

FINAL TECHNICAL REPORT (VERSION 2.0)

PHYSICAL OCEANOGRAPHY
OF THE POINT THOMSON
UNIT AREA:
1997 AND 1998
REGIONAL STUDIES

Prepared for

BP AMOCO

and

Pt. Thomson Unit Owners

May 25, 1999

URS Greiner Woodward Clyde

A Division of URS Corporation

3501 Denali Street, Suite 101
Anchorage, Alaska 99503

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BP AMOCO and its lease partners are currently evaluating coastal petroleum reservoirs for commercial development in the Pt. Thomson Unit. Foreseeable development may include a gravel-fill dock extending to the 10-ft isobath, coastal well pads, a central process facility, an in-field road and a pipeline system, an airstrip, and a transportation pipeline connecting with the Badami pipeline. Federal permits will be required to construct the proposed development, thus, an environmental impact analysis will be completed based on procedures promulgated in the National Environmental Policy Act (NEPA) of 1969.

There is a lack of available physical environment and ecology data available for the Pt. Thomson Unit to support a NEPA analysis, thus, BP AMOCO initiated several studies to collect area-wide or regional data sets. The goal of these studies is to collect baseline information on the physical environment and ecology such that potential habitat alteration and wildlife disturbance can be evaluated during the NEPA analysis. Site-specific environmental studies will be developed in subsequent years as facility engineering design evolves. The combination of regional and site-specific studies is necessary to meet U.S. Federal and State of Alaska regulatory requirements.

This report presents the findings from the 1997 and 1998 regional physical oceanography studies conducted within the lagoon system that extends the length of the Pt. Thomson Unit from Bullen Point to Brownlow Point (Figure 1-1). The lagoon, known as Lions Lagoon, is separated from the Beaufort Sea by a barrier island complex that includes the Maguire Islands and Flaxman Island. These reconnaissance studies were designed to:

- Collect a representative data set to verify that regional processes observed throughout the Beaufort Sea are valid to describe the behavior and character of lagoon waters
- Collect baseline water quality and current velocity data to support environmental permit applications
- Build a multi-year regional physical oceanography data set to support a comprehensive Environmental Impact Statement.

2.1 REGIONAL PROCESSES

During the early 1980s, Kinnetic Laboratories, Inc. (1983) conducted an environmental study with physical oceanographic components that documented conditions within Lions Lagoon and adjacent waters. The study objectives were broad and focused on describing regional processes. Nearly two decades later, numerous observations and analyses throughout the coastal Beaufort Sea have provided a well-founded understanding of the regional oceanography (Colonell and Gallaway 1990). These studies indicate that the hydrography of virtually any location along the Alaska Beaufort coast is governed primarily by proximity of a freshwater source and recent wind history, and secondarily by the occasional profound effects of regional upwelling and downwelling phenomena. Substantial fresh water input results in brackish nearshore waters immediately adjacent to the river delta. Wind stress serves to advect this freshwater discharge down current and promotes vertical mixing. The prevailing winds tend to parallel the coast, such that easterly winds result in an offshore movement of surface water which is replaced with upwelled marine bottom waters. Conversely, westerly winds force surface waters onshore, resulting in elevated water levels and typically uniform brackish nearshore waters.

Lions Lagoon is not unique; Simpson Lagoon located west of Prudhoe Bay is similar in size, depth, orientation to prevailing winds, and fresh water input. Environmental studies (summarized by Colonell and Gallaway 1990) conducted within Simpson Lagoon indicate that the regional oceanographic processes influence the water quality and movement throughout the lagoon system. Thus, Simpson Lagoon serves as an useful analog to provide insight to the dynamics of Lion Lagoon.

2.2 STUDY OBJECTIVES

The 1997 and 1998 physical oceanography studies are based on the current understanding of regional physical oceanographic processes for the nearshore Beaufort Sea and Simpson Lagoon. The study objectives are to:

- Collect representative hydrodynamic (current velocity and water level), hydrographic (water column structure), water quality, and meteorological records for multiple years to construct a regional physical oceanography database
- Verify that the regional physical oceanographic processes control the water movement, water column structure, and water quality within the lagoon system

The sample design includes documenting the water exchange through the barrier island channels that separate the lagoon system with the Beaufort Sea. Sampling stations are positioned to document freshwater input from local rivers and observe marine water intrusions into the lagoon system. Relative water level measurements, correlated to wind stress and marine water intrusions serve to confirm the regional upwelling and downwelling phenomena. The objectives of the 1997 and 1998 physical oceanography studies have been to describe the regional physical oceanographic conditions for the Pt. Thomson Unit nearshore waters. They are not site-specific studies that will satisfy the data requirements for a comprehensive NEPA analysis. As the conceptual engineering process evolves to the point that coastal facilities can be determined, site-

specific studies can be developed and integrated with regional studies to assure sufficient representative data are available.

