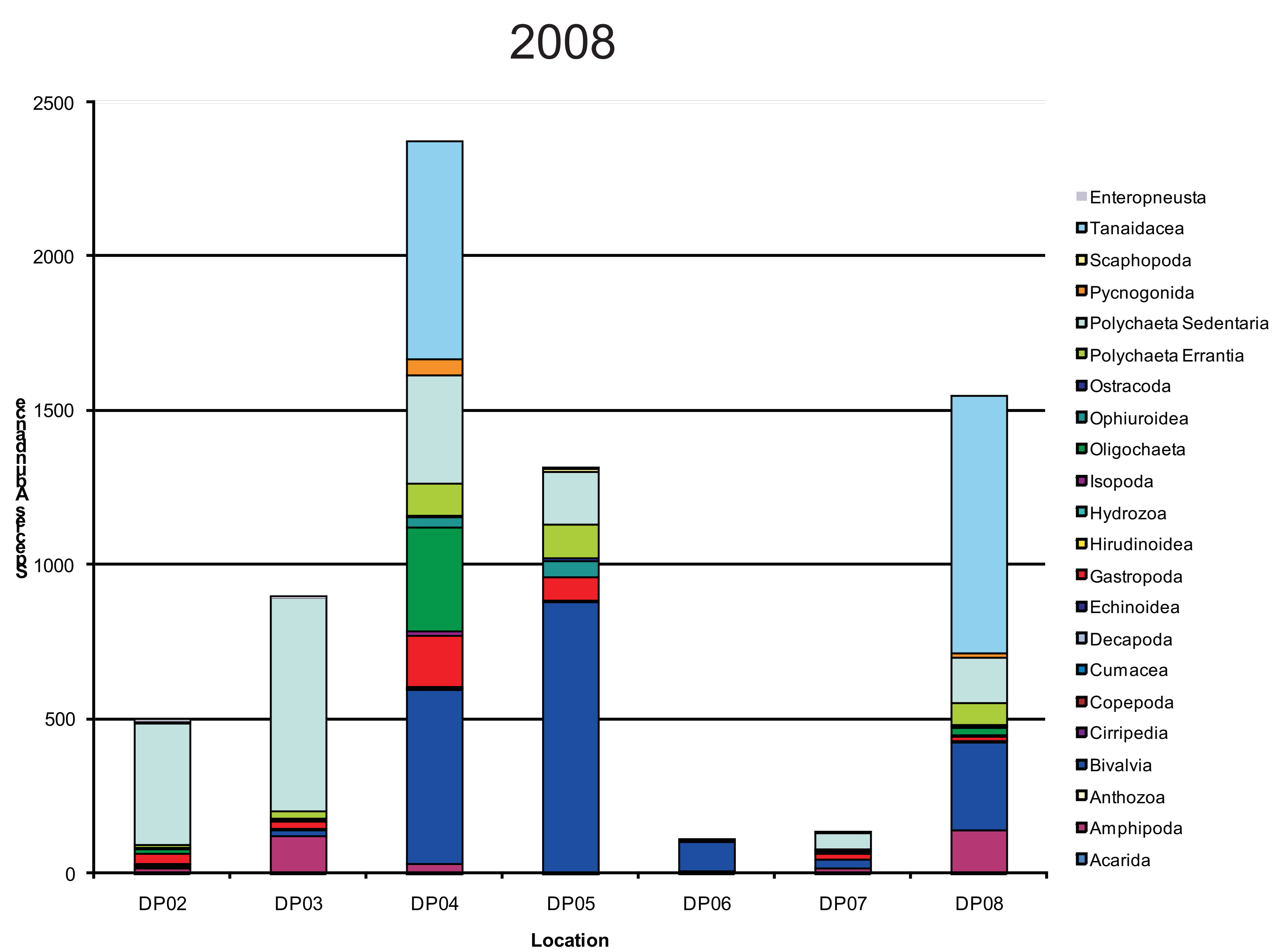
Scale - 1:10,000

400 200 0 400 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4935	September 2009

Figure 40





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CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2008 ANNUAL REPORT

BENTHIC INVERTEBRATE ABUNDANCE BY CLASS IN 2007 and 2008

PROJECT No. 499-002.11	September 2009	FIGURE 41

Legend

- Study Stations

Species Count

- 1 - 10
- 11 - 50
- 51 - 100
- 101 - 250
- 251 - 500

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DELTAPORT THIRD BERTH -
ADAPTIVE MANAGEMENT STRATEGY PROGRAM
2008 ANNUAL REPORT

Great Blue Heron Distribution and Cumulative Abundance within the Inter-causeway Area during Low Tide Events, 2008

PROJECT NO: 499-002.11	SEPT 2009	FIGURE 42

Legend

- Study Stations

Species Count

- 1 - 50
- 51 - 100
- 101 - 500
- 501 - 1000

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DELTAPORT THIRD BERTH -
ADAPTIVE MANAGEMENT STRATEGY PROGRAM
2008 ANNUAL REPORT

Brant Distribution and Cumulative Abundance within the Inter-causeway Area during High Tide Events, 2008

PROJECT NO: 499-002.11	SEPT 2009	FIGURE 43

Legend

- Study Stations

Species Count

- 1 - 10
- 11 - 50
- 51 - 100
- 101 - 250
- 251 - 500

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DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

Great Blue Heron Distribution and Cumulative Abundance within the Inter-causeway Area during Low Tide Events, 2007

PROJECT NO: 499-002.11	SEPT 2009	FIGURE 44

Legend

- Study Stations

Species Count

- 1 - 10
- 11 - 50
- 51 - 100
- 101 - 250
- 251 - 500

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DELTAPORT THIRD BERTH -
ADAPTIVE MANAGEMENT STRATEGY PROGRAM
2008 ANNUAL REPORT

Great Blue Heron Distribution and Cumulative Abundance within the Inter-causeway Area during Low Tide Events, October 2003 - August 2004

PROJECT NO: 499-002.11	SEPT 2009	FIGURE 45

Legend

- Study Stations

Species Count

- 1 - 50
- 51 - 100
- 101 - 500
- 501 - 1000

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DELTAPORT THIRD BERTH -
ADAPTIVE MANAGEMENT STRATEGY PROGRAM
2008 ANNUAL REPORT

Brant Distribution and Cumulative Abundance
within the Inter-causeway Area
during High Tide Events, 2007

PROJECT NO: 499-002.11	SEPT 2009	FIGURE 46

Legend

- Study Stations

Species Count

- 1 - 50
- 51 - 100
- 101 - 500
- 501 - 1000

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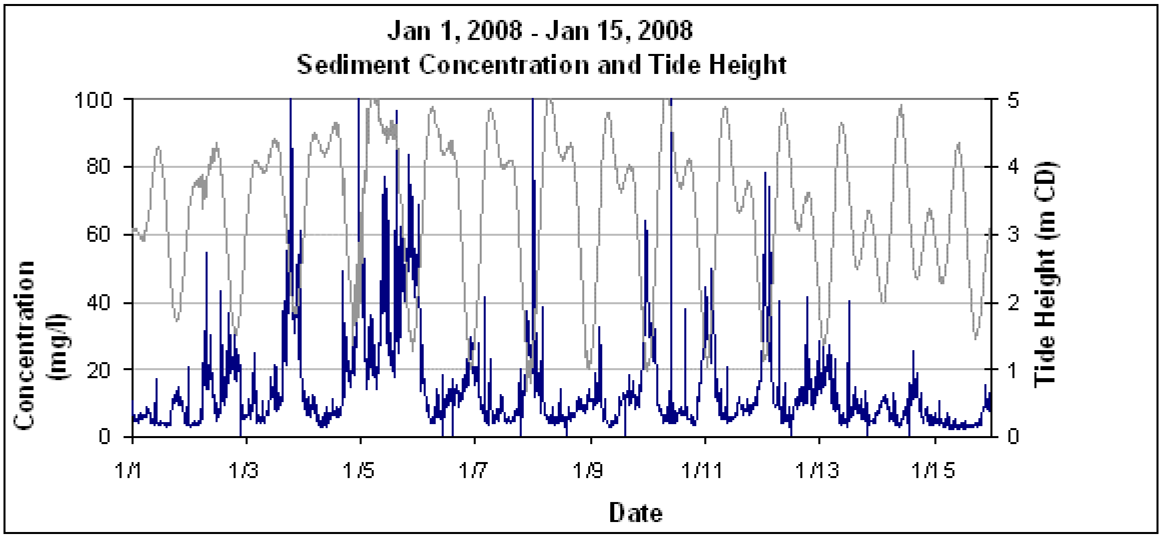
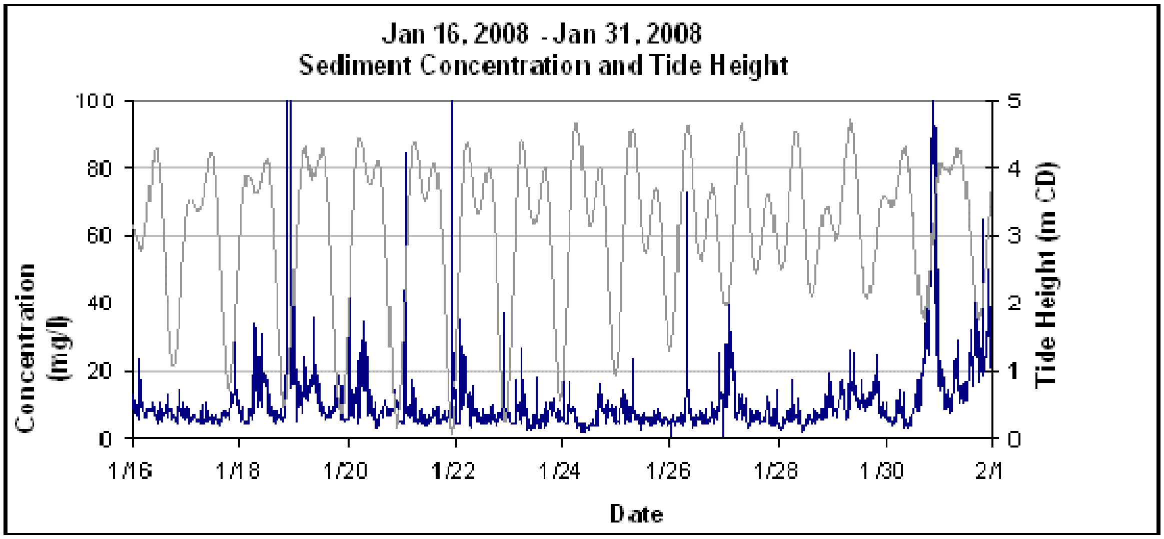
DELTAPORT THIRD BERTH -
ADAPTIVE MANAGEMENT STRATEGY PROGRAM
2008 ANNUAL REPORT

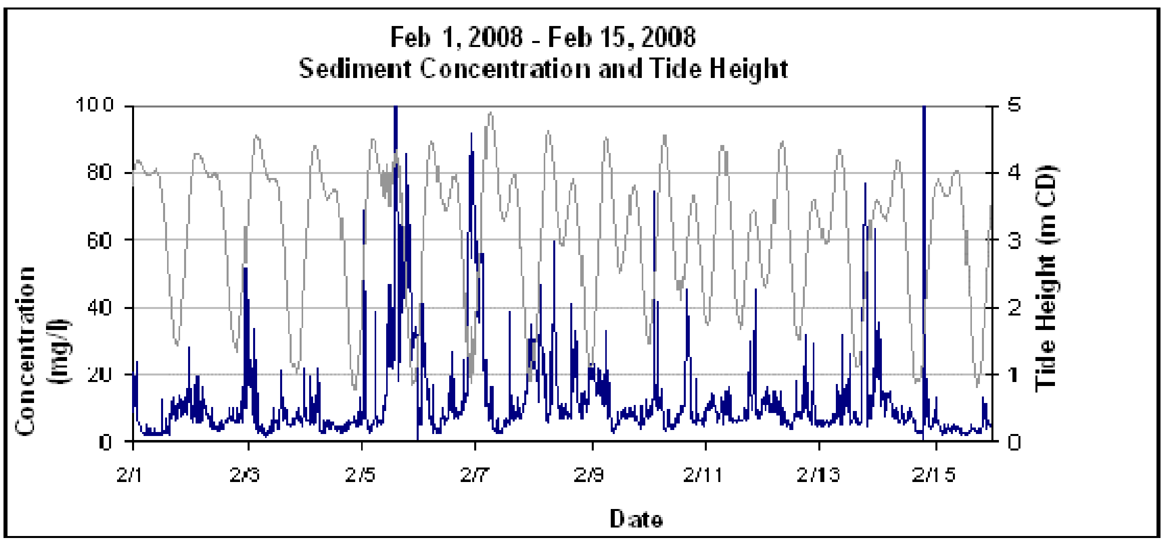
Brant Distribution and Cumulative Abundance within the Inter-causeway Area during High Tide Events, October 2003 - August 2004

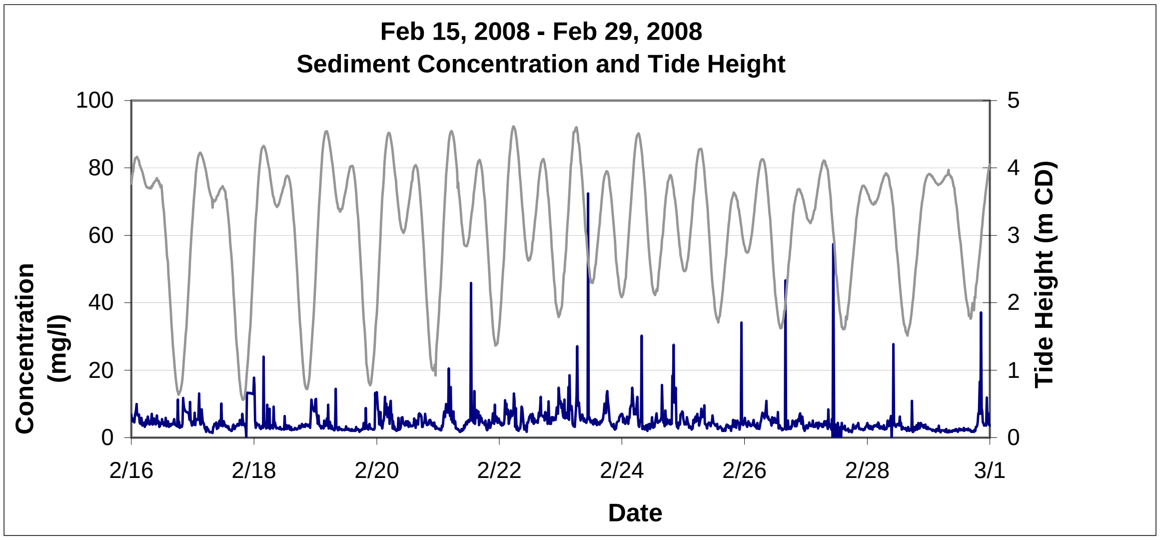
PROJECT NO: 499-002.11	SEPT 2009	FIGURE 47

Figure 48. Time series of turbidity and sediment concentration data from Sensor 2 for the period from January 1 to April 10, 2008 at approximately 15-day intervals. Tide height is represented by the grey line and sediment concentration is shown in blue.

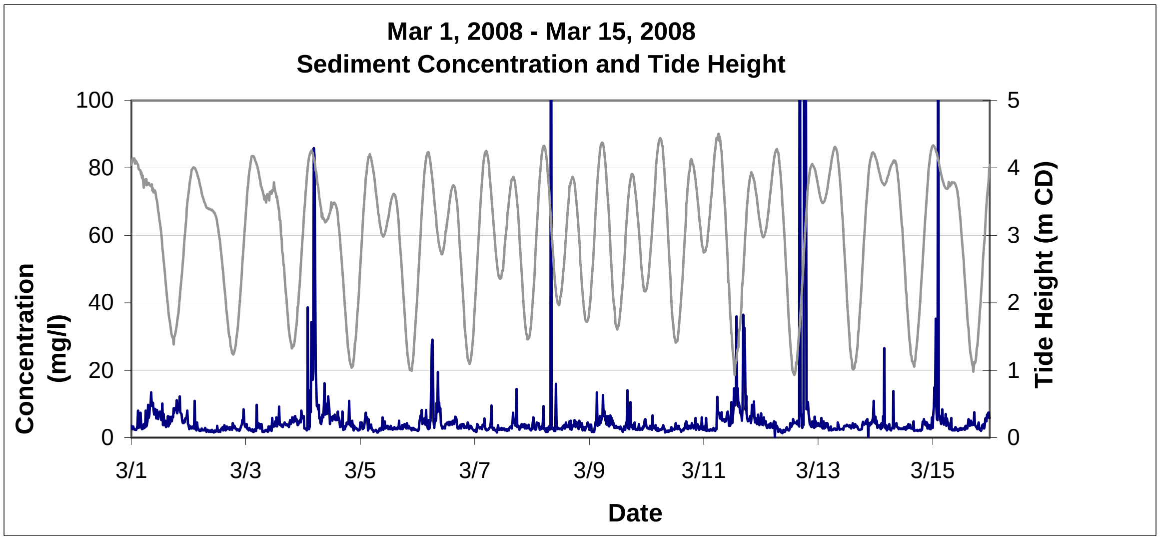




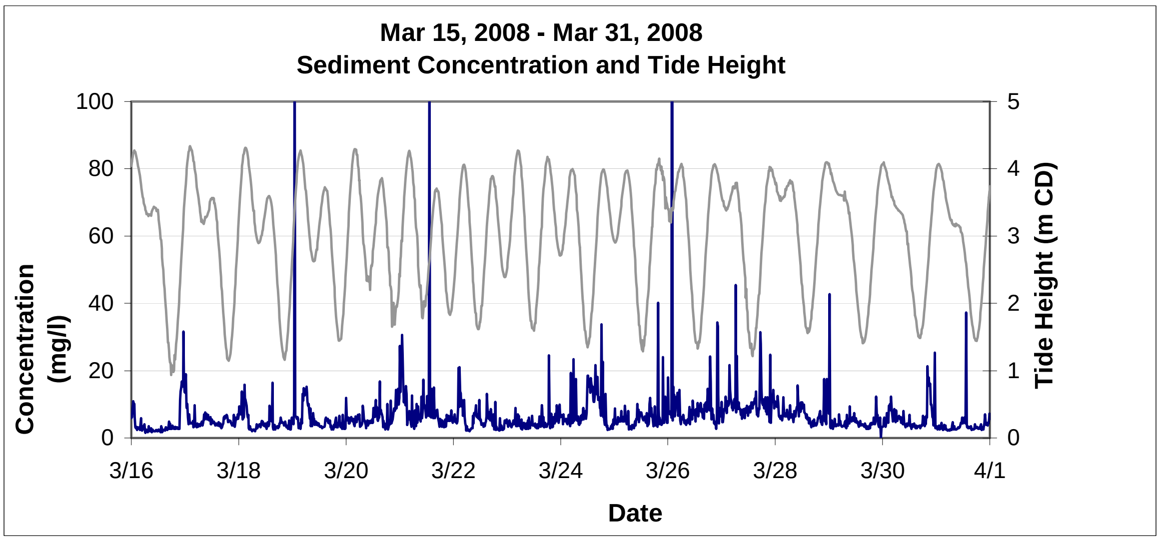




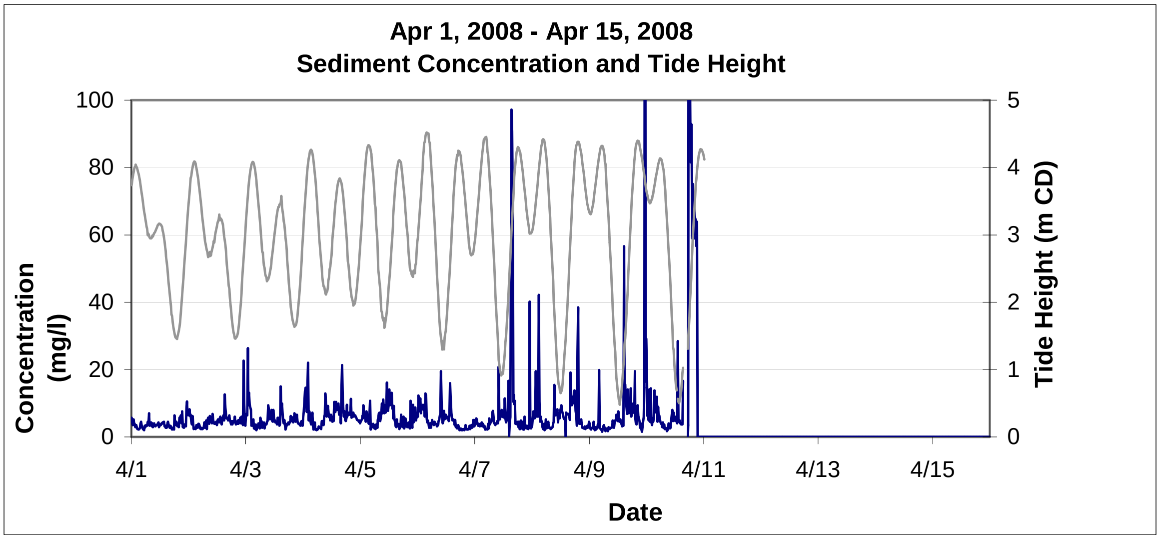
Feb 15, 2008 - Feb 29, 2008
Sediment Concentration and Tide Height
Concentration (mg/l)
Tide Height (m CD)
Date
100
80
60
40
20
0
5
4
3
2
1
0
2/16
2/18
2/20
2/22
2/24
2/26
2/28
3/1

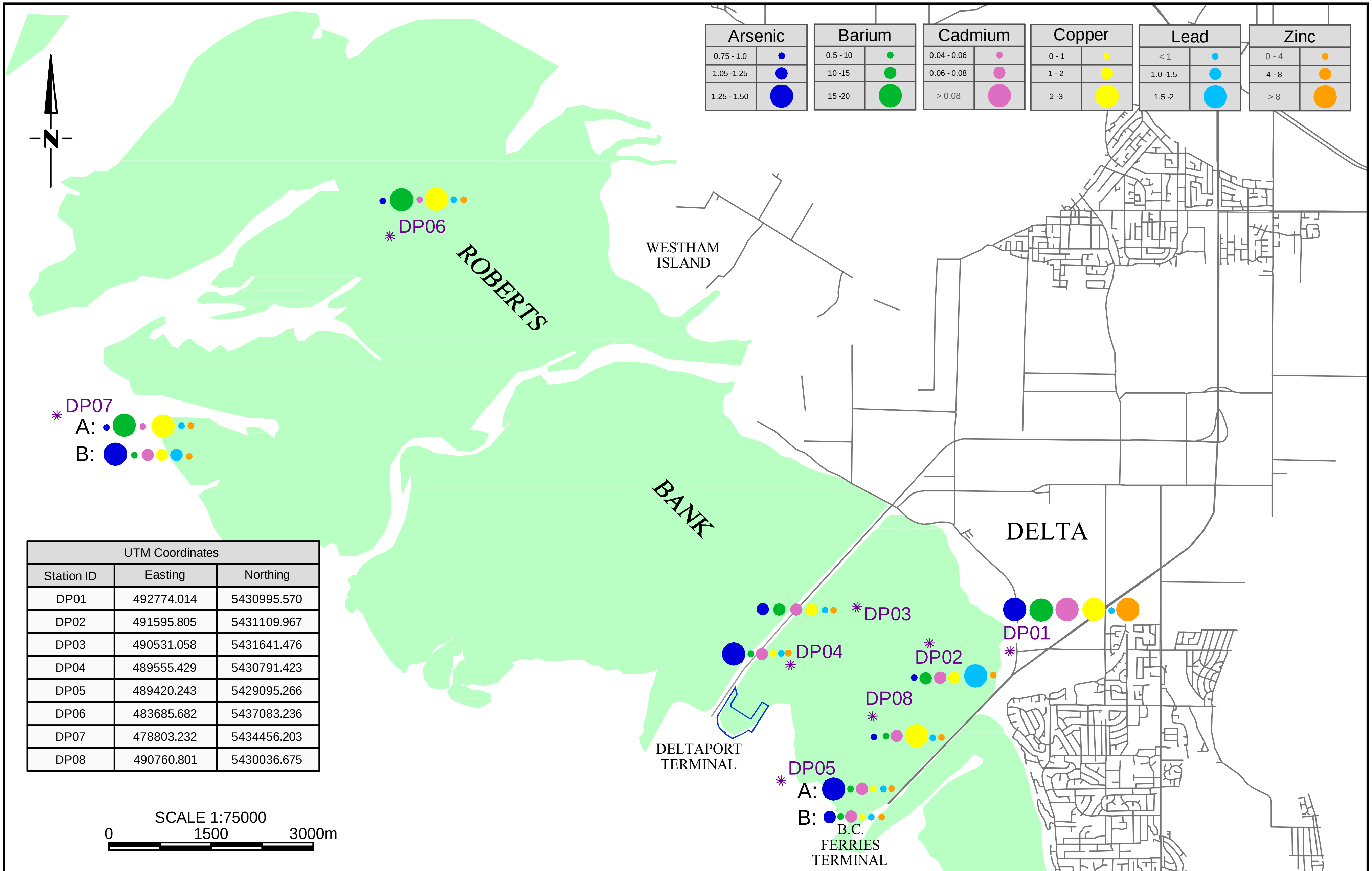


Mar 1, 2008 - Mar 15, 2008
Sediment Concentration and Tide Height
Concentration (mg/l)
Tide Height (m CD)
Date
100
80
60
40
20
0
5
4
3
2
1
0
3/1
3/3
3/5
3/7
3/9
3/11
3/13
3/15



Mar 15, 2008 - Mar 31, 2008
Sediment Concentration and Tide Height
Concentration (mg/l)
Tide Height (m CD)
Date
100
80
60
40
20
0
5
4
3
2
1
0
3/16
3/18
3/20
3/22
3/24
3/26
3/28
3/30
4/1


Apr 1, 2008 - Apr 15, 2008
Sediment Concentration and Tide Height
Concentration (mg/l)
Tide Height (m CD)
Date
100
80
60
40
20
0
5
4
3
2
1
0
4/1
4/3
4/5
4/7
4/9
4/11
4/13
4/15



UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203
DP08	490760.801	5430036.675

LEGEND
- Water
- Tidal Mud & Sand
- ✳ Sampling Station

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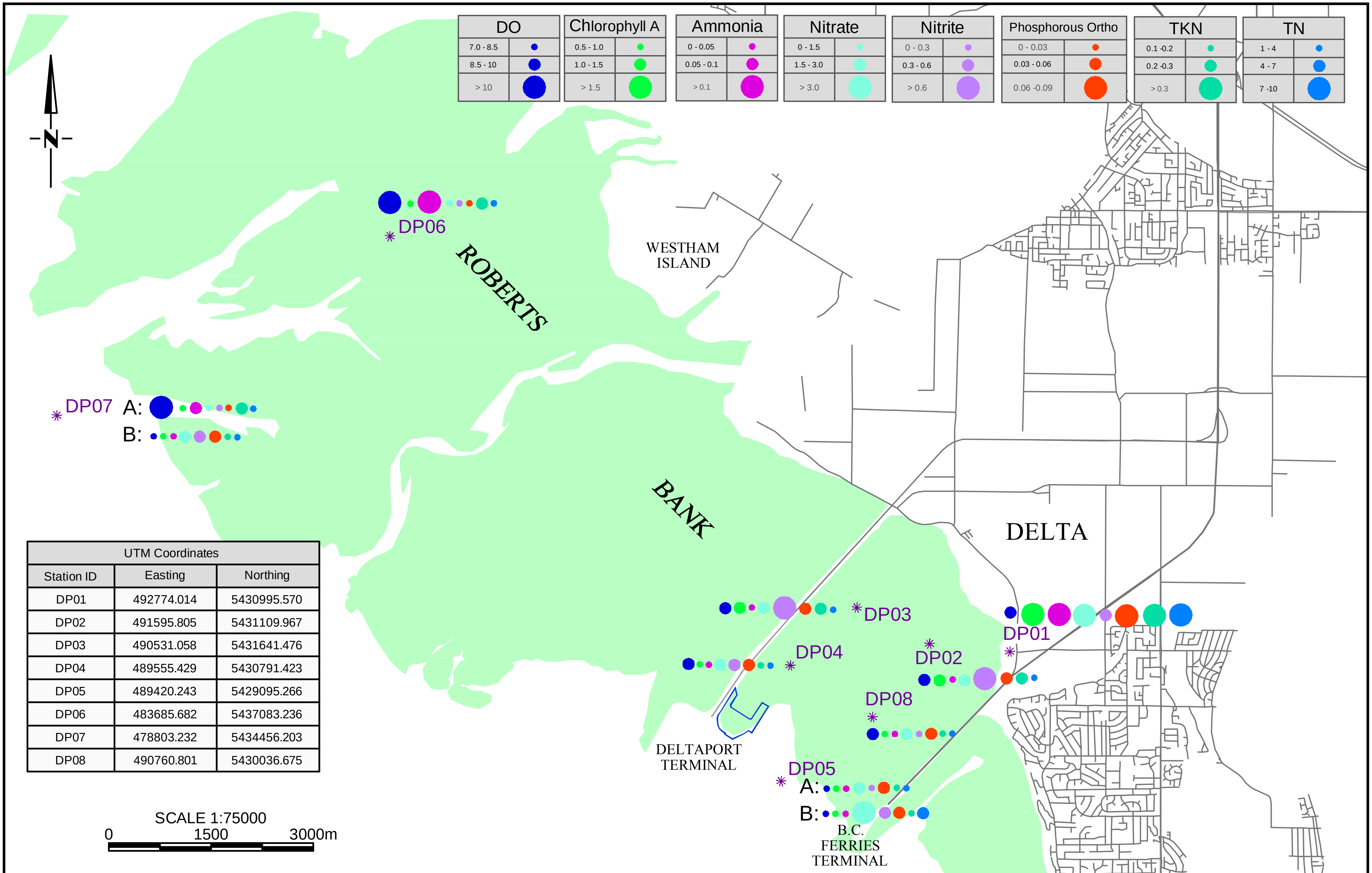
CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2008 ANNUAL REPORT

SPATIAL TRENDS OF METAL PARAMETERS IN SURFACE WATER

PROJECT No. 499-002.11	SEPTEMBER 2009	FIGURE 49



UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203
DP08	490760.801	5430036.675

LEGEND
Water
Tidal Mud & Sand
Sampling Station

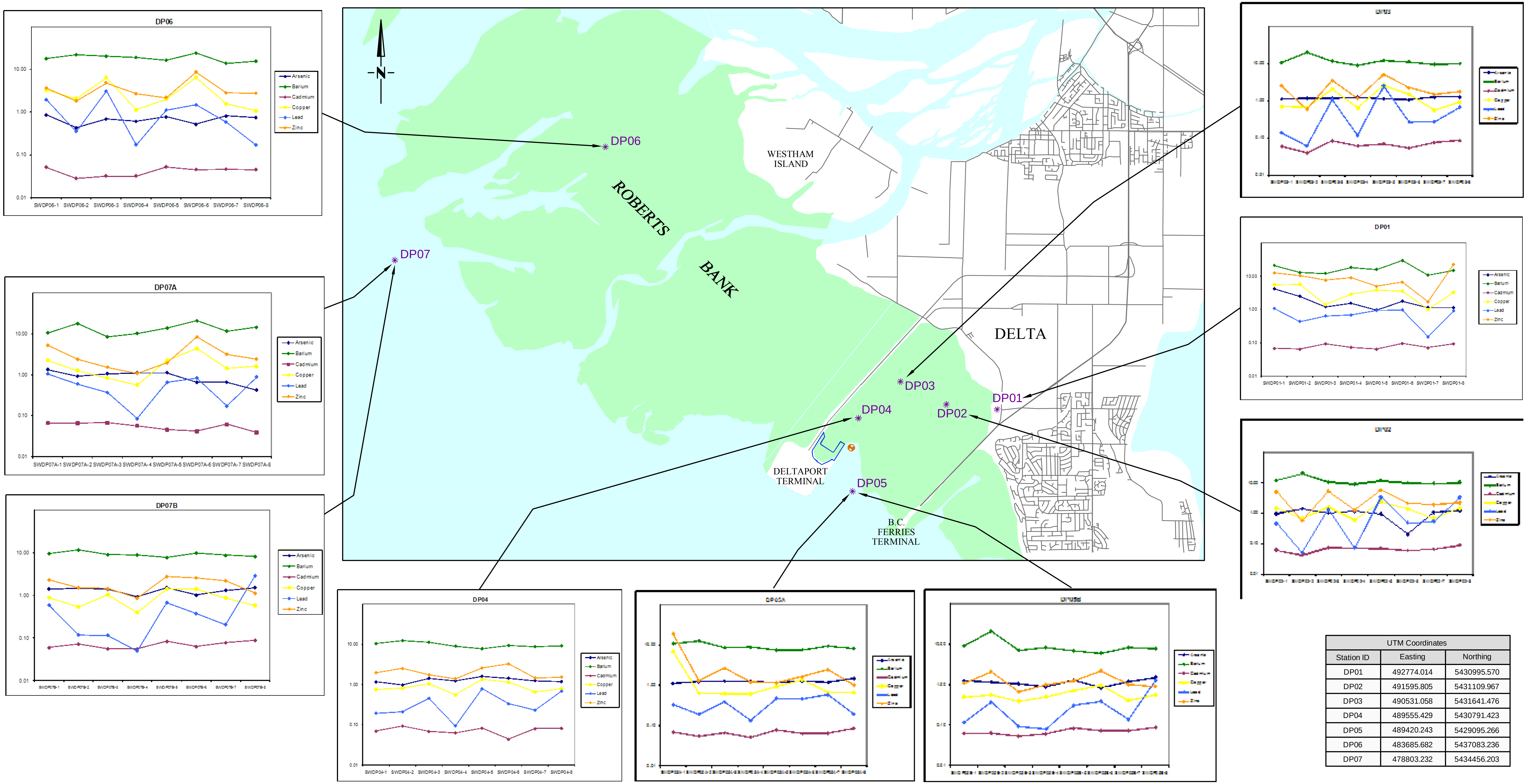
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2008 ANNUAL REPORT

SPATIAL TRENDS OF EUTROPHICATION-RELATED PARAMETERS IN SURFACE WATER

PROJECT No. 499-002.11	SEPTEMBER 2009	FIGURE 50



UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203

LEGEND
- Water
- Tidal Mud & Sand
- Water Quality Sampling Station
- YSI Sonde

SCALE 1:75000
0 1500 3000m

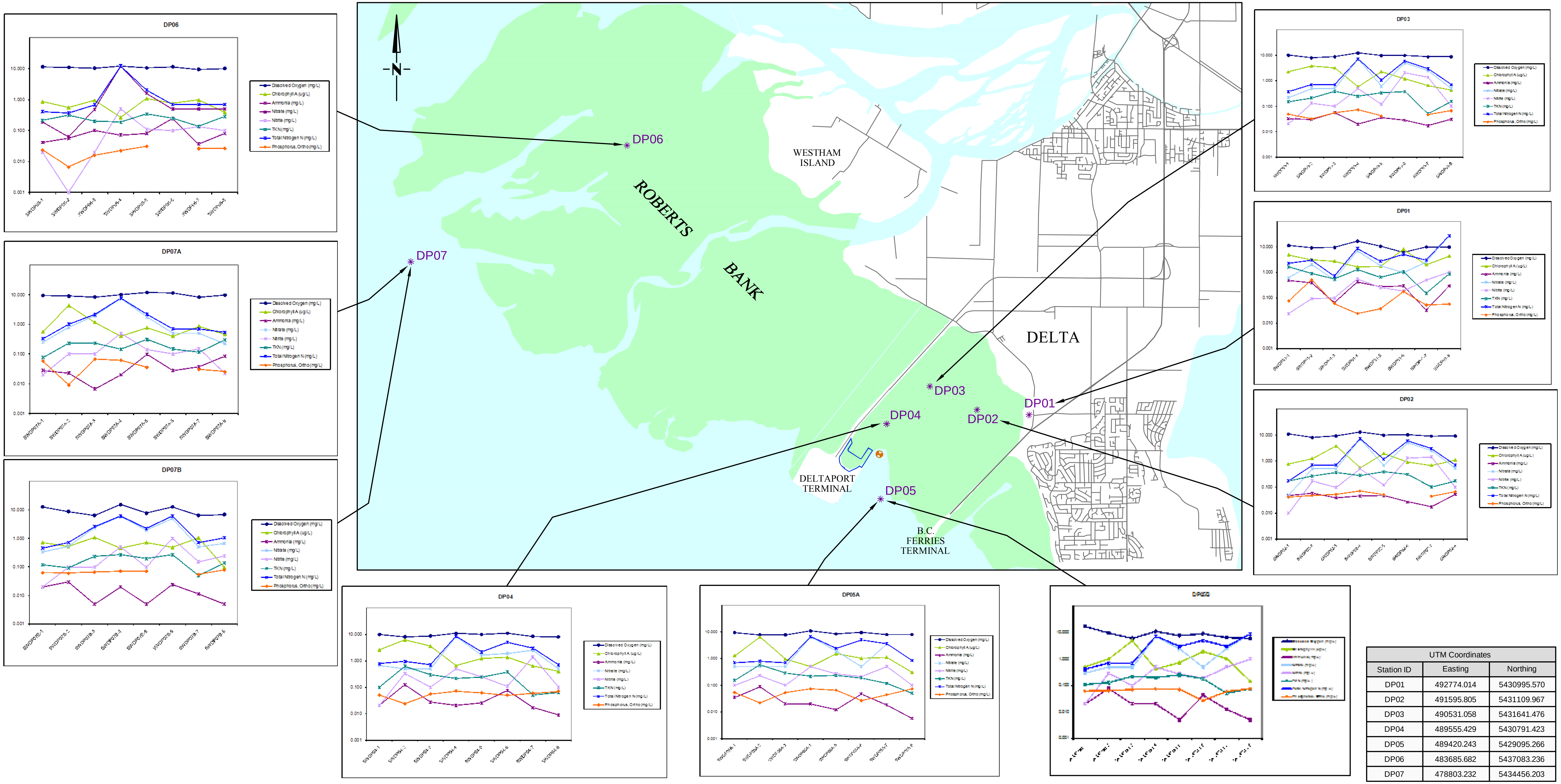
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

TEMPORAL TRENDS OF METALS IN SURFACE WATER

PROJECT No.		
499-002.11	SEPTEMBER 2009	FIGURE 51



UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203

LEGEND
- Water
- Tidal Mud & Sand
- Water Quality Sampling Station
- YSI Sonde

SCALE 1:75000

0 1500 3000m

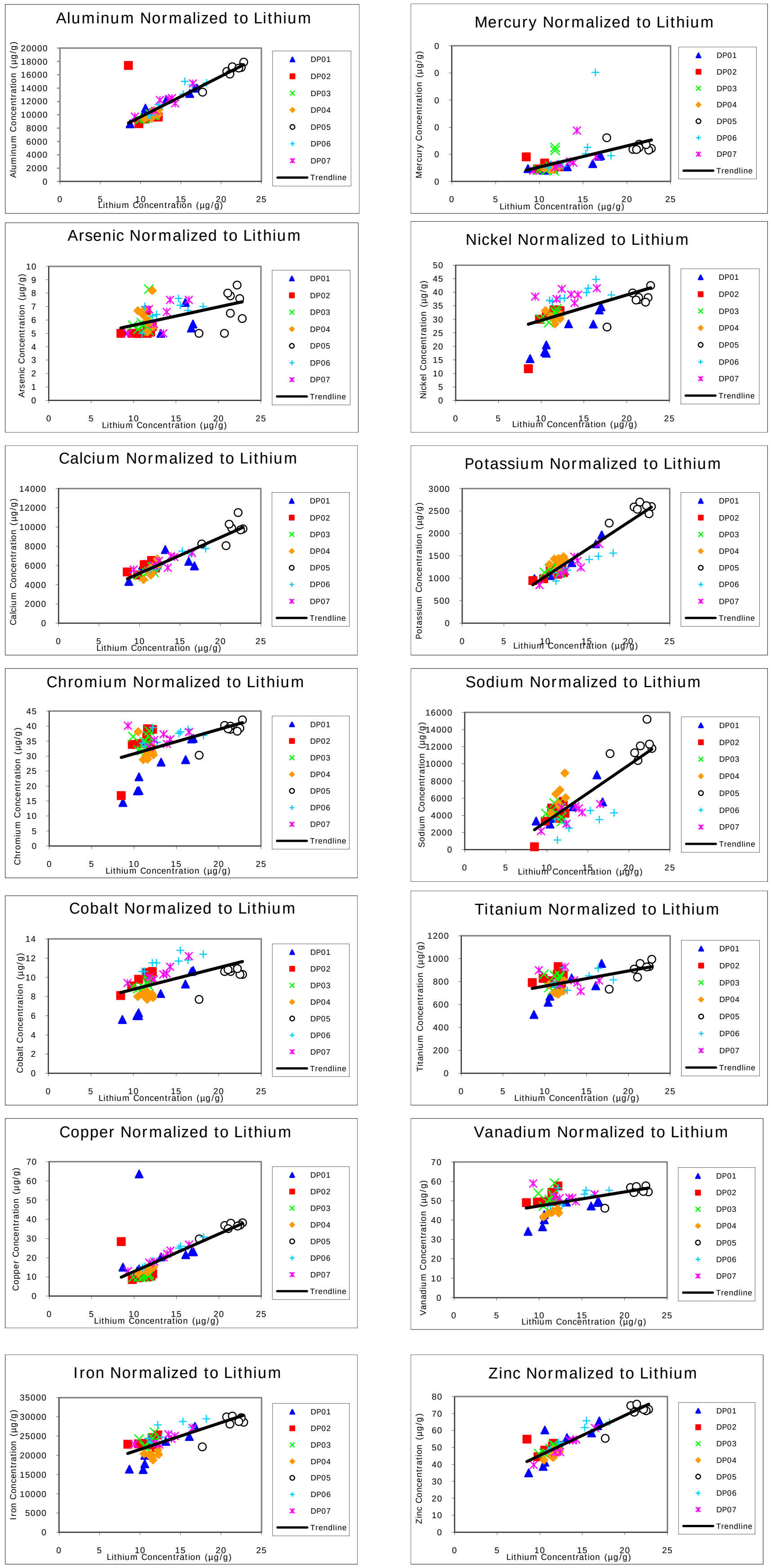
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

TEMPORAL TRENDS OF EUTROPHICATION-RELATED PARAMETERS IN SURFACE WATER

PROJECT No. 499-002.11 | SEPTEMBER 2009 | FIGURE 52



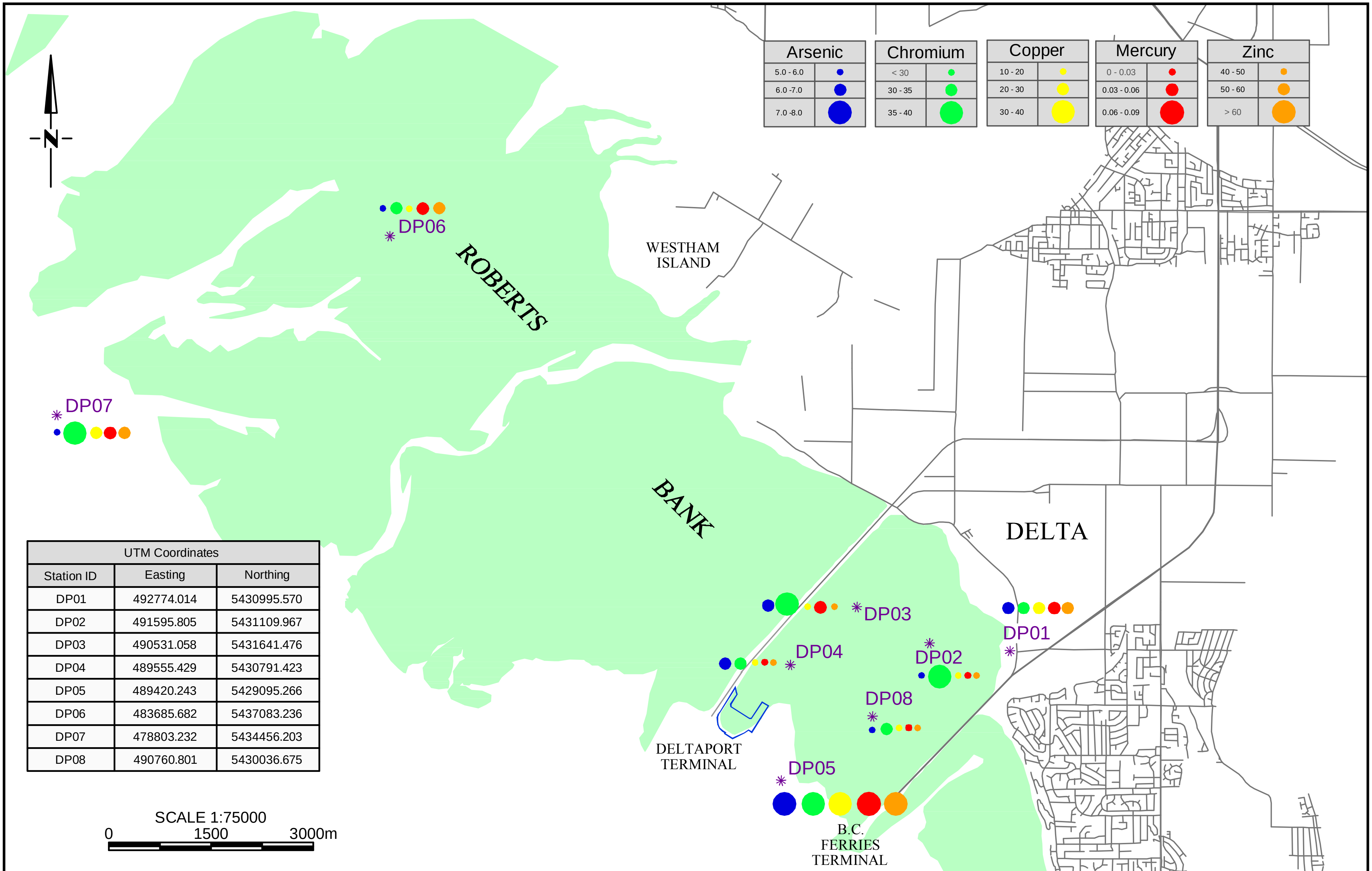
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH – ADAPTIVE MANAGEMENT STRATEGY PROGRAM – 2008 ANNUAL REPORT

TRENDS OF METAL IN SEDIMENT NORMALIZED TO LITHIUM

PROJECT No. 499-002.11	September 2009	FIGURE 53



UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203
DP08	490760.801	5430036.675

LEGEND
Water
Tidal Mud & Sand
Sampling Station

HEMMERA

CLIENT: PORT METRO vancouver

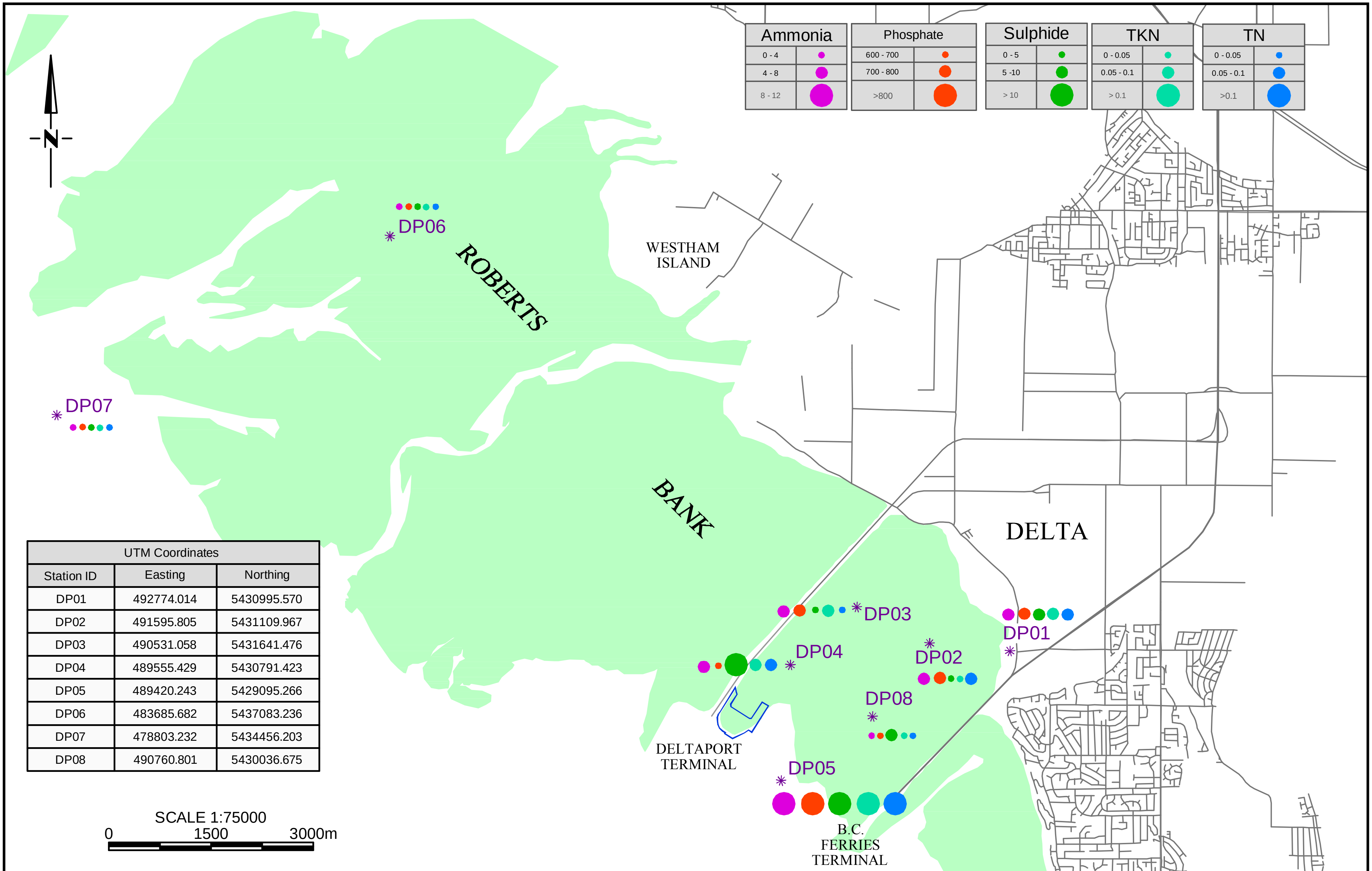
DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2008 ANNUAL REPORT

SPATIAL TRENDS OF METALS IN SEDIMENT

PROJECT No. 499-002.11

SEPTEMBER 2009

FIGURE 54



UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203
DP08	490760.801	5430036.675

LEGEND
Water
Tidal Mud & Sand
Sampling Station

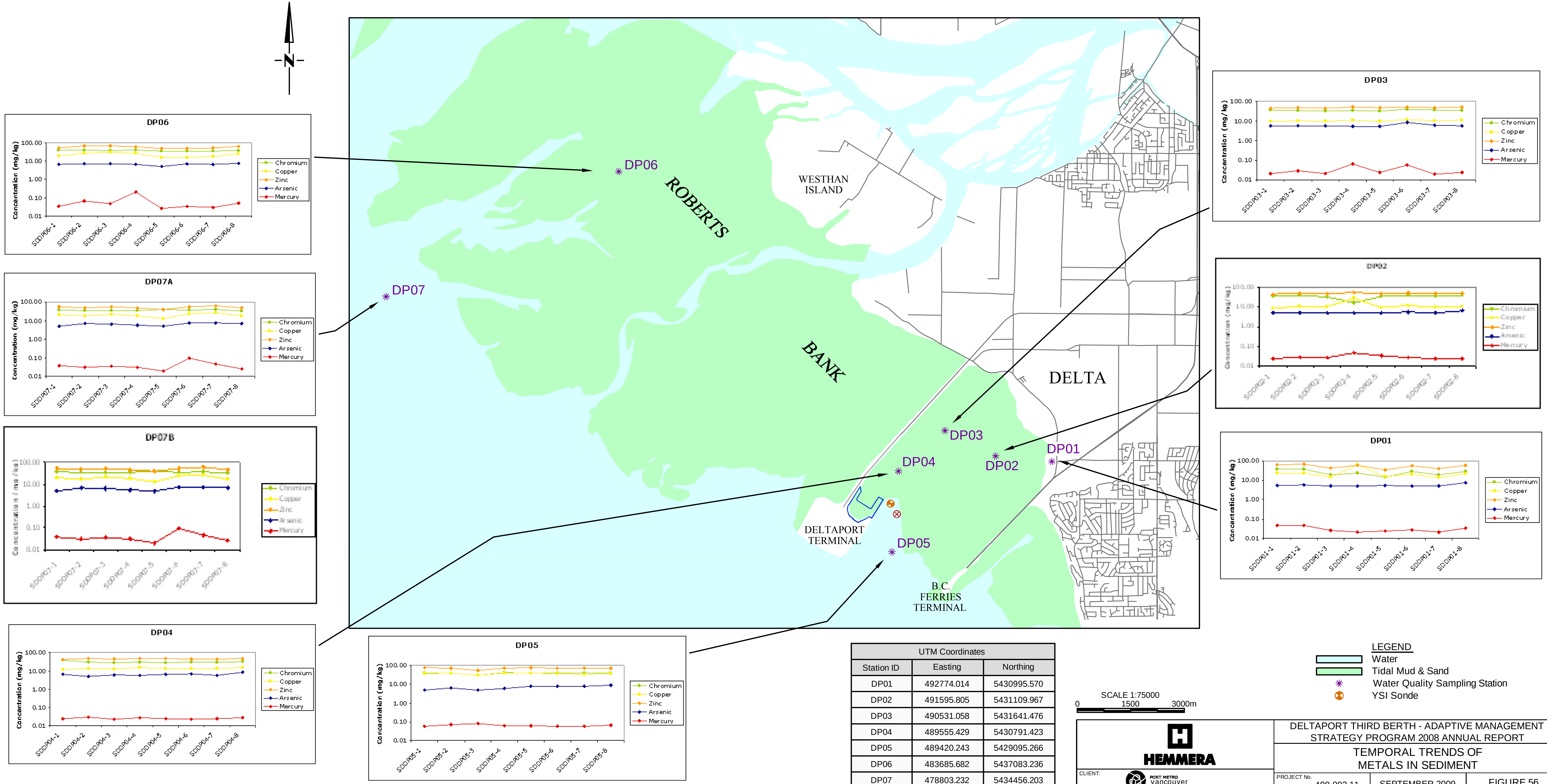
HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM - 2008 ANNUAL REPORT

SPATIAL TRENDS OF EUTROPHICATION-RELATED PARAMETERS IN SEDIMENT

PROJECT No. 499-002.11	SEPTEMBER 2009	FIGURE 55



UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203

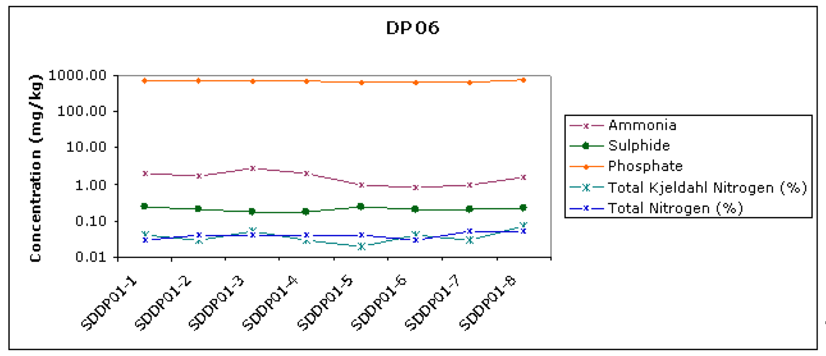
HEMMERA

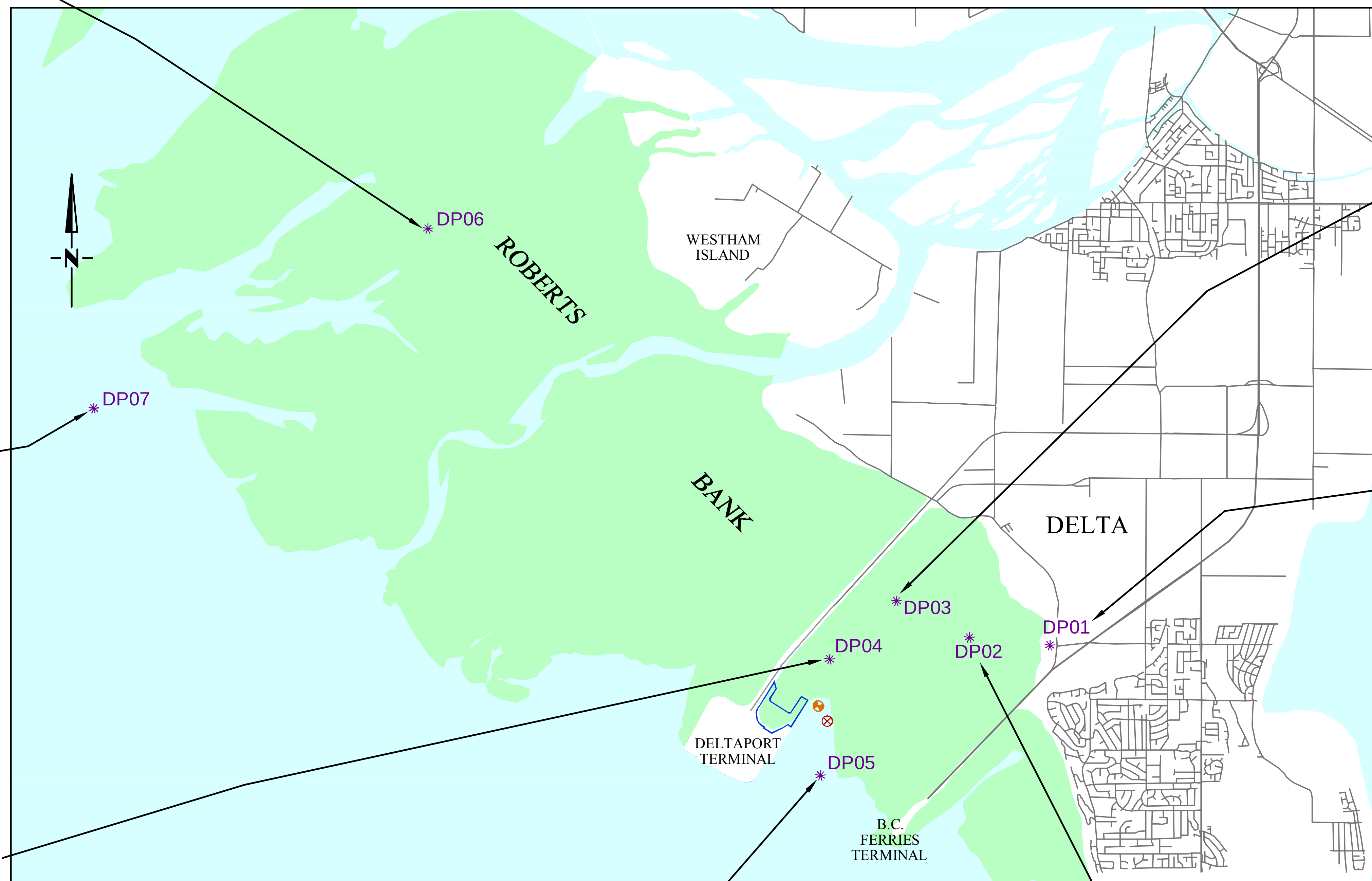
CLIENT: PORT METRO vancouver

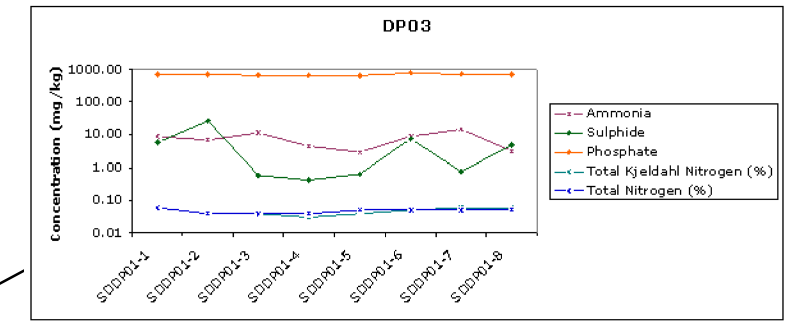
DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

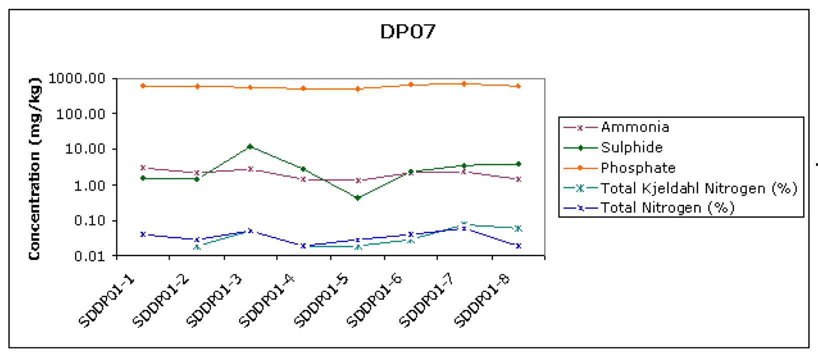
TEMPORAL TRENDS OF METALS IN SEDIMENT

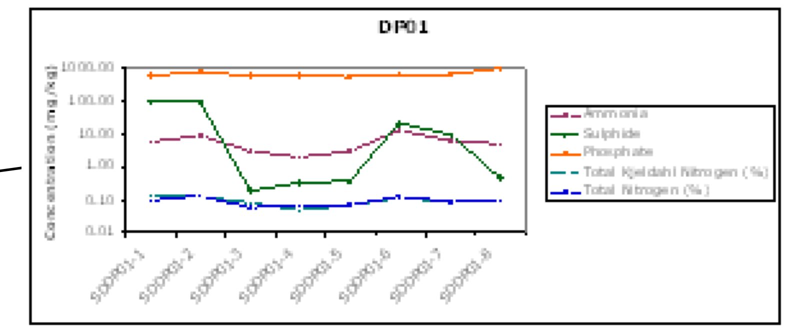
PROJECT No. 499-002.11 | SEPTEMBER 2009 | FIGURE 56

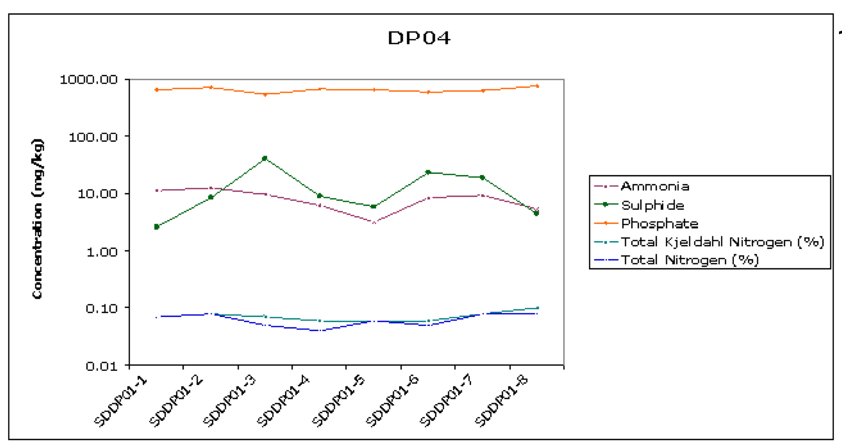


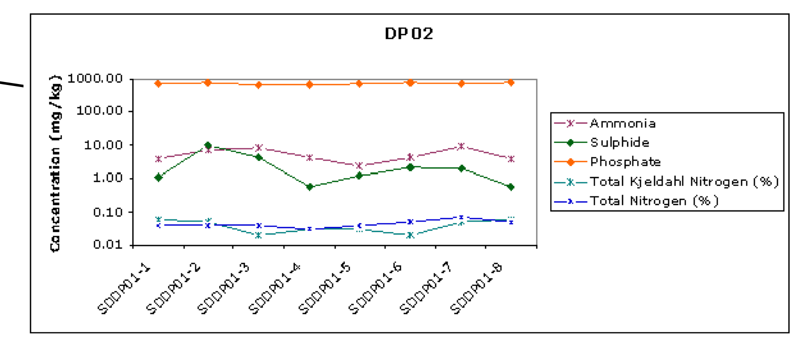


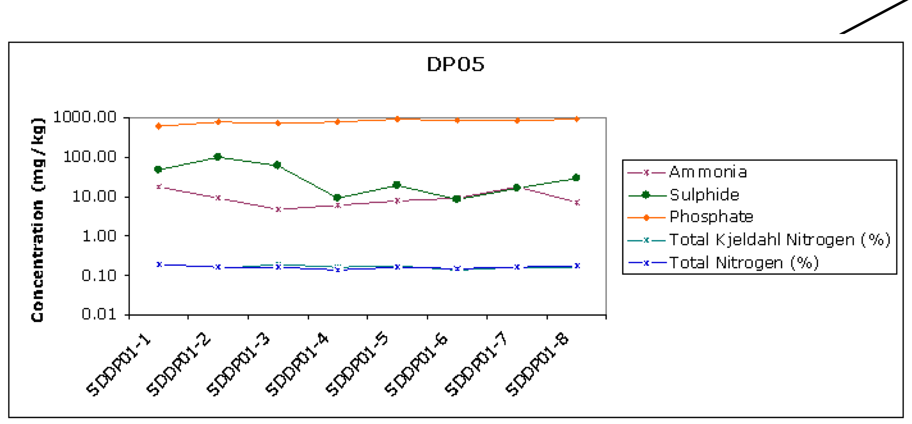












UTM Coordinates		
Station ID	Easting	Northing
DP01	492774.014	5430995.570
DP02	491595.805	5431109.967
DP03	490531.058	5431641.476
DP04	489555.429	5430791.423
DP05	489420.243	5429095.266
DP06	483685.682	5437083.236
DP07	478803.232	5434456.203

SCALE 1:75000
0 1500 3000m

LEGEND
- Water
- Tidal Mud & Sand
- Water Quality Sampling Station
- YSI Sonde

HEMMERA

CLIENT: PORT METRO vancouver

DELTAPORT THIRD BERTH - ADAPTIVE MANAGEMENT STRATEGY PROGRAM 2008 ANNUAL REPORT

TEMPORAL TRENDS OF EUTROPHICATION-RELATED PARAMETERS IN SEDIMENT

PROJECT No.		
499-002.11	SEPTEMBER 2009	FIGURE 57

TABLES

Table 1
Monitoring Dates

Year	Quarter	Date	Monitoring Activity
2007	1	March 22 - 24	Hemmera Sediment, Surface Water, and Benthic Invertebrate Samples
		March 24 - 25	Bird Survey
		April 7 - 12	Bird Survey
		April 20	Crest Protection Monitoring - photos only Install DoD Rods NHC Sediment Samples
		April 23 - 24	Bird Survey
	2	May 7 - 8	Bird Survey
		May 22 - 23	Bird Survey
		June 5 - 6	Bird Survey
		June 18 - 19	Bird Survey
		June 20 - 21	Hemmera Sediment and Surface Water
		July 3 - 4	Bird Survey
		July 12 - 16	Eelgrass Survey
		July 16 - 17	Bird Survey
		July 30	Crest Protection Monitoring - photos & surveys Turbidity Sensor Download DoD Rods Aerial Photographs
	3	July 30 - 31	Bird Survey
		August 17 - 18	Bird Survey
		August 30 - 31	Bird Survey
		September 14 - 15	Bird Survey
		October 1 - 2	Hemmera Sediment and Surface Water
		October 2	Crest Protection Monitoring - surveys only DoD Rods NHC Sediment Samples
		October 2 - 3	Bird Survey
		October 18 - 20	Bird Survey
		October 29	Turbidity Sensor Download Remaining DoD Rods Remaining NHC Sediment Samples
	4	November 1 - 4	Bird Survey
		November 15 - 16	Bird Survey
		November 27	Crest Protection Monitoring - no surveys (equipment failure) Turbidity Sensor Download - Sensor 2 only DoD Rods
		November 29 - 30	Bird Survey
		December 10	Hemmera Sediment and Surface Water
		December 15	Bird Survey
		December 28	Bird Survey

Table 1
Monitoring Dates

Year	Quarter	Date	Monitoring Activity
2008	1	January 11	Bird Survey
		January 21	Crest Protection Monitoring - surveys only Turbidity Sensor Download - Sensor 2 only DoD Rods
		January 23	Bird Survey
		February 8	Bird Survey
		February 22 - 25	Bird Survey
		March 3-5	Hemmera Sediment, Surface Water, and Benthic Invertebrate Samples
		March 10 - 12	Bird Survey
		March 27 - 29	Bird Survey
	2	April 9	Crest Protection Monitoring - photos & surveys Turbidity Sensor Download - Sensor 2 only DoD Rods Installation of 6 additional DoD Rods NHC Sediment Samples Install Wave Sensors
		April 10 - 11	Bird Survey
		April 24 - 25	Bird Survey
		May 8 - 9	Bird Survey
		May 22 - 23	Bird Survey
		May 29 - 30	Hemmera Sediment and Surface Water
		June 23	Bird Survey
	3	July 3	Crest Protection Monitoring - photos & surveys Turbidity Sensor Download - Sensor 2 only DoD Rods Installation of 2 additional DoD Rods Aerial Photographs Wave Sensors
		July 22	Bird Survey
		August 14 - 17	Eelgrass Survey
		August 19	Bird Survey
		September 20 - 21	Bird Survey
		September 23 - 24	Hemmera Sediment and Surface Water
	4	October 14	Bird Survey
		October 17	Turbidity Sensor Download - Sensor 2 only DoD Rods NHC Sediment Samples Wave Sensors - #1 & #2 only
		November 20	Bird Survey
		December 10	Hemmera Sediment and Surface Water
		December 17 - 20	Bird Survey

Table 2
Chronology of Adaptations to the Monitoring Programs

Activity & Sub-task	Date	Event	Description
Crest Protection Structure			
Photographs	April 19, 2007	Program Inception	Established initial photo points (CRST 01 to 14).
	July 30, 2007	Q2-2007	Establish additional photo monitoring point (CRST 15).
	July 3, 2008	Q3-2008	Last quarterly monitoring - switch to annual photos.
Surveys	July 30, 2007	Q2-2007	Establish 5 monitoring cross sections.
	July 3, 2008	Q3-2008	Last quarterly monitoring - switch to bi-annual surveys.
Turbidity Monitoring			
Sensors	June 14, 2007	Sensor Installation	Two sensors installed in study area.
	July 12, 2007	Move Sensor	Sensor 1 from tide channel to new location inside Crest Protection Structure.
	July 31, 2007	Replace Sensor	Sensor 2 malfunctioning so replaced with temporary instrument.
	Oct 30, 2007	Sensor Failure	Sensor 1 malfunctioning due to water penetration, replaced with temporary instrument.
	Mar 6, 2008	Sensor Failure	Temporary instrument failed due to water penetration, replaced with original repaired Sensor 1
	April 10, 2008	Sensor Failure	Original Sensor 1 instrument failed due to water penetration. Sensor 1 removed from site permanently.
Tide Gauge	June 14, 2007	Gauge Installation	Installation on caisson.
	Sept 6, 2007	Gauge Damaged	Gauge damaged and repaired, loss of some data.
	Oct 29, 2007	Gauge Damaged	Instrument dangling from rope, apparently tampered with.
	April 10, 2008	Gauge Damaged	Pipe housing missing
	April 21, 2008	Gauge Repaired	Pipe housing replaced
	July 3, 2008	Gauge Damaged	Pipe housing missing - instrument secured temporarily
	Oct 17, 2008	Gauge Damaged	Removed from site permanently. Rely on CHS gauge data.
Water Samples	May 17, 2007	Data Collection	Collection of water samples. Turbidity of samples very low.
	Nov 5, 2007	TSS Memo	NHC memo outlining methodology for relating turbidty to total suspended solids. Suspend collection of water samples.
Monitoring of Erosion and Deposition			
DoD Rods	April 19, 2007	Installation	Twenty-six rods installed.
	April 9, 2008	Installation	Additional six rods installed in area of new drainage channels
	July 3, 2008	Installation	Additional 2 rods installed in pond feature.
Sediment Samples			
Sediment Sampling	April 19, 2007	Program Inception	Samples collected at each DoD rod location on a bi-annual basis.
Orthophotographic Interpretation			
Aerial Photos	July 14, 2007	Photos	Aerial photos of the study area flown.
	July 2, 2008	Photos	Aerial photos of the study area flown.
Coastal Geomorphology Mapping			
Bathymetric & Topographic Surveys	July 8, 2007	Surveys	Combined bathymetric and topographic surveys.
	July 13, 2007	Surveys	Topographic surveys, bathymetric surveys suspended due to rough seas.
	Nov 7, 2007	Surveys	Bathymetric surveys completed.

Table 2
Chronology of Adaptations to the Monitoring Programs

Activity & Sub-task	Date	Event	Description
Wave and Current Monitoring			
AWAC	Feb 20, 2007	AWAC Deployed	
	April 20, 2007	AWAC Recovered	Found to have been dragged several hundred metres, pressure sensors not functioning.
	June 6, 2007	AWAC Re-Deployed	
	Sept 27, 2007	AWAC Damaged	Burial by temporary sediment placement. Recovered but damaged beyond repair.
NHC Wave Sensors	Jan 30, 2008	NHC Memo	Alternative strategy for current and wave monitoring
	April 10, 2008	Wave Sensors Installed	
	May 4, 2008	Sensor 3 Dragged	NHC contacted by Vancouver Pile and Dredge on 19 June.
	23 Jun, 2008	Sensor 3 Re-Deployed	
	Sept, 2008	Sensor 3 Removed	Sensor removed by DP3 construction worker to facilitate construction activity.
	Spring 2009	Sensor 3 Re-Deployment	Scheduled
Sediment, Surface Water, and Benthic Invertebrate Sampling			
	June 20, 2007	Q2-2007	PAH and TBT dropped from sediment analytical program
			Dissolved iron added to surface water analytical program
	Mar 3, 2008	Q1-2008	Three replicates per station retained for benthic sampling events
	Mar 3, 2008	Q1-2008	Additional sampling station (DP08) added for benthic invertebrate sampling events
Bird Surveys			
Surveys	June 23, 2008	Q2-2008	Survey frequency reduced to monthly
			Distance categories changed to larger categories
			TFN transect discontinued
			Point count stations on TFN merged
	Nov 20, 2008	Q4-2008	Implementation of windshield surveys for focal species (brant)

Table 3
Rationale for Adaptations to the Adaptive Management Strategy

Change	Reason for Change	Reference
Dissolved iron analysis added for surface water	To determine if total iron exceedances were linked to particulate matter	Sec 2.2.2 (Q1-2007)
TBT not analyzed in sediment	No TBT source associated with DP3 construction, none detected in Q1-2007	Sec 1.3.1 (Q2-2007)
PAHs not analyzed in surface water	No PAH source associated with DP3 construction, none detected in Q1-2007	Sec 1.3.2 (Q2-2007)
Addition of 8 new DoD rods	To provide greater resolution in area of new drainage channels & pond	Sec 4.1.1 (2007 Annual Report)
Removal of Turbidity Sensor 1	Turbidity levels not very high; harsh operating conditions; expensive repairs; redundancy with Turbidity Sensor 2	Sec 4.1.3 (2007 Annual Report)
Modifications to bird survey methodology	To increase the efficiency of data collection	Sec 4.6 (2007 Annual Report)
Reduction in Crest Protection surveys	Reduction to twice a year because measured very little change.	Sec 4.1.2 (2007 Annual Report)
Windshield surveys for Brant and Heron	To obtain a more accurate assessment of brant and heron numbers after reduction in point count stations at TFN and Tsawwassed Ferry transects	Sec 4.6 (2007 Annual Report)
Addition of 3 wave sensors	To replace destroyed AWAC and monitor wave height and wave period	NHC memo to VFPA of Jan 30, 2008
DP08 station added to benthic invertebrate sampling program	To provide better spatial coverage in the inter-causeway area	Sec 1.3.5 (Q1-2008)
Removal of Tide Gauge	Harsh operating conditions; developed relation between Point Atkinson station and local tide gauge	Sec 1.3.1.2 (Q3-2008)

Table 4
Crest Protection Monitoring Stations

Monitor Point	Northing	Easting	Elevation (m CD)
CRST-01	5430224.0	489096.7	0.899
CRST-02	5430234.8	489095.9	1.759
CRST-03	5430294.1	489130.4	1.884
CRST-04	5430338.8	489161.0	0.970
CRST-05	5430370.9	489189.9	0.540
CRST-06	5430388.6	489200.6	0.596
CRST-07	5430431.4	489229.2	0.447
CRST-08	5430471.2	489252.1	1.070
CRST-09	5430475.4	489308.0	0.564
CRST-10	5430482.1	489364.8	0.663
CRST-11	5430440.7	489434.0	1.050
CRST-12	5430410.8	489489.7	1.116
CRST-13	5430256.7	489629.8	1.229
CRST-14	5430131.6	489656.9	1.250
CRST-15	5429940.9	489678.3	1.033

CD = Chart Datum

Table 5
Surveys Conducted for Waterfowl and Coastal Seabirds, 2003-2008

Where bi-weekly surveys were conducted one survey/month was selected (in bold) for comparison with 2008 data.