2.3 DATA COLLECTION

The 1997 physical oceanography-meteorology study characterized the lagoon waters east of Pt. Thomson, in the vicinity of Flaxman Island. Current meters were deployed in Mary Sachs Entrance, east end of Flaxman Island, and in the lagoon north of an abandoned mainland drill pad. The lagoon mooring was lost, resulting in no data. A tide gauge was deployed on the south shore of Flaxman Island to measure the water level fluctuations within the lagoon. Nearby, a meteorological station was deployed on a bluff at the east end of Flaxman Island (Figure 2-1).

The 1998 study area was enlarged to include all of the lagoon system, extending from Bullen Point to Brownlow Point. Current meters, a tide gauge, and a meteorological station were deployed in the same locations as the 1997 survey; however, the lagoon mooring was lost, another current meter failed, and the other mooring could not be recovered due to sediment burial of the anchor. Four hydrography surveys were conducted between July and September 1998 to observe the natural variations in the water column structure and water quality (Figure 2-2). In situ measurements were made during all surveys, and water samples for chemical analyses were collected during the July and September surveys.

2.3.1 Meteorology

Coastal observations of wind velocity (e.g., speed and direction) collected within the study area support the physical oceanographic analyses. During 1997 and 1998, a portable meteorological station was established on top of a bluff at the east end of Flaxman Island. The 1997 record set was complete; however, the 1998 record was truncated when a severe storm damaged the station. The National Oceanic and Atmospheric Administration (NOAA) meteorological station at West Dock provided additional data to support analyses of regional processes.

2.3.2 Hydrodynamics (Water Movement)

The initial engineering design included one dock located east of Pt. Thomson. To reduce costs, all current meters and tide gauge moorings were located east of Pt. Thomson. Two moorings were positioned in the channels at each end of Flaxman Island to observe the water exchange between the Beaufort Sea and the eastern portion of Lions Lagoon. The current meter mooring deployed in the lagoon was to measure current velocities, temperature, and conductivity in the vicinity of the proposed dock.

2.3.3 Hydrography (Temperature and Salinity) and Water Quality

At each sampling station, a conductivity-temperature-depth (CTD) instrument recorded nearly continuous (0.5 second intervals) measurements of conductivity, temperature, and pressure as it was lowered through the water column. While salinity and density cannot be directly measured, they can be derived from CTD measurements. The CTD data (i.e., cast) collected at each station

were presented as a vertical profile of temperature and salinity to delineate the water column structure.