Year	Month	Day	Event #
2003	October	6	3
		20	**4**
	November	5	5
		20	**6**
	December	5	7
		19	**8**
2004	January	**9**	**9**
		26	10
	February	**11**	**11**
		24	12
	March	**11**	**13**
		25	14
	April	**8**	**15**
		21	**16**
	May	**6**	**17**
		21	18
	June	4	19
		16	**20**
		30	21
	July	**14**	**22**
		28	23
	August	**12**	**24**
		26	25
2007	March	**25**	**1**
		26	
	April	**7**	**2**
		10	
		12	
		23	**3**
		24	
	May	**7**	**4**
		8	
		22	5
		23	
	June	5	6
		18	**7**
		19	
		3	8
		4	
	July	**16**	**9**
		17	
		30	10
		31	

Table 5
Surveys Conducted for Waterfowl and Coastal Seabirds, 2003-2008

Year	Month	Day	Event #
2007	August	**17**	**11**
		18	
		30	12
		31	
	September	**14**	**13**
		15	
	October	2	14
		3	
		18	**15**
		19	
		20	
	November	1	16
		2	
		4	
		15	**17**
		16	
		19	
		29	18
		30	
	December	**15**	**19**
		28	20
2008	January	**11**	**21**
		23	22
	February	8	23
		22	**24**
		25	
	March	**10**	**25**
		12	
		27	26
		28	
		29	
	April	**10**	**27**
		11	
		24	**28**
		25	
	May	**8**	**29**
		9	
		22	30
		23	
	June	**23**	**31**
	July	**22**	**32**
	August	**19**	**33**
	September	**20**	**34**
		21	
	October	**14**	**35**
	November	**20**	**36**
	December	**17**	**37**
		20	

Table 6
Summary of Wind Speed and Direction January to March, 2008

Wind Speed (km/h)	N	NE	E	SE	S	SW	W	NW
0-5	30	14	35	25	12	13	19	12
5-10	42	35	228	62	43	38	38	41
10-15	1	11	312	80	43	26	52	42
15-20		4	228	45	38	26	26	43
20-25	1	1	74	18	20	11	13	19
25-30		2	47	22	18	12	19	13
30-35			13	11	9	4	19	1
35-40			6	5	1		9	1
40-45	1			4	4	2	3	1
45-50				1	1			
50-55								
55-60							1	2
60-65							2	1
65-70							2	1
Total (hours)	75	67	943	273	189	132	201	176

Note:
Total records = 2056 h
Total time winds calm = 125 h
Total observations = 2181 h

Hourly Wind Speed and Direction Recorded at Vancouver International Airport-January to March, 2008

Table 7
Summary of Wind Speed and Direction April to June, 2008

Wind Speed (km/h)	N	NE	E	SE	S	SW	W	NW
0-5	22	8	20	14	12	8	15	13
5-10	17	19	178	83	68	68	104	45
10-15	2	21	252	95	58	79	114	58
15-20	1	2	164	77	29	48	60	53
20-25			36	23	7	18	31	28
25-30			7	15		9	48	21
30-35			1	1		1	12	9
35-40							2	5
40-45							7	1
45-50								
50-55								
55-60								
60-65								
65-70								
Total (hours)	42	50	658	308	174	231	393	233

Note:
Total records = 2089 h
Total time winds calm = 95 h
Total observations = 2184 h

Hourly Wind Speed and Direction Recorded at Vancouver International Airport-April to June, 2008

Table 8
Summary of Wind Speed and Direction July to September, 2008

Wind Speed (km/h)	N	NE	E	SE	S	SW	W	NW
0-5	23	12	26	13	18	7	18	16
5-10	50	14	159	94	65	61	74	79
10-15	6	6	221	136	45	83	113	111
15-20			136	111	22	37	35	93
20-25			23	31	3	4	10	46
25-30			8	7	1	4	21	28
30-35			3	3		1	9	7
35-40			1				6	3
40-45							8	4
45-50							5	
50-55								
55-60								
60-65								
65-70								
Total (hours)	79	32	577	395	154	197	299	387

Note:
Total records = 2120 h
Total time winds calm = 88 h
Total observations = 2208 h

Hourly Wind Speed and Direction Recorded at Vancouver International Airport-July to September, 2008

Table 9
Summary of Wind Speed and Direction October to December, 2008

Wind Speed (km/h)	N	NE	E	SE	S	SW	W	NW
0-5	24	13	26	20	15	11	22	15
5-10	57	37	277	75	38	23	37	40
10-15	5	35	402	61	17	12	27	50
15-20	2	29	228	26	25	13	22	46
20-25			80	11	6	4	15	16
25-30		2	34	12	11	6	30	19
30-35			10	6	3	4	20	8
35-40			1	2	2		7	2
40-45				2	2	2	7	2
45-50							7	
50-55							2	
55-60							2	
60-65							1	
65-70							2	
Total (hours)	67	79	954	315	171	59	203	225

Note:

Total records =	2073	h
Total time winds calm =	138	h
Total observations =	2211	h

Hourly Wind Speed and Direction Recorded at Vancouver International Airport-October to December, 2008

Table 10
Storm Events During 2008 Monitoring Period

Start Date	Start time *PST*	End Date	End time *PST*	Time at Max Speed	Water Level at Start *m*	Water Level at End *m*	Water Level at Max *m*	Wind Speed Maximum *km/h*	Wind Speed Average *km/h*	Probability of Exceedence *%*	Wind Direction at Max	Wind Direction Average	Hs *m*	Tp *sec*
1/3/2008	12:00	1/3/2008	17:00	16:00	4.46	2.99	3.49	44	35.0	0.81%	SE	SE	1.30	4.64
1/4/2008	9:00	1/4/2008	13:00	10:00	4.17	4.69	4.25	39	34.4	1.67%	E	E	0.43	2.35
1/4/2008	16:00	1/5/2008	4:00	0:00	4.07	5.05	2.79	48	38.5	0.46%	S	SE	1.53	4.89
1/5/2008	7:00	1/5/2008	20:00	13:00	4.99	1.77	4.63	41	33.6	1.18%	SE	S	1.12	4.31
1/14/2008	13:00	1/15/2008	1:00	20:00	3.66	2.72	3.09	70	55.8	0.01%	NW	NW	2.70	7.00
2/5/2008	8:00	2/5/2008	18:00	12:00	4.22	3.40	3.80	37	34.8	2.40%	S	S	1.10	4.29
2/6/2008	19:00	2/6/2008	23:00	22:00	2.92	0.78	1.02	43	38.6	0.93%	SE	SE	1.41	4.83
2/12/2008	19:00	2/13/2008	5:00	19:00	2.58	3.24	2.58	41	35.1	1.18%	W	W	1.59	5.39
3/3/2008	20:00	3/4/2008	1:00	23:00	1.26	3.07	1.85	44	35.7	0.81%	W	W	1.72	5.49
3/15/2008	14:00	3/16/2008	1:00	21:00	2.66	4.10	1.84	43	33.8	0.93%	W	W	1.37	4.74
3/23/2008	16:00	3/23/2008	18:00	17:00	2.87	4.00	3.51	44	40.7	0.81%	SW	SW	0.99	3.87
4/17/2008	20:00	4/18/2008	8:00	0:00	3.60	1.89	3.46	44	39.1	0.81%	W	W	1.50	4.92
5/22/2008	22:00	5/23/2008	11:00	5:00	4.38	1.52	3.76	41	35.0	1.18%	NW	NW	1.98	5.90
7/10/2008	0:00	7/10/2008	19:00	8:00	4.15	3.34	2.23	48	39.9	0.46%	W	W	2.72	6.97
8/29/2008	19:00	8/30/2008	4:00	0:00	4.28	4.19	3.02	46	38.7	0.61%	W	W	1.49	4.89
9/8/2008	23:00	9/9/2008	9:00	0:00	3.64	2.05	3.49	41	33.8	1.18%	NW	NW	2.13	6.22
9/21/2008	23:00	9/22/2008	3:00	0:00	3.56	1.28	3.05	43	34.0	0.93%	W	W	1.17	4.43
10/4/2008	11:00	10/4/2008	19:00	17:00	4.42	4.19	4.00	43	35.7	0.93%	S	S	1.24	4.55
10/13/2008	22:00	10/14/2008	5:00	1:00	1.30	3.92	2.04	46	39.5	0.61%	W	W	1.99	5.85
10/23/2008	3:00	10/23/2008	7:00	4:00	2.47	1.45	2.02	39	37.0	1.67%	W	W	1.95	5.91
11/4/2008	0:00	11/4/2008	12:00	2:00	2.13	4.44	1.47	41	32.7	1.18%	NW	W	2.19	6.30
11/13/2008	3:00	11/13/2008	15:00	8:00	3.31	4.32	4.35	69	50.4	0.01%	W	W	2.23	5.75
12/7/2008	12:00	12/7/2008	18:00	15:00	4.46	1.97	3.55	41	33.5	1.18%	W	W	1.07	4.17
12/29/2008	13:00	12/29/2008	16:00	14:00	3.82	4.08	3.86	67	53.2	0.02%	W	W	1.94	5.28
12/30/2008	19:00	12/31/2008	10:00	2:00	3.68	N/A	N/A	43	34.6	0.93%	S	S	1.33	5.49

Note 1: Water level data taken from Station #7795 (Point Atkinson) which has shown good correlation with local tide gauge
Note 2: Wind data from Vancouver International Airport
Note 3: Wave hindcasting made at seaward end of Deltaport Causeway
Note 4: Annual probability of exceedence for maximum hourly wind speed based on analysis of 1953 to 2006 hourly wind data from Vancouver International Airport

Table 11
Bed Elevation Changes at DoD Rods in Q1-2008

Site #	Height Above Ground (cm)	Height Above Washer (cm)	Reset: Height Above Ground/ Washer (cm)	Previous Quarter Reset Height (cm)	Deposition (cm)	Erosion (cm)	Net Change (cm)
A03	68.3	68.3	68.3	68.2	0.0	0.1	-0.1
A04	44.8	45.0	45.0	45.5	0.2	**0.0**	0.2
A05	47.0	47.7	47.0	47.2	0.7	0.5	0.2
A06	41.6	42.1	41.4	41.7	0.5	0.4	0.1
B02	51.4	51.4	50.3	52.0	0.0	**0.0**	0.0
B03	48.9	49.4	49.4	48.7	0.5	0.7	-0.2
B04	26.6	27.3	27.9	26.5	0.7	0.8	-0.1
B05	46.0	46.2	46.5	48.1	0.2	**0.0**	0.2
B06	34.7	35.0	34.4	34.1	0.3	0.9	-0.6
C01	46.9	47.1	46.5	46.4	0.2	0.7	-0.5
C02	46.4	46.4	46.4	46.0	0.0	0.4	-0.4
C03	35.3	35.3	35.3	34.9	0.0	0.4	-0.4
C04	48.4	49.2	48.7	46.9	0.8	2.3	-1.5
C05	72.2	72.2	72.2	73.8	0.0	**0.0**	0.0
C06	37.8	38.6	37.6	38.1	0.8	0.5	0.3
D01	56.0	56.3	56.0	55.6	0.3	0.7	-0.4
D02	46.5	46.5	46.4	46.6	0.0	**0.0**	0.0
D03	57.9	58.5	58.9	56.4	0.6	2.1	-1.5
D04	45.7	47.0	43.0	43.8	1.3	3.2	-1.9
D05	46.7	48.9	45.7	47.2	2.2	1.7	0.5
D06	38.9	41.1	39.5	39.0	2.2	2.1	0.1
E01	39.5	39.5	39.5	39.1	0.0	0.4	-0.4
E02	36.9	37.0	36.9	36.5	0.1	0.5	-0.4
E06	44.7	44.7	44.7	43.3	0.0	1.4	-1.4
F06	32.4	35.6	31.8	30.6	3.2	5.0	-1.8
G06	50.9	55.1	48.8	50.2	4.2	4.9	-0.7

Note: Negative erosion values have been replaced by zeros (in bold font) as they represent minor measurement errors.

Table 12
Bed Elevation Changes at DoD Rods in Q2-2008

Site #	Height Above Ground (cm)	Height Above Washer (cm)	Reset: Height Above Ground/ Washer (cm)	Previous Quarter Reset Height (cm)	Deposition (cm)	Erosion (cm)	Net Change (cm)
A03	68.4	68.6	68.3	68.3	0.2	0.3	-0.1
A04	44.9	45.4	45.1	45.0	0.5	0.4	0.1
A05	46.4	47.3	46.7	47.0	0.9	0.3	0.6
A06	40.9	41.6	41.4	41.4	0.7	0.2	0.5
B02	50.4	50.4	49.6	50.3	0.0	0.1	-0.1
B03	48.0	49.3	48.6	49.4	1.3	**0.0**	1.3
B04	26.4	26.4	26.4	27.9	0.0	**0.0**	0.0
B05	45.4	46.0	45.4	46.5	0.6	**0.0**	0.6
B06	33.9	36.0	34.6	34.4	2.1	1.6	0.5
C01	46.3	50.1	46.8	46.5	3.8	3.6	0.2
C02	46.6	47.1	46.8	46.4	0.5	0.7	-0.2
C03	35.0	35.4	35.2	35.3	0.4	0.1	0.3
C04	46.7	47.6	46.9	48.7	0.9	**0.0**	0.9
C05	71.6	72.3	71.6	72.2	0.7	0.1	0.6
C06	37.6	38.4	37.8	37.6	0.8	0.8	0.0
D01	55.9	55.9	54.6	56.0	0.0	**0.0**	0.0
D02	44.7	45.9	45.4	46.4	1.2	**0.0**	1.2
D03	58.3	59.1	57.4	58.9	0.8	0.2	0.6
D04	45.4	47.2	44.0	43.0	1.8	4.2	-2.4
D05	44.9	48.1	44.1	45.7	3.2	2.4	0.8
D06	38.1	44.2	39.4	39.5	6.1	4.7	1.4
E01	40.0	40.1	39.4	39.5	0.1	0.6	-0.5
E02	36.6	36.6	36.0	36.9	0.0	**0.0**	0.0
E06	44.0	47.5	43.0	44.7	3.5	2.8	0.7
F06	32.8	33.0	29.5	31.8	0.2	1.2	-1.0
G06	53.2	54.0	49.7	48.8	0.8	5.2	-4.4
Z01			69.8				
Z02			88.9				
Z03			57.0				
Z04			56.7				
Z05			87.2				
Z06			56.0				

Note: Negative erosion values have been replaced by zeros (in bold font) as they represent minor measurement errors.

Table 13
Bed Elevation Changes at DoD Rods in Q3-2008

Site #	Height Above Ground (cm)	Height Above Washer (cm)	Reset: Height Above Ground/ Washer (cm)	Previous Quarter Reset Height (cm)	Deposition (cm)	Erosion (cm)	Net Change (cm)
A03	68.7	68.7	68.9	68.3	0.0	0.4	-0.4
A04	44.9	45.1	44.9	45.1	0.2	0.0	0.2
A05	46.0	46.2	46.4	46.7	0.2	**0.0**	0.2
A06	40.8	42.1	40.9	41.4	1.3	0.7	0.6
B02	50.1	52.8	52.6	49.6	2.7	3.2	-0.5
B03	47.9	48.8	48.9	48.6	0.9	0.2	0.7
B04	26.1	26.5	25.7	26.4	0.4	0.1	0.3
B05	44.5	44.8	44.8	45.4	0.3	**0.0**	0.3
B06	33.5	33.6	33.6	34.6	0.1	**0.0**	0.1
C01	45.2	46.6	45.5	46.8	1.4	**0.0**	1.4
C02	46.5	47.4	46.8	46.8	0.9	0.6	0.3
C03	34.5	35.6	35.3	35.2	1.1	0.4	0.7
C04	46.1	46.1	46.1	46.9	0.0	**0.0**	0.0
C05	70.7	70.8	70.5	71.6	0.1	**0.0**	0.1
C06	36.9	40.9	37.8	37.8	4.0	3.1	0.9
D01	54.5	55.8	55.4	54.6	1.3	1.2	0.1
D02	45.5	45.9	45.4	45.4	0.4	0.5	-0.1
D03	56.2	58.2	56.4	57.4	2.0	0.8	1.2
D04	46.9	46.9	45.4	44.0	0.0	2.9	-2.9
D05	46.2	48.0	44.6	44.1	1.8	3.9	-2.1
D06	37.3	37.5	37.3	39.4	0.2	**0.0**	0.2
E01	38.9	39.8	39.2	39.4	0.9	0.4	0.5
E02	33.2	36.9	35.1	36.0	3.7	0.9	2.8
E06	43.3	44.0	43.0	43.0	0.7	1.0	-0.3
F06	29.1	34.1	31.2	29.5	5.0	4.6	0.4
G06	53.9	57.5	53.1	49.7	3.6	7.8	-4.2
Z01	69.9	71.3	70.3	69.8	1.4	1.5	-0.1
Z02	89.4	90.0	90.0	88.9	0.6	1.1	-0.5
Z03	57.5	58.0	57.5	57.0	0.5	1.0	-0.5
Z04	56.9	57.5	57.0	56.7	0.6	0.8	-0.2
Z05	85.8	89.8	87.3	87.2	4.0	2.6	1.4
Z06	55.1	58.4	55.4	56.0	3.3	2.4	0.9
Z07			58.0				
Z08			47.8				

Note: Negative erosion values have been replaced by zeros (in bold font) as they represent minor measurement errors.

Table 14
Bed Elevation Changes at DoD Rods in Q1-2008

Site #	Height Above Ground (cm)	Height Above Washer (cm)	Reset: Height Above Ground/ Washer (cm)	Previous Quarter Reset Height (cm)	Deposition (cm)	Erosion (cm)	Net Change (cm)
A03	67.9	69.0	68.5	68.9	1.1	0.1	1.0
A04	44.5	44.5	44.5	44.9	0.0	**0.0**	0.0
A05	45.9	46.2	46.0	46.4	0.3	**0.0**	0.3
A06	40.6	40.6	40.6	40.9	0.0	**0.0**	0.0
B02	51.3	54.5	50.1	52.6	3.2	1.9	1.3
B03	46.6	48.2	46.5	48.9	1.6	**0.0**	1.6
B04	24.2	27.4	25.1	25.7	3.2	1.7	1.5
B05	44.8	45.5	44.6	44.8	0.7	0.7	0.0
B06	32.6	33.9	33.2	33.6	1.3	0.3	1.0
C01	44.5	46.0	43.9	45.5	1.5	0.5	1.0
C02	45.1	46.2	44.8	46.8	1.1	**0.0**	1.1
C03	33.1	35.0	34.0	35.3	1.9	**0.0**	1.9
C04	45.7	47.2	46.1	46.1	1.5	1.1	0.4
C05	72.0	76.6	70.7	70.5	4.6	6.1	-1.5
C06	36.2	36.6	36.5	37.8	0.4	**0.0**	0.4
D01	54.1	56.4	52.8	55.4	2.3	1.0	1.3
D02	44.9	44.9	44.9	45.4	0.0	**0.0**	0.0
D03	56.0	57.0	56.5	56.4	1.0	0.6	0.4
D04	45.3	47.1	41.9	45.4	1.8	1.7	0.1
D05	45.8	47.9	43.8	44.6	2.1	3.3	-1.2
D06	37.3	37.3	37.3	37.3	0.0	0.0	0.0
E01	38.8	39.9	38.7	39.2	1.1	0.7	0.4
E02	35.5	36.0	35.2	35.1	0.5	0.9	-0.4
E06	43.8	46.0	42.5	43.0	2.2	3.0	-0.8
F06	Could not locate due to high water			31.2			
G06	65.5	65.5	62.5	53.1	0.0	12.4	-12.4
Z01	69.7	71.0	69.1	70.3	1.3	0.7	0.6
Z02	88.3	91.4	91.0	90.0	3.1	1.4	1.7
Z03	59.0	60.1	58.5	57.5	1.1	2.6	-1.5
Z04	57.2	57.5	56.2	57.0	0.3	0.5	-0.2
Z05	87.0	89.0	87.2	87.3	2.0	1.7	0.3
Z06	57.7	58.6	56.5	55.4	0.9	3.2	-2.3
Z07	58.4	59.6	57.9	58.0	1.2	1.6	-0.4
Z08	47.9	47.9	46.7	47.8	0.0	0.1	-0.1

Note: Negative erosion values have been replaced by zeros (in bold font) as they represent minor measurement errors.

Table 15
Total Organic Carbon Content (Percent by Weight) of Sediment Samples Collected in April and October 2008

Sediment Sample Analysis
Total Organic Carbon

Site #	April (%)	October (%)
A03	0.8	0.7
A04	0.4	0.5
A05	0.3	0.5
A06	0.3	0.5
B02	0.3	0.4
B03	0.6	0.6
B04	0.3	0.4
B05	0.3	0.5
B06	0.2	0.4
C01	0.2	0.3
C02	0.2	0.4
C03	0.4	0.4
C04	0.4	0.4
C05	0.1	0.5
C06	0.4	0.5
D01	0.2	0.3
D02	1	0.4
D03	0.2	0.3
D04	0.2	0.2
D05	0.1	0.2
D06	0.2	0.4
E01	0.6	0.7
E02	0.9	0.5
E06	0.2	0.3
F06	0.1	N/A
G06	0.1	0.2

Table 16
Silt Content (Percent by Weight) of Sediment Samples Collected in April and October 2008

Sediment Sample Analysis
Percent Weight of Silt (<0.063 mm)

Site #	April (%)	October (%)
A03	37	24
A04	14	30
A05	10	13
A06	13	14
B02	12	14
B03	21	24
B04	11	14
B05	10	10
B06	12	9
C01	8	10
C02	12	16
C03	11	10
C04	12	10
C05	13	9
C06	11	10
D01	14	14
D02	53	11
D03	8	11
D04	5	5
D05	6	4
D06	11	10
E01	25	27
E02	28	18
E06	6	9
F06	7	n/a
G06	5	7

Table 17
Summary of Quality Assurance/Quality Control Issues

Surface Water	
Q1 2008	TSS, lead, molybdenum, nickel, and zinc had RPDs in excess of the DQO. Due to rough weather conditions, the containers for the duplicates were filled one after the other from the Van Dorn to minimize the risk of spillage. Particulate matter likely accounted for the difference between the duplicates, as the RPD for TSS was 73%. The RDL for vanadium was above the WQG. The elevated RDL for vanadium was due to the dilution required to avoid sodium interference.
Q2 2008	TSS, aluminum, nickel, and zinc had RPDs in excess of the DQO. Not considered to be indicative of low precision. Likely due to variability associated with suspended particulate matter.
Q3 2008	TSS, lead, manganese, and silicon had RPDs in excess of the DQO. Not considered to be indicative of low precision. Likely due to variability associated with suspended particulate matter.
Q4 2008	TSS and zinc had RPDs in excess of the DQO. The RPDs for TSS and zinc exceeded the DQO by 18.9% and 12.6% respectively.

Sediment

Q1 2008	Sulphide had an RPD in excess of the DQO. The sampling methodology and laboratory handling procedure was revised to minimize loss via volatilization in Q2 2007. In 2008, sulphide samples were collected directly from the ponar without homogenization.
Q2 2008	Sulphide had an RPD in excess of the DQO.
Q3 2008	Sulphide had an RPD in excess of the DQO.
Q4 2008	All of the sediment parameters met the DQO.

DQO: Data Quality Objective
RDL: Reported Detection Limit
RPD: Relative Percent Difference
TSS: Total Suspended Solids
WQG: Water Quality Guideline

Table 18
2008 Surface Water Chemistry Results

Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]															
		Location ID:	DP01								DP02							
		Sample ID:	SWDP01-1	SWDP01-2	SWDP01-3	SWDP01-4	SWDP01-5	SWDP01-6	SWDP01-7	SWDP01-8	SWDP02-1	SWDP02-2	SWDP02-3	SWDP02-4	SWDP02-5	SWDP02-6	SWDP02-7	SWDP02-8
		Date Sampled:	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2008-03-03	2008-05-29	2008-09-20	2008-11-26
Sample Info																		
Sample Depth, Below Water Surface (m)	-	-	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.3m	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5m
Secchi Depth (m)	-	-	0.5	0.5	0.5	sampled in dark	0.8	0.8	0.8	0.5	0.7	1.2	1.0	-	1.0	-	1.9	1.1
Field Tests																		
Field Conductivity (uS/cm)	-	-	6696	9810	31208	23489	38716	11400	42835	24952	32960	36600	31678	44274	40843	34500	43985	29268
Field Dissolved Oxygen (mg/L)	-	-	11.26	-	9.48	16.67	10.56	6.14	9.92	9.7	10.99	-	9.18	13.01	9.87	10.23	9.04	9.24
Field pH	-	-	7.31	7.38	-	7.79	7.96	8.16	7.94	7.49	7.89	8.38	-	7.67	8.06	7.79	7.8	7.69
Field Redox, Uncorrected (mV)	-	-	121.3	136.2	207	199	-16.6	82.1	-83	-292	248.7	231	214	274	-25.6	255.6	-13	-336
Field Salinity	-	-	3650000	-	27110000	13980000	24940000	-	27080000	26700000	20490000	-	27440000	27870000	25850000	-	28340000	28640000
Field Temperature (ºC)	-	-	7.93	22.8	12.4	2.73	8.14	14.8	14.8	4.4	6.94	16.1	11.4	4.95	7.31	14.98	13.27	6.78
Field Total Dissolved Solids	-	-	-	-	-	-	-	-	-	29590000	-	-	-	-	-	-	-	28640000
Field Turbidity (NTU)	-	-	46.16	220	-	-	-	-	-	9.4	-	1.7	-	-	-	-	-	1.95
Physical Tests																		
Hardness, Total (CaCO3) (mg/L)	-	-	651	974	4740	2879	3990	1460	5280	4500	3550	4060	4850	5379	4620	4050	5190	5540
pH	-	7-8.7 [14]	7.81	8.04	7.84	7.83	7.74	7.8	7.92	7.71	7.83	8.25	7.84	7.85	7.8	8.02	7.86	7.72
Salinity	-	10-X [15]	3700000	22300000	27300000	14300000	-	8400000	-	-	19900000	23100000	27700000	27900000	25900000	-	-	27800000
Total Suspended Solids (mg/L)	-	-	22	27.2	43.7	21.5	22.2	35.9	20.7	14.4	12	28	21.7	8.8	13	30.7	34	21.1
Turbidity (NTU)	-	-	-	-	-	15.9	5.31	19.3	7.18	11.7	-	-	-	1.79	1.62	2.9	1.22	3.16
Dissolved Inorganics																		
Phosphate (mg/L)	-	-	0.147	0.485	0.0569	0.0276	0.0387	0.215	0.0562	0.0643	0.0457	0.0579	0.0515	0.0707	<0.002	-	0.0499	0.0653
Inorganics																		
Ammonia (mg/L)	-	-	0.48	0.391	0.066	0.419	0.267	0.293	0.0331	0.287	0.048	0.058	0.039	0.046	0.0471	0.027	0.0175	0.053
Nitrate (mg/L)	-	16	0.595	1.99	<0.500	6.9	1.82	0.94	<2.500	26.6	<0.050	<0.500	<0.500	7	0.67	<5.000	<2.500	0.53
Nitrite (mg/L)	-	-	0.024	0.094	<0.100	0.54	0.25	0.18	<0.500	<1.000	<0.010	0.17	<0.100	<0.500	0.12	1.3	1.43	<0.100
Phosphate, Ortho (mg/L)	-	-	0.0761	0.503	0.06	0.0245	0.0367	0.175	0.0524	0.057	0.042	0.0479	0.0527	0.0724	0.0519	-	0.0449	0.0669
Total Inorganics																		
Chlorine (mg/L)	-	-	-	<0.200	<0.200	<0.200	<0.200	<0.100	<0.100	<0.100	-	-	-	-	-	-	-	-
Phosphate (mg/L)	-	-	0.299	0.654	0.0948	0.203	0.0819	0.411	0.0802	0.103	0.0568	0.0688	0.0637	0.0735	0.0606	-	0.0588	0.0742
Phosphorus (mg/L)	-	-	<0.60	0.64	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.0	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000
Total Kjeldahl Nitrogen (mg/L)	-	-	1.61	0.879	0.535	1.24	0.628	1.05	0.147	0.852	0.171	0.262	0.355	0.276	0.381	0.304	0.102	0.17
Total Nitrogen (mg/L)	-	-	2.23	2.97	<0.700	8.7	2.7	<5.000	<3.000	27.5	0.17	<0.700	<0.700	7.3	1.17	<6.000	<3.000	0.7
Organics																		
Organic Nitrogen (mg/L)	-	-	1.13	0.488	-	0.819	0.36	0.757	0.114	0.565	0.123	-	-	0.23	0.334	0.277	0.085	0.117
Dissolved Metals																		
Iron	50 [9]	-	-	14	<300	10	<10	32	<10	25	-	<10	<300	<10	<10	<10	<10	<10

Hemmera
File: 499-002.11
September 2009

Table 18
2008 Surface Water Chemistry Results

		Location ID:	DP01								DP02							
		Sample ID:	SWDP01-1	SWDP01-2	SWDP01-3	SWDP01-4	SWDP01-5	SWDP01-6	SWDP01-7	SWDP01-8	SWDP02-1	SWDP02-2	SWDP02-3	SWDP02-4	SWDP02-5	SWDP02-6	SWDP02-7	SWDP02-8
		Date Sampled:	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2008-03-03	2008-05-29	2008-09-20	2008-11-26
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]																
Total Metals																		
Aluminum	-	-	674	<500	<500	388	110	150	<200	<300	<100	<200	<100	<100	<100	160	<100	<100
Antimony	-	-	<2.0	<2	<10	<5	<10	<10	<10	<10	<10	21	<10	<10	<10	<10	<10	<10
Arsenic	12.5 [7]	12.5	4.22	2.52	1.22	1.54	0.97	1.78	1.14	1.13	0.97	1.41	1.01	1.16	0.95	<0.2	1.08	1.24
Barium	200 [8]	-	21	12.9	12.2	18.1	16	29.5	10.8	15	11.9	<20	10.5	9.1	11.6	10	9.4	10.1
Beryllium	100 [9]	-	<10	<10	<50	<25	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Bismuth	-	-	<10	<10	<50	<25	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Boron	1200 [10]	-	610	860	3500	2010	2800	2000	3200	3000	2700	2900	3700	3600	3000	2700	3400	3500
Cadmium	0.12 [11]	0.12	0.068	0.065	0.095	0.073	0.065	0.097	0.072	0.094	0.063	0.043	0.076	0.072	0.07	0.06	0.066	0.09
Calcium	-	-	65800	79800	346000	203000	266000	110000	343000	301000	236000	267000	348000	340000	284000	261000	342000	353000
Chromium	56 [11]	56	<10	<10	<50	<25	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Cobalt	-	-	1.51	0.781	0.348	1.33	0.782	0.546	0.226	0.762	0.136	0.092	0.1	0.112	0.06	0.158	0.071	0.085
Copper	3 [10]	-	5.59	5.71	1.4	2.9	3.85	3.56	1.01	3.27	1.49	0.696	1.58	0.591	2.36	1.4	0.69	1.5
Iron	50 [9]	-	2070	718	451	1060	490	1080	324	590	116	46	111	69	31	138	67	84
Lead	140 [10]	-	1.08	0.437	0.637	0.687	0.935	0.96	0.154	0.912	0.469	<0.05	1.36	0.074	3.31	0.484	0.535	3.33
Lithium	-	-	<100	<100	<500	<250	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500
Magnesium	-	-	118000	188000	1070000	576000	808000	288000	1070000	911000	718000	825000	1100000	1100000	950000	824000	1050000	1130000
Manganese	-	-	175	75	13.5	135	80.5	63.8	11.1	68.2	11.2	6.21	7.45	8.25	6.21	13.2	5.23	8.63
Mercury	2 [10]	0.016	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	0.019	<0.01
Molybdenum	-	-	2.6	5.8	8.2	6.1	8	6.3	8.4	8.3	5.5	12.4	9.1	9.4	9	5.6	9.6	7.7
Nickel	-	-	8.25	5.62	1.49	5.71	4.15	2.92	1.12	6.14	0.879	0.612	0.758	0.737	0.835	0.994	0.611	0.759
Potassium	-	-	45200	64900	355000	188000	273000	92000	329000	280000	242000	271000	366000	362000	281000	249000	331000	344000
Selenium	-	-	<0.50	0.56	0.88	<0.5	<0.5	<0.5	<0.5	<0.5	<0.50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Silicon	-	-	5070	3170	2960	7370	2680	3040	1660	4590	1650	880	1540	1930	1370	1260	1150	1920
Silver	3 [12]	-	<0.20	<0.2	<1	<0.5	<1	<1	<1	<1	<1.0	<1	<1	<1	<1	<1	<1	<1
Sodium	-	-	1070000	1480000	7990000	4580000	6470000	2330000	8620000	7300000	6340000	7230000	8250000	8150000	7900000	7060000	8690000	8930000
Strontium	-	-	892	1200	6600	3270	4590	3300	5720	4880	4470	5060	7200	5820	5610	4520	6050	5480
Thallium	-	-	<2.0	<2	<10	<5	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Tin	-	-	<2.0	<2	<10	<5	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Titanium	-	-	21	<20	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Uranium	100 [9]	-	0.629	0.392	1.99	1.41	1.92	0.197	2.03	2.16	1.56	0.949	2.09	2.08	1.75	1.79	2.1	2.26
Vanadium	50 [13]	-	<20	<20	<100	<50	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Zinc	10 [10]	-	12.6	10.4	7.64	9.08	4.96	6.66	1.71	22.3	5.1	0.56	5.35	1.24	5.72	2.11	1.88	2.25

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Table 18
2008 Surface Water Chemistry Results

		Location ID:	DP01								DP02							
		Sample ID:	SWDP01-1	SWDP01-2	SWDP01-3	SWDP01-4	SWDP01-5	SWDP01-6	SWDP01-7	SWDP01-8	SWDP02-1	SWDP02-2	SWDP02-3	SWDP02-4	SWDP02-5	SWDP02-6	SWDP02-7	SWDP02-8
		Date Sampled:	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2008-03-03	2008-05-29	2008-09-20	2008-11-26
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]																
PAHs																		
Acenaphthene	6 [10]	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Acenaphthylene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Acridine	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Anthracene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(a)anthracene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(a)pyrene	0.01 [10]	-	<0.010	-	-	-	-	-	-	-	<0.010	-	-	-	-	-	-	-
Benzo(b)fluoranthene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(k)fluoranthene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Chrysene	0.1 [10]	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Dibenz(a,h)anthracene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Fluoranthene	-	-	0.198	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Fluorene	12 [10]	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Naphthalene	1 [10]	1.4	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Phenanthrene	-	-	0.165	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Pyrene	-	-	0.116	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Quinoline	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Bacteriological Tests																		
Chlorophyll A	-	-	4.84	3.15	2.72	1.65	1.7	8.1	1.98	4.32	0.758	1.25	3.79	0.547	1.94	0.905	0.675	1.09
Surrogate Recovery																		
Acenaphthene-d10, surrogate (%)	-	-	89	-	-	-	-	-	-	-	93	-	-	-	-	-	-	-
Acridine-d9, surrogate (%)	-	-	88	-	-	-	-	-	-	-	88	-	-	-	-	-	-	-
Chrysene-d12, surrogate (%)	-	-	89	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-
Naphthalene-d8, surrogate (%)	-	-	89	-	-	-	-	-	-	-	93	-	-	-	-	-	-	-
Phenanthrene-d10, surrogate (%)	-	-	89	-	-	-	-	-	-	-	92	-	-	-	-	-	-	-

Table 18
2008 Surface Water Chemistry Results

		Location ID:	DP03								DP04							
		Sample ID:	SWDP03-1	SWDP03-2	SWDP03-3	SWDP03-4	SWDP03-5	SWDP03-6	SWDP03-7	SWDP03-8	SWDP04-1	SWDP04-2	SWDP04-3	SWDP04-4	SWDP04-5	SWDP04-6	SWDP04-7	SWDP04-8
		Date Sampled:	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2008-03-03	2008-05-29	2008-09-20	2008-11-26	2007-03-23	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-20	2008-11-26
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]																
Sample Info																		
Sample Depth, Below Water Surface (m)	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5m	0.5	0.5	0.5	0.5	0.5	-	0.5	0.5m
Secchi Depth (m)	-	-	-	-	0.7	-	1.3	-	1.9	1.4	-	-	1.7	-	2.2	-	1.9	2.2
Field Tests																		
Field Conductivity (uS/cm)	-	-	10089	31300	31175	44401	38157	37169	44296	30029	42603	35800	32241	44592	45283	37722	45518	31575
Field Dissolved Oxygen (mg/L)	-	-	10.14	-	8.87	12.65	9.85	10.01	8.72	8.86	9.79	-	8.66	10.95	9.8	11.02	8.29	7.92
Field pH	-	-	7.8	8.55	-	7.73	8.01	7.88	7.8	7.76	7.89	8.47	-	7.75	7.99	7.95	7.73	7.76
Field Redox, Uncorrected (mV)	-	-	236.1	258.6	230	252	-249.2	235.2	-1	-325.9	261.2	214.7	242	239	-36.9	205.4	54	-325.7
Field Salinity	-	-	-	-	26410000	28260000	23960000	-	28550000	28890000	25620000	-	28160000	28450000	28940000	-	29430000	29780000
Field Temperature (ºC)	-	-	8.53	14.9	11.6	6.38	6.57	16.16	13.23	7.46	7.6	13.7	11.1	6.96	6.9	14.69	12.23	8.56
Field Total Dissolved Solids	-	-	-	-	-	-	-	-	-	29390000	-	-	-	-	-	-	-	30090000
Field Turbidity (NTU)	-	-	1.2	5.2	-	-	-	-	-	1.72	0	0.53	-	-	-	-	-	1.37
Physical Tests																		
Hardness, Total (CaCO3) (mg/L)	-	-	4750	3440	4590	5671	4170	4460	5380	5450	5060	4280	4970	5673	5140	4510	5610	5790
pH	-	7-8.7 [14]	7.84	8.3	7.83	7.83	7.88	8.28	7.84	7.78	7.86	7.95	7.85	7.88	7.82	8.26	7.8	7.77
Salinity	-	10-X [15]	24.4	20800000	26400000	28300000	24000000	-	-	28100000	26100000	20300000	28200000	28600000	-	24000000	-	29100000
Total Suspended Solids (mg/L)	-	-	8	23.3	26.3	16.8	14.3	33.3	25.3	19.1	6	27.2	26.3	23.5	19.6	3.2	27.3	22.4
Turbidity (NTU)	-	-	-	-	-	1.69	1.42	3.7	1.12	2.47	-	-	-	1.44	1.16	1.49	1.1	1.68
Dissolved Inorganics																		
Phosphate (mg/L)	-	-	0.0499	0.0405	0.0551	0.0693	0.0395	-	0.0535	0.0667	0.0548	0.0286	0.0493	0.0714	0.0626	0.0588	0.06	0.0687
Inorganics																		
Ammonia (mg/L)	-	-	0.032	0.03	0.056	<0.020	0.0354	0.028	0.0172	0.0309	<0.020	0.123	0.027	<0.020	0.025	0.0753	0.0167	0.0088
Nitrate (mg/L)	-	16	0.22	<0.500	<0.500	7	0.62	<5.000	<2.500	<0.500	0.67	<0.500	<0.500	8.3	1.64	1.93	<2.500	<0.500
Nitrite (mg/L)	-	-	<0.02	0.13	<0.100	<0.500	0.12	2.1	1.37	<0.100	<0.020	0.33	<0.100	<0.500	0.25	0.11	1.41	<0.100
Phosphate, Ortho (mg/L)	-	-	0.0482	0.0317	0.0555	0.072	0.0412	-	0.0467	0.0664	0.0507	0.0241	0.0552	0.0712	0.0613	0.0501	0.0591	0.0695
Total Inorganics																		
Chlorine (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate (mg/L)	-	-	0.0589	0.0641	0.0764	0.0734	0.0474	-	0.0605	0.0721	0.0612	0.0489	0.0687	0.076	0.0652	0.0666	0.0709	0.0714
Phosphorus (mg/L)	-	-	<3	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000
Total Kjeldahl Nitrogen (mg/L)	-	-	0.15	0.211	0.385	0.246	0.331	0.378	<0.050	0.153	0.099	0.62	0.294	0.214	0.238	0.369	<0.050	0.062
Total Nitrogen (mg/L)	-	-	0.37	<0.700	<0.700	7.3	1.07	<6.000	<3.000	<0.700	0.77	0.95	<0.700	8.5	2.13	<5.000	<3.000	<0.700
Organics																		
Organic Nitrogen (mg/L)	-	-	0.12	-	-	0.246	0.296	0.351	<0.060	0.122	-	0.497	-	0.214	0.213	0.294	<0.060	<0.060
Dissolved Metals																		
Iron	50 [9]	-	-	<10	<300	<10	<10	12	<10	<10	-	<10	<300	<10	<10	23	<10	<10