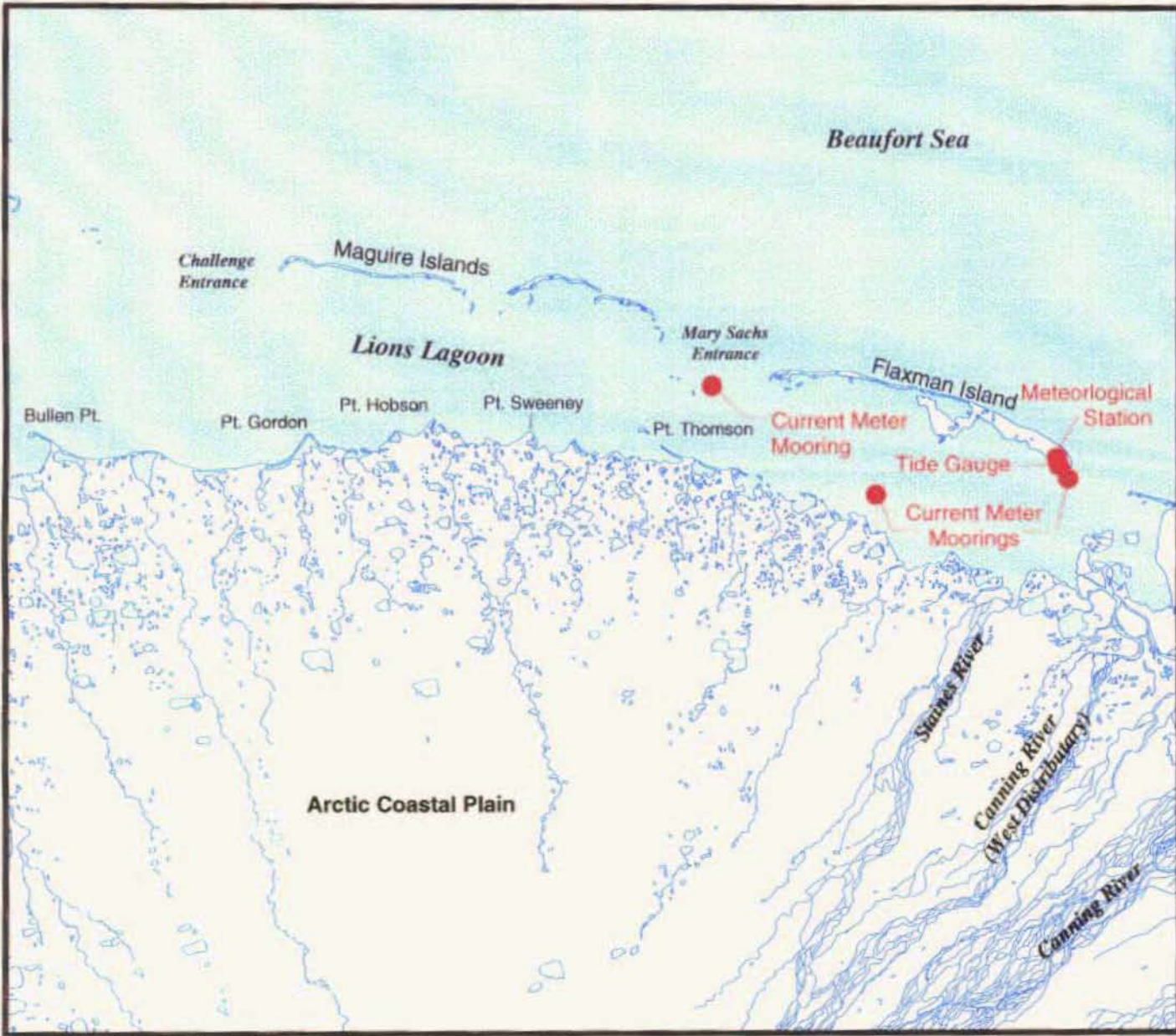
Standard water quality parameters monitored for typical industrial wastewater discharges were also measured in situ. Dissolved oxygen (DO), pH, and turbidity measurements were collected at depth intervals at selected stations to describe natural variations of Lions Lagoon waters.

2.3.4 Water Chemistry

Discrete water samples were collected for laboratory analysis at three water depths at the lagoon current meter mooring (Station FLW-CM) with a Niskin Sample Bottle. Each sample was analyzed for selected heavy metals, total suspended sediment (TSS), total organic carbon (TOC), and chemical oxygen demand (COD). Table 2.1 presents the laboratory methods used for each analysis.

Table 2.1 Laboratory analyses for samples collected during the 1998 summer open-water season.

Analysis	Laboratory	Method
BOD ₅	Prudhoe Bay Unit Laboratory (ARCO)	BOD 5-day method
TOC	MultiChem Analytical Services	9060
TSS	CT&E Environmental Services	160.2
COD	CT&E Environmental Services	410.1
Metal - Mercury	Quanterra Environmental Services	SW7470
Metals - Ar, Ba, Cr, Pb	Quanterra Environmental Services	6020M



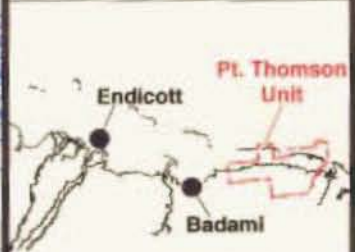
BP
**Pt. Thomson
 Unit Area
 Development**

Figure 2-1
**1997 Physical
 Oceanography
 Study Sampling
 Locations**



Scale (Statute Miles)
 0 1 2 3 4

Data Sources:
 BPXA Cartography
 U.S. Geological Survey



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Pt. Thomson Unit Area Development