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		Location ID:	DP03								DP04							
		Sample ID:	SWDP03-1	SWDP03-2	SWDP03-3	SWDP03-4	SWDP03-5	SWDP03-6	SWDP03-7	SWDP03-8	SWDP04-1	SWDP04-2	SWDP04-3	SWDP04-4	SWDP04-5	SWDP04-6	SWDP04-7	SWDP04-8
		Date Sampled:	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2008-03-03	2008-05-29	2008-09-20	2008-11-26	2007-03-23	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-20	2008-11-26
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]																
Total Metals																		
Aluminum	-	-	<100	<200	<200	<100	<100	130	<100	<100	<100	<100	<100	<100	<100	110	<100	<100
Antimony	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	12.5 [7]	12.5	1.11	1.2	1.18	1.26	1.14	1.09	1.27	1.28	1.17	0.97	1.42	1.23	1.6	1.43	1.24	1.18
Barium	200 [8]	-	10.6	<20	11.5	9	12	11.1	9.5	9.9	10.4	12.2	11.2	9	7.8	9.3	8.7	9.2
Beryllium	100 [9]	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Bismuth	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Boron	1200 [10]	-	3500	2600	3700	3500	2800	3100	3400	3600	3500	3300	3800	3600	3700	2900	3500	3700
Cadmium	0.12 [11]	0.12	0.06	0.04	0.085	0.062	0.069	0.054	0.076	0.087	0.07	0.093	0.068	0.063	0.082	0.044	0.08	0.082
Calcium	-	-	305000	216000	338000	358000	258000	286000	344000	347000	322000	251000	362000	359000	337000	309000	357000	372000
Chromium	56 [11]	56	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Cobalt	-	-	0.069	0.079	0.166	0.052	0.065	0.156	0.059	0.066	<0.05	0.056	0.081	0.055	0.057	0.107	0.056	<0.05
Copper	3 [10]	-	0.709	0.672	2.06	0.652	2.61	1.49	0.562	0.921	0.743	0.804	1.04	0.552	1.34	1.13	0.652	0.784
Iron	50 [9]	-	55	63	186	59	31	158	58	71	21	17	72	52	32	80	61	44
Lead	140 [10]	-	0.137	0.061	1.09	0.117	2.49	0.269	0.273	0.674	0.192	0.21	0.454	0.093	0.785	0.332	0.231	0.682
Lithium	-	-	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500
Magnesium	-	-	968000	703000	1080000	1160000	857000	909000	1100000	1110000	1030000	886000	1170000	1160000	1040000	908000	1150000	1180000
Manganese	-	-	5.88	7.13	11.4	4.16	7.7	12.9	5.44	6.07	3.22	5.77	6.86	4.5	4.85	10.1	5.6	4.22
Mercury	2 [10]	0.016	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	-	-	7.6	7.6	9.8	8.8	7.6	6.5	10.3	8.5	7.5	9.1	9.4	9.9	9.7	5.6	10.3	8.5
Nickel	-	-	0.528	0.536	1.01	0.446	0.675	0.943	0.465	0.612	0.421	0.56	0.798	0.508	0.559	0.762	0.473	0.507
Potassium	-	-	309000	226000	363000	385000	251000	275000	338000	332000	331000	264000	387000	376000	361000	288000	357000	345000
Selenium	-	-	0.51	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.82	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Silicon	-	-	1410	1360	1890	1860	1260	1130	1700	1680	1170	1010	1420	1920	1430	910	1930	1500
Silver	3 [12]	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.4	<1	<1	<1
Sodium	-	-	7340000	5770000	8290000	8620000	7130000	7740000	8850000	8610000	7840000	6840000	8790000	8450000	8440000	8000000	9410000	8900000
Strontium	-	-	5970	4270	6850	5960	5220	5060	6010	5590	6100	5040	7200	6250	5740	4800	6410	5690
Thallium	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Tin	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Titanium	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Uranium	100 [9]	-	1.96	1.24	1.99	1.77	1.85	1.9	2.24	2.4	1.74	1.28	1.9	1.94	2.27	1.67	2.4	2.38
Vanadium	50 [13]	-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Zinc	10 [10]	-	2.55	0.6	3.56	1.17	5.04	2.27	1.5	1.79	1.96	2.5	1.74	1.39	2.56	3.25	1.45	1.52

Table 18
2008 Surface Water Chemistry Results

		Location ID:	DP03								DP04							
		Sample ID:	SWDP03-1	SWDP03-2	SWDP03-3	SWDP03-4	SWDP03-5	SWDP03-6	SWDP03-7	SWDP03-8	SWDP04-1	SWDP04-2	SWDP04-3	SWDP04-4	SWDP04-5	SWDP04-6	SWDP04-7	SWDP04-8
		Date Sampled:	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2008-03-03	2008-05-29	2008-09-20	2008-11-26	2007-03-23	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-20	2008-11-26
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]																
PAHs																		
Acenaphthene	6 [10]	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Acenaphthylene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Acridine	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Anthracene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Benzo(a)anthracene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Benzo(a)pyrene	0.01 [10]	-	<0.05	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-
Benzo(b)fluoranthene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Benzo(k)fluoranthene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Chrysene	0.1 [10]	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Dibenz(a,h)anthracene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Fluoranthene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Fluorene	12 [10]	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Naphthalene	1 [10]	1.4	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Phenanthrene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Pyrene	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Quinoline	-	-	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
Bacteriological Tests																		
Chlorophyll A	-	-	2.25	3.77	3.19	0.572	2.3	1.17	0.652	0.427	2.54	6.09	3.55	0.645	1.22	1.34	0.629	0.393
Surrogate Recovery																		
Acenaphthene-d10, surrogate (%)	-	-	-	-	-	-	-	-	-	-	93	-	-	-	-	-	-	-
Acridine-d9, surrogate (%)	-	-	-	-	-	-	-	-	-	-	95	-	-	-	-	-	-	-
Chrysene-d12, surrogate (%)	-	-	-	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-
Naphthalene-d8, surrogate (%)	-	-	-	-	-	-	-	-	-	-	93	-	-	-	-	-	-	-
Phenanthrene-d10, surrogate (%)	-	-	-	-	-	-	-	-	-	-	94	-	-	-	-	-	-	-

Table 18
2008 Surface Water Chemistry Results

		Location ID:	DP05								DP05							
		Sample ID:	SWDP05A-1	SWDP05A-2	SWDP05A-3	SWDP05A-4	SWDP05A-5	SWDP05A-6	SWDP05A-7	SWDP05A-8	SWDP05B-1	SWDP05B-2	SWDP05B-3	SWDP05B-4	SWDP05B-5	SWDP05B-6	SWDP05B-7	SWDP05B-8
		Date Sampled:	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27	2007-03-24	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]																
Sample Info																		
Sample Depth, Below Water Surface (m)	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5m	10	15	0.5	0.5	14	13	0.5	14
Secchi Depth (m)	-	-	-	-	3.6	4.3	-	-	2.8	2	-	-	-	-	-	-	-	-
Field Tests																		
Field Conductivity (uS/cm)	-	-	43311	33000	32657	44533	44250	37260	40733	32678	45143	44700	33099	44917	46613	42172	45770	33418
Field Dissolved Oxygen (mg/L)	-	-	9.42	-	7.73	10.86	8.48	9.5	7.91	7.9	16.92	-	6.02	10.86	7.66	9.06	6.42	6.08
Field pH	-	-	7.77	8.3	-	7.58	7.87	7.53	791	7.69	7.76	8.07	-	7.62	7.82	7.6	7.63	7.65
Field Redox, Uncorrected (mV)	-	-	251.9	248.3	253	221	-40.2	201.4	-86	-322.7	227.2	241.1	251	230	-73.5	206.9	-66	-305.7
Field Salinity	-	-	27590000	-	29040000	28450000	28300000	-	25820000	30280000	27190000	-	29860000	28760000	29900000	-	29550000	31000000
Field Temperature (ºC)	-	-	7.59	13.8	10.6	7.77	7.08	13.47	12.46	8.92	7.3	10.3	10.1	7.54	7.22	11.66	11.14	9.13
Field Total Dissolved Solids	-	-	-	-	-	-	-	-	-	30520000	-	-	-	-	-	-	-	31160000
Field Turbidity (NTU)	-	-	3.87	1.03	-	-	-	-	-	0.71	10.19	1.2	-	-	-	-	-	1.11
Physical Tests																		
Hardness, Total (CaCO3) (mg/L)	-	-	4370	3750	5040	-	5250	4430	4800	5470	-	5210	5120	-	5300	4790	5500	5600
pH	-	7-8.7 [14]	7.83	7.85	7.85	7.85	7.79	7.99	7.83	7.76	7.82	7.93	7.81	7.82	7.79	7.98	7.79	7.75
Salinity	-	10-X [15]	24000000	28700000	28100000	28400000	-	23900000	-	-	28500000	<1000000	29600000	28800000	-	25600000	-	-
Total Suspended Solids (mg/L)	-	-	8.7	18.5	15.7	30.8	14.2	9.9	11.3	7.1	20.2	36.5	51.7	14.8	12.9	19.9	11.3	4.4
Turbidity (NTU)	-	-	-	-	-	0.88	0.58	1.66	1.87	1.17	-	-	-	1.46	0.72	2.04	1.07	1.32
Dissolved Inorganics																		
Phosphate (mg/L)	-	-	0.058	0.0253	0.0527	0.0733	0.0634	0.0312	0.0462	0.0732	0.0688	0.0648	0.0683	0.067	0.0704	0.0326	0.0622	0.0777
Inorganics																		
Ammonia (mg/L)	-	-	0.035	0.088	<0.020	<0.020	0.012	0.0478	0.0182	0.0057	<0.020	0.076	<0.020	<0.020	<0.005	0.0426	0.0125	<0.005
Nitrate (mg/L)	-	16	<0.50	<0.500	<0.500	6.4	1.9	<0.500	3.5	0.84	0.3	<0.500	<0.500	7	2.39	<0.500	<2.500	8.8
Nitrite (mg/L)	-	-	<0.10	0.23	<0.100	<0.500	0.27	0.21	<0.500	<0.100	<0.020	0.29	<0.100	<0.500	0.27	0.19	<0.500	<1.000
Phosphate, Ortho (mg/L)	-	-	0.0531	0.0217	0.0527	0.0735	0.0654	0.0264	0.0438	0.0727	0.062	0.0634	0.0708	0.0745	0.0713	0.0273	0.0608	0.0754
Total Inorganics																		
Chlorine (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate (mg/L)	-	-	0.0634	0.0418	0.0604	0.0766	0.0687	0.0409	0.0501	0.0811	0.0705	0.0716	0.0713	0.0844	0.0726	0.0435	0.0638	0.078
Phosphorus (mg/L)	-	-	<3.0	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.0	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000
Total Kjeldahl Nitrogen (mg/L)	-	-	0.155	0.585	0.289	0.217	0.232	0.187	0.117	<0.050	0.107	0.128	0.222	0.201	0.251	0.179	<0.050	0.074
Total Nitrogen (mg/L)	-	-	<0.70	0.81	<0.700	6.6	2.41	<5.000	3.6	0.84	0.41	<0.700	<0.700	7.2	2.91	<5.000	<3.000	8.9
Organics																		
Organic Nitrogen (mg/L)	-	-	0.12	0.497	-	0.217	0.22	0.139	0.099	<0.060	-	<0.070	-	0.201	0.251	0.136	<0.060	0.074
Dissolved Metals																		
Iron	50 [9]	-	-	<10	<300	<10	<10	22	<10	12	-	<10	<300	<10	<10	22	<10	14

Table 18
2008 Surface Water Chemistry Results

Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]	SWDP05A-1	SWDP05A-2	SWDP05A-3	SWDP05A-4	SWDP05A-5	SWDP05A-6	SWDP05A-7	SWDP05A-8	SWDP05B-1	SWDP05B-2	SWDP05B-3	SWDP05B-4	SWDP05B-5	SWDP05B-6	SWDP05B-7	SWDP05B-8
		Location ID:	DP05								DP05							
		Date Sampled:	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27	2007-03-24	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27
Total Metals																		
Aluminum	-	-	<100	<100	<100	<100	<100	160	<100	<100	<100	<300	<100	<100	<100	130	<100	<100
Antimony	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	12.5 [7]	12.5	1.11	1.24	1.28	1.25	1.17	1.26	1.19	1.49	1.26	1.16	1.05	0.88	1.31	0.84	1.19	1.51
Barium	200 [8]	-	10.8	12.6	8.6	8.9	7.5	7.5	9.4	8.2	9.3	21.2	7.1	8.3	7	6	8.3	7.8
Beryllium	100 [9]	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Bismuth	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Boron	1200 [10]	-	3300	3000	3700	3500	3500	2800	3000	3700	3800	3900	3500	3500	3700	3100	3500	3600
Cadmium	0.12 [11]	0.12	0.069	0.055	0.066	0.051	0.078	0.064	0.065	0.085	0.064	0.064	0.054	0.062	0.085	0.073	0.073	0.088
Calcium	-	-	285000	228000	359000	350000	346000	300000	312000	350000	345000	309000	395000	359000	348000	320000	357000	364000
Chromium	56 [11]	56	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Cobalt	-	-	0.082	0.059	0.064	<0.05	<0.05	0.098	0.064	<0.05	<0.050	0.052	<0.05	<0.05	<0.05	0.086	<0.05	<0.05
Copper	3 [10]	-	6.99	0.636	0.615	0.617	0.924	1.37	0.666	0.652	0.496	0.562	0.389	0.507	0.721	0.974	0.408	0.561
Iron	50 [9]	-	68	18	47	23	22	81	54	41	29	51	22	38	27	109	35	46
Lead	140 [10]	-	0.33	0.189	0.386	0.135	0.468	0.457	0.585	0.195	0.119	0.373	0.094	0.081	0.315	0.387	0.139	1.29
Lithium	-	-	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500
Magnesium	-	-	887000	772000	1170000	1140000	1070000	893000	978000	1120000	1090000	1080000	1290000	1170000	1080000	970000	1120000	1140000
Manganese	-	-	6.48	7.97	5.43	2.28	2.49	8.43	5.85	3.33	2.47	3.58	2.31	2.89	1.76	7.02	3.68	2.59
Mercury	2 [10]	0.016	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	-	-	6.9	7.1	9.4	9.5	7.2	6.5	9.8	8	8.9	9.4	8.2	10.5	8.7	7.8	9.8	8.5
Nickel	-	-	0.593	0.568	0.582	0.356	0.59	0.941	0.546	0.493	0.64	0.52	0.416	0.425	0.565	0.735	0.479	0.481
Potassium	-	-	296000	239000	384000	374000	366000	277000	306000	316000	348000	329000	415000	387000	371000	298000	352000	319000
Selenium	-	-	<0.50	0.62	<0.5	0.59	<0.5	<0.5	<0.5	<0.5	<0.50	<0.5	0.69	<0.5	<0.5	<0.5	<0.5	<0.5
Silicon	-	-	1580	1380	1380	1750	1550	850	1350	1730	1340	1380	1560	1810	1530	750	1470	1630
Silver	3 [12]	-	<1.0	<1	<1	<1	<1	<1	<1	<1	<1.0	<1	<1	<1	<1	<1	<1	<1
Sodium	-	-	7620000	6280000	8700000	8370000	8590000	7800000	8060000	9750000	8230000	8620000	9380000	8660000	8660000	8200000	9270000	9900000
Strontium	-	-	5750	4330	7050	6170	5860	4790	5250	5670	6680	6300	6460	6290	5700	5320	6340	5730
Thallium	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Tin	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Titanium	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Uranium	100 [9]	-	1.92	1.32	2.05	1.74	2.19	1.81	2	2.56	1.97	1.28	1.82	1.87	2.4	2.29	2.27	2.65
Vanadium	50 [13]	-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Zinc	10 [10]	-	19	1.3	2.67	1.21	1.16	1.65	2.46	1.01	1.09	2.1	0.67	1	1.24	2.2	1.02	0.9

Table 18
2008 Surface Water Chemistry Results

		Location ID:	DP05								DP05							
		Sample ID:	SWDP05A-1	SWDP05A-2	SWDP05A-3	SWDP05A-4	SWDP05A-5	SWDP05A-6	SWDP05A-7	SWDP05A-8	SWDP05B-1	SWDP05B-2	SWDP05B-3	SWDP05B-4	SWDP05B-5	SWDP05B-6	SWDP05B-7	SWDP05B-8
		Date Sampled:	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27	2007-03-24	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]																
PAHs																		
Acenaphthene	6 [10]	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Acenaphthylene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Acridine	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Anthracene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(a)anthracene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(a)pyrene	0.01 [10]	-	<0.010	-	-	-	-	-	-	-	<0.010	-	-	-	-	-	-	-
Benzo(b)fluoranthene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(k)fluoranthene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Chrysene	0.1 [10]	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Dibenz(a,h)anthracene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Fluoranthene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Fluorene	12 [10]	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Naphthalene	1 [10]	1.4	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Phenanthrene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Pyrene	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Quinoline	-	-	<0.050	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Bacteriological Tests																		
Chlorophyll A	-	-	1.26	6.42	0.96	0.504	1.5	1.01	1.11	0.304	0.5	1	4.96	0.422	0.722	1.95	1.03	0.142
Surrogate Recovery																		
Acenaphthene-d10, surrogate (%)	-	-	95	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-
Acridine-d9, surrogate (%)	-	-	94	-	-	-	-	-	-	-	92	-	-	-	-	-	-	-
Chrysene-d12, surrogate (%)	-	-	90	-	-	-	-	-	-	-	88	-	-	-	-	-	-	-
Naphthalene-d8, surrogate (%)	-	-	95	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-
Phenanthrene-d10, surrogate (%)	-	-	94	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-

Table 18
2008 Surface Water Chemistry Results

		Location ID:	DP06								DP07							
		Sample ID:	SWDP06-1	SWDP06-2	SWDP06-3	SWDP06-4	SWDP06-5	SWDP06-6	SWDP06-7	SWDP06-8	SWDP07A-1	SWDP07A-2	SWDP07A-3	SWDP07A-4	SWDP07A-5	SWDP07A-6	SWDP07A-7	SWDP07A-8
		Date Sampled:	2007-03-23	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26	2007-03-24	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]																
Sample Info																		
Sample Depth, Below Water Surface (m)	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Secchi Depth (m)	-	-	-	-	0.6	0.9	0.4	-	0.5	1	-	-	5.2	2	1.8	-	1	1.2
Field Tests																		
Field Conductivity (uS/cm)	-	-	20042	25500	4877	11517	24116	20042	23071	24000	43933	19590	32350	39268	23905	48340	31003	25693
Field Dissolved Oxygen (mg/L)	-	-	11.4	-	10.4	12.26	10.55	11.4	9.35	9.95	9.27	-	8.27	10.1	11.81	11.5	8.2	96
Field pH	-	-	7.81	7.65	6.5	7.45	7.97	7.81	7.83	7.47	7.8	8.29	-	7.64	7.94	6.1	7.6	7.78
Field Redox, Uncorrected (mV)	-	-	207	199.2	212	176	-64.9	207	-22	-273.9	180.3	170.1	257	172	-74	290.5	135	-276.2
Field Salinity	-	-	24230000	-	3550000	30340000	14760000	-	13920000	22450000	24890000	-	28890000	24770000	14410000	-	19580000	23720000
Field Temperature (ºC)	-	-	6.4	14.1	12.4	3.96	6.23	6.4	13.51	7.74	7.85	13.5	10.8	6.62	6.27	12.05	13.36	8.07
Field Total Dissolved Solids	-	-	-	-	-	-	-	-	-	23290000	-	-	-	-	-	-	-	23740000
Field Turbidity (NTU)	-	-	18.92	34	-	-	-	-	-	5.48	1.2	7.72	-	-	-	-	-	5.45
Physical Tests																		
Hardness, Total (CaCO3) (mg/L)	-	-	1950	212	-	-	2530	139	2640	1710	-	2140	-	-	2510	484	3380	5840
pH	-	7-8.7 [14]	7.8	7.89	7.59	7.79	7.79	7.96	7.83	7.77	7.78	7.84	7.73	7.84	7.79	7.76	7.81	7.78
Salinity	-	10-X [15]	10300000	11900000	3500000	6500000	-	-	-	8900000	27300000	27600000	28700000	24300000	-	-	-	8100000
Total Suspended Solids (mg/L)	-	-	12.7	28.5	12.9	12.2	25.3	94.7	35.3	9.1	33.6	21.2	3.7	22.2	12.7	48.7	6	11.8
Turbidity (NTU)	-	-	-	-	-	8.75	14	86.3	16.5	7.93	-	-	-	2.21	4.88	50	4.86	7.07
Dissolved Inorganics																		
Phosphate (mg/L)	-	-	0.027	0.008	0.0167	0.0218	0.0306	-	0.0284	0.0277	0.0618	0.0134	0.0624	0.0603	0.0338	-	0.0336	0.0258
Inorganics																		
Ammonia (mg/L)	-	-	0.041	0.056	0.1	0.071	0.0814	0.242	0.0365	0.0815	0.028	0.023	0.0067	<0.020	0.0974	0.028	0.0372	0.0848
Nitrate (mg/L)	-	16	0.19	0.0634	0.49	12	1.59	<0.500	<0.500	<0.500	0.25	0.79	1.93	7.4	1.75	<0.500	<0.500	0.218
Nitrite (mg/L)	-	-	<0.020	<0.001	<0.020	<0.500	0.11	<0.100	0.13	<0.100	<0.020	<0.100	<0.100	<0.500	0.14	<0.100	0.15	0.022
Phosphate, Ortho (mg/L)	-	-	0.0237	0.0067	0.016	0.0224	0.031	-	0.0264	0.0267	0.0578	0.0091	0.0672	0.0618	0.0356	-	0.0302	0.0253
Total Inorganics																		
Chlorine (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate (mg/L)	-	-	0.0486	0.0477	0.0298	0.0343	0.0528	-	0.0602	0.0415	0.0644	0.0352	0.0638	0.069	0.0452	-	0.0447	0.0349
Phosphorus (mg/L)	-	-	<3.000	<0.300	<3.000	<3.000	<3.000	<0.300	<3.000	<3.000	<3.0	<1.500	<3.000	<3.000	<3.000	<0.300	<3.000	<3.000
Total Kjeldahl Nitrogen (mg/L)	-	-	0.214	0.312	0.2	0.186	0.343	0.247	0.137	0.284	0.075	0.23	0.233	0.143	0.31	0.146	0.115	0.296
Total Nitrogen (mg/L)	-	-	0.41	0.375	0.69	12.2	2.04	<0.700	<0.700	<0.700	0.33	1.02	2.16	7.6	2.2	<0.700	<0.700	0.54
Organics																		
Organic Nitrogen (mg/L)	-	-	-	0.256	-	0.115	0.261	<0.070	0.1	0.203	-	0.207	-	0.143	0.213	0.119	0.078	0.211
Dissolved Metals																		
Iron	50 [9]	-	-	21	-	11	<10	59	<10	19	-	<10	-	<10	<10	24	<10	18

Table 18
2008 Surface Water Chemistry Results

		Location ID:	DP06								DP07							
		Sample ID:	SWDP06-1	SWDP06-2	SWDP06-3	SWDP06-4	SWDP06-5	SWDP06-6	SWDP06-7	SWDP06-8	SWDP07A-1	SWDP07A-2	SWDP07A-3	SWDP07A-4	SWDP07A-5	SWDP07A-6	SWDP07A-7	SWDP07A-8
		Date Sampled:	2007-03-23	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26	2007-03-24	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]																
Total Metals																		
Aluminum	-	-	226	1110	170	200	282	1170	<500	181	<100	<400	<100	<100	102	723	<200	<200
Antimony	-	-	<5	<0.5	<10	<2	<5	<0.2	<10	<5	<10	<5	<10	<10	<5	<1	<10	<10
Arsenic	12.5 [7]	12.5	0.86	0.43	0.69	0.61	0.77	0.52	0.81	0.74	1.34	0.92	1.06	1.11	1.12	0.65	0.65	0.42
Barium	200 [8]	-	17.8	22	20.3	19	16.2	24.2	13.7	15.5	10.6	17.9	8.5	10.3	14	21.2	11.7	14.6
Beryllium	100 [9]	-	<25	<2.5	<50	<10	<25	<1	<50	<25	<50	<25	<50	<50	<25	<5	<50	<50
Bismuth	-	-	<25	<2.5	<50	<10	<25	<1	<50	<25	<50	<25	<50	<50	<25	<5	<50	<50
Boron	1200 [10]	-	1310	129	<1000	740	1760	65	1700	1120	3900	1560	4000	3000	1860	300	2100	1000
Cadmium	0.12 [11]	0.12	0.051	0.028	0.032	0.032	0.052	0.045	0.046	0.045	0.067	0.066	0.068	0.057	0.046	0.042	0.062	0.039
Calcium	-	-	133000	24500	49400	79900	168000	19300	170000	111000	332000	133000	338000	296000	167000	41600	215000	371000
Chromium	56 [11]	56	<25	4.1	<50	<10	<25	2.2	<50	<25	<50	<25	<50	<50	<25	<5	<50	<50
Cobalt	-	-	0.252	0.394	0.189	0.161	0.252	1.2	0.398	0.147	<0.050	0.123	<0.05	0.056	0.108	0.864	0.181	0.131
Copper	3 [10]	-	3.27	2.07	6.45	1.12	2.01	6.45	1.57	1.07	2.25	1.27	0.825	0.563	2.25	4.38	1.45	1.62
Iron	50 [9]	-	300	369	161	218	329	1350	599	231	36	92	<10	55	127	1020	240	205
Lead	140 [10]	-	1.95	0.349	3.1	0.171	1.11	1.47	0.58	0.169	1.06	0.601	0.368	0.085	0.657	0.841	0.172	0.882
Lithium	-	-	<250	<25	<500	<100	<250	<10	<500	<250	<500	<250	<500	<500	<250	<50	<500	<500
Magnesium	-	-	393000	36600	119000	225000	513000	22100	539000	348000	1060000	439000	1040000	942000	508000	92300	690000	1190000
Manganese	-	-	22.8	38.8	39.1	21.9	21.3	74	23.9	18.8	2.3	13.9	1.93	5.33	12.3	55.7	15.4	16.8
Mercury	2 [10]	0.016	<0.01	<0.01	<0.01	<0.01	<0.01	0.017	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.013	<0.01	<0.01
Molybdenum	-	-	2.6	1.26	<5	2.3	5.1	0.62	5.3	3.1	10.5	4.4	9.5	8.7	4.9	0.97	5.8	<5
Nickel	-	-	1.16	1.43	0.953	0.834	1.32	4.47	1.57	0.928	0.558	0.767	0.453	0.503	0.898	3.43	0.947	0.901
Potassium	-	-	123000	12000	37000	75000	178000	7000	170000	104000	333000	137000	297000	318000	178000	28100	221000	354000
Selenium	-	-	<0.5	0.61	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Silicon	-	-	2320	3330	2250	2840	2620	5340	2890	2810	1120	1990	1350	1890	2180	3960	2090	1490
Silver	3 [12]	-	<0.5	<0.05	<1	<0.2	<0.5	0.022	<1	<0.5	<1.0	<0.5	<1	<1	<0.5	<0.1	<1	<1
Sodium	-	-	3090000	257000	905000	1890000	4140000	162000	5040000	3140000	7920000	3570000	8420000	7170000	4110000	753000	5800000	9170000
Strontium	-	-	2080	253	869	1320	2860	164	3020	1860	6530	2520	7580	5190	2980	562	3690	1670
Thallium	-	-	<5	<0.5	<10	<2	<5	<0.2	<10	<5	<10	<5	<10	<10	<5	<1	<10	<10
Tin	-	-	<5	2.22	<10	<2	<5	<0.2	<10	<5	<10	<5	<10	<10	<5	<1	<10	<10
Titanium	-	-	<100	25	<100	<100	<100	53	<100	<100	<100	<50	<100	<100	<100	34	<100	<100
Uranium	100 [9]	-	0.937	0.221	0.432	0.58	1.34	0.263	1.26	0.872	2.08	0.762	1.94	1.76	1.25	0.399	1.52	0.783
Vanadium	50 [13]	-	<50	5	<100	<20	<50	3.5	<100	<50	<100	<50	<100	<100	<50	<10	<100	<100
Zinc	10 [10]	-	3.65	1.82	4.83	2.68	2.19	8.68	2.81	2.76	5.22	2.4	1.54	1.09	1.95	8.38	3.18	2.43

		Location ID:	DP06								DP07							
		Sample ID:	SWDP06-1	SWDP06-2	SWDP06-3	SWDP06-4	SWDP06-5	SWDP06-6	SWDP06-7	SWDP06-8	SWDP07A-1	SWDP07A-2	SWDP07A-3	SWDP07A-4	SWDP07A-5	SWDP07A-6	SWDP07A-7	SWDP07A-8
		Date Sampled:	2007-03-23	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26	2007-03-24	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26
Parameter	**BCWQG MAL [3,4]**	**CCME MAL [5,6]**																
PAHs																		
Acenaphthene	6 [10]	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Acenaphthylene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Acridine	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Anthracene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(a)anthracene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(a)pyrene	0.01 [10]	-	<0.01	-	-	-	-	-	-	-	<0.010	-	-	-	-	-	-	-
Benzo(b)fluoranthene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Benzo(k)fluoranthene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Chrysene	0.1 [10]	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Dibenz(a,h)anthracene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Fluoranthene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Fluorene	12 [10]	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Naphthalene	1 [10]	1.4	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Phenanthrene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Pyrene	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Quinoline	-	-	<0.05	-	-	-	-	-	-	-	<0.050	-	-	-	-	-	-	-
Bacteriological Tests																		
Chlorophyll A	-	-	0.847	0.554	0.932	0.267	1.07	0.747	0.964	0.389	0.561	4.3	1.17	0.401	0.766	0.407	0.864	0.462
Surrogate Recovery																		
Acenaphthene-d10, surrogate (%)	-	-	88	-	-	-	-	-	-	-	95	-	-	-	-	-	-	-
Acridine-d9, surrogate (%)	-	-	85	-	-	-	-	-	-	-	97	-	-	-	-	-	-	-
Chrysene-d12, surrogate (%)	-	-	87	-	-	-	-	-	-	-	93	-	-	-	-	-	-	-
Naphthalene-d8, surrogate (%)	-	-	87	-	-	-	-	-	-	-	95	-	-	-	-	-	-	-
Phenanthrene-d10, surrogate (%)	-	-	88	-	-	-	-	-	-	-	95	-	-	-	-	-	-	-

Table 18
2008 Surface Water Chemistry Results

		Location ID:	DP07								DP08
		Sample ID:	SWDP07B-1	SWDP07B-2	SWDP07B-3	SWDP07B-4	SWDP07B-5	SWDP07B-6	SWDP07B-7	SWDP07B-8	SWDP08-5
		Date Sampled:	2007-03-24	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26	2008-03-04
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]									
Sample Info											
Sample Depth, Below Water Surface (m)	-	-	13	18	0.5	0.5	22	20.5	19	20	0.5
Secchi Depth (m)	-	-	-	-	-	-	-	-	-	-	2.1
Field Tests											
Field Conductivity (uS/cm)	-	-	45970	45000	32733	41778	46773	45970	45421	34323	42599
Field Dissolved Oxygen (mg/L)	-	-	12.75	-	6.39	15.58	7.71	12.75	6.38	6.91	9.04
Field pH	-	-	7.73	7.95	-	7.61	7.78	7.73	7.53	7.65	7.94
Field Redox, Uncorrected (mV)	-	-	200.2	160	255	223	-92.7	200.2	-25	-272.2	89.7
Field Salinity	-	-	26010000	-	29100000	26520000	29960000	-	29780000	30900000	27080000
Field Temperature (ºC)	-	-	7.85	9.9	10.3	7.12	7.23	7.85	11.32	9.19	6.76
Field Total Dissolved Solids	-	-	-	-	-	-	-	-	-	31120000	-
Field Turbidity (NTU)	-	-	0.09	2.6	-	-	-	-	-	0.42	-
Physical Tests											
Hardness, Total (CaCO3) (mg/L)	-	-	-	5130	-	-	5420	4260	5460	6060	4720
pH	-	7-8.7 [14]	7.83	7.95	7.79	7.85	7.73	7.86	7.77	7.75	7.8
Salinity	-	10-X [15]	27900000	20400000	28800000	27800000	-	-	-	30400000	-
Total Suspended Solids (mg/L)	-	-	10.9	25.2	51	9.5	15.3	38	31.3	18.4	9.3
Turbidity (NTU)	-	-	-	-	-	1.7	0.48	4.3	5.84	0.9	1.1
Dissolved Inorganics											
Phosphate (mg/L)	-	-	0.0656	0.0597	0.059	0.0667	0.0711	-	0.0588	0.0774	0.0485
Inorganics											
Ammonia (mg/L)	-	-	<0.020	0.03	<0.005	<0.020	<0.005	0.024	0.0114	<0.005	0.0194
Nitrate (mg/L)	-	16	0.33	0.52	2.36	5.9	1.92	<5.000	<0.500	0.66	1.87
Nitrite (mg/L)	-	-	<0.020	<0.100	<0.100	<0.500	0.1	<1.000	0.15	0.24	<0.100
Phosphate, Ortho (mg/L)	-	-	0.063	0.0606	0.0665	0.0719	0.0717	-	0.0554	0.0788	0.0493
Total Inorganics											
Chlorine (mg/L)	-	-	-	-	-	-	-	-	-	-	-
Phosphate (mg/L)	-	-	0.0671	0.0666	0.0678	0.0745	0.0856	-	0.0771	0.0723	0.0531
Phosphorus (mg/L)	-	-	<3.0	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000
Total Kjeldahl Nitrogen (mg/L)	-	-	0.119	0.094	0.229	0.263	0.191	0.259	<0.050	0.138	0.283
Total Nitrogen (mg/L)	-	-	0.45	<0.700	2.59	6.1	2.21	<6.000	<0.700	1.04	2.15
Organics											
Organic Nitrogen (mg/L)	-	-	-	<0.070	-	0.263	0.191	0.235	<0.060	0.138	0.263
Dissolved Metals											
Iron	50 [9]	-	-	<10	-	<10	<10	<10	<10	<10	<10

Table 18
2008 Surface Water Chemistry Results

		Location ID:	DP07								DP08
		Sample ID:	SWDP07B-1	SWDP07B-2	SWDP07B-3	SWDP07B-4	SWDP07B-5	SWDP07B-6	SWDP07B-7	SWDP07B-8	SWDP08-5
		Date Sampled:	2007-03-24	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26	2008-03-04
Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]									
Total Metals											
Aluminum	-	-	<100	<300	<100	<100	<100	260	<300	<200	<100
Antimony	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	12.5 [7]	12.5	1.41	1.51	1.4	0.93	1.53	1.02	1.32	1.53	1.13
Barium	200 [8]	-	9.6	11.7	9	8.9	7.8	9.9	8.8	8.2	8.3
Beryllium	100 [9]	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
Bismuth	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
Boron	1200 [10]	-	4000	4000	4000	3400	3600	2900	3500	3800	3400
Cadmium	0.12 [11]	0.12	0.06	0.073	0.056	0.056	0.084	0.064	0.078	0.089	0.071
Calcium	-	-	346000	305000	334000	344000	364000	282000	352000	382000	317000
Chromium	56 [11]	56	<50	<50	<50	<50	<50	<50	<50	<50	<50
Cobalt	-	-	<0.050	0.065	<0.05	<0.05	<0.05	0.225	0.224	<0.05	0.07
Copper	3 [10]	-	0.887	0.539	1.04	0.396	1.41	1.42	0.868	0.584	2.23
Iron	50 [9]	-	32	49	<10	32	17	315	363	28	32
Lead	140 [10]	-	0.597	0.119	0.116	<0.05	0.682	0.376	0.207	2.92	0.728
Lithium	-	-	<500	<500	<500	<500	<500	<500	<500	<500	<500
Magnesium	-	-	1100000	1060000	1060000	1110000	1100000	863000	1110000	1240000	954000
Manganese	-	-	2.03	9.46	1.86	2.87	1.68	15.5	10.4	2.32	5.74
Mercury	2 [10]	0.016	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	-	-	9.9	9.3	9.9	8.3	10.3	6.2	10.1	9.2	10.2
Nickel	-	-	0.362	0.646	0.42	0.388	0.265	1.14	1.07	0.457	0.422
Potassium	-	-	351000	321000	297000	367000	379000	262000	343000	370000	335000
Selenium	-	-	<0.50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.58	<0.5
Silicon	-	-	1380	1300	1330	1770	1610	1760	1660	1540	1360
Silver	3 [12]	-	<1.0	<1	<1	<1	<1	<1	<1	<1	<1
Sodium	-	-	8270000	8350000	8300000	8220000	8400000	7430000	8960000	9520000	7440000
Strontium	-	-	6850	6130	7450	5900	5910	4750	6330	5930	5560
Thallium	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10
Tin	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10
Titanium	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100
Uranium	100 [9]	-	2.01	1.44	1.79	1.8	1.86	1.87	2.35	2.5	2.11
Vanadium	50 [13]	-	<100	<100	<100	<100	<100	<100	<100	<100	<100
Zinc	10 [10]	-	2.31	1.5	1.46	0.86	2.75	2.57	2.21	1.13	1.84

Table 18
2008 Surface Water Chemistry Results

Parameter	BCWQG MAL [3,4]	CCME MAL [5,6]	SWDP07B-1	SWDP07B-2	SWDP07B-3	SWDP07B-4	SWDP07B-5	SWDP07B-6	SWDP07B-7	SWDP07B-8	SWDP08-5
		Location ID:	DP07								DP08
		Date Sampled:	2007-03-24	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26	2008-03-04
PAHs											
Acenaphthene	6 [10]	-	<0.050	-	-	-	-	-	-	-	-
Acenaphthylene	-	-	<0.050	-	-	-	-	-	-	-	-
Acridine	-	-	<0.050	-	-	-	-	-	-	-	-
Anthracene	-	-	<0.050	-	-	-	-	-	-	-	-
Benzo(a)anthracene	-	-	<0.050	-	-	-	-	-	-	-	-
Benzo(a)pyrene	0.01 [10]	-	<0.010	-	-	-	-	-	-	-	-
Benzo(b)fluoranthene	-	-	<0.050	-	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	-	-	<0.050	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	-	-	<0.050	-	-	-	-	-	-	-	-
Chrysene	0.1 [10]	-	<0.050	-	-	-	-	-	-	-	-
Dibenz(a,h)anthracene	-	-	<0.050	-	-	-	-	-	-	-	-
Fluoranthene	-	-	<0.050	-	-	-	-	-	-	-	-
Fluorene	12 [10]	-	<0.050	-	-	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	<0.050	-	-	-	-	-	-	-	-
Naphthalene	1 [10]	1.4	<0.050	-	-	-	-	-	-	-	-
Phenanthrene	-	-	<0.050	-	-	-	-	-	-	-	-
Pyrene	-	-	<0.050	-	-	-	-	-	-	-	-
Quinoline	-	-	<0.050	-	-	-	-	-	-	-	-
Bacteriological Tests											
Chlorophyll A	-	-	0.714	0.521	1.07	0.445	0.71	0.481	1.05	0.0944	1.45
Surrogate Recovery											
Acenaphthene-d10, surrogate (%)	-	-	89	-	-	-	-	-	-	-	-
Acridine-d9, surrogate (%)	-	-	95	-	-	-	-	-	-	-	-
Chrysene-d12, surrogate (%)	-	-	93	-	-	-	-	-	-	-	-
Naphthalene-d8, surrogate (%)	-	-	88	-	-	-	-	-	-	-	-
Phenanthrene-d10, surrogate (%)	-	-	97	-	-	-	-	-	-	-	-

(1) All values are reported as µg/L unless otherwise noted
(2) - = No standard or not analyzed
(3) BCWQG = British Columbia Approved Water Quality Guidelines, 1998, updated to August 2006; and A Compendium of Working Water Quality Guidelines for British Columbia, 1998, updated to August 2006
(4) BCWQG MAL = Marine and Estuarine Aquatic Life criteria from Approved Guidelines Tables 2 to 50 and/or Working Guidelines Table 1
(5) CCME = Canadian Council of Ministers of the Environment, Canadian Environmental Quality Guidelines, 1999, updated to December 2007 (v7.1)
(6) CCME MAL = Chapter 4, Canadian Water Quality Guidelines for the Protection of Aquatic Life, Summary Table, Marine, Update 7.0, September 2007
(7) Approved - Tables 2 to 50 - Maximum, Interim
(8) Working - Table 1 - Maximum, Adverse Effects on a Bivalve
(9) Working - Table 1 - Maximum, Minimal Risk
(10) Approved - Tables 2 to 50 - Maximum
(11) Working - Table 1 - Maximum for Cr(III)
(12) Approved - Tables 2 to 50 - Maximum, Open Coast and Estuaries
(13) Working - Table 1 - Trigger Value for 99% Protection
(14) CCME MAL stipulates pH not < 7 and not > 8.7
(15) CCME MAL stipulates Salinity not <= 10

Table 19
2008 Sediment Chemistry Results

	Location ID:	DP01								DP02							
	Sample ID:	SDDP01-1	SDDP01-2	SDDP01-3	SDDP01-4	SDDP01-5	SDDP01-6	SDDP01-7	SDDP01-8	SDDP02-1	SDDP02-2	SDDP02-3	SDDP02-4	SDDP02-5	SDDP02-6	SDDP02-7	SDDP02-8
	Date Sampled:	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2008-03-03	2008-05-29	2008-09-20	2008-11-26
	Sample Depth Interval (m):	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05
Parameter	CSR SedQC(SS) Marine [3,4]																
Field Observations																	
Field Odour (text)	-	sulphur	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Physical Tests																	
Moisture (%)	-	36.9	44	30.8	23.6	25.6	29.1	25.8	25.8	28	32.2	33	34	30.8	33.2	33.8	34
Oxidation Reduction Potential (mV)	-	-150	50	-120	-100	60	-300	-270	-350	-170	-	-200	-170	-170	-250	-280	-60
pH	-	8.03	7.89	8.01	7.75	8.02	8.12	7.63	7.75	7.92	7.74	8.17	8.04	7.89	7.97	7.82	7.71
Saturation (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Inorganics																	
Ammonia	-	5.9	8.7	3.1	2	3.1	13.1	6.6	5	3.9	7.3	8.1	4.3	2.4	4.4	9	3.9
Nitrate	-	-	-	-	-	-	-	-	-	-	2.4	-	-	-	-	-	-
Nitrite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate	-	610	795	580	590	563	668	635	1040	730	764	670	630	703	763	718	760
Phosphorus	-	654	-	619	585	563	668	635	1040	691	764	698	365	703	763	718	760
Sulfate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfide	-	95	97.5	<0.19	0.33	0.38	21.2	9.86	0.49	1.15	9.74	4.16	0.55	1.2	2.17	1.91	0.56
Total Kjeldahl Nitrogen (%)	-	0.13	0.12	0.08	0.05	0.07	0.11	0.09	0.1	0.06	0.05	<0.02	0.03	0.03	<0.02	0.05	0.06
Total Nitrogen (%)	-	0.1	0.14	0.06	0.07	0.07	0.12	0.09	0.1	0.04	0.04	0.04	0.03	0.04	0.05	0.07	0.05
Organics																	
Dissolved Organic Carbon (%)	-	0.98	1.12	0.7	-	-	-	-	-	0.16	0.29	0.1	-	-	-	-	-
Organic Nitrogen (%)	-	0.13	-	0.08	0.05	0.07	0.11	0.09	0.1	0.06	0.05	<0.02	0.03	0.03	<0.02	0.05	0.06
Total Organic Carbon (%)	-	-	-	-	0.7	1	1	0.8	0.8	-	-	-	0.2	0.3	0.2	0.4	0.5

Table 19
2008 Sediment Chemistry Results

	Location ID:	DP01								DP02							
	Sample ID:	SDDP01-1	SDDP01-2	SDDP01-3	SDDP01-4	SDDP01-5	SDDP01-6	SDDP01-7	SDDP01-8	SDDP02-1	SDDP02-2	SDDP02-3	SDDP02-4	SDDP02-5	SDDP02-6	SDDP02-7	SDDP02-8
	Date Sampled:	2007-03-22	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27	2007-03-22	2007-06-21	2007-10-02	2007-12-10	2008-03-03	2008-05-29	2008-09-20	2008-11-26
	Sample Depth Interval (m):	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05
Parameter	**CSR SedQC(SS) Marine [3,4]**																
Total Metals																	
Aluminum	-	14000	-	10700	11000	8640	12300	9930	13200	8680	10300	10200	17400	9380	9670	9700	9670
Antimony	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	26	5.4	5.7	<5.0	<5.0	5.2	<5.0	<5.0	7.3	<5.0	5.4	5.1	<5.0	<5.0	5.5	<5.0	6.7
Barium	-	44.8	43.7	25.5	40	22.8	33.8	32	38.9	24.3	35.7	28.4	91.8	28	30.2	27.3	30.4
Beryllium	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Bismuth	-	<20	-	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Cadmium	2.6	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Calcium	-	5960	-	5860	6140	4340	7660	6020	6430	5020	6140	5750	5330	6090	6040	5600	6530
Chromium	99	35.7	35.9	18.5	23.1	14.5	28	18.4	28.8	33.9	39.1	32.4	16.8	34.2	38.9	34.9	36.2
Cobalt	-	10.6	10.7	6	6.3	5.6	8.3	6	9.3	9.1	10.4	9.8	8.1	9.8	10.6	10.5	10.2
Copper	67	23.1	23.1	14.2	63.7	15.1	20.4	13.3	21.6	8.6	10.8	10.4	28.4	9.6	11.6	10	10.3
Iron	-	27500	-	17800	20000	16400	23600	16300	24900	23000	24200	22000	22900	23100	25300	22700	24600
Lead	69	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Lithium	-	16.8	-	10.6	10.6	8.7	13.2	10.4	16.1	9.8	11.6	12	8.5	10.6	12.2	11.6	11.5
Magnesium	-	10400	-	7080	6450	5840	8390	6490	9570	8020	9520	9370	4930	8510	9340	9120	8910
Manganese	-	292	-	257	254	235	279	227	330	240	278	246	403	262	272	258	274
Mercury	0.43	0.0464	0.0476	0.0249	0.0208	0.0237	0.0272	0.0212	0.033	0.0233	0.0284	0.0276	0.0453	0.0339	0.027	0.0244	0.0234
Molybdenum	-	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Nickel	-	33.4	34.6	17.4	20.5	15.4	28.3	17.9	28.2	30	33.5	31	11.7	31.7	33.2	32.8	33.4
Potassium	-	1970	-	1180	1060	990	1350	1110	1770	990	1240	1320	950	1180	1130	1200	1090
Selenium	-	<2.0	<3.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Silver	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Sodium	-	5570	-	4250	3640	3330	5000	2980	8720	3320	3650	5630	340	4850	4250	4870	3780
Strontium	-	42.9	-	28.9	38.6	29.1	37.9	28.6	45.4	28.7	32.9	28.2	41.7	28.7	28.5	27.6	30.3
Thallium	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tin	-	<5.0	<5.0	<5.0	<5.0	<5.0	5.1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Titanium	-	959	-	673	786	513	833	620	764	828	931	784	792	808	858	734	863
Vanadium	-	49.1	49.4	42.9	40.2	34.2	49.3	36.6	47.3	49.3	54.3	49.9	49	49.6	57.6	49.6	54.3
Zinc	170	62.8	65.6	41.3	60.3	35	55.8	38.8	58.6	44.5	52.4	48.1	54.9	48.4	51.2	49	50.6

Table 19
2008 Sediment Chemistry Results

	Location ID:	DP03								DP04							
	Sample ID:	SDDP03-1	SDDP03-2	SDDP03-3	SDDP03-4	SDDP03-5	SDDP03-6	SDDP03-7	SDDP03-8	SDDP04-1	SDDP04-2	SDDP04-3	SDDP04-4	SDDP04-5	SDDP04-6	SDDP04-7	SDDP04-8
	Date Sampled:	2007-03-23	2007-06-21	2007-10-02	2007-12-10	2008-03-03	2008-05-29	2008-09-20	2008-11-26	2007-03-23	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-20	2008-11-26
	Sample Depth Interval (m):	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05
Parameter	**CSR SedQC(SS) Marine [3,4]**																
Field Observations																	
Field Odour (text)	-	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Physical Tests																	
Moisture (%)	-	25.5	31.2	30.4	29.5	32.8	30.2	30.5	34.6	36.8	41.5	33.3	33.6	35.5	32.6	33.7	47.4
Oxidation Reduction Potential (mV)	-	-170	-	-170	-150	-180	-240	-220	-260	-200	-220	-190	-120	-190	-320	-280	-220
pH	-	7.99	7.9	8.13	7.83	7.96	7.96	7.94	7.81	7.86	8.55	8.21	7.88	8.06	7.92	7.95	7.72
Saturation (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Inorganics																	
Ammonia	-	8.7	6.5	11.4	4.3	2.8	9.1	14	3.2	10.9	12.3	9.6	6.2	3.1	8.4	9.1	5.3
Nitrate	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate	-	690	708	630	680	648	788	725	734	650	712	540	660	640	599	620	752
Phosphorus	-	723	708	662	694	648	788	725	734	664	-	591	684	640	599	620	752
Sulfate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfide	-	5.73	25.4	0.6	0.43	0.62	7.63	0.72	4.72	2.58	8.25	39.9	8.76	5.71	23.5	18.8	4.44
Total Kjeldahl Nitrogen (%)	-	0.06	0.04	0.04	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.07	0.06	0.06	0.06	0.08	0.1
Total Nitrogen (%)	-	0.06	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.07	0.08	0.05	0.04	0.06	0.05	0.08	0.08
Organics																	
Dissolved Organic Carbon (%)	-	0.27	0.24	0.3	-	-	-	-	-	0.39	0.58	0.4	-	-	-	-	-
Organic Nitrogen (%)	-	0.06	0.04	0.04	0.03	0.04	0.05	0.06	0.06	0.07	-	0.07	0.06	0.06	0.06	0.08	0.1
Total Organic Carbon (%)	-	-	-	-	0.3	0.3	0.2	0.3	0.4	-	-	-	0.5	0.5	0.4	0.5	0.7

Table 19
2008 Sediment Chemistry Results

	Location ID:	DP03								DP04							
	Sample ID:	SDDP03-1	SDDP03-2	SDDP03-3	SDDP03-4	SDDP03-5	SDDP03-6	SDDP03-7	SDDP03-8	SDDP04-1	SDDP04-2	SDDP04-3	SDDP04-4	SDDP04-5	SDDP04-6	SDDP04-7	SDDP04-8
	Date Sampled:	2007-03-23	2007-06-21	2007-10-02	2007-12-10	2008-03-03	2008-05-29	2008-09-20	2008-11-26	2007-03-23	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-20	2008-11-26
	Sample Depth Interval (m):	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05
Parameter	CSR SedQC(SS) Marine [3,4]																
Total Metals																	
Aluminum	-	9280	10100	9500	10300	9470	9920	10100	9900	9420	-	9850	10800	9750	9530	9970	9990
Antimony	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	26	5.6	5.6	5.8	5.2	5.3	8.3	6	5.5	6.7	5.1	6	5.5	6.4	6.8	5.8	8.2
Barium	-	28.1	30.5	28.5	32.9	26	32.3	29.7	29.4	26.8	30	25.3	36.2	24.9	25.2	30.2	31.1
Beryllium	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Bismuth	-	<20	<20	<20	<20	<20	<20	<20	<20	<20	-	<20	<20	<20	<20	<20	<20
Cadmium	2.6	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Calcium	-	5000	5360	5220	5310	4920	5910	5740	5850	4530	-	5200	6000	5390	5000	5910	6680
Chromium	99	36.5	34.8	31.8	34	32	38.4	36.7	34.4	38.1	30.7	29	30.4	28.8	29.9	30.9	31.3
Cobalt	-	9	8.9	8.6	9.1	8.8	9.7	9.6	9.4	8	8.1	7.7	7.9	8.3	7.9	8.5	8.2
Copper	67	9.8	10.3	9.7	11.2	10	11.5	10.3	11	11.8	13.6	12.7	15.1	13.7	13.2	13.3	15.1
Iron	-	24200	23400	21800	23200	22400	26000	23400	24500	20400	-	18800	20200	20100	20200	19700	21300
Lead	69	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Lithium	-	9.9	11.2	10.9	11.8	10.5	11.8	11.7	11.6	10.5	-	11.6	12.3	11.1	11.4	11.6	12.2
Magnesium	-	8190	8810	8420	7960	7950	8960	8780	8780	7670	-	8690	7940	8360	7960	8380	8790
Manganese	-	236	247	239	267	250	266	260	264	226	-	217	250	238	226	228	258
Mercury	0.43	0.0211	0.0283	0.0213	0.0627	0.0242	0.0573	0.0199	0.0233	0.0245	0.0288	0.0227	0.0281	0.0236	0.0222	0.0239	0.0274
Molybdenum	-	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Nickel	-	30.1	31	28.8	33.8	30.1	32.5	32.2	32.9	33.2	29.8	28.3	31.7	31.3	30.2	30	30.2
Potassium	-	1130	1270	1210	1140	1210	1120	1240	1230	1310	-	1440	1420	1430	1210	1350	1480
Selenium	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Silver	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Sodium	-	4200	4200	5440	3800	4480	3280	4910	5610	4240	-	6950	6050	6490	5360	4950	8930
Strontium	-	29.6	30.7	27.4	31.8	25.7	30	30.3	30.2	30.4	-	27.4	38.5	29.2	27.5	29.4	35.7
Thallium	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tin	-	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Titanium	-	865	851	724	838	750	854	763	814	774	-	690	808	703	697	704	719
Vanadium	-	53.8	50.6	49.5	49.4	47.2	59.1	51.9	53.3	41.7	44.7	44.2	43.8	43.6	44	44.7	45.8
Zinc	170	46.3	49.4	46.4	50.2	46.5	51.1	49	51.7	42.6	48.7	44.1	47.4	46.8	44.8	45.9	48.9

Table 19
2008 Sediment Chemistry Results

	Location ID:	DP05								DP06							
	Sample ID:	SDDP05-1	SDDP05-2	SDDP05-3	SDDP05-4	SDDP05-5	SDDP05-6	SDDP05-7	SDDP05-8	SDDP06-1	SDDP06-2	SDDP06-3	SDDP06-4	SDDP06-5	SDDP06-6	SDDP06-7	SDDP06-8
	Date Sampled:	2007-03-24	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27	2007-03-23	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26
	Sample Depth Interval (m):	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05
Parameter	**CSR SedQC(SS) Marine [3,4]**																
Field Observations																	
Field Odour (text)	-	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Physical Tests																	
Moisture (%)	-	46.7	54.4	51.5	52	51.7	49.6	54.6	54.6	30.4	32.6	32.4	27.2	34	27.4	26.6	32.6
Oxidation Reduction Potential (mV)	-	-160	-200	-200	-200	-200	-280	-310	-430	-60	-50	-20	-140	70	-140	-170	-190
pH	-	8.17	7.98	8.1	7.86	7.83	7.89	7.71	7.91	7.87	7.92	7.99	7.95	8	8.01	7.82	7.83
Saturation (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Inorganics																	
Ammonia	-	17.9	9	4.9	6.1	7.5	8.9	17.4	7.3	2	1.7	2.8	2	1	<0.8	1	1.6
Nitrate	-	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrite	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate	-	610	812	720	800	885	825	851	955	730	733	710	740	656	649	690	781
Phosphorus	-	814	-	644	837	885	825	851	955	723	-	802	713	656	649	690	781
Sulfate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfide	-	46.2	101	61.6	9.1	19.7	8.69	15.9	28.5	0.24	0.21	<0.17	<0.18	0.24	<0.20	0.21	0.22
Total Kjeldahl Nitrogen (%)	-	-	0.15	0.19	0.17	0.18	0.14	0.17	0.17	0.04	0.03	0.05	0.03	0.02	0.04	0.03	0.07
Total Nitrogen (%)	-	0.19	0.16	0.17	0.14	0.16	0.15	0.16	0.18	0.03	0.04	0.04	0.04	0.04	0.03	0.05	0.05
Organics																	
Dissolved Organic Carbon (%)	-	1.72	1.66	1.9	-	-	-	-	-	0.32	0.46	0.5	-	-	-	-	-
Organic Nitrogen (%)	-	-	-	0.19	0.16	0.18	0.14	0.17	0.17	0.04	-	0.05	0.03	0.02	0.04	0.03	0.07
Total Organic Carbon (%)	-	-	-	-	1.8	1.8	1.6	1.8	2.1	-	-	-	0.4	0.3	<0.1	0.3	0.5

Table 19
2008 Sediment Chemistry Results

	Location ID:	DP05								DP06							
	Sample ID:	SDDP05-1	SDDP05-2	SDDP05-3	SDDP05-4	SDDP05-5	SDDP05-6	SDDP05-7	SDDP05-8	SDDP06-1	SDDP06-2	SDDP06-3	SDDP06-4	SDDP06-5	SDDP06-6	SDDP06-7	SDDP06-8
	Date Sampled:	2007-03-24	2007-06-20	2007-10-02	2007-12-10	2008-03-05	2008-05-30	2008-09-21	2008-11-27	2007-03-23	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26
	Sample Depth Interval (m):	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05
Parameter	**CSR SedQC(SS) Marine [3,4]**																
Total Metals																	
Aluminum	-	16500	-	13400	17900	17200	17100	16100	17000	11500	-	14800	14500	10000	9890	11400	13100
Antimony	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	26	<5.0	6.5	5	6.1	7.8	7.6	8	8.6	6.3	7.1	7	6.7	5	7	6.4	7.6
Barium	-	49.2	51.2	40.3	60.8	53.5	56	51.4	58.1	47	69.4	60.1	65.4	38.8	41.1	46.8	58.1
Beryllium	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.54	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Bismuth	-	<20	-	<20	<20	<20	<20	<20	<20	<20	-	<20	<20	<20	<20	<20	<20
Cadmium	2.6	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.52
Calcium	-	8070	-	8240	9810	9910	9710	10300	11500	5660	-	7750	7210	5560	5550	6070	7490
Chromium	99	40.2	38.9	30.3	42.1	40	39.3	39.1	38.3	39.5	38.1	36.9	38.9	34.3	33.4	34.6	37.6
Cobalt	-	10.6	10.6	7.7	10.3	10.9	10.3	10.8	10.9	11.5	12.8	12.4	11.8	10.6	10.6	11.5	11.7
Copper	67	36.8	37.8	29.8	38.2	38	37	35.1	36.5	18.3	26	30.8	25.9	15	15.4	18.1	25
Iron	-	30000	-	22200	28600	30200	29800	28100	28800	27900	-	29500	27300	24400	23400	24700	28800
Lead	69	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Lithium	-	20.7	-	17.7	22.8	21.4	22.5	21.1	22.2	12.2	-	18.2	16.4	11	11.3	12.7	15.3
Magnesium	-	12200	-	10200	11600	12300	12100	12500	12500	9720	-	11900	10100	8990	9080	9560	10500
Manganese	-	330	-	246	341	347	337	327	334	376	-	416	386	364	345	366	392
Mercury	0.43	0.0592	0.0686	0.0805	0.0608	0.0623	0.0578	0.059	0.0678	0.0326	0.0629	0.0474	0.201	0.0251	0.0323	0.0283	0.0513
Molybdenum	-	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Nickel	-	39.7	37.3	27.1	42.5	38.1	38	37.1	36.3	37.7	41.5	39	44.7	37	36.6	37.8	39.9
Potassium	-	2590	-	2230	2600	2700	2440	2540	2620	1230	-	1560	1490	1120	940	1180	1420
Selenium	-	<2.0	<2.0	<3.0	<2.0	<2.0	<3.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Silver	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Sodium	-	11300	-	11200	11800	12100	12300	10400	15200	3110	-	4300	3510	3580	1120	2520	4570
Strontium	-	47.7	-	41.8	58.7	54.2	53.2	51	59.7	36.7	-	40.4	43.9	31.3	29	31.6	39.2
Thallium	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tin	-	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Titanium	-	910	-	734	995	959	932	839	928	921	-	816	917	788	754	724	850
Vanadium	-	56.8	56	46.1	54.6	57.3	57.7	54.2	54.8	56.6	55.4	55.4	53	47.5	47.3	47.8	53.4
Zinc	170	74.7	72.8	55.4	72.4	75.5	71.6	70.8	72.4	53	65.7	64.9	60.6	48	49.3	52.2	61.7

Table 19
2008 Sediment Chemistry Results

	Location ID:	DP07								DP08
	Sample ID:	SDDP07-1	SDDP07-2	SDDP07-3	SDDP07-4	SDDP07-5	SDDP07-6	SDDP07-7	SDDP07-8	SDDP08-5
	Date Sampled:	2007-03-24	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26	2008-03-04
	Sample Depth Interval (m):	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05
Parameter	CSR SedQC(SS) Marine [3,4]									
Field Observations										
Field Odour (text)	-	none	none	none	none	none	none	none	none	none
Physical Tests										
Moisture (%)	-	28.5	29.4	26.1	26.3	24.5	24.4	36.7	31.8	30.2
Oxidation Reduction Potential (mV)	-	-110	-170	-200	-170	110	-250	-260	-270	-120
pH	-	8.04	8.16	8.13	8.1	8.24	8.11	7.86	8	7.84
Saturation (%)	-	-	-	36.9	-	-	-	-	-	-
Total Inorganics										
Ammonia	-	3.1	2.2	2.9	1.4	1.3	2.2	2.4	1.4	1.5
Nitrate	-	1.8	-	-	-	-	-	-	-	-
Nitrite	-	<0.4	-	-	-	-	-	-	-	-
Phosphate	-	590	613	580	530	534	680	740	597	607
Phosphorus	-	692	-	649	548	534	680	740	597	607
Sulfate	-	-	-	753	-	-	-	-	-	-
Sulfide	-	1.59	1.42	12.5	2.87	0.42	2.34	3.6	3.84	7.76
Total Kjeldahl Nitrogen (%)	-	-	<0.02	0.05	0.02	<0.02	0.03	0.08	0.06	0.05
Total Nitrogen (%)	-	0.04	0.03	0.05	<0.02	0.03	0.04	0.06	0.02	0.05
Organics										
Dissolved Organic Carbon (%)	-	0.55	0.25	0.4	-	-	-	-	-	-
Organic Nitrogen (%)	-	-	-	0.05	0.02	<0.02	0.03	0.08	0.06	0.05
Total Organic Carbon (%)	-	-	-	-	0.2	0.2	0.2	0.6	0.4	0.3

Table 19
2008 Sediment Chemistry Results

	Location ID:	DP07								DP08
	Sample ID:	SDDP07-1	SDDP07-2	SDDP07-3	SDDP07-4	SDDP07-5	SDDP07-6	SDDP07-7	SDDP07-8	SDDP08-5
	Date Sampled:	2007-03-24	2007-06-20	2007-10-01	2007-12-10	2008-03-04	2008-05-29	2008-09-20	2008-11-26	2008-03-04
	Sample Depth Interval (m):	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05	0-0.05
Parameter	**CSR SedQC(SS) Marine [3,4]**									
Total Metals										
Aluminum	-	12300	-	12500	12200	9720	11700	14700	10600	8960
Antimony	-	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	26	<5.0	7	6.6	5.7	<5.0	7.5	7.5	6.8	<5.0
Barium	-	44.8	45.8	45.9	46.3	28.5	44.5	59.3	36.6	24.1
Beryllium	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.5	<0.50	<0.50
Bismuth	-	<20	-	<20	<20	<20	<20	<20	<20	<20
Cadmium	2.6	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Calcium	-	5760	-	6970	6480	5580	6880	7300	5970	4700
Chromium	99	37.3	34.1	34.1	35.4	40.1	35.6	38	33	30.6
Cobalt	-	10.3	10.1	10.4	9.8	9.4	11.1	12.2	10	7.1
Copper	67	20.2	17.2	22	17.9	13	23.7	26.8	17.4	10
Iron	-	25500	-	24300	22800	22900	25000	27100	23100	19000
Lead	69	<30	<30	<30	<30	<30	<30	<30	<30	<30
Lithium	-	13.5	-	13.9	12.4	9.3	14.3	16.5	11.8	9.4
Magnesium	-	10300	-	10400	9010	8890	10700	11100	9340	7540
Manganese	-	329	-	313	319	296	355	362	304	230
Mercury	0.43	0.0372	0.0316	0.0346	0.0317	0.0201	0.0939	0.0458	0.0262	0.025
Molybdenum	-	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Nickel	-	39.2	35.7	36	41.2	38.4	39.1	41.5	37.5	28.1
Potassium	-	1480	-	1390	1160	850	1240	1770	1100	1160
Selenium	-	<2.0	<2.0	<2.0	<2.0	<3.0	<2.0	<2.0	<2.0	<2.0
Silver	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Sodium	-	5080	-	4810	3020	2160	4340	5310	4920	4640
Strontium	-	33.8	-	32.3	33.9	25.6	32.9	37.2	27.6	26.5
Thallium	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tin	-	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Titanium	-	811	-	791	928	899	716	809	775	750
Vanadium	-	51.6	50.1	51.4	51.3	58.9	49.7	53.3	52.2	40.9
Zinc	170	54.3	48.6	54.2	47.2	39.7	54.7	61.5	47.1	42.1

Table 19
2008 Sediment Chemistry Results

(1) All values are reported as µg/g unless otherwise noted
(2) - = No standard or not analyzed
(3) CSR = BC Environmental Management Act, Contaminated Sites Regulation, B.C. Reg. 375/96, including amendments up to B.C. Reg. 239/2007, effective July 1, 2007
(4) CSR SedQC(SS) Marine = Schedule 9, Column IV, Marine and Estuarine Sediment, Sensitive Site

Table 20
Q1-2008 Grain Size Results

Grain Size	DP02	DP03	DP04	DP05	DP06	DP07	DP08
% Gravel (>2mm)	<1	<1	<1	<1	<1	<1	<1
% Sand (2.0mm - 0.063mm)	93	94	80	33	88	93	94
% Silt (0.063mm - 4um)	4	3	15	53	8	4	3
% Clay (<4um)	3	3	3	15	3	2	2

Table 21
2008 Benthic Invertebrate Community Results

Hemmera - Vancouver Port Authority Data
2008

TAXON	2007	2008	No. of individuals			DP02A-5			DP02B-5			DP02C-5			DP03A-5			DP03B-5			DP03C-5			DP04A-5		
			A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
CNIDARIA																										
Hydrozoa																										
Campanularia groenlandica	✓																									
Obelia dichotoma	✓																									
Anthozoa																										
Actinaria indet.		✓			2						1															
Edwardsiidae indet.	✓	✓		1									1													
PLATYHELMINTHES																										
Pseudostylochus burchami	✓																									
NEMERTEA																										
Cerebratulus californiensis	✓	✓	28	14																				2	1	
Lineus bilineatus	✓																									
Lineidae indet.	✓																									
Nemertea indet.	✓	✓		1	2																					2
Paranemertes nigrina		✓		1						1																
Paranemertes sp.	✓																									
Procephalothrix sp.		✓	2	1																				1	1	
Tetrastemma nigrifrons		✓	2																					1		
Tetrastemmidae indet.	+																									
Tubulanus polymorphus	✓	✓	1																							
ANNELIDA																										
Polychaeta Errantia																										
Diopatra ornata	✓																									
Epidiopatra hupferiana monroi	✓																									
Eteone californica	✓	✓	18			2			1			2			7			2			1			1		
Eteone longa complex		✓	7																							
Eteone spilotus	✓																									
Eteone sp.		✓		1																						
Eulalia quadrioculata	✓	✓	3	1																						
Glycera nana	✓	✓	8																							
Glycera pacifica	✓																									
Glycinde armigera	✓																									
Glycinde polygnatha	✓	✓	85	12					2			1			3			2			5			5	4	
Glycinde spp.	+																									
Harmothoe imbricata		✓	1																							
Harmothoe spp.	+																									
Lumbrineris cruzensis	✓	✓	21	2																						
Micropodarke dubia	✓																									
Nephtys caecoides	✓	✓	19			1						1						1						3		
Nephtys cornuta	✓	✓	24																							
Nephtys ferruginea	✓	✓	1																							
Nereidae indet.		✓		1																						
Nereis procera		✓	3																					1		
Ophiodromus pugettensis		✓	4	3																				2		
Onuphis geophiliformis	✓																									
Pholoe glabra	✓	✓	21																					2		

Hemmera - Vancouver Port Authority Data
2008

TAXON	2007	2008	No. of individuals			DP02A-5			DP02B-5			DP02C-5			DP03A-5			DP03B-5			DP03C-5			DP04A-5		
			A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Pholoe minuta	✓	✓	21																					8		
Pholoe sp. N-1		✓	2																							
Phyllodoce groenlandica		✓	1																							
Phyllodoce hartmanae	✓																									
Phyllodoce williamsi	✓	✓	4																							
Phyllodoce spp.	✓	✓		1																						
Pilargis berkeleyae	✓	✓	3		1																					
Platynereis bicanaliculata	✓	✓	18	7																				3	1	
Podarkeopsis glabrus	✓																									
Scoletoma luti	✓	✓	28	2	1																					
Sphaerosyllis ranunculus	+																									
Sphaerodoropsis sphaerulifer	+																									
Polychaeta Sedentaria																										
Ampharete labrops	✓	✓	6	4	1																					
Ampharete spp.	✓	✓		2	4																				1	3
Amphicteis glabra		✓	1									1														
Aphelochaeta sp. 2 *	✓	✓	6	1																						
Aphelochaeta spp.	+																									
Arenicolidae indet.	✓	✓			4												3									
Aricidea minuta		✓	2																							
Aricidea wassi	+																									
Armandia brevis *	✓	✓	14	2											3			4			3			1	1	
Asabellides nr.*lineata*		✓	2																					1		
Asabellides sp.		✓			1																					
Barantolla nr. *americana*	+	✓	4																							
Boccardia polybranchia	✓																									
Capitella capitata complex *^	✓	✓	41	8	7				3	1		7	1		5	1			3		1	1	1	2		
Chaetozone nr. *columbiana*		✓	2																							
Chone magna		✓		1																						
Cirratulus spectabilis	✓		4																							
Clymenella nr. *torquata*		✓	14	2														1						9	1	
Cossura pygodactylata	✓	✓	6																							
Decamastus nr. *gracilis* *	✓	✓	2																							
Dipolydora quadrilobata	✓	✓	6		7							1												1		
Dipolydora socialis		✓	1																					1		
Dipolydora spp.	✓																									
Euclymene nr. *zonalis* *	✓	✓	3	1																						
Euclymeninae indet.	✓																									
Galathowenia oculata	✓	✓	56																							
Heteromastus filobranchus *	✓	✓	23	11	3																					
Lanassa venusta venusta	+																									
Laonice spp.	+																									
Leitoscoloplos pugettensis	✓	✓	47	3																				12		
Levinsenia gracilis	✓	✓	1																							
Magelona longicornis	✓																									
Mediomastus ambiseta *	✓																									
Mediomastus californiensis *	✓	✓	52	9	4																			9	3	1
Monticellina spp.	✓																									
Notomastus spp.	✓																									
Ophelina acuminata	+																									

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TAXON	2007	2008	No. of individuals			DP02A-5			DP02B-5			DP02C-5			DP03A-5			DP03B-5			DP03C-5			DP04A-5		
			A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Owenia nr. collaris	✓																									
Owenia nr. *johnsoni*	✓	✓	*194*	*5*																				23	2	
Paraprionospio pinnata	✓	✓	*12*	*5*	*1*																					
Pectinaria californiensis	✓																									
Pectinaria granulata	✓	✓	*1*	*2*																						
Polycirrus sp. I (Banse 1980)	✓																									
Polydora cornuta	✓	✓	*4*												1						2					
Polydora sp.	✓																									
Prionospio (Prionospio) jubata	✓	✓	*3*																							
Prionospio (Minuspio) lighti *	✓	✓	*36*	*2*																				12	1	
Prionospio (Minuspio) multibranchiata	✓	✓	*3*																							
Prionospio (Prionospio) steenstrupi	✓	✓	*8*																					2		
Pseudopolydora kempi ^	✓	✓	*101*			24			26			22			10			7			11					
Pseudopolydora paucibranchiata ^	✓	✓	*316*	*38*	*6*	25	1		65	14	4	116	9		25		2	19	1		59	12		2		
Pseudopolydora spp.	✓																									
Pygospio elegans	✓	✓	*442*	*1*	*44*	1			2			9			184		2	115		7	127	1	35			
Rhynchospio glutaea	✓	✓	*89*			1									6			2						13		
Scoloplos acmeceps	✓	✓	*11*	*1*																						
Scoloplos armiger	✓	✓	*29*						2			1						1								
Spio cirrifera	✓																									
Spionidae indet.	+	✓	*3*																					3		
Spiophanes berkeleyorum	✓	✓	*4*	*2*																						
Sternaspis nr. *fossor*	✓	✓	*1*																							
Terebellides spp.	+																									
Tharyx parvus *	✓	✓	*86*	*9*	*9*	10			3	3	1	42	1		16	5	5	10		1	1		2	2		
Oligochaeta																										
Enchytraeidae indet.	✓	✓		*1*												1										
Enchytraeus multiannulatus		✓	*1*															1								
Grania incerta		✓	*4*																							
Grania sp.		✓	*8*																							
Tubificoides brevicolus	+																									
Tubificoides sp.		✓	*3*																							
Tubificidae indet. Group 5	✓	✓	*51*	*72*	*18*		1		1	5		2	10		1	1			1		3	3		17	18	3
Limnodriloides victoriensis	✓																									
Limnodriloides sp.	+																									
Tectidrilus diversus	✓																									
Tectidrilus spp.	✓	✓	*132*	*46*	*61*																			48	18	31
Hirudinoidea																										
Notostomum sp.	✓																									
ECHIURA																										
Arhynchite pugettensis	✓																									
Echiuridae indet.	✓																									

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TAXON	2007	2008	No. of individuals			DP02A-5			DP02B-5			DP02C-5			DP03A-5			DP03B-5			DP03C-5			DP04A-5		
			A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
MOLLUSCA																										
Gastropoda																										
Aeolidacea indet.	+																									
Alvania compacta	✓	✓	152																					1		
Amphissa versicolor	✓	✓	2	8		2													3			5				
Amphissa sp.	✓	✓		8	3		4			1			1			2	2			1						
Astyris gausapata	✓	✓	12	1																						
Batillaria cumingi	✓	✓	15		3	9		3				4			1			1								
Columbellidae indet.		✓		1																						
Cyclostremella concordia	✓	✓			7																					3
Clinchna attonsa		✓	1																							
Cylichna culcitella	✓	✓	1																							
Cylichnella sp.	✓	✓		5	1						1		3			1						1				
Gastropoda indet.		✓		3	2												1					1			1	1
Haminoea vesicula	✓	✓		1						1																
Haminoea sp.	+																									
Lacuna variegata	✓	✓		64	2																				6	
Lacuna sp.	✓	✓			4																					
Lottia parallela	✓	✓	38	42																				7	4	
Nassariidae indet.		✓	2																							
Nassarius fraterculus		✓	7									3			2			2								
Odostomia sp.	+	✓		5																						
Olivella baetica		✓	1																							
Turbonilla sp.	✓	✓	2	1																						
Volvulella sp.	✓																									
Bivalvia																										
Acila castrensis	✓	✓		4																						
Axinopsida serricata	✓	✓	300	111																						
Bivalvia indet.	+	✓	2	3	7																					
Cardiidae indet.	✓	✓			4									1												3
Clinocardium ciliatum		✓			2																					
Clinocardium nuttallii	✓	✓			10																					
Clinocardium sp.	✓	✓			2																					
Compsomyax subdiaphana	✓	✓			2																					
Ennucula tenuis	✓	✓	6	73	8																					
Hiatella arctica		✓			6			1						1			1						2			
Lucinoma annulatum	✓	✓		1	3																					1
Lyonsia californica	+																									
Macoma balthica	✓	✓	11	54	5					1			1			2					2	1		2	4	
Macoma carlottensis	✓	✓		29	15																					
Macoma elimata	✓																									
Macoma golikovi		✓		9	5																					
Macoma nasuta	✓	✓	2	51	25					1						2	1	2	1	4			2		16	7
Macoma sp.	✓	✓		22	58																				2	3
Mactromeris sp.		✓			1																					
Megayoldia martyria	✓																									
Modiolus modiolus	✓	✓			152									1												9
Modiolus sp.		✓			1																		1			
Mya arenaria	✓																									
Mya sp.		✓			9																					