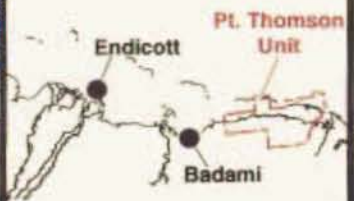
Figure 2-2

1998 Physical Oceanography Study Sampling Locations

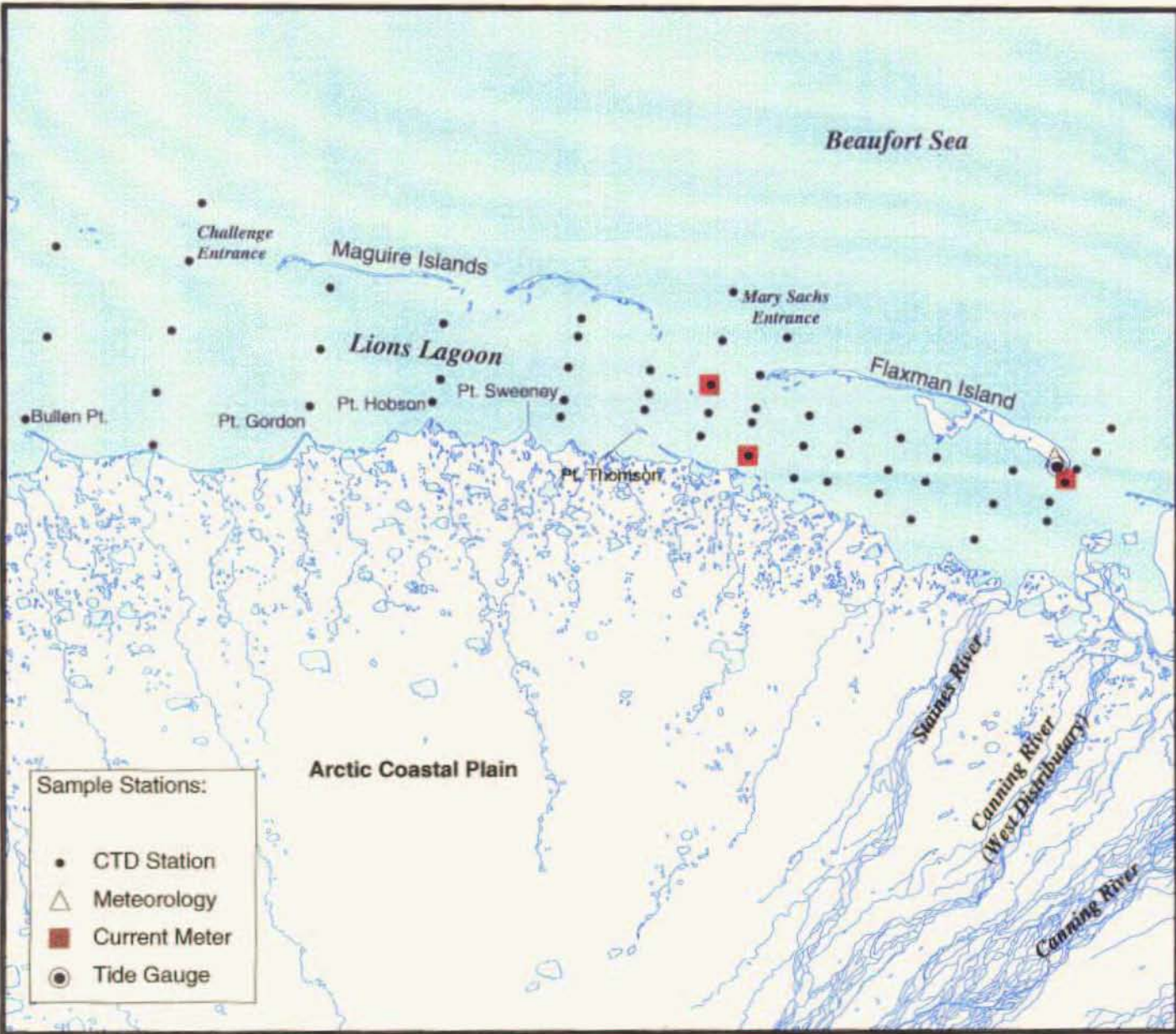


Scale (Statute Miles)
0 1 2 3 4

Data Sources:
BPXA Cartography
U.S. Geological Survey



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- Sample Stations:
- CTD Station
 - △ Meteorology
 - Current Meter
 - ⊙ Tide Gauge

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3.1 1997 PHYSICAL OCEANOGRAPHY RESULTS

The 1997 study collected time-series records from a meteorological station, a tide gauge (water level), and two current meter moorings. These instruments were deployed on 04 August 1997 and collected data until recovery on 12 September 1997.