Table 21
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TAXON	2007	2008	No. of individuals			DP02A-5			DP02B-5			DP02C-5			DP03A-5			DP03B-5			DP03C-5			DP04A-5		
			A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Mytilidae indet.	✓																									
Nemocardium centifilosum	✓																									
Nuculana hamata	✓																									
Nuculana minuta		✓		*2*																						
Nuculana sp.	+																									
Nutricola tantilla	✓	✓	*1*																							
Nutricola sp.	+	✓	*5*	*24*																						
Nuttallia obscurata	✓	✓		*3*	*1*																					
Pandora bilirata		✓		*3*																						
Parvilucina tenuisculpta	✓	✓	*29*	*35*	*23*																				1	
Protothaca tenerrima	✓	✓			*1*															1						
Rochefortia tumida	✓	✓	*717*	*9*																				161		
Rochefortia sp.	+																									
Tellina modesta	✓	✓	*11*	*12*	*12*																			4	2	1
Tellina sp.	+																									
Tellinidae indet.		✓		*1*																						
Venerupis philippinarum	✓	✓	*2*		*7*	2																				
Yoldia seminuda	✓	✓			*1*																					
Scaphopoda																										
Pulsellum salishorum	✓	✓	*14*																							
ARTHROPODA																										
CHELICERATA																										
Pycnogonida																										
Anoplodactylus viridintestinalis	✓	✓	*70*									1						1						5		
Acarida																										
Hydracarina indet.	✓	✓	*1*																					1		
CRUSTACEA																										
Copepoda																										
Cyclopoida indet.	✓																									
Harpacticoida indet.	✓	✓	*7*									3												1		
Porcellidium sp.		✓	*1*																							
Ostracoda																										
Bathyleberis sp.	✓																									
Cyprideis sp.	✓																									
Diastylis abbotti		✓	*1*																							
Euphilomedes carcharodonta	✓	✓	*12*																							
Euphilomedes producta	+	✓	*6*																							
Ostracoda indet.	+	✓	*1*			1																				
Philomedidae indet.		✓	*1*																							
Philomedes dentata	+	✓	*2*																							
Cirripedia																										
Balanus crenatus		✓	*1*															1								
Semibalanus balanoides	✓																									
Cumacea																										
Cumella vulgaris	✓	✓	*1*																					1		
Hemilamprops californicus	✓																									
Eudorella pacifica	+																									
Leucon subnasica	+																									

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TAXON	2007	2008	No. of individuals			DP02A-5			DP02B-5			DP02C-5			DP03A-5			DP03B-5			DP03C-5			DP04A-5		
			A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Tanaidacea																										
Leptochelia savigyni	✓	✓	*615*	*928*	*2*							2	3											75	138	
Isopoda																										
Idotea rescata	✓	✓	*11*	*7*																						
Munna ubiquita	✓																									
Synidotea nodulosa	✓																									
Amphipoda																										
Americhelidium shoemakeri	✓	✓	*13*																							
Americorophium brevis	✓																									
Anisogammarus pugettensis	✓	✓	*8*	*1*																						
Caprella laeviuscula	✓	✓	*19*	*4*																					3	
Caprella sp.	✓																									
Chromopleustes oculatus	✓																									
Eobrolgus chumashi	✓	✓	*5*									2			1									1		
Grandidierella japonica	✓	✓	*72*	*37*		2			1			4	3		41	8		12	9		11	17				
Heterophoxus affinis	✓																									
Ischyrocerus anguipes	✓	✓	*1*	*1*																						
Monocorophium acherusicum	✓	✓	*17*									2			6			2			6					
Monocorophium carlottensis		✓	*3*												3											
Monocorophium insidiosum	✓	✓	*4*																		4					
Monocorophium sp.		✓		*6*									3			3										
Orchomene decipens	✓																									
Orchomene minutus		✓	*3*																							
Pachynus barnardi	✓																									
Pacifoculodes zernovi		✓	*2*																							
Photis brevipes	✓	✓	*104*	*11*								1														
Photis sp.	+																									
Pontogeneia rostrata	✓	✓	*4*																							
Protomedeia grandimana	✓	✓		*1*																						
Protomedeia sp.	✓	✓		*1*																						
Rhepoxynius boreovariatus	✓	✓	*14*	*4*																						
Rhepoxynius fatigans	+																									
Rhepoxynius sp.	+																									
Wecomedon wecomus	✓																									
Wecomedon sp.	+																									
Decapoda																										
Cancer gracilis	✓																									
Crangon alaskensis		✓	*1*																							
Pagarus sp.	✓																									
Pinnixa schmitti	✓	✓	*4*	*1*																						
PHORONIDA																										
Phoronis muelleri	+																									
Phoronopsis harmeri		✓	*1*																							
BRYOZOA																										
Celleporella hyalina	✓	✓	*8*																					2		

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TAXON	2007	2008	No. of individuals			DP02A-5			DP02B-5			DP02C-5			DP03A-5			DP03B-5			DP03C-5			DP04A-5		
			A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
ECHINODERMATA																										
Ophiuroidea																										
Amphiodia urtica	✓	✓	30	22																				8	3	
Amphiodia sp.	✓	✓		20	21												1								6	1
Amphiuridae indet.		✓			4																					
Ophiura sp.	✓	✓			1																					
Echinoidea																										
Strongylocentrotus droebachiensis	✓																									
HEMICHORDATA																										
Enteropneusta indet.		✓	1									1														
Saccoglossus sp.		✓			1												1									
Total Number of Organisms by Stage			4537	1905	587	80	6	4	106	28	7	228	36	3	315	26	19	186	18	14	236	42	43	456	238	69
Total Number of Organisms			7029			90			141			267			360			218			321			763		
Organisms per m2			140580			1800			2820			5340			7200			4360			6420			15260		
Total Number of Taxa			580			14			17			29			26			23			19			48		
MEIOFAUNA																										
Nematoda indet.			285	61								3	13											77	16	
MEMO																										
Amphipoda indet. larvae	✓																									
Araneae indet.		✓	1																							
Calanoida indet.	✓	✓	1																							
Caridea indet. zoea	+																									
Capitella capitata complex in tube with eggs		✓	4																							
Capitellidae indet. posterior fragment		✓	1																							
Cirripedia indet. nauplius	+																									
Coleoptera indet.		✓	1																							
Decapoda indet. brachyuran zoea	✓																									
Diptera indet. pupae		✓	1																							
Euclymeninae indet. posterior fragment		✓	2																							
Gastropoda indet. egg case	✓																									
Invertebrate eggs	✓	✓	22																							
Invertebrate egg mass	✓	✓	39																					11		
Mysidacea indet. larvae	✓																									
Nephtys spp. posterior fragment		✓	4						1						1						1					
Pholoe spp. posterior fragment	+																									
Pinnixa sp. dead	✓																									
Pisces indet. eggs	+																									
Scoletoma luti posterior fragment		✓	1																							
Tharyx parvus posterior fragment	✓	✓	1																							

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TAXON	DP04B-5			DP04C-5			DP05A-5			DP05B-5			DP05C-5			DP06A-5			DP06B-5			DP06C-5			DP07A-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
CNIDARIA																											
Hydrozoa																											
Campanularia groenlandica																											
Obelia dichotoma																											
Anthozoa																											
Actinaria indet.									1																		
Edwardsiidae indet.																											
PLATYHELMINTHES																											
Pseudostylochus burchami																											
NEMERTEA																											
Cerebratulus californiensis	3			4	1		14	11		2	1														3		
Lineus bilineatus																											
Lineidae indet.																											
Nemertea indet.																											
Paranemertes nigrina																											
Paranemertes sp.																											
Procephalothrix sp.				1																							
Tetrastemma nigrifrons	1																										
Tetrastemmidae indet.																											
Tubulanus polymorphus							1																				
ANNELIDA																											
Polychaeta Errantia																											
Diopatra ornata																											
Epidiopatra hupferiana monroi																											
Eteone californica	1												1														
Eteone longa complex							2			4																	
Eteone spilotus																											
Eteone sp.					1																						
Eulalia quadrioculata	2			1	1																						
Glycera nana							5			1			2														
Glycera pacifica																											
Glycinde armigera																											
Glycinde polygnatha	5			13	4					2	1								1								
Glycinde spp.																											
Harmothoe imbricata				1																							
Harmothoe spp.																											
Lumbrineris cruzensis							4	2		8			9														
Micropodarke dubia																											
Nephtys caecoides	1			5																							
Nephtys cornuta							5			14			5														
Nephtys ferruginea							1																				
Nereidae indet.		1																									
Nereis procera							1						1														
Ophiodromus pugettensis				2	2																						
Onuphis geophiliformis																											
Pholoe glabra	10			2			1			2			2												1		

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TAXON	DP04B-5			DP04C-5			DP05A-5			DP05B-5			DP05C-5			DP06A-5			DP06B-5			DP06C-5			DP07A-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Pholoe minuta	6			7																							
Pholoe sp. N-1							2																				
Phyllodoce groenlandica							1																				
Phyllodoce hartmanae																											
Phyllodoce williamsi	1																										
Phyllodoce spp.																											
Pilargis berkeleyae							1			1			1		1												
Platynereis bicanaliculata	5			4	3																						
Podarkeopsis glabrus																											
Scoletoma luti							6	2		13		1	8												1		
Sphaerosyllis ranunculus																											
Sphaerodoropsis sphaerulifer																											
Polychaeta Sedentaria																											
Ampharete labrops	5	4	1																								
Ampharete spp.											1																
Amphicteis glabra																											
Aphelochaeta sp. 2 *							3	1		2			1														
Aphelochaeta spp.																											
Arenicolidae indet.			1																								
Aricidea minuta																											
Aricidea wassi																											
Armandia brevis *				1																							
Asabellides nr.*lineata*				1																							
Asabellides sp.												1															
Barantolla nr. *americana*							3																				
Boccardia polybranchia																											
Capitella capitata complex *^	17	1	6																								
Chaetozone nr. *columbiana*																									2		
Chone magna																											
Cirratulus spectabilis																											
Clymenella nr. *torquata*	1			3																							
Cossura pygodactylata							4			1			1														
Decamastus nr. *gracilis* *																									2		
Dipolydora quadrilobata	4		7																								
Dipolydora socialis																											
Dipolydora spp.																											
Euclymene nr. *zonalis* *							3	1																			
Euclymeninae indet.																											
Galathowenia oculata							11			18			27														
Heteromastus filobranchus *							7	2	1	10	6	1	6	3	1												
Lanassa venusta venusta																											
Laonice spp.																											
Leitoscoloplos pugettensis	7			5			1			2	1		3	1											10		
Levinsenia gracilis							1																				
Magelona longicornis																											
Mediomastus ambiseta *																											
Mediomastus californiensis *	18	4	3	9																							
Monticellina spp.																											
Notomastus spp.																											
Ophelina acuminata																											

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TAXON	DP04B-5			DP04C-5			DP05A-5			DP05B-5			DP05C-5			DP06A-5			DP06B-5			DP06C-5			DP07A-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Owenia nr. collaris																											
Owenia nr. *johnsoni*	55			46			1			11	1		3	1													
Paraprionospio pinnata							6	5	1	4			2														
Pectinaria californiensis																											
Pectinaria granulata													1													1	
Polycirrus sp. I (Banse 1980)																											
Polydora cornuta	1																										
Polydora sp.																											
Prionospio (Prionospio) jubata				1																							
Prionospio (Minuspio) lighti *	7	1		6						4			5												1		
Prionospio (Minuspio) multibranchiata	2																										
Prionospio (Prionospio) steenstrupi	1						1			2															1		
Pseudopolydora kempi ^																			1								
Pseudopolydora paucibranchiata ^		1																									
Pseudopolydora spp.																											
Pygospio elegans																			2			2					
Rhynchospio glutaea	14			7																							
Scoloplos acmeceps				2			1			2			1	1													
Scoloplos armiger																									6		
Spio cirrifera																											
Spionidae indet.																											
Spiophanes berkeleyorum							1	2		2			1														
Sternaspis nr. *fossor*							1																				
Terebellides spp.																											
Tharyx parvus *				2																							
Oligochaeta																											
Enchytraeidae indet.																											
Enchytraeus multiannulatus																											
Grania incerta																											
Grania sp.																											
Tubificoides brevicolus																											
Tubificoides sp.				1																							
Tubificidae indet. Group 5	24	28	15																								
Limnodriloides victoriensis																											
Limnodriloides sp.																											
Tectidrilus diversus																											
Tectidrilus spp.	78	24	30		1																						
Hirudinoidea																											
Notostomum sp.																											
ECHIURA																											
Arhynchite pugettensis																											
Echiuridae indet.																											

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TAXON	DP04B-5			DP04C-5			DP05A-5			DP05B-5			DP05C-5			DP06A-5			DP06B-5			DP06C-5			DP07A-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
MOLLUSCA																											
Gastropoda																											
Aeolidacea indet.																											
Alvania compacta	48			32			18			14			35														
Amphissa versicolor																											
Amphissa sp.																											
Astyris gausapata																									1		
Batillaria cumingi																											
Columbellidae indet.		1																									
Cyclostremella concordia			4																								
Clinchna attonsa																									1		
Cylichna culcitella										1																	
Cylichnella sp.																											
Gastropoda indet.														1													
Haminoea vesicula																											
Haminoea sp.																											
Lacuna variegata		22			28			2							2												
Lacuna sp.																											
Lottia parallela	14	15		15	20																						
Nassariidae indet.																									2		
Nassarius fraterculus																											
Odostomia sp.		2						3																			
Olivella baetica																											
Turbonilla sp.								1					1														
Volvulella sp.																											
Bivalvia																											
Acila castrensis								1			1			2													
Axinopsida serricata							79	25		98	42		118	42											2	2	
Bivalvia indet.						3		1	3							1	1		1				1				
Cardiidae indet.																											
Clinocardium ciliatum						2																					
Clinocardium nuttallii			4									3															
Clinocardium sp.									2																		
Compsomyax subdiaphana									1						1												
Ennucula tenuis							5	30	3		26	4	1	17	1												
Hiatella arctica																								1			
Lucinoma annulatum														1	2												
Lyonsia californica																											
Macoma balthica																	2		5	24	4	2	17	1			
Macoma carlottensis								6	4		15	7		7	3												
Macoma elimata																											
Macoma golikovi		4			1																		3	4			
Macoma nasuta		7	6		11	4																					
Macoma sp.		5	10		4				7		5	3		1	4		1	7			7					3	4
Mactromeris sp.									1																		
Megayoldia martyria																											
Modiolus modiolus			60			20																					
Modiolus sp.																											
Mya arenaria																											
Mya sp.																		4			4						

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TAXON	DP04B-5			DP04C-5			DP05A-5			DP05B-5			DP05C-5			DP06A-5			DP06B-5			DP06C-5			DP07A-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Mytilidae indet.																											
Nemocardium centifilosum																											
Nuculana hamata																											
Nuculana minuta											1			1													
Nuculana sp.																											
Nutricola tantilla																											
Nutricola sp.	1	1						8			6			6												1	
Nuttallia obscurata																							3	1			
Pandora bilirata											1			2													
Parvilucina tenuisculpta		1					2	8	6	18	8	9	9	17	8												
Protothaca tenerrima																											
Rochefortia tumida	108			90			75	4		53			42	5													
Rochefortia sp.																											
Tellina modesta	5	1		1					3		1	6		4	2											1	
Tellina sp.																											
Tellinidae indet.																										1	
Venerupis philippinarum																		4			3						
Yoldia seminuda																											
Scaphopoda																											
Pulsellum salishorum							5			5			4														
ARTHROPODA																											
CHELICERATA																											
Pycnogonida																											
Anoplodactylus viridintestinalis	20			26																							
Acarida																											
Hydracarina indet.																											
CRUSTACEA																											
Copepoda																											
Cyclopoida indet.																											
Harpacticoida indet.	2																										
Porcellidium sp.	1																										
Ostracoda																											
Bathyleberis sp.																											
Cyprideis sp.																											
Diastylis abbotti										1																	
Euphilomedes carcharodonta	1						4			1			1												2		
Euphilomedes producta							2						2														
Ostracoda indet.																											
Philomedidae indet.													1														
Philomedes dentata	1																								1		
Cirripedia																											
Balanus crenatus																											
Semibalanus balanoides																											
Cumacea																											
Cumella vulgaris																											
Hemilamprops californicus																											
Eudorella pacifica																											
Leucon subnasica																											

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TAXON	DP04B-5			DP04C-5			DP05A-5			DP05B-5			DP05C-5			DP06A-5			DP06B-5			DP06C-5			DP07A-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Tanaidacea																											
Leptochelia savigyni	166	114	1	92	119								1														
Isopoda																											
Idotea rescata	5			6	2																						
Munna ubiquita																											
Synidotea nodulosa																											
Amphipoda																											
Americhelidium shoemakeri				3																							
Americorophium brevis																											
Anisogammarus pugettensis	4			2	1																						
Caprella laeviuscula	2			5																							
Caprella sp.																											
Chromopleustes oculatus																											
Eobrolgus chumashi																											
Grandidierella japonica																											
Heterophoxus affinis																											
Ischyrocerus anguipes				1	1																						
Monocorophium acherusicum																											
Monocorophium carlottensis																											
Monocorophium insidiosum																											
Monocorophium sp.																											
Orchomene decipens																											
Orchomene minutus																									1		
Pachynus barnardi																											
Pacifoculodes zernovi																											
Photis brevipes	4			1																							
Photis sp.																											
Pontogeneia rostrata	1			1																							
Protomedeia grandimana														1													
Protomedeia sp.								1																			
Rhepoxynius boreovariatus													1						1	2		1	1		1	1	
Rhepoxynius fatigans																											
Rhepoxynius sp.																											
Wecomedon wecomus																											
Wecomedon sp.																											
Decapoda																											
Cancer gracilis																											
Crangon alaskensis										1																	
Pagarus sp.																											
Pinnixa schmitti				2			1			1				1													
PHORONIDA																											
Phoronis muelleri																											
Phoronopsis harmeri	1																										
BRYOZOA																											
Celleporella hyalina																											

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TAXON	DP04B-5			DP04C-5			DP05A-5			DP05B-5			DP05C-5			DP06A-5			DP06B-5			DP06C-5			DP07A-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
ECHINODERMATA																											
Ophiuroidea																											
Amphiodia urtica	1	4		5	7		6	4		3	2		5	2											1		
Amphiodia sp.					1			5	8		3	4		4	4												1
Amphiuridae indet.									1						2												
Ophiura sp.																											1
Echinoidea																											
Strongylocentrotus droebachiensis																											
HEMICHORDATA																											
Enteropneusta indet.																											
Saccoglossus sp.																											
Total Number of Organisms by Stage	654	241	148	406	208	29	285	125	42	301	122	39	301	120	31	1	4	15	11	26	18	5	25	7	39	10	6
Total Number of Organisms	1043			643			452			462			452			20			55			37			55		
Organisms per m2	20860			12860			9040			9240			9040			400			1100			740			1100		
Total Number of Taxa	51			44			49			41			42			3			7			6			23		
MEIOFAUNA																											
Nematoda indet.	134	2		18	3																						
MEMO																											
Amphipoda indet. larvae																											
Araneae indet.																											
Calanoida indet.																											
Caridea indet. zoea																											
Capitella capitata complex in tube with eggs	4																										
Capitellidae indet. posterior fragment																			1								
Cirripedia indet. nauplius																											
Coleoptera indet.	1																										
Decapoda indet. brachyuran zoea																											
Diptera indet. pupae																											
Euclymeninae indet. posterior fragment																									1		
Gastropoda indet. egg case																											
Invertebrate eggs																											
Invertebrate egg mass	28																										
Mysidacea indet. larvae																											
Nephtys spp. posterior fragment																											
Pholoe spp. posterior fragment																											
Pinnixa sp. dead																											
Pisces indet. eggs																											
Scoletoma luti posterior fragment																											
Tharyx parvus posterior fragment	1																										

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TAXON	DP07B-5			DP07C-5			DP08A-5			DP08B-5			DP08C-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
CNIDARIA															
Hydrozoa															
Campanularia groenlandica															
Obelia dichotoma															
Anthozoa															
Actinaria indet.															
Edwardsiidae indet.															
PLATYHELMINTHES															
Pseudostylochus burchami															
NEMERTEA															
Cerebratulus californiensis															
Lineus bilineatus															
Lineidae indet.															
Nemertea indet.											1				
Paranemertes nigrina															
Paranemertes sp.															
Procephalothrix sp.															
Tetrastemma nigrifrons															
Tetrastemmidae indet.															
Tubulanus polymorphus															
ANNELIDA															
Polychaeta Errantia															
Diopatra ornata															
Epidiopatra hupferiana monroi															
Eteone californica															
Eteone longa complex													1		
Eteone spilotus															
Eteone sp.															
Eulalia quadrioculata															
Glycera nana															
Glycera pacifica															
Glycinde armigera															
Glycinde polygnatha							15	1		9	1		22	1	
Glycinde spp.															
Harmothoe imbricata															
Harmothoe spp.															
Lumbrineris cruzensis															
Micropodarke dubia															
Nephtys caecoides				1			1			2			3		
Nephtys cornuta															
Nephtys ferruginea															
Nereidae indet.															
Nereis procera															
Ophiodromus pugettensis								1							
Onuphis geophiliformis															
Pholoe glabra													1		

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TAXON	DP07B-5			DP07C-5			DP08A-5			DP08B-5			DP08C-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Pholoe minuta															
Pholoe sp. N-1															
Phyllodoce groenlandica															
Phyllodoce hartmanae															
Phyllodoce williamsi										1			2		
Phyllodoce spp.											1				
Pilargis berkeleyae															
Platynereis bicanaliculata							3	1			2		3		
Podarkeopsis glabrus															
Scoletoma luti															
Sphaerosyllis ranunculus															
Sphaerodoropsis sphaerulifer															
Polychaeta Sedentaria															
Ampharete labrops							1								
Ampharete spp.									1						
Amphicteis glabra															
Aphelochaeta sp. 2 *															
Aphelochaeta spp.															
Arenicolidae indet.															
Aricidea minuta	1			1											
Aricidea wassi															
Armandia brevis *										1	1		1		
Asabellides nr.*lineata*															
Asabellides sp.															
Barantolla nr. *americana*													1		
Boccardia polybranchia															
Capitella capitata complex *^							5						1		
Chaetozone nr. *columbiana*															
Chone magna					1										
Cirratulus spectabilis							3			1					
Clymenella nr. *torquata*								1							
Cossura pygodactylata															
Decamastus nr. *gracilis* *															
Dipolydora quadrilobata															
Dipolydora socialis															
Dipolydora spp.															
Euclymene nr. *zonalis* *															
Euclymeninae indet.															
Galathowenia oculata															
Heteromastus filobranchus *															
Lanassa venusta venusta															
Laonice spp.															
Leitoscoloplos pugettensis				1	1		2			2			2		
Levinsenia gracilis															
Magelona longicornis															
Mediomastus ambiseta *															
Mediomastus californiensis *							2	1		7			7	1	
Monticellina spp.															
Notomastus spp.															
Ophelina acuminata															

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TAXON	DP07B-5			DP07C-5			DP08A-5			DP08B-5			DP08C-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Owenia nr. collaris															
Owenia nr. *johnsoni*							20	1		14			21		
Paraprionospio pinnata															
Pectinaria californiensis															
Pectinaria granulata					1										
Polycirrus sp. I (Banse 1980)															
Polydora cornuta															
Polydora sp.															
Prionospio (Prionospio) jubata	1			1											
Prionospio (Minuspio) lighti *							1								
Prionospio (Minuspio) multibranchiata													1		
Prionospio (Prionospio) steenstrupi				1											
Pseudopolydora kempi ^															
Pseudopolydora paucibranchiata ^							1			1			3		
Pseudopolydora spp.															
Pygospio elegans															
Rhynchospio glutaea							33			7			6		
Scoloplos acmeceps	3						1						1		
Scoloplos armiger	11			8											
Spio cirrifera															
Spionidae indet.															
Spiophanes berkeleyorum															
Sternaspis nr. *fossor*															
Terebellides spp.															
Tharyx parvus *															
Oligochaeta															
Enchytraeidae indet.															
Enchytraeus multiannulatus															
Grania incerta										1			3		
Grania sp.							8								
Tubificoides brevicolus															
Tubificoides sp.													2		
Tubificidae indet. Group 5							1			2	5				
Limnodriloides victoriensis															
Limnodriloides sp.															
Tectidrilus diversus															
Tectidrilus spp.							6	1						2	
Hirudinoidea															
Notostomum sp.															
ECHIURA															
Arhynchite pugettensis															
Echiuridae indet.															

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TAXON	DP07B-5			DP07C-5			DP08A-5			DP08B-5			DP08C-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
MOLLUSCA															
Gastropoda															
Aeolidacea indet.															
Alvania compacta							1			2			1		
Amphissa versicolor															
Amphissa sp.															
Astyris gausapata	8	1		3											
Batillaria cumingi															
Columbellidae indet.															
Cyclostremella concordia															
Clinchna attonsa															
Cylichna culcitella															
Cylichnella sp.															
Gastropoda indet.															
Haminoea vesicula															
Haminoea sp.															
Lacuna variegata											2			4	
Lacuna sp.												4			
Lottia parallela										1	1		1	2	
Nassariidae indet.															
Nassarius fraterculus															
Odostomia sp.															
Olivella baetica				1											
Turbonilla sp.	1														
Volvulella sp.															
Bivalvia															
Acila castrensis															
Axinopsida serricata				3											
Bivalvia indet.									1						
Cardiidae indet.															
Clinocardium ciliatum															
Clinocardium nuttallii									2						1
Clinocardium sp.															
Compsomyax subdiaphana															
Ennucula tenuis															
Hiatella arctica															
Lucinoma annulatum															
Lyonsia californica															
Macoma balthica											2				
Macoma carlottensis		1	1												
Macoma elimata															
Macoma golikovi								1	1						
Macoma nasuta								4			6	1		3	
Macoma sp.						2		1	2			4			5
Mactromeris sp.															
Megayoldia martyria															
Modiolus modiolus									17			15			30
Modiolus sp.															
Mya arenaria															
Mya sp.									1						

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2008

TAXON	DP07B-5			DP07C-5			DP08A-5			DP08B-5			DP08C-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Mytilidae indet.															
Nemocardium centifilosum															
Nuculana hamata															
Nuculana minuta															
Nuculana sp.															
Nutricola tantilla							1								
Nutricola sp.		1		2	1					1			1		
Nuttallia obscurata															
Pandora bilirata															
Parvilucina tenuisculpta															
Protothaca tenerrima															
Rochefortia tumida				1			55			68			64		
Rochefortia sp.															
Tellina modesta		1			1		1				1				
Tellina sp.															
Tellinidae indet.															
Venerupis philippinarum															
Yoldia seminuda			1												
Scaphopoda															
Pulsellum salishorum															
ARTHROPODA															
CHELICERATA															
Pycnogonida															
Anoplodactylus viridintestinalis				1			1			11			4		
Acarida															
Hydracarina indet.															
CRUSTACEA															
Copepoda															
Cyclopoida indet.															
Harpacticoida indet.							1								
Porcellidium sp.															
Ostracoda															
Bathyleberis sp.															
Cyprideis sp.															
Diastylis abbotti															
Euphilomedes carcharodonta	1									2					
Euphilomedes producta	2														
Ostracoda indet.															
Philomedidae indet.															
Philomedes dentata															
Cirripedia															
Balanus crenatus															
Semibalanus balanoides															
Cumacea															
Cumella vulgaris															
Hemilamprops californicus															
Eudorella pacifica															
Leucon subnasica															

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2008

TAXON	DP07B-5			DP07C-5			DP08A-5			DP08B-5			DP08C-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
Tanaidacea															
Leptochelia savigyni							158	292		42	91		79	171	1
Isopoda															
Idotea rescata											2			3	
Munna ubiquita															
Synidotea nodulosa															
Amphipoda															
Americhelidium shoemakeri										5			5		
Americorophium brevis															
Anisogammarus pugettensis										2					
Caprella laeviuscula							1	1		6			5		
Caprella sp.															
Chromopleustes oculatus															
Eobrolgus chumashi													1		
Grandidierella japonica										1					
Heterophoxus affinis															
Ischyrocerus anguipes															
Monocorophium acherusicum							1								
Monocorophium carlottensis															
Monocorophium insidiosum															
Monocorophium sp.															
Orchomene decipens															
Orchomene minutus	2														
Pachynus barnardi															
Pacifoculodes zernovi	1			1											
Photis brevipes							35	2		48	8		15	1	
Photis sp.															
Pontogeneia rostrata										1			1		
Protomedeia grandimana															
Protomedeia sp.															
Rhepoxynius boreovariatus	5			5											
Rhepoxynius fatigans															
Rhepoxynius sp.															
Wecomedon wecomus															
Wecomedon sp.															
Decapoda															
Cancer gracilis															
Crangon alaskensis															
Pagarus sp.															
Pinnixa schmitti															
PHORONIDA															
Phoronis muelleri															
Phoronopsis harmeri															
BRYOZOA															
Celleporella hyalina										1			5		

Table 21
2008 Benthic Invertebrate Community Results

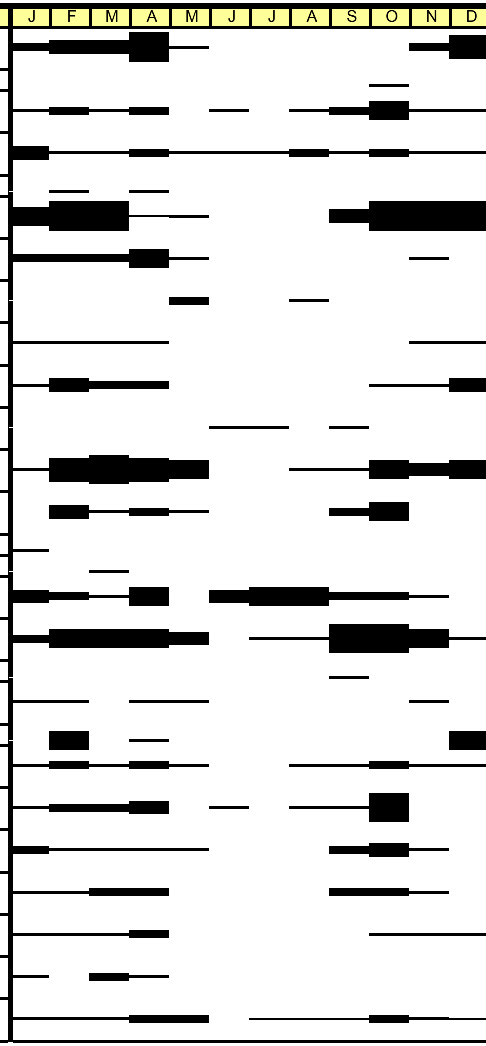
Hemmera - Vancouver Port Authority Data
2008

TAXON	DP07B-5			DP07C-5			DP08A-5			DP08B-5			DP08C-5		
	A	Int	J	A	Int	J	A	Int	J	A	Int	J	A	Int	J
ECHINODERMATA															
Ophiuroidea															
Amphiodia urtica							1								
Amphiodia sp.		1	2												
Amphiuridae indet.			1												
Ophiura sp.															
Echinoidea															
Strongylocentrotus droebachiensis															
HEMICHORDATA															
Enteropneusta indet.															
Saccoglossus sp.															
Total Number of Organisms by Stage	36	5	5	30	5	2	359	308	25	239	124	24	263	188	37
Total Number of Organisms	46			37			692			387			488		
Organisms per m2	920			740			13840			7740			9760		
Total Number of Taxa	16			18			34			34			36		
MEIOFAUNA															
Nematoda indet.							35	19		6	8		12		
MEMO															
Amphipoda indet. larvae															
Araneae indet.										1					
Calanoida indet.	1														
Caridea indet. zoea															
Capitella capitata complex in tube with eggs															
Capitellidae indet. posterior fragment															
Cirripedia indet. nauplius															
Coleoptera indet.															
Decapoda indet. brachyuran zoea															
Diptera indet. pupae							1								
Euclymeninae indet. posterior fragment										1					
Gastropoda indet. egg case															
Invertebrate eggs	22														
Invertebrate egg mass															
Mysidacea indet. larvae															
Nephtys spp. posterior fragment							1								
Pholoe spp. posterior fragment															
Pinnixa sp. dead															
Pisces indet. eggs															
Scoletoma luti posterior fragment				1											
Tharyx parvus posterior fragment															

Table 21
2008 Benthic Invertebrate Community Results

NOTES: Nematodes were present in most samples but because the numbers are unreliable we have not included them in the data.
(✦) Organism present in the 0.5 mm samples
(*) Polychaetes that like organic rich environments
(^) These Polychaetes can be considered opportunistic
In 2008 further investigation into the genus *Lacuna* has confirmed that the species identified in 2007 as *L. vincta* is actually *L. variegata*.

Table 22
Summary of Bird Abundance Data



Location	FamilyGroup	Family	Species	Tide	J	F	M	A	M	J	J	A	S	O	N	D
Deltaport	Brant	Geese, Ducks, Swans	BRAN	H	55		134	2492	8						86	1021
				L		140	23	2603								
	Coastal Waterbirds	Cormorant	BRCO	H										2		
			DCCO	H	2	34	5	15		3		2	24	178	13	2
				L		11	4	15				2	59	291		
			PECO	H	179	3	8	16	5	2	6	12	7	16	3	8
				L			2	6	10	2	1	13	4	30		
			UNCO	H		1		4								
		Geese, Ducks, Swans	AMWI	H	973	1368	1445	12	2				3	6820	3295	3729
				L		1223	719	9					184	9058		
			BUFF	H	37	40	56	86	1						11	
				L		34	36	171								
			CAGO	H					40							
				L								1				
			COGO	H	9	7	8	3							2	10
				L		8	2	2								
			EUWI	H	6	116	19	7						3	2	111
				L		58	47	22						2		
			GADW	H						3	8					
				L							10		13			
			GRSC	H	6	790	954	251	231			1	2	293	144	393
				L		303	1180	781	160					200		
			GWTE	H		7	5							106		
				L		95		25	4				86	678		
			LESC	H	3											
			LTDU	H			2									
			MALL	H	118	14	12	32		32	145	235	21	9	3	
				L		36		307		88	140	418	47	33		
			NOPI	H	56	17	92	96	9			1	271	6707	734	3
				L		717	197	238	104		5	9	2573	5347		
			NSHO	L									2			
			RBME	H	2	2		4	16						12	
				L		2										
			SNGO	H		227		2								254
			SUSC	H	17	9	4	39	7			7	1	26	3	1
				L		23		17	2			12		23		
			UNDU	H	5	52	67			3		5	5			
				L				102						3300		
			WWSC	H	23	11	6	10	4				25	30	9	
				L									12	77		
		Grebes	HOGR	H	9	10	23	18					33	63	9	
				L		5	9	21					26	19		
			RNGR	H	3	2	4	7						4	1	6
				L		2	2	18								
			WEGR	H	8		37	1								
				L				9								
		Loon	COLO	H	10	11	11	22	37		1	1	15	46	7	1
				L		7	8	16	6				6	23		

Hemmera
File: 499-002.11
September 2009

Table 22
Summary of Bird Abundance Data

Location	FamilyGroup	Family	Species	J F M A M J J A S O N D	Tide	J	F	M	A	M	J	J	A	S	O	N	D
Deltaport			RTLO		H			13									
					L		1	2	13								
		Skuas, Gulls, Terns, Skimmers	CAGU		H							2					
					L						1		7				
			CATE		H				2	6	2	10	7	1			
					L						1	1	1	10			
			GWGU		H	37	75	7	40	14	9	108	10	10	8	3	46
					L		106	67	96	45	18	113	81	42	86		
			MEGU		H	1	5	3	70	1				16			
					L		378	180	315	2				10			
			RBGU		H					4	35	25	186	21	21	28	8
					L						89	178	127	104	59		
			THGU		H	1											
					L			1									
			UNGU		H	2	15	1			8	1		1		2	15
					L		283	6	8	32	2	23	42				
	Heron	Herons	GBHE		H				14	19	60	47	3	2	9		
					L		2	1	182	152	245	87	123	57	9		
	Other	Crows, Jays	CORA		H							1	1				
					L								1				
			NOCR		H		2			1	5	4					
					L						3						
		Emberizids	SAVS		H									1			
					L						1			1			
			SOSP		L				1								
			WCSP		H							1					
					L							1					
		Pigeons, Doves	ROPI		H												5
		Starlings	EUST		H	8					20	30		20	105		1
					L									400	35		
		Swallows	BARS		H						2	14	1				
					L						1	3					
			TRES		H					7							
					L					1							
	Raptors	Caracaras, Falcons	MERL		L										1		
			PEFA		H									1			1
		Hawks, Kites, Eagles	BAEA		H	17	2	1	3	4	3	2	1		2	2	2
					L		6	2	6	7	2	1	2				
			NOHA		H	1											
					L				1								
			OSPR		H				1		2		1				
	Shorebirds	Lapwings, Plovers	BBPL		L				292		4			200			
			KILL		H					1	8	1					
					L						4						
			SEPL		L				4								
			UNPL		L						6						
		Oystercatchers	BLOY		H		1				1						
					L		9	5			7						
		Sandpipers, Phalaropes	BLTU		H	12										160	15
			DUNL		H	896	2	350	114	77						3500	1502
					L		364	505	1762	1					35		
			UNCA		L				4500								
			WESA		H				985	1911		148	1518	157			
					L				916				50				
TFN	Brant	Geese, Ducks, Swans	BRAN		H	142	10									427	510
					L				37								
	Coastal Waterbirds	Cormorant	DCCO		H			3						1	1	6	

Table 22
Summary of Bird Abundance Data

Location	FamilyGroup	Family	Species	Tide	J	F	M	A	M	J	J	A	S	O	N	D
TFN				L			1									
		Geese, Ducks, Swans	AMWI	H	314	212	185	23	2				89	660	21650	16545
				L		68	305							2450		
			BUFF	H			1									
			CAGO	H		17	1	4	1				1			
				L					2							
			COGO	H		3	2									
				L		2										
			COME	H												3
			EUWI	H								1		40	8	
				L		3										
			GADW	H	14	5		4	2	2	30					
				L						4						
			GRSC	H	50			250								
			GWTE	H	34	185	277	868	14				39	258	12	567
				L		210	412	373	2				46	800		
			HOME	H	2											
			MALL	H	20	8	19	4	6	15	100	490		116	14	144
				L			6	4					170	11		
			NOPI	H	1151	791	650	163	2		61	88	2443	3888	4009	11674
				L		209	105						1187	3052		
			NSHO	H	20	2	4	1				2	3	1		7
				L			1						6	5		
			RBME	H				14	2							
			SNGO	H	74									57		
			SUSC	H											3	
			TRUS	L										1		
			UNDU	H										303	1000	
				L		5						180	78			
			WWSC	H	5											
		Loon	COLO	H		1	1		2					1		
				L			1						3			
		Skuas, Gulls, Terns, Skimmers	CAGU	H												
				L				5								
			CATE	H				3		1	13	43	46			
				L				2		3		29				
			GWGU	H	84	51	46	10			74	25	22	137	8	10
				L		50	50	9	2		260	37	46	76		
			MEGU	H	55	10	4			3					7	
				L		435	243	12								
			RBGU	H		1		4		79	432	195	303	56	23	27
				L			4			51	97	27	341	69		
			THGU	H	4	1	2									
				L				2								
			UNGU	H	9		5	1				10		8		6
				L		165	46	91		6		7				
	Heron	Herons	GBHE	H	15	14	10	53	36	134	110	51	7	27	10	
				L		11	63	66	3	179	105	4	73	34		
	Other	Blackbirds	RWBL	H		2	4	1	1							
				L		1		1								
		Crows, Jays	NOCR	H			1		1		1		1			
				L				6	3							
		Emberizids	COYE	H					2		1					
			DEJU	H												1
			GCSP	H				2								
			SAVS	H				14	6	3		2		1		
				L		2		13		4		2		1		

Table 22
Summary of Bird Abundance Data

Location	FamilyGroup	Family	Species	Tide	J	F	M	A	M	J	J	A	S	O	N	D
TFN			SOSP	H		1	1	3		1						4
			WCSP	H				2	2							
				L				2						1		
		Emberzids	SPTO	H				1								
		Finches	AMGO	H				3	2	2	5					
				L				1	4					3		
			HOFI	H		2	1	1								
				L		2	1	6	2		1		1			
		Hummingbirds	RUHU	H					1							
		Kingfishers	BEKI	H			1				2					
				L			1							1		
		Other	WEME	H									1			
		Starlings	EUST	H			4	6			115				100	
		Swallows	BARS	H				1	3	16	3	12	1			
				L				4	19	5		45		1		
			TRES	H					3							
				L				2	11	3						
			VGSW	H						3	4					
		Thrushes	AMRO	H			1	1	1							
				L			1	3	1							
		Wood Warblers	YRWA	H					1							
		Woodpeckers	NOFL	H			1	1								
		Wrens	MAWR	H					1							
	Raptors	Caracaras, Falcons	MERL	H				1								
				L				1	1							
			PEFA	L		1										
		Hawks, Kites, Eagles	BAEA	H	5	7	2	5	3		3			4		2
				L		4	6	2	2	3	5			1		
			NOHA	H	2	2		3	2	1	1		3	1	1	2
				L		5			1				2	4		
			OSPR	L				1								
			RLHA	L										2		
			RTHA	H		1			1						1	
				L		3					1					
	Shorebirds	Lapwings, Plovers	BBPL	H	134		100	44		28				1		5
				L				2					1			
			KILL	H				11	1	10	2	2				7
				L				7	6							
			SEPL	H					1							
				L					9							
		Oystercatchers	BLOY	H							1					
		Sandpipers, Phalaropes	BLTU	H											3	
			DUNL	H	490	150	705	1441	81						200	8747
				L			810									
			GRYE	H				6								
				L					1							
			MAGO	H				1								
			REKN	H								1				
			SESA	H							2					
			UNCA	H							151					
				L							50					
			WESA	H				12333	1211		39	715				
				L				159	299			262	5			
			WHIM	H						7	5					
				L					1				1			

Table 23
Summary Statistics for DoD Rod Data

Results from 2007/2008 Analysis

		Group 1	Group 2	Group 3
Deposition	Q1 Mean (2008 only)	2.2	0.1	0.4
	Q2 Mean	5.2	3.3	1.7
	Q3 Mean	1.7	2.3	0.9
	Q4 Mean	3	0.8	1.2
	Annual Mean	3.1	1.8	1.1
Erosion	Q1 Mean (2008 only)	-3.2	-0.5	-0.7
	Q2 Mean	-2.5	-0.6	-0.9
	Q3 Mean	-4.9	-1.5	-0.5
	Q4 Mean	-4.9	-1.4	-1.3
	Annual Mean	-3.9	-1.2	-0.9
Combined Erosion and Deposition	Min	-14.9	-3.2	-7.7
	Max	21	8.5	8.5
	Mean	-0.40	0.30	0.13
	Std. Dev. (s)	5.13	2.23	1.74
	1.282 Std. Dev. (1.282s)	6.58	2.86	2.23
	Deposition Threshold	6.18	3.15	2.36
	Erosion Threshold	-6.98	-2.56	-2.10

Note: negative numbers denote erosion

APPENDIX A
Methodology

A-1 GEOMORPHOLOGY

A-1.1 INVESTIGATION METHODOLOGY

The main components of the monitoring program are based on the recommendations provided in the Deltaport Third Berth (DP3) Adaptive Management Strategy (AMS). Based on this information and Northwest Hydraulic Consultants' (NHC) general understanding of the processes at Deltaport, the detailed geomorphological monitoring work plan is described below. The Acoustic Wave and Current Meter (AWAC) was destroyed on September 27, 2007. An alternate monitoring methodology is currently being developed.

A-1.1.1 Crest Protection Monitoring

The purpose of crest protection monitoring is to detect channel incision, headcutting or dendritic channel formation around perimeter crest protection. The monitoring covers the entire perimeter of the crest protection structure, with particular focus in the vicinity of the tug basin and DP3 structures. Field reconnaissance and site observations are made quarterly during low tide by a qualified geomorphologist. Fixed points were established on the ground for taking repeat photography and for conducting terrestrial surveys. Ground surveys are carried out using a Real Time Kinematic (RTK) global positioning system (GPS) station to measure the dimensions of channels that are present or subsequently form.

A-1.1.2 Water Sampling of Suspended Solids

Periodic collection of water samples during a tidal cycle was initially proposed in order to derive a relationship between turbidity and total suspended sediment (TSS) concentration. NHC's memo of November 2007 presents the rationale for revising this methodology. With the development of a TSS-Turbidity relationship by laboratory methods, water samples will no longer be collected. Turbidity monitoring stations provide a continuous record of measured turbidity from which TSS will be computed using the expression **x=y/0.5123** (where x=TSS and y=turbidity).

A-1.1.3 Automated Turbidity Monitoring

The purpose of this monitoring activity is to measure turbidity continuously at fixed locations to provide a proxy record of sediment transport over the tidal flats. Two monitoring sites were chosen on the shoreward side of the crest protection structure, with Analite NEP495 Turbidity Logging Probes installed within a 2-inch PVC pipe with a flared base to protect the optics from debris. The pipe is securely attached within a stainless-steel pyramidal cage, which is weighted by 4 lb weights and marked by a small float. The instruments are programmed to record turbidity levels of up to 400 NTU every 15 minutes. A wiper assembly is programmed to clean the optics at 4-hour intervals to ensure consistent readings.

This sampling interval was selected to capture the effects of storms and other weather events with durations of several hours or more and is not designed to capture the impact of individual waves on turbidity. No cables or external power are required, which minimizes the risk of damage or loss of data. Regular maintenance of the equipment is carried out to ensure fouling or debris does not degrade the sensors. Data retrieval is performed by physically connecting the instrument to a laptop or PDA and directly downloading the data each month.

Analysis of data collected from the turbidity probes is supported by auxiliary tide level data. In order to monitor tide height, a local tide gauge was installed on a caisson at the Deltaport site. The monitoring station consists of a Solinst Levelogger, which records and stores stage (water-level) values at 15-minute intervals. The stage sensors record combined atmospheric and hydrostatic pressure. A Solinst Barologger is installed adjacent to the tide gauge in the DCL Site Office to independently record atmospheric pressure as a correction to the tide gauge. The Levelogger is housed inside a capped 2-inch PVC pipe secured to a pre-existing steel ladder on the caisson face.

A-1.1.4 Automated Monitoring of Erosion and Deposition

Measurements of the temporal variation in erosion and deposition at specified locations are collected using conventional erosion pins (depth of disturbance pins). The depth of disturbance (DoD) rods are monitored at three-month intervals during the course of other field investigations (crest protection monitoring and bed sediment sampling).

The DoD rods have been spaced at 150-m intervals and located on the tidal flats above 0.5 m chart datum in elevation. A DoD rod consists of a smooth length of galvanized steel pipe installed in the sediments by hand to a depth that will resist movement (typically 2 to 2.5 m) with a washer placed over the rod resting at the sediment surface. The initial distance from the top of the rebar to the disk is recorded at the time of installation. If the ground is lowered as a result of scour, the distance from the top of the rebar to the disk will increase over time. If deposition occurs, the sediment buries the disk. Vegetation accumulation on the DoD rod may occur on a seasonal basis related to growth and die off of the various plant species found at Roberts Bank. The presence of vegetation is noted and photo-documented and the height of accumulated weed is recorded. Accumulated weed is carefully removed to expose the bare sediments underneath and allow measurement of washer burial or scour as described above. Quarterly observations are made, and/or observations after any significant storm events, to determine the magnitude of erosion and deposition.

A-1.1.5 Sediment Samples

Sediment samples are scheduled for collection twice yearly, once in the spring and once in the fall, post Fraser River freshet. Samples are collected at each DoD rod site using a shallow hand corer. The top 10 cm of the sample are removed from the core and stored in a freezer until analysis to ensure that biological activity does not alter the percent fines. A sampling depth of 10 cm was chosen to ensure that there is sufficient sediment to perform a robust grain size analysis and to ensure that the sample captures undisturbed sediments at depth as well as newly deposited sediments. Preliminary monitoring of the DoD rods has demonstrated that a 10 cm sampling depth is appropriate at a majority of the sites. The first set of samples was collected at a distance of 5 m to the north of each rod. To avoid re-sampling in the same hole, subsequent sampling is rotated around the rod location.

The primary purpose of the laboratory analysis is to determine the particle size distribution of the samples. Subsequent results will be compared to determine if a fining or coarsening trend is occurring. The following is a description of the methodology used to determine the organic content of the sample, analyzed by ALS Laboratories:

> The sample is introduced into a quartz tube where it undergoes combustion at 900° C in the presence of oxygen. Combustion gases are first carried through a catalyst bed in the bottom of the combustion tube, where oxidation is completed and then carried through a reducing agent (copper), where the nitrogen oxides are reduced to elemental nitrogen. This mixture of N_2, CO_2, and H_2O is then passed through an absorber column containing magnesium perchlorate to remove water. N_2 and CO_2 gases are then separated in a gas chromatographic column and detected by thermal conductivity.

The remaining sample is then put through a series of sieves and a hydrograph to provide a graph of percent finer by weight down to 0.5 mm. The following graphs and tables show the results of the analysis.

A-1.1.6 Interpretation of Ortho Photographs

Aerial photographs are evaluated to assess trends and patterns of erosion and/or accretion on the tidal flats. This evaluation is conducted annually and covers the entire inter-causeway tidal flat area. The methodology consists of overlaying successive ortho-rectified photographs using GIS mapping techniques to delineate and identify morphological changes on the tidal flats. The maps show areas of erosion or sand accretion and changes in vegetation between successive surveys.

A-1.1.7 Coastal Geomorphology Mapping

This task assesses topographic changes due to long-term erosion or accretion adjacent to the terminal. An initial baseline survey was completed at the start of the study. The surveys will be repeated every three to four years. The highest resolution surveys are made near DP3. More limited surveys are made across the shallow inter-tidal flats where the relief is very low. Precise bathymetric surveying is performed using RTK GPS positioning for horizontal control and single beam digital echo sounding.

A-1.2 DATA EVALUATION

This section summarizes the geomorphological data that will be evaluated and interpreted for the monitoring components presented above. Interpretation of the DoD measurements and bathymetric survey data is straightforward, and is not included below. Results are provided only in the quarterly reports with data interpretation and discussion provided in the annual reports.

A-1.2.1 Crest Protection Monitoring

Comparisons of repeat terrestrial photographs will be performed to show seasonal and long-term changes. Comparison of ground surveys to document scour or erosion from channel formation or headcutting processes. This interpretation will be supplemented by assessment of annual aerial photography and periodic low-level over flights from a fixed wing aircraft, as described in **Section A-1.1.6**.

A-1.2.2 Water Sampling of Suspended Solids

Plots of suspended sediment concentration versus turbidity will be made to provide a basis for calibrating the continuous turbidity sensors. Variations in suspended sediment concentration will be related to tidal current velocities, tide levels and ambient conditions in the Lower Fraser River estuary.

A-1.2.3 Automated Turbidity Monitoring

Suspended sediment concentration will be computed from the turbidity values using correlations established from the manual sampling program. Time series plots of turbidity and suspended sediment concentration will be made and compared with tide levels, tidal current magnitude and wave climate conditions (as recorded by the AWAC unit provided by others). Predicted sediment concentrations and sediment transport rates under tidal currents and waves will be compared with the observed values.

The primary objective of the automated turbidity monitoring stations is to monitor sediment concentrations and sediment transport rates to assess long-term deposition/erosion processes and long-term changes in sediment concentration that might affect habitat (such as eelgrass). However, localized higher turbidity values generated from construction activities may be reflected in the record.

A-1.2.4 Sediment Samples

Measurements of short-term accretion and erosion will be correlated with met-ocean conditions (wave and tide conditions), construction activities and changes in vegetation or eelgrass. Comparisons will also be made with surveyed topographic changes along the crest protection and results of the photographic monitoring.

A-1.2.5 Interpretation of Ortho Photographs

Overlay maps will be interpreted to assess the key factors that are controlling morphological changes on the tidal flats. Results will be compared with other long-term assessments (as documented previously in the Coastal Geomorphology Study). The results of this investigation will be integrated with other related studies on eelgrass extent and distribution in order to provide a complete understanding of any habitat changes.

A-2 SURFACE WATER

A-2.1 INVESTIGATION METHODOLOGY

Fixed sediment quality monitoring stations will be established adjacent to the Deltaport facility, within the inter-causeway area and at two reference locations along Robert's Bank. The proposed locations are are described as follows:

- One station (Station 1) in the ditch near the base of the BC Ferries Causeway to monitor nutrient and sediment loading from upland sources
- Two stations (Stations 2 and 3) located in the intertidal portion of the inter-causeway area within the eelgrass beds
- One station (Station 4) in the intertidal portion of the inter-causeway area at the head of the ship turning basin adjacent to DP3
- One station (Station 5) in the subtidal portion of the inter-causeway area within the ship turning basin adjacent to DP3
- One intertidal reference station (Station 6) located off Westham Island northwest of Deltaport
- One subtidal reference station (Station 7) located off Westham Island northwest of Deltaport

The surface water sampling methodology outlined below, including sample implement decontamination procedures, is based on the protocols developed for the Puget Sound Estuary Program (PSEP 1996). Representative surface water samples will be collected from each of the sampling stations.

A vessel equipped with a 5-litre Van Dorn sampler, constructed of clear lexan, will be used to collect surface water samples at each station. One water sample will be collected just below the surface and for the subtidal samples; one surface water sample will also be collected at a depth of two metres above the seafloor. As with the sediment sample, the surface water sampling stations will be located using a GPS. The vessel will be equipped with a depth sounder, however, to ensure that the sampler is triggered at an appropriate depth a two metre rope with a weight at the end will be attached to the base of the Van Dorn. To minimize the turbidity plume from disturbed sediment, the sampler will be lowered slowly and carefully as it approaches the bottom (based on depth sounder readings). Tripping the sampler is then delayed approximately one minute is used to allow currents at the site to transport turbidity generated by the weight out of the area of the sampler. Each recovered water sample will be examined to ensure acceptable sample quality, including no entrained sediment, and the water in the sampler decanted into laboratory prepared sample bottles. The five litre Van Dorn volume is sufficient to meet sample volume requirements. Similar to the sediment sampling process, field observations will be recorded at each station during sample collection. Field observations will include general information (e.g., station name, date, time), and a description of the site location, GPS coordinates, water depth and characteristics (e.g., colour, odour, turbidity).

As part of our quality assurance program, Hemmera will also undertake a number of measures including consistent use of the same field technicians, daily field reporting between field technicians and project manager, and submission of samples in laboratory supplied sterile sampling containers under chain of custody, following the directions provided by the analytical laboratory, etc. The required laboratory reported detection limits have been pre-determined with the laboratory so that the results can be compared to the appropriate regulatory screening levels. The detection limits and regulatory screening levels are provided in the AMS Detailed Workplan. One blind field duplicate sediment sample will also be collected during each sampling event to further assist in the evaluation of data quality. The data quality objective (DQO) for precision will be measured using the relative percent differences (RPD) between characterization and duplicate samples (to evaluate data precision) as well as percent completeness to evaluate the effectiveness of the sampling program with respect to the project objectives. Due to the limited number of samples, the DQO for completeness is 100%. The DQOs for precision will be 20% RPD for inorganic parameters and 50% RPD for organic parameters. Where reported concentrations of less than five times the detection limit are obtained, the DQO of a difference factor (DF) of < 2 will be used. The quality assurance program will also include review of the analytical laboratory's quality control results.

The samples will be stored in coolers on ice and transported directly to the laboratory at the end of the sampling day (approximately 1.5 hour travel time).

Data from Station 4, nearest the DP3 construction area, will also be monitored continuously for a number of water quality parameters (pH, temperature, conductivity, dissolved oxygen, and turbidity) using a YSI buoy-mounted sonde operated in conjunction with the DP3 construction environmental monitoring program. Data for the remaining water quality and sediment quality parameters will be collected during quarterly sampling programs.

A-2.2 SAMPLE ANALYSES

The parameters analyzed to facilitate data interpretation include:

- Temperature
- pH
- Hardness
- Salinity

The parameters being analyzed to assess the presence/absence of toxicants include:

- Metals
- Chlorine[1]

Several of the water quality parameters were also selected for their use in facilitating identification of marine eutrophication and/or construction impacts. These include:

- Turbidity, TSS, Clarity (secchi disk)
- Nutrients (Phosphate, Phosphorus, Ortho-phosphorus, Total Kjeldahl Nitrogen (TKN), Total Nitrogen, Ammonia, Nitrate, Nitrite and Organic Nitrogen N)
- Chlorophyll *a*

A-2.3 DATA EVALUATION

As indicated above, a number of the monitored surface water parameters are to support data interpretation purposes and therefore do not require action levels. The other parameters collected, as indicators of potential toxicity to marine organisms, will be compared against the applicable provincial and federal water quality screening levels:

- British Columbia Approved Water Quality Guidelines (Criteria), 1998 Edition
- A Compendium of Working Water Quality Guidelines for British Columbia, 2001 Update
- Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines, 2006 Update

These analytical results will be provided in the quarterly reports with data interpretation and discussion of the sampling results provided only in the annual reports.

[1] Chlorine will be collected from the ditch station only. The purpose is to evaluate potential impacts from chlorine to the inter-causeway area as historical releases of water from a nearby upland water park have been documented. Polycyclic aromatic hydrocarbons (PAHs) have been dropped from the program as no exceedances were noted during the Q1-2007 event.

The remaining results will be presented in each quarterly report with evaluation for negative trends occurring within each annual report. As with the sediment sampling program, the data collected within the inter-causeway area will be tabulated, graphed, and statistically compared with the results from the relevant reference stations elsewhere along Robert's Bank. A 20-percent difference between the eutrophication parameter inter-causeway and far-field results will be used as a preliminary indicator of a potential for eutrophication impacts and will warrant discussion within the annual report. For some parameters, such as oxygen, where critical thresholds exist and changes of less than 20% may impact biota, the absolute value of the parameter will also be evaluated.

A-3 SEDIMENT

A-3.1 INVESTIGATION METHODOLOGY

As with the surface water sampling program, representative sediment grab samples will be collected from each sampling station on a quarterly basis (four times per year). The sampling methodology outlined below, including sample implement selection and decontamination procedures, is based on the protocols developed for the Puget Sound Estuary Program (PSEP 1996)[2]. A shallow draft vessel equipped with an 8.2 L Ponar grab sampler will be used to collect the sediment samples. Field staff will work from the ditch bank to collect samples from the sediments at Station 1. Sampling stations will be located using global positioning system (GPS) coordinates. Each recovered grab sample will be examined to ensure acceptable sample quality, the supernatant water in the sampler will be decanted and the upper 5 cm of sediment will be placed in a clean stainless steel mixing bowl. Repeated grab samples may be required to fulfill sample volume requirements. The sample will be mixed with a stainless steel spoon until homogenous in texture and colour. However, sediment for hydrogen sulphide analysis will be collected prior to mixing to minimize oxidation and volatilization. Field observations will be recorded at each station during sample collection and will include general information (e.g., station name, date, time), a description of the site location, GPS coordinates, water depth, sediment characteristics (e.g., grain size, colour, odour, debris, visual contamination), and a record of the amount of effort required for sediment collection.

Aliquots of sediment for chemical analysis will be collected in 250mL laboratory prepared glass jars with Teflon lids for submission to the project laboratory for analysis of the parameters listed in **Section A-3.2**. The sediment samples are collected and transported to the lab generally by 5:30 pm the day the samples are collected. Sediment samples are placed in jars and immediately stored in a covered cooler with ice to keep them at a cold state, at or near $4^{o}C$ for delivery to the laboratory. All samples are analysed within the laboratory holding time.

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2 Puget Sound Estuary Program (PSEP) 1996. Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound. Prepared by King County Environmental Laboratory for Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Sediment samples for sulphide analysis are collected prior to homogenization and are placed in jars with no headspace in order to minimize the potential for oxidation. As with the other parameters, sulphide sample jars are then placed immediately on ice. The laboratory holding time for sulphides was 7 days during Q1 and Q2; however, it was reduced to 24 hours for subsequent events, to minimize potential loss through volatilization and increase the reliability of results. Sulphide analysis is via the laboratory method is described below:

- Add 8 – 12 drops of sodium hydroxide to a centrifuge tube to 5 g (based on dry weight) of sample into the tube.
- Add water.
- Shake for 20 minutes, then centrifuge.
- Filtered supernatant through a 0.45 micro filter.
- Transfer an aliquot to a test tube containing zinc acetate.
- Bulk the sample with Milli-Quartz water and analyze colourimetrically.

The field sampling equipment (i.e., Ponar, bowls and spoons, etc.) will be decontaminated prior to sample collection at each station. This involves an initial rinse with site seawater, followed by washing with Alconox soap, a second rinse with site seawater, and final rinse with distilled water in accordance with the PSEP (1996) methodology.

Quality assurance measures (staff, sample handling, field duplicates and DQO) for the sediment sampling program will be the same as those outlined for the surface water sampling program (**Section A-2.1**) above. The detection limits and regulatory screening levels for sediment samples are provided in the AMS Detailed Workplan.

A-3.2 SAMPLE ANALYSES

Sediment samples are analyzed for the following parameters:

1. Metals were analyzed as indicators of potential toxicity to marine organisms (Tributlytin was analyzed only during the Q1-2007 event).
2. Parameters measured to evaluate sediment eutrophication include:
   - Total nitrogen
   - Ammonia
   - TKN
   - Total organic nitrogen
   - Phosphorous
   - Redox (Eh)
   - Hydrogen sulphide (H_2S)

Sediment grain size samples are collected annually.

A-3.3 DATA EVALUATION

The toxicity parameters, when sampled, will be compared against the BC Contaminated Sites Regulation, Schedule 9 Generic Numerical Sediment Criteria for sensitive marine and estuarine sediments ($SedQC_{ss}$) and the Puget Sound Dredge Disposal Analysis (PSDDA) criteria for TBT as indicated in the AMS workplan document. These analytical results will be provided in the quarterly reports. Anomalous results will be highlighted and briefly discussed. Data interpretation and discussion of the sampling results will be provided only in the annual reports

The remaining sediment quality parameters will be evaluated within each annual report for observable trends. The data collected within the inter-causeway area will be tabulated, graphed, and statistically compared with the sediment results from the reference stations and with data from previous years sampling. A 20-percent difference between the eutrophication parameter inter-causeway and far-field results or between results from year to year will be used as an indicator of a potential for eutrophication impacts and will warrant discussion within the annual report.

A-4 EELGRASS

A-4.1 INVESTIGATION METHODOLOGY

A-4.1.1 Eelgrass Distribution and Mapping

Aerial photograph interpretation will be used to develop a base layer for mapping the current distribution of eelgrass in the inter-causeway area. Aerial photograph flights used for the eelgrass monitoring program are to be flown in July 2007 and at the same time in subsequent years. The amount of cloud cover, sun angle, and season at the time when the photos are flown; and the resolution of the photos, will determine whether it is possible to distinguish between areas that support a monoculture of *Z. japonica* and areas that support a monoculture of *Zostra marina*. There is a 'transition' zone between these two habitats in the inter-causeway area where the two species co-exist. It may be possible to approximate the boundaries of the transition area from the photos. Homogenous habitat types will be delineated to form polygons. We have proposed a minimum polygon size of 50 m by 50 m; however, this may be modified through discussions with Vancouver Fraser Port Authority (VFPA).

A field survey will follow the aerial photograph interpretation to confirm and/or determine the species composition of each polygon. The boundaries of the transition area will likely need to be determined on-site and mapped using a GPS. *Zostra japonica* is an annual species; although a small percentage of the shoots may survive throughout the winter. To accurately map the distribution of this species the field survey should be completed between June and early September.

The data collected during the field survey would be incorporated onto the base layer by Hemmera to create a GIS map that accurately depicts the current distribution of eelgrass in the inter-causeway area.

A-4.1.2 Monitoring Eelgrass Vigour & Health at the Established Stations

The annual eelgrass vigour and health survey will be conducted during one of the low tide cycles between mid July and mid August and will assess the health and growth of eelgrass at nine of the eelgrass monitoring stations that were established for the 2003 DP3 Environmental Assessment (Hemmera 2003), including four stations in the inter-causeway area, two stations west of the Deltaport Causeway and three reference stations in Boundary Bay.

The parameters that will be monitored at each of the stations will include those assessed for the baseline study; shoot density, shoot length, and shoot width[3]. This data will be used to calculate Leaf Area Indices (LAI) at each location.

The distribution of *Zostra marina* at each station will be classified as patchy, continuous, or absent. The percent cover of *Zostra japonica* will be ranked according to the following scale: <1% present; 1% to 40% sparse; 41% – 75% moderate; >75% dense.

The monitoring plan includes noting the presence or absence of epiphytes at each of the stations. It would be possible for Ms. Durance, based on her 25 experience with this population of eelgrass to further classify the presence of epiphytes in the inter-causeway area as typical, less than usual, or more than usual.

The presence or absence of *Beggiatoa* sp. will also be noted. Ms. Durance has never observed *Beggiatoa* sp. at Roberts Bank. In the unlikely event that it is noted during an annual monitoring event, a strategy would need to be developed so that increases or decreases in the area covered by this species could be assessed. The location of the *Beggiatoa* sp. would be recorded using a GPS, for future reference. If there is sufficient time available the crew will map the area covered by *Beggiatoa* sp. VFPA will be notified immediately, with suggestions as to how to modify the AMS to include mapping and monitoring changes in the distribution of this species.

A-4.1.3 SIMS Survey

A Subtidal Imaging and Mapping System (SIMS) survey will be used to determine the lower limit of eelgrass in the inter-causeway during the summer of 2009. The SIMS method and equipment is only available through Archipelago Marine Research (AMR).

SIMS is a towed video system developed to carry out systematic mapping of marine vegetation, macroinvertebrates, seafloor substrates and morphology from the intertidal zone to depths of about 40m. The field of view is approximately 1 m by 2-3 m. The acquired imagery (digital video format) is

[3] Quadrat sampling along Transects as described in *Methods for Mapping and Monitoring Eelgrass Habitat in British Columbia* (Precision 2002).

geo-referenced using differential GPS with positions and time “burned onto” the video imagery with one-second update intervals. Depth of the towfish is also shown on the image. The towfish is maintained at an elevation of 1-1.5 m above the seafloor. Tow speed for SIMS is about 1 knot (2 km/hr) yielding a line coverage of 12 to 15 km in a typical survey day. A seven metre vessel provided and operated by Arrawac Marine Services is used to conduct the survey. A laptop computer is used for pre-plotting the navigation lines and for showing the vessel track lines during the survey. The position, depth and video time data is stored in custom MS Access database format developed for the SIMS classification system.

The video imagery is classified (by a geologist and a biologist) for substrate, epiflora (macrophytes) and epifauna (including fish) using a standard substrate and biotic classification system initially developed for the Province of British Columbia. The SIMS database system allows data entry for each second of video imagery collected. The interpreted data are interfaced with ArcView for map production. Typically the survey product is a comprehensive portfolio of maps, developed in GIS format, showing sediment type, major vegetative features, macroinvertebrates and fish observations and an interpretation of valued and sensitive biophysical features.

A-4.2 DATA EVALUATION

An eelgrass distribution map will be produced annually, based on aerial photograph interpretation and confirmed by ground truthing. A brief report will accompany a map that assesses changes that were observed in a local and regional context. This information will be compiled and summarized within each annual report for consideration by the Scientific Advisory Committee (SAC).

Natural eelgrass densities may vary significantly between years due to climatic changes. Although the mean density tends to be stable over time, environmental change such as El Niňo events may lead to severe changes in density. An El Niňo winter followed by a La Niňa summer once resulted in a ten-fold density increase in at least several eelgrass beds in British Columbia and Washington State. Data (vigour and epiphyte load) from the inter-causeway would be compared with many other sites in addition to Boundary Bay to ascertain whether changes subsequent to development at Roberts Bank are due to impacts attributable to the DP3 project, other non-DP3 anthropogenic causes, or natural causes.

A-5 BENTHIC COMMUNITY

A-5.1 INVESTIGATION METHODOLOGY

Benthic community health in the inter-causeway area is linked to sediment quality and water quality; and it is anticipated that if significant changes are seen in benthic community health, effects would also be observed in surface water quality and/or sediment quality (see **Sections A-2** and **A-3**). Therefore, sediment samples for benthic community analysis will be co-located with surface water and sediment samples from six of the seven sampling stations identified for the surface water and sediment quality monitoring programs. No benthic samples will be collected for station DP-01 as this station is located in a drainage ditch discharging to the inter-causeway area. The samples for benthic invertebrate analysis will be collected separately during the sediment sampling program. Samples will be preserved and packaged in the field, as required, and shipped to Biologica Environmental Services, Ltd., who process the samples and report taxonomic results to Hemmera.

The first benthic community sampling event will be completed during the first quarterly sampling event prior to the start of dredging. The next benthic invertebrate sample collection event is scheduled to occur during the Q1-2008 sampling event in March 2008. During the March 2008 event, a fourth benthic sampling station will be sampled. The location will form the fourth corner of a rectangle created by connecting stations DP02, DP03 and DP04 and the new station. Water quality and sediment samples will be collected at this station only during the benthic community sampling event and not during subsequent quarterly monitoring events. Further benthic community sampling will be completed at the end of construction during the first post-construction quarterly sediment sampling event. To facilitate data management, a fixed naming convention will be used. For instance, DP01A-1 will denote a sample collected at DP01, with the letter distinguishing between the three benthic invertebrate samples collected at this location, and the number specifying that the sample was collected during the first benthic invertebrate sampling event.

To capture inherent variability potentially present at the stations, three replicates will be initially collected per station for the benthic community sampling (*Benthic Marine Habitats and Communities of the Southern Kaipara*, Aukland Regional Council Technical Publication 275). Should the results of statistical analysis of variance of richness and abundance in the first year's benthic community sampling indicate acceptable variance observed between the replicates, we propose to reduce the sampling to one replicate sample per station during the second event. We have proposed an acceptable level of variance as being less than 20%.

Sampling methodology will be similar to that for the sediment sampling described in **Section A-3.1** but with some modifications. For the benthic community sample, the supernatant water is not decanted. After examination of grab quality, including consistent sample volume between stations, the sediment is placed in a plastic container (Tupperware bin) and transferred to a pre-cleaned stainless steel screening station on shore. The sample contents are gently rinsed through a 1.0 mm mesh sieve using seawater strained for zooplankton using a fine nylon mesh. The sample material remaining on 1.0 mm sieves is transferred into 1 L plastic containers and preserved in a 10% solution of formalin buffered with marble chips. These samples are then transported to Biologica for taxonomic identification. Taxonomic identification of benthic invertebrates will be down to the species level, where practical, and include both the diversity (number of species) and abundance of individuals for adult, juvenile and intermediate life stages.

A-5.2 DATA INTERPRETATION

As stated in the AMS, infaunal and epifaunal benthic community results will be evaluated and the data collected within the inter-causeway area will be tabulated, graphed, and statistically compared with the benthic results from reference stations elsewhere along Robert's Bank. A 20-percent difference from elsewhere along Robert's Bank will be used as an indicator of a potential for benthic community impacts in the inter-causeway area requiring further discussion within the final annual report.

Benthic community health is linked to sediment quality and water quality; therefore, it is expected that if significant changes are seen in benthic community health, effects would also be observed in surface sediment quality and/or water quality.

The sampling results will also be compared to video observations made during the SIMS survey that is part of the Eelgrass program (**Section A-4.1.3**). As stated above, the video imagery will be used for epiflora (macrophytes) and epifauna (including demersal fish) classification using a standard system initially developed for the Province of British Columbia. The SIMS database system allows data entry for each second of video imagery collected. The interpreted data are interfaced with ArcView showing sediment type, major vegetative features, macroinvertebrates and fish observations and an interpretation of valued and sensitive biophysical features.

A-6 BIRDS

A-6.1 INVESTIGATION METHODOLOGY

Bird studies will be completed along the south side of the Deltaport Causeway, north side of the BC Ferries Causeway and the intervening shoreline at the head of the inter-causeway area. Multiple, fixed-distance point counts will be completed along the following 3 Transects:

- Deltaport Transect: Deltaport Causeway (point count stations 12 – 19)
- Tsawwassen First Nation (TFN) Transect: TFN Lands (point count stations 105 – 115)
- BC Ferries (BCF) Transect: Tsawwassen Ferry Jetty (point count stations 118 – 126)

The sample plot associated with each point count station will be approximately 500 m^2. The coordinates of the point count stations will be determined using GPS. Point count stations will be identified with either flagging tape or paint sprayed on the ground surface. Stakes will be used along the South Roberts Bank Transects to mark the point count stations at intervals of 500 m. Point count estimates will also be made at distances ranging from greater than 500 m to approximately 1 km.

One monitoring event will be completed every two weeks. Observations will be made at a frequency of twice each day, as daylight permits, or on two consecutive days within a 3-day monitoring window.

Observations will be made once during a daily high tide and once during a daily low tide. Low-tide observations along the Deltaport Transect will commence approximately 30 minutes before the daily low tide, and will be made when a minimum of 500 m of mudflat is exposed. The low-tide surveys will progress from the tip of the causeway to the base. Observers will use binoculars, spotting scopes and range-finding binoculars to identify species and their distances from the point count stations. Observers will count individuals and groups of birds and document bird behaviour. Observational data will be recorded on survey forms that are consistent with those used by VFPA and Canadian Wildlife Service (CWS) in past bird studies.

The Deltaport Transect (point count stations 12 - 19) will undergo a more intensive survey in comparison to the other observational Transects. Observers will use consistent survey methodology along all Transects; however, observers working along the Deltaport Transect will conduct fixed-distance point counts within smaller sub-plots, according to the following scheme:

- 0 – 100 m from the shore
- 100 – 200 m from shore
- 200 – 300 m from shore
- 300 – 400 m from shore
- 400 – 500 m from shore
- > 500 m to approximately 1 km

Observers along the TFN and BC Ferries Transects will count birds within relatively larger sub-plots, according to the following scheme:

- 100 m inland to the shore
- 0 – 250 m from shore
- 250 – 500 m from the shore
- > 500 m to approximately 1 km

If large numbers of birds are observed within a sample plot, then observers will count a group of 100 individuals and then multiply the total number of groups within the sample plot. Birds observed in flight will be recorded as ‘flyovers’ and the flight direction will also be recorded; these records will be distinguished from records made for birds occurring on water or land. The duration of observation at each point count station will be 20 minutes, during which time all birds will be counted within the boundaries of the sample plot (approximately 500 m^2 and up to distance of 1 km from land, and 100 m inland).

As of May 2008, the bird survey methodology described above has been modified following adaptations to the scope of the AMS. Following discussion with the SAC and CWS, the following adaptations have been implemented pursuant to SAC and CWS recommendations:

- Bi-weekly survey events will be reduced to monthly survey events with the exception of a six-week window during the spring western sandpiper migration;
- Point count stations on the TFN Transect will be reduced from 5 to 3 (PCs 113 and 115 will be merged, PCs 105 and 107 will be merged, and PC 109 will be retained);
- Surveys along the BC Ferries Transect will be discontinued;
- Subplots on the Deltaport Transect will now be consistent with subplots on the TFN Transect and consistent with CWS methodology from 2004 surveys along Robert's Bank (**0-250 m, 250 – 500 m, and 500 m – 1 km)**.

One tidal survey event (as opposed to a low and high-tide event) will be conducted during the winter months (December to February) as previously agreed by CWS (R. Butler and B. Elner pers. comm., Nov 2007).

A-6.2 DATA EVALUATION

Hemmera will document changes in species distributions that are linked to construction or post-construction activities. Hemmera's analysis of the bird monitoring data will yield: (1) total estimated counts and relative abundance of birds for a particular sample plot and/or sub-plot, and (2) the number of birds per unit area (i.e., km^2) or density. A total estimated count is indicated by the sum of the total number of birds observed in each sample plot, along a specific Transect and at a given time. Species densities will be derived from the census data collected during the pre-construction (baseline) monitoring as well as the construction and post-construction monitoring conducted as part of the AMS monitoring program. Densities will be determined using the formula below.

$$D = B/A$$

Where:

D = density of birds (i.e., birds / km^2)

B = No. of birds observed

A = area surveyed

Census data collected during construction and post-construction periods will be compared to pre-construction baseline data to determine whether construction and post-construction activities result in significant changes in species populations. Hemmera will import the baseline data into its data management system to facilitate interpretation. Data interpretation will include comparisons between baseline monitoring results and construction and post-construction results, as well as spatial and temporal trend analyses using a standard statistical package (i.e., T-test, linear regression) to detect positive or negative trends occurring among the sample plots. VFPA will be immediately notified if negative trends are observed during data interpretation. Additionally, Hemmera will provide VFPA with recommendations, if necessary, to implement or modify mitigation measures to prevent or attenuate observed negative ecosystem trends. The data will be reported in post-survey reports, quarterly reports and annual reports.