3.1.1 Meteorological Data Set

The wind velocity (speed and direction) record indicated early to mid-August 1997 was a mixture of relatively short periods of east and west winds (Figure 3-1). Typically, winds shifted direction every 24 to 36 hours. Persistent easterly winds started on the 19 August 1997 and continued until the end of the survey, 12 September 1997. These persistent easterly winds were associated with relatively high wind speeds, with hourly averages reaching 30 knots on 26 August 1997. This 23 to 27 August storm caused damage to a marine geophysical survey working in the area.

3.1.2 Water Level

The tide gauge installed in a sheltered cove within Lions Lagoon at the east end of Flaxman Island provided a continuous water level record (Figure 3-1). All water elevations were relative, since the tide gauge elevation was not surveyed to a local datum. Astronomical tide fluctuations were evident by the 12-hour signal (period) that was an approximate height (magnitude) of 15 centimeters (cm) (0.5 foot); these measurements are consistent with regional observations.

The instrument record indicated that the water level varied approximately 1.2 meters (3.9 feet). During periods with persistent easterly winds, the water level dropped within the lagoon system, while periods of elevated water levels coincided with westerly winds. The water level can change rapidly; during the 23 to 27 August storm, the water level dropped 65 cm (2.1 feet) within 48 hours.

3.1.3 Hydrodynamics (Water Movement)

Two current meter moorings were recovered: one was positioned mid-channel in Mary Sachs Entrance and the other was located in the channel that separates the east end of Flaxman Island from Brownlow Point (Flaxman Pass). Both meters recorded mid-depth current velocities, water temperature, and conductivity. The current velocity records indicated that the direction of water movement was similar in both channels (Figure 3-2). The current direction records were correlated with local wind direction, indicating that water flowed toward the west during easterly winds and flowed eastward during westerly winds.

Current speeds were different; the median current speed recorded in Mary Sachs Entrance was 17 cm/s as compared to 35 cm/s in the Flaxman Pass. The cumulative frequency diagram (Figure 3-3) indicates that the current speeds in Flaxman Pass were higher than Mary Sachs Entrance.

3.1.4 Hydrography (Water Column Structure)

During instrument deployment, the field crew attempted to collect vertical water column profiles of conductivity and temperature; however, the CTD instrument failed. Complications in retrieving current moorings prevented a CTD survey at the end of the field program. However, the two recovered current meters provided an understanding of the interaction in water mass movement between the Beaufort Sea and the eastern portion of Lions Lagoon.

The computed salinity records for the Mary Sachs Entrance and Flaxman Pass current meter are similar (Figure 3-4). During deployment, both records indicated brackish, 21 to 23 part per thousand (‰) waters were present at mid-depth in both channels. Brackish conditions persisted for the next 6 days. On 10 August 1997, salinity abruptly rose to 30‰, in response to a period of easterly winds. This marked the first 1997 observation of marine water entering Lions Lagoon. After a period of mixed (easterly and westerly) winds, the salinity dropped back to brackish, 18 to 20‰, conditions.

During the 23 to 27 August storm, there was a sharp rise in salinity at the Mary Sachs Entrance mooring; however, salinity values at the Flaxman Pass mooring did not respond in a similar manner. The Flaxman Pass mooring is close to the Staines and Canning rivers and thus was exposed to a significant amount of fresh water compared to the Mary Sachs Entrance mooring. After the 23 to 27 August storm, the salinity values at the two moorings reflected nearly constant 30‰ marine conditions for the remainder of the deployment.

Temperature records from the two moorings corresponded with the salinity values. Water temperatures were relatively warm (5 to 6° Celsius [C]) for brackish waters, and dropped below 1°C during marine intrusions.

3.2 1998 PHYSICAL OCEANOGRAPHY RESULTS

The 1998 study attempted to collect time-series meteorological, current meter, and tide gauge data at the same locations as the 1997 study. However, the loss of current meter moorings and damage to the meteorological station resulted in a limited data set. Four CTD and two water quality surveys were conducted between late July and mid-September 1998. These surveys provided discrete snapshots of the regional water column structure and distribution of selected physical and chemical water quality parameters.

3.2.1 Meteorological Data Set

A partial wind velocity record was recovered from the meteorological station deployed on a bluff at the east end of Flaxman Island. The West Dock NOAA tide gauge and meteorological station were used to construct a complete record. Data from the two stations were compared for the period of overlapping records, and it was concluded that the records were sufficiently similar to support hydrography analysis. It is unlikely that the West Dock data would be adequate for detailed site-specific hydrodynamic analysis for Pt. Thomson waters; however, the loss of current meter moorings reduced the need for local meteorological observations.