APPENDIX B
NHC Photos

Photo 1: Crest Protection Monitoring XS 1 looking back at Deltaport, July 2008

Photo 2: Crest Protection Monitoring XS 2 looking north, July 2008

Photo 3: Crest Protection Monitoring XS 3 looking northeast, July 2008

Photo 4: Crest Protection Monitoring XS 4 looking east, July 2008

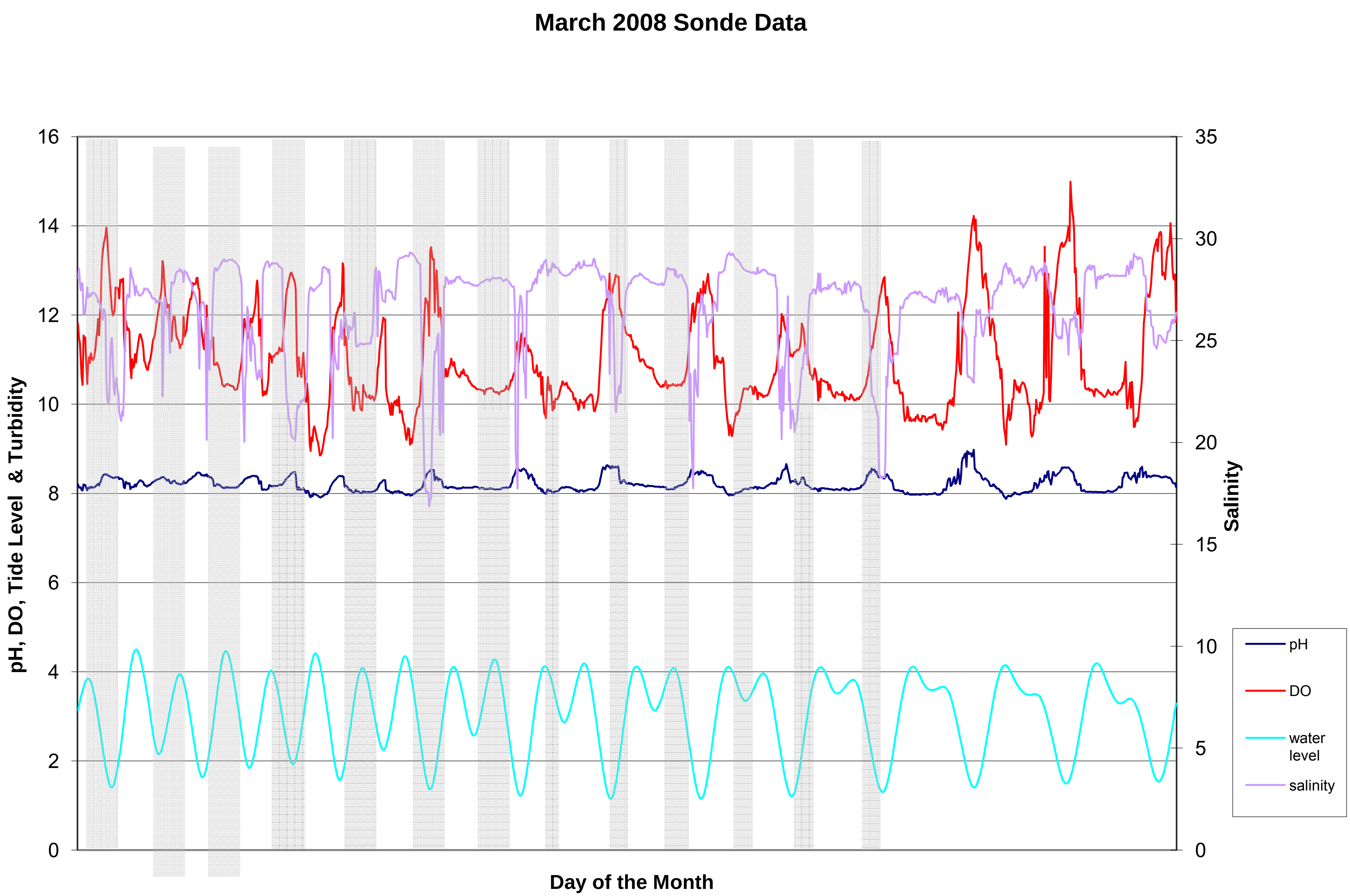
Photo 5: Crest Protection Monitoring XS 5 looking southeast, July 2008

Photo 6: New drainage channels looking towards the Western limb of the Perimeter Dike at 1.0 m CD water level. Photo taken on February 3, 2009.

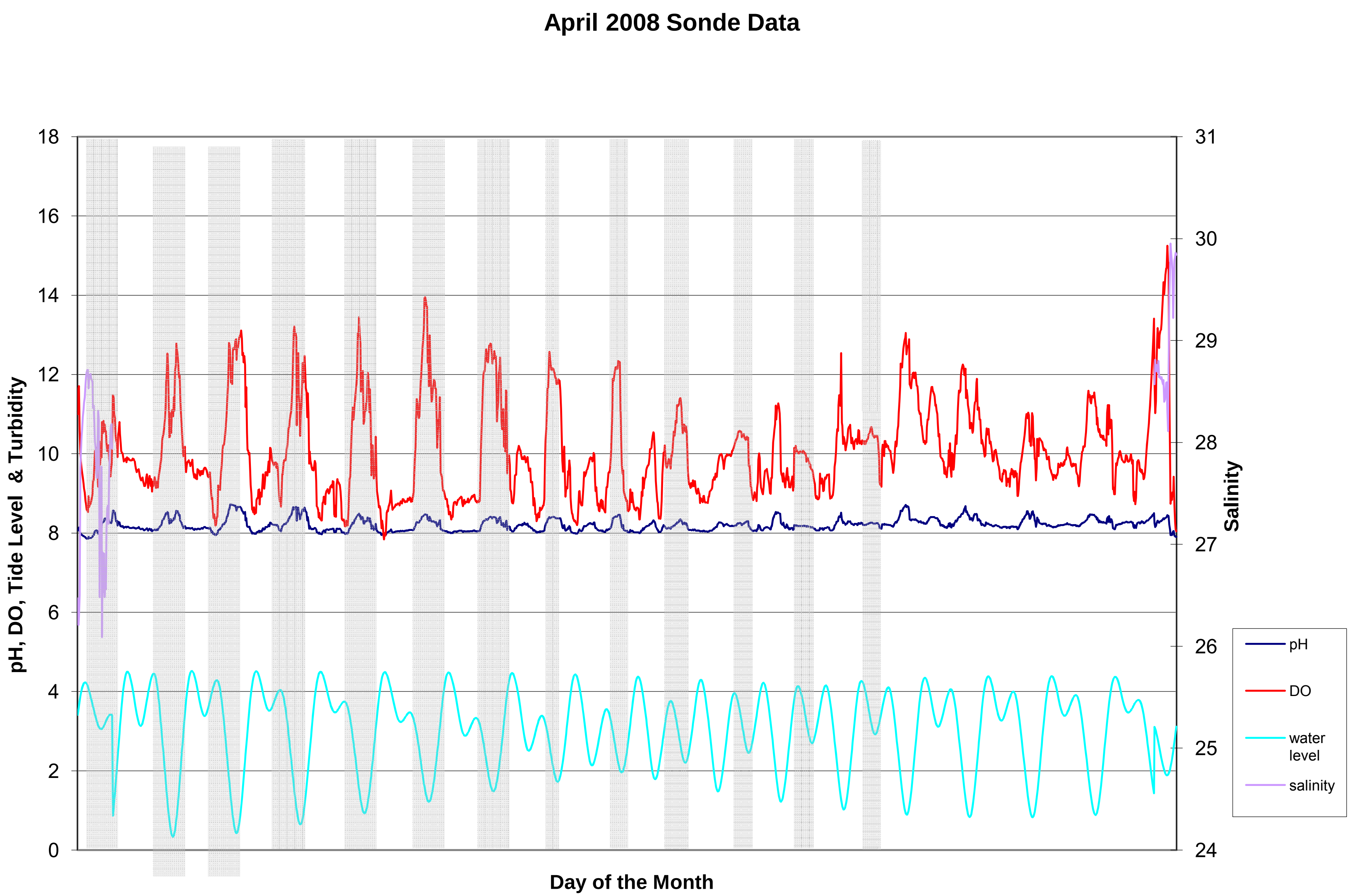
Photo 7: New drainage channels looking towards the East

APPENDIX C

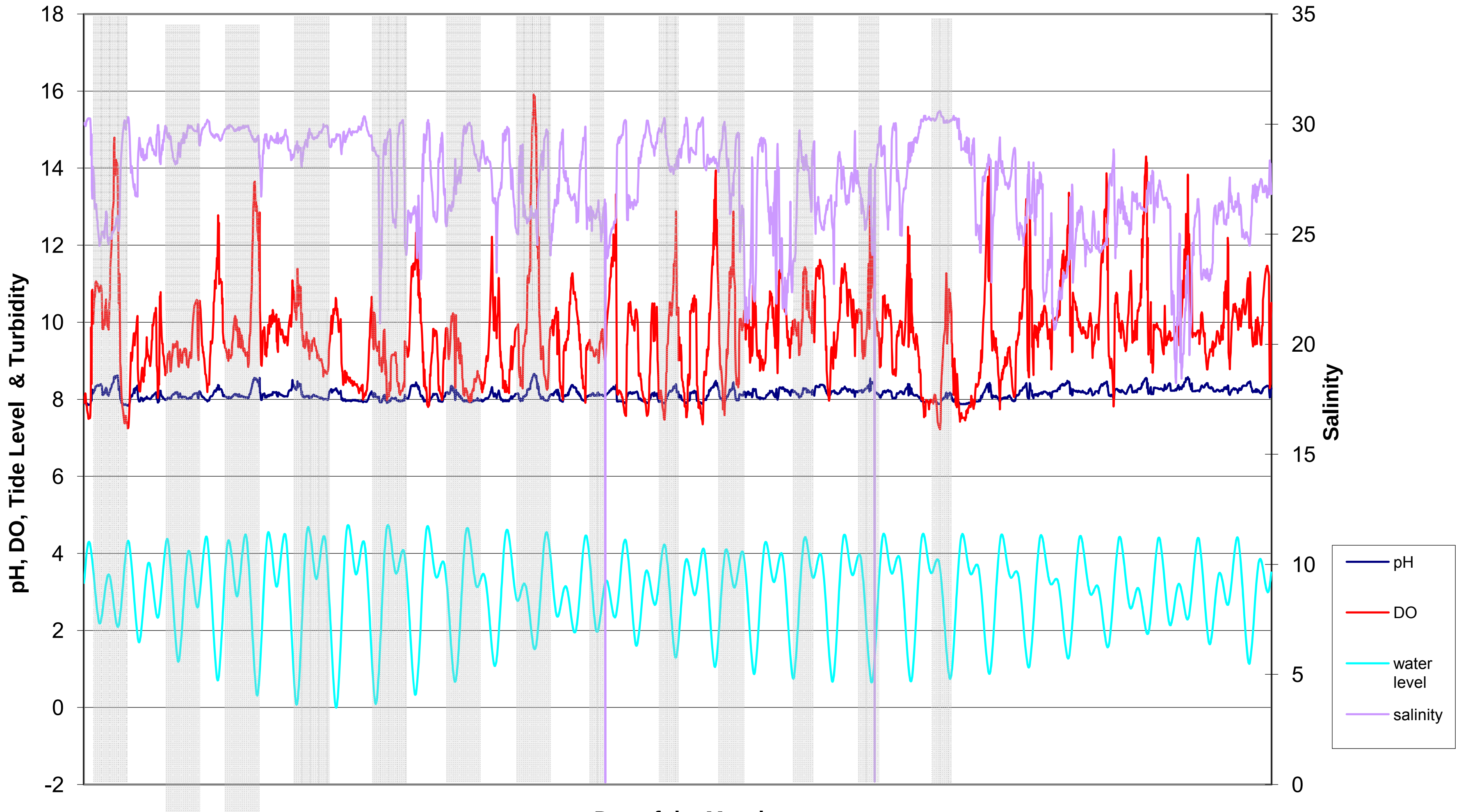
Sonde Data

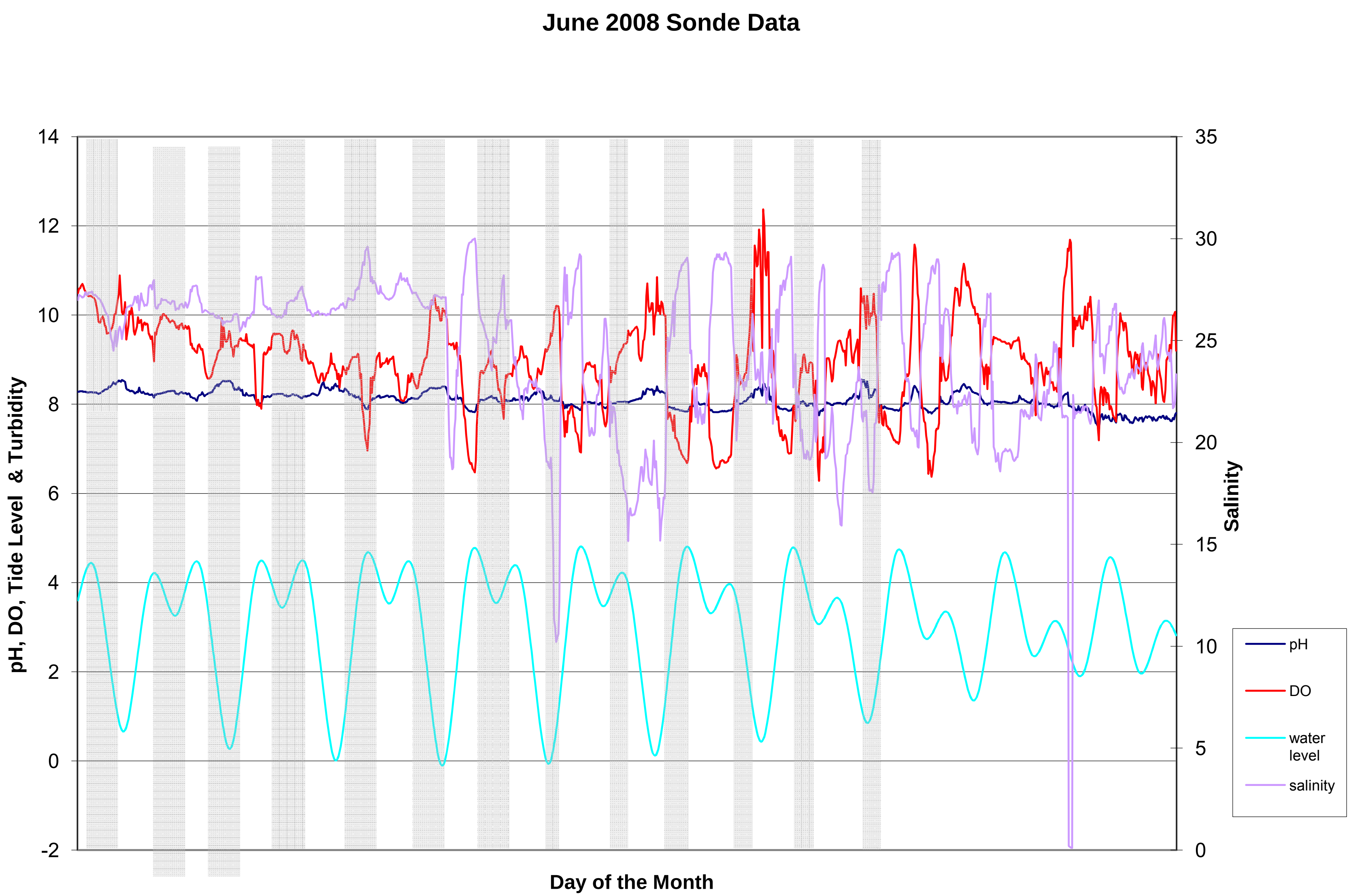


March 2008 Sonde Data
pH, DO, Tide Level & Turbidity
Salinity
Day of the Month
16
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
pH
DO
water level
salinity

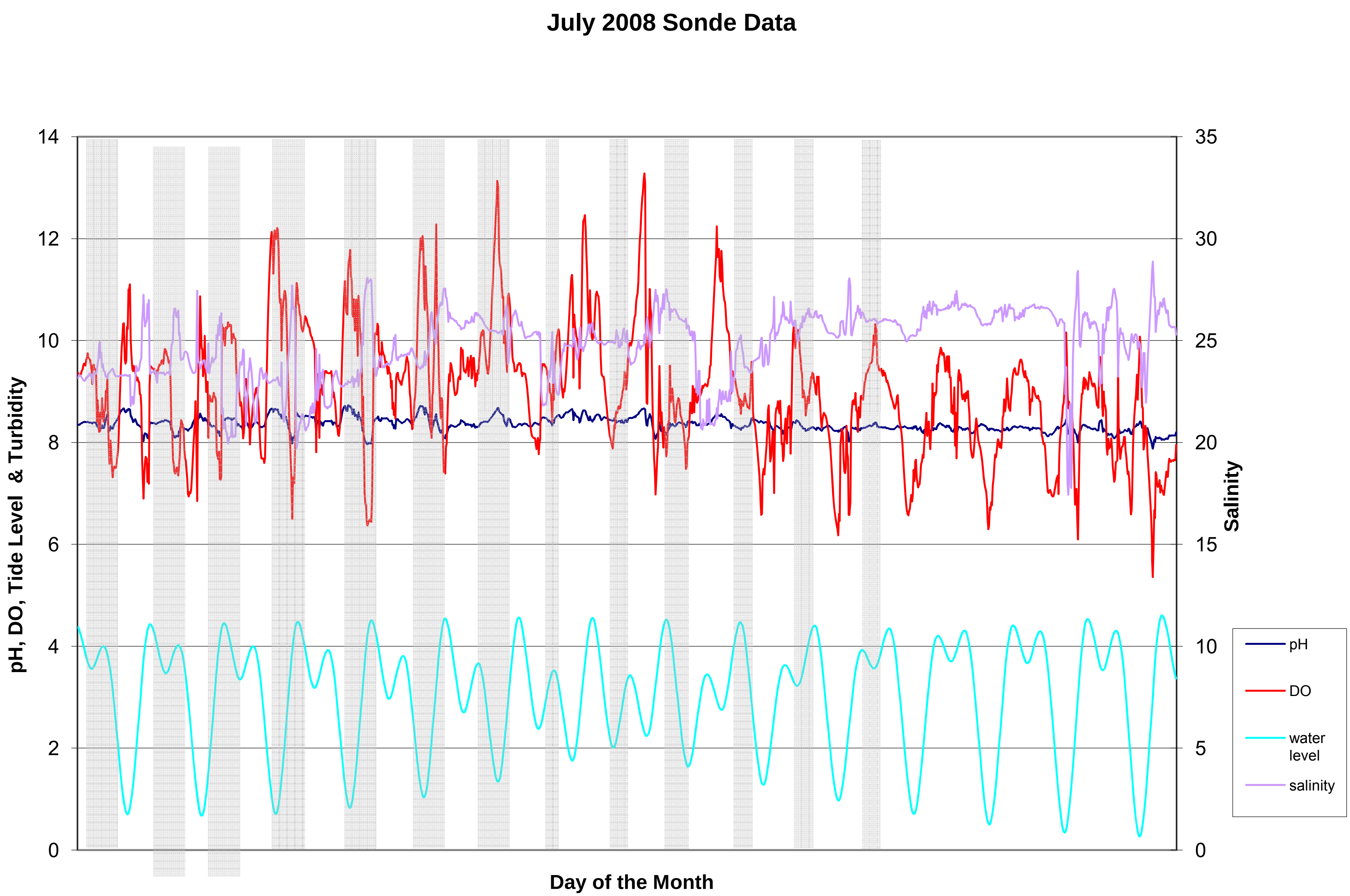

April 2008 Sonde Data
pH, DO, Tide Level & Turbidity
Salinity
Day of the Month
18
16
14
12
10
8
6
4
2
0
31
30
29
28
27
26
25
24
pH
DO
water level
salinity

May 2008 Sonde Data

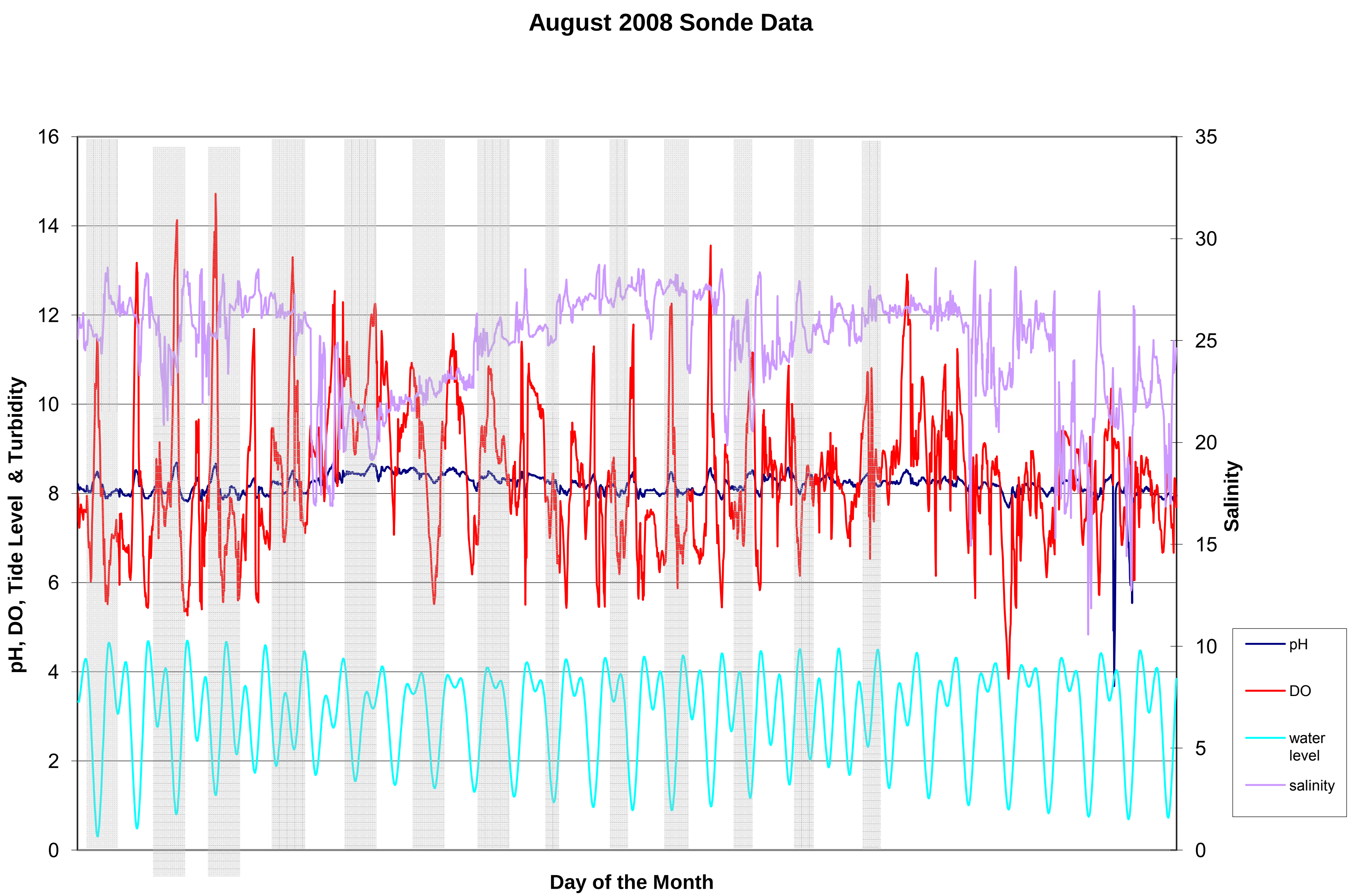




June 2008 Sonde Data
pH, DO, Tide Level & Turbidity
Salinity
Day of the Month
14
12
10
8
6
4
2
0
-2
35
30
25
20
15
10
5
0
pH
DO
water level
salinity



July 2008 Sonde Data
pH, DO, Tide Level & Turbidity
Salinity
Day of the Month
14
12
10
8
6
4
2
0
35
30
25
20
15
10
5
0
pH
DO
water level
salinity



August 2008 Sonde Data
16
14
12
10
8
6
4
2
0
pH, DO, Tide Level & Turbidity
35
30
25
20
15
10
5
0
Salinity
Day of the Month
pH
DO
water level
salinity

APPENDIX D

Eelgrass Statistical Analysis Results

Bonferroni adjusted probability values using separate variances are provided followed by the probability values calculated using pooled variance in brackets. p-values <0.0025 were considered significant (0.05/20). The Bonferroni adjustment requires that each data set has variation; standard two-sample, 2-tailed t-tests were used to analyze data in cases where the variance was zero.

Table I Bonferroni adjusted probability values attained for each parameter using a two-sample t-test comparing data sets from 2008 and 2007

Site #	Total Density	Length	Width	LAI	Reproductive Density
Inter-causeway near Coal Port Causeway					
1	1.0 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	*0.0004
2	0.022 (0.019)	0.004 (0.004)	1.0 (1.0)	0.004 (0.004)	0.012 (0.009)
Inter-causeway near Ferry Causeway					
5	1.0 (1.0)	0.0 (0.0)	0.038 (0.035)	0.0 (0.0)	0.295 (0.269)
6	0.637 (0.636)	1.0 (1.0)	1.0 (1.0)	0.879 (0.874)	0.370 (0.352)
West of Coal Port Causeway					
3	0.567 (0.566)	1.0 (1.0)	1.0 (1.0)	0.786 (0.785)	0.150 (0.145)
4	0.0 (0.0)	1.0 (1.0)	0.634 (0.630)	0.0 (0.0)	1.0 (1.0)
Boundary Bay					
WR1	0.470 (0.469)	0.624 (0.613)	1.0 (1.0)	0.500 (0.480)	0.102 (0.093)
WR2	0.891 (0.888)	0.378 (0.375)	1.0 (1.0)	0.220 (0.220)	0.0 (0.0)
WR3	0.0 (0.0)	0.001 (0.001)	1.0 (1.0)	0.0 (0.0)	0.122 (0.109

Note: * Standard t-test p-value (not adjusted)

Table II Bonferroni adjusted probability values attained for each parameter using a two-sample t-test comparing data sets from 2008 and 2003

Site #	Total Density	Length	Width	LAI	Reproductive Density
Inter-causeway near Coal Port Causeway					
1	1.0 (1.0)	0.0 (0.0)	*1.21E-5	0.0 (0.0)	*0.0008
2	0.0 (0.0)	0.0 (0.0)	*6.07E-6	0.0 (0.0)	1.0 (1.0)
Inter-causeway near Ferry Causeway					
5	0.004 (0.004)	0.019 (0.018)	0.001 (0.001)	0.012 (0.012)	0.109 (0.095)
6	0.002 (0.002)	1.0 (1.0)	0.537 (0.510)	0.042 (0.042)	0.705 (0.697)
West of Coal Port Causeway					
3	1.0 (1.0)	1.0 (1.0)	0.0 (0.0)	0.001 (0.001)	0.842 (0.841)
4	0.0 (0.0)	0.312 (0.289)	0.0 (0.0)	1.0 (1.0)	1.0 (1.0)
Boundary Bay					
WR1	0.0 (0.0)	0.192 (0.173)	1.0 (1.0)	0.003 (0.001)	0.0 (0.0)
WR2	0.0 (0.0)	1.0 (1.0)	1.0 (1.0)	0.0 (0.0)	0.0 (0.0)
WR3	0.0 (0.0)	0.468 (0.453)	1.0 (1.0)	0.009 (0.007)	0.025 (0.017)

Note: * Standard t-test p-value (not adjusted)

APPENDIX E

Bird Identification Codes

Bird Identification Codes

Code	Species	sp	su	f	w
AMAV	American Avocet			ac	ac
ABDU	American Black Duck [I]			ca	ca
AMCO	American Coot	u			u
AMDI	American Dipper				ac
AGPL	American Golden-Plover			ca	
AMGO	American Goldfinch	f	f	f	f
AMKE	American Kestrel	r	r	r	ca
AMPI	American Pipit	u		f	ca
AMRO	American Robin	f	f	f	f
ATSP	American Tree Sparrow	ca			ca
AMWI	American Wigeon	a	r	a	a
ANHU	Anna's Hummingbird		ca	ca	ca
BASA	Baird's Sandpiper	r		u	
BAEA	Bald Eagle	c	f	f	c
BTPI	Band-tailed Pigeon	r	r	r	ca
BKSW	Bank Swallow		r	r	
BNOW	Barn Owl	r	r	r	r
BASW	Barn Swallow	f	f	c	ac
BDOW	Barred Owl				ac
BAGO	Barrow's Goldeneye	r		r	r
BEKI	Belted Kingfisher	u	u	u	u
BEWR	Bewick's Wren	r	ca	r	r
BLSC	Black Scoter	r		r	r
BLSW	Black Swift	f	f		
BLTU	Black Turnstone			r	r
BBPL	Black-bellied Plover	a	u	a	c
BCCH	Black-capped Chickadee	f	f	f	f
BCNH	Black-crowned Night-Heron			ac	
BHGR	Black-headed Grosbeak	r	r		
BLKI	Black-legged Kittiwake	ac			
BTWE	Blue-winged Teal	r	r	r	
BOGU	Bonaparte's Gull	a	c	a	r
BRCO	Brandt's Cormorant				r
BRAN	Brant	a	r	u	c
BRBL	Brewer's Blackbird	c	u	c	a
BRCR	Brown Creeper				r
BHCO	Brown-headed Cowbird	f	u	u	r
BUFF	Bufflehead	c	r	c	f
BUOR	Bullock's Oriole		ca		
BUSH	Bushtit	f	f	f	c
CAGU	California Gull	c	f	c	r
CAGO	Canada Goose	a	f	c	a
CANV	Canvasback	r		r	r
CATE	Caspian Tern	f	f	f	
CAVI	Cassin's Vireo	ca		ca	
CEWA	Cedar Waxwing	u	f	f	ca
CBCH	Chestnut-backed Chickadee				r
CHSP	Chipping Sparrow			ca	
CITE	Cinnamon Teal	r	r	r	ca
CLGR	Clark's Grebe			ca	
CLSW	Cliff Swallow	u	u	u	
COGO	Common Goldeneye	u	r	u	f
COGR	Common Grackle				ac
COLO	Common Loon	a	u	a	c
COME	Common Merganser			r	r
COMU	Common Murre			r	r
CONI	Common Nighthawk		ca	ca	
CORA	Common Raven	r	r	r	r
CORE	Common Redpoll				ac
COSN	Common Snipe	r	ca	r	r
COTE	Common Tern	u	r	f	
COYE	Common Yellowthroat	u	u	u	
COHA	Cooper's Hawk	u	u	u	u
DEJU	Dark-eyed Junco	f	ca	f	f

Code	Species	sp	su	f	w
DCCO	Double-crested Cormorant	f	u	f	f
DOWO	Downy Woodpecker	r	r	r	r
DUNL	Dunlin	a		a	a
EAGR	Eared Grebe				ca
EAKI	Eastern Kingbird	r	r		
EMGO	Emperor Goose				ac
EUWI	Eurasian Wigeon	f		f	f
EUST	European Starling [I]	c	c	c	a
EVGR	Evening Grosbeak	r		r	r
FOSP	Fox Sparrow	u		u	u
FRGU	Franklin's Gull		r	r	
GADW	Gadwall	f	u	f	f
GLGU	Glaucous Gull				r
GWGU	Glaucous-winged Gull	a	a	a	a
GOEA	Golden Eagle	ca			
GCKI	Golden-crowned Kinglet				r
GCSP	Golden-crowned Sparrow	u		u	u
GCRF	Gray-crowned Rosy-Finch				ac
GBHE	Great Blue Heron	c	c	c	c
GREG	Great Egret		ca		
GHOW	Great Horned Owl		ca		
GRSC	Greater Scaup	a	r	a	a
GWFG	Greater White-fronted Goose	ca			ca
GRYE	Greater Yellowlegs	f	r	f	u
GRHE	Green Heron	r	r	r	
GWTE	Green-winged Teal	a	r	a	a
GYRF	Gyrfalcon	ca			r
HAWO	Hairy Woodpecker				ca
HADU	Harlequin Duck	r			r
HASP	Harris's Sparrow			ca	ca
HEEG	Heermann's Gull			ca	
HETH	Hermit Thrush				ca
HEGU	Herring Gull	u		u	u
HOME	Hooded Merganser			r	r
HOGR	Horned Grebe	c		c	c
HOLA	Horned Lark			r	
HOFI	House Finch	f	f	f	c
HOSP	House Sparrow [I]	c	c	c	c
HUGO	Hudsonian Godwit			ca	
HUVI	Hutton's Vireo	ca			
KILL	Killdeer	f	u	f	u
LZBU	Lazuli Bunting		ac		
LESA	Least Sandpiper	a	r	a	
LESC	Lesser Scaup	f	ca	f	f
LEYE	Lesser Yellowlegs	c	ca	c	
LISP	Lincoln's Sparrow	r		r	r
LIST	Little Stint			ac	
LBCU	Long-billed Curlew			ca	
LBDO	Long-billed Dowitcher	f	ca	c	u
LEOW	Long-eared Owl				ac
LTDU	Long-tailed Duck (formerly Oldsquaw)		ca	r	r
MALL	Mallard	a	f	a	a
MAGO	Marbled Godwit		ca	ca	ac
MAMU	Marbled Murrelet				ac
MAWR	Marsh Wren	u	u	u	r
MERL	Merlin	r	r		r
MEGU	Mew Gull	a	r	a	a
MOBL	Mountain Bluebird	ca			
MODO	Mourning Dove	r	r	r	
MUSW	Mute Swan [I]	ca			ca
NOFL	Northern Flicker	f	ca	f	u
NOGO	Northern Goshawk			ca	ca
NOHA	Northern Harrier	u	u	u	u
NHOW	Northern Hawk Owl				ac

Bird Identification Codes

Code	Species	sp	su	f	w
NOPI	Northern Pintail	a	r	a	a
NRWS	Northern Rough-winged Swallow	r	r	r	
NOSL	Northern Shoveler	u	f	u	f
NOSH	Northern Shrike	r		r	r
NOCR	Northwestern Crow	c	f	c	c
OSFL	Olive-sided Flycatcher	ca			
OCWA	Orange-crowned Warbler	f	u	f	ac
OSPR	Osprey		ca	ca	
PALO	Pacific Loon	r		r	r
PSFL	Pacific-slope Flycatcher	r			
PAJA	Parasitic Jaeger			r	
PESA	Pectoral Sandpiper		r	f	
PECO	Pelagic Cormorant	u		u	f
PEFA	Peregrine Falcon	u	r	u	u
PBGR	Pied-billed Grebe	r		r	r
PIGU	Pigeon Guillemot				ca
PIWO	Pileated Woodpecker				ac
PISI	Pine Siskin	f	r	f	f
PRFA	Prairie Falcon				ca
PUFI	Purple Finch	r		r	r
RECR	Red Crossbill	r	r	r	r
REKN	Red Knot			ca	
RBME	Red-breasted Merganser	f	ca	f	u
RBNU	Red-breasted Nuthatch				ca
RBSA	Red-breasted Sapsucker				ac
REVI	Red-eyed Vireo	ca		ca	
REDH	Redhead				ca
RNGR	Red-necked Grebe	u		c	u
RNPL	Red-necked Phalarope	r		r	
RNST	Red-necked Stint			ac	
RTHA	Red-tailed Hawk	u	r	u	u
RTLO	Red-throated Loon	f		u	f
RWBL	Red-winged Blackbird	a	f	a	a
RBGU	Ring-billed Gull	a	a	a	f
RNPH	Ring-necked Pheasant [I]	u	u	u	u
RODO	Rock Dove [I]	f	f	f	f
ROSA	Rock Sandpiper				ca
RLHA	Rough-legged Hawk	r		r	r
RCKI	Ruby-crowned Kinglet	r		r	ca
RUDU	Ruddy Duck	r		r	r
RUTU	Ruddy Turnstone	r		r	ca
RUFF	Ruff			ca	
RUHU	Rufous Hummingbird	f	u	u	
SAND	Sanderling	c		c	c
SACR	Sandhill Crane	ca			
SAVS	Savannah Sparrow	f	f	f	f
SEPL	Semipalmated Plover	f	ca	f	ca
SESA	Semipalmated Sandpiper	ca		u	
SSHA	Sharp-shinned Hawk	r		r	r
SBDO	Short-billed Dowitcher	f		f	ca
SEOW	Short-eared Owl	r	r	r	r
SNBU	Snow Bunting			ca	
SNGO	Snow Goose	u		u	f
SNOW	Snowy Owl				ca
SOSA	Solitary Sandpiper		r	r	
SOSP	Song Sparrow	f	u	f	f
SORA	Sora	r	r		
SPSA	Spotted Sandpiper	u	r	u	ca
SPTO	Spotted Towhee	u	u	u	f
STJA	Steller's Jay			ca	r
STSA	Stilt Sandpiper		r	r	
SUSC	Surf Scoter	a	r	a	a
SURF	Surfbird				ca
SWTH	Swainson's Thrush	r	r		
SWSP	Swamp Sparrow			ca	ca
THGU	Thayer's Gull	f		f	f
TOSO	Townsend's Solitaire	r			
TOWA	Townsend's Warbler				ac
TRSW	Tree Swallow	f	f	c	
TRUS	Trumpeter Swan	r		r	r
TUSW	Tundra Swan	c			c
TUVU	Turkey Vulture	r	ca	r	ca
UNCA	Unknown *Calidris* Species				
UNDU	Unknown Duck Species				
UNGU	Unknown Gull Species				
VATH	Varied Thrush				ca
VASW	Vaux's Swift	f	f	u	
VGSW	Violet-green Swallow	f	f	c	
VIRA	Virginia Rail	ca	ca		ca
WAVI	Warbling Vireo	ca		ca	
WEGR	Western Grebe	u		c	u
WEGU	Western Gull	r		r	r
WEKI	Western Kingbird		ca		
WEME	Western Meadowlark	r	ca	r	r
WESA	Western Sandpiper	a	r	a	r
WSOW	Western Screech-Owl				ac
WETA	Western Tanager		ca		
WWPE	Western Wood-Pewee	ca			
WHIM	Whimbrel	ca	ca	ca	
WCSP	White-crowned Sparrow	f	u	f	u
WWSC	White-winged Scoter	f	r	f	f
WILL	Willet			ac	
WIFL	Willow Flycatcher	r	r	r	
WIPH	Wilson's Phalarope			r	
WIWA	Wilson's Warbler	r		r	
WIWR	Winter Wren			ca	ca
WODU	Wood Duck	ca			ca
YEWA	Yellow Warbler	f	u	f	
YHBL	Yellow-headed Blackbird	ac			
YRWA	Yellow-rumped Warbler	f	r	f	r

Seasonal Occurrence
Sp = Spring (Mar. - May; including spring migrants)
S = Summer (June - mid Aug.; including spring arrival and fall departure)
F = Fall (mid Aug. - Nov.; including fall migrants)
W = Winter (Nov./Dec. - Feb.; including fall arrival and spring departures)

Relative Abundance
a = abundant [100 or more per day]
c = common [25 to 100 per day]
f = fairly common [5 to 25 per day]
u = uncommon [1 to 5 per day, with at least 10 records per year]
r = rare, but regular [1 to 10 records per year]
ca = casual [2 to 10 documented records in checklist area]
ac = accidental [only 1 documented record in checklist area during the specified season]