Easterly winds persisted throughout much of July, with three consecutive storms having maximum average hourly speeds reaching 30 knots (Figure 3-5). By the end of July, the weather

patterns switched to a period of mixed westerly and easterly winds for most of early and mid-August, with the exception of the 4 to 7 August easterly wind event. Easterly winds events dominated of record after 23 August 1998.

3.2.2 Hydrography (Water Column Structure)

Fifty four stations aligned on fifteen transects were occupied during the summer field study to describe the ambient waters within Lions Lagoon. The initial survey conducted on 31 July 1998 encountered saline marine conditions after nearly a month of steady easterly winds (Figure 3-6). Lagoon waters were vertically uniform and relatively warm, with temperatures between 7 and 8°C (Figure 3-7). Fresh water, discharged directly into the east end of Lions Lagoon from the Staines and Canning rivers, was not significant at the time of the survey as indicated by saline (31.5‰) waters adjacent to the river mouths.

Winds alternated between the prevailing easterly and westerly directions such that by the 12 August 1998 survey, Lion Lagoon waters were brackish and warm (Figure 3-8). Freshwater discharge was evident by the low (<5‰) salinities adjacent to the Staines and Canning river mouths located at the east end of the lagoon. A strong salinity front situated in Flaxman Pass marked the location of mixing between the relatively fresh waters from the river discharge and the Beaufort Sea shelf waters. Mixing of the fresh water within the shallow eastern portion of the lagoon indicated that saltier shelf waters were entering the lagoon through the Mary Sachs Entrance. Surface and bottom salinities increased toward the north for waters west of the Mary Sachs Entrance. As in the 31 July 1998 survey, surface salinities were slightly lower near Bullen Pt. This could have been a result of tundra stream runoff that entered into the protected lagoon, where there was an absence of notable river discharge and mixing with shelf waters.

The 25 August 1998 survey coincided with a persistent easterly wind event, and revealed upwelled marine (30‰) bottom waters entering the lagoon through the gaps between the barrier islands (Figure 3-9). These marine waters reached the water surface in Mary Sachs Entrance (Figures 3-10 and 3-11). Freshwater discharge from the Staines and Canning rivers quickly mixed with nearshore waters south of Flaxman Island, creating brackish (22 to 27‰) conditions.

Easterly winds continued and the 13 September 1998 survey observed >30‰ marine waters dominating the lagoon from Pt. Thomson to Bullen Pt (Figure 3-12). Freshwater discharge from the Staines and Canning rivers resulted in a brackish (26 to 30‰) plume extending from the delta, westward along the mainland shore. A cross-section along the length of Lions Lagoon illustrates the uniform marine conditions in the west of Mary Sachs Entrance, and the brackish distal portion of the river discharge plume toward the east (Figure 3-13).

3.2.3 Water Quality

Dissolved oxygen measurements were conducted in the field, and discrete water samples were sent to a Prudhoe Bay laboratory for the July and September surveys. For all samples, the dissolved oxygen values indicated that Lions Lagoon waters were saturated or supersaturated with values typically above 9.5 milligrams per liter (mg/L) (Appendix F). Surface waters tended to have a slightly higher dissolved oxygen value than bottom water; however, the differences were probably not statistically significant.

The average pH value for the summer measurements was 8.0 standard units. Water column profiles indicated that there was a slight increase in pH with depth; however, there was no relationship established with any other water quality parameter collected during the 1998 summer study.

In situ turbidity measurements results confirmed that the influence of wind and waves affected the clarity of the water column. The 12 August 1998 survey was conducted under calm conditions and turbidity measurements averaged 3.4 nephelometric turbidity units (NTU) west of the river mouths. Elevated turbidity values up to 173 NTU were recorded in the shallow waters adjacent to the Staines and Canning river mouths at the east end of Lions Lagoon.

During the 25 August 1998 survey, recent easterly winds exceeded 15 knots, and thus, turbidity values were >10 NTU for waters throughout Mary Sachs Entrance and waters adjacent to the river mouths. Other measurements collected within the protected areas of the lagoon system typically were ≤ 8 NTU. Similar turbidity values and distribution were observed during the 13 September 1998 survey.

3.2.4 Water Chemistry

Water samples were collected during the 29 July and 11 September surveys to determine the natural concentrations of selected metals and TOC (Appendix F). Arsenic, chromium, lead, and mercury were not detected above method detection limits in these water samples. Barium concentrations during the 29 July survey averaged 0.015 milligrams per liter (mg/L), while the 11 September survey averaged 0.019 mg/L. However, the differences were probably not statistically significant.