SECTION 1
Introduction

1.1 Overview

The King County Department of Natural Resources and Parks and its predecessor agency Metro have a long history of water quality improvements and monitoring water quality in Puget Sound. As part of an ongoing intergovernmental effort to maintain and improve Puget Sound's water quality, the King County Wastewater Treatment Division oversees regional sewerage collection, treatment processes, and disposal systems that discharge wastewater to the Central Puget Sound Basin and waters flowing into the Sound. King County's Water and Land Resources Division's (WLRD) Marine and Sediment Assessment Group supports a comprehensive long-term marine monitoring program that assesses water quality in the Central Puget Sound Basin on behalf of and in coordination with the King County Wastewater Treatment Division.

The marine monitoring program is part of an intergovernmental monitoring effort, the Puget Sound Ambient Monitoring Program (PSAMP), with the County's program focusing primarily on water quality within King County boundaries. Other agencies involved in PSAMP that monitor water quality and/or environmental health of Puget Sound include the Washington Department of Ecology (water and sediment quality), Washington Department of Fish & Wildlife (contaminants in fish tissues, herring and rockfish populations), Washington Department of Natural Resources (nearshore vegetation and habitat), Washington Department of Health (shellfish growing areas and contaminants), National Oceanic and Atmospheric Administration (contaminants in fish), and U.S. Fish & Wildlife (contaminants in birds and fish). These agencies have monitoring stations throughout the Sound, including sites within King County. The main distinction between these programs and King County’s monitoring program is that the County has a larger number of stations within a concentrated area which are targeted near wastewater treatment plant discharges. Although other agencies have monitoring stations within King County, the stations do not overlap with the County's stations which allows a broader area of Puget Sound marine waters to be monitored.

The objectives of the marine monitoring program are to provide an understanding of water quality within King County and to assess water quality near the County's wastewater plant outfalls to identify if discharges are affecting water quality. The County maintains a long-term dataset, with over 35 years of data collected at some sites, that provides insight to natural variations and a basis to assess and measure recent water quality conditions near outfalls and throughout the entire study area.

King County is planning to build a new regional wastewater treatment plant in southern Snohomish County that will discharge secondary treated effluent through a marine outfall located in southwest Snohomish County. In support of siting a suitable location for the

marine outfall, an extensive marine monitoring program called the Marine Outfall Siting Study (MOSS) was initiated in October 1998 and continued throughout 2002.

This report summarizes results of King County's National Pollutant Discharge Elimination System (NPDES) and ambient marine monitoring programs for 2002 and 2003. In addition, MOSS water quality sampling results for 2002 are summarized in this report. The report provides an overview of the sites monitored, matrices (e.g., water and sediment) sampled, parameters measured, and includes a summary of analytical results.

1.2 Wastewater Collection and Treatment

Wastewater from homes, businesses, and industries within King County and southern Snohomish County is transported through pipelines belonging to local sewer agencies and then through King County's system of larger pipelines (interceptors) to the treatment plants operated by King County. At the plants, solids are separated from liquids. The liquids are then treated, disinfected, and discharged into Puget Sound marine waters. The separated solids are also treated and the resulting rich organic material, known as biosolids, is utilized to enrich agricultural and forest soils. Biosolids are also turned into compost, marketed in the greater Seattle area as GroCo®, which can be used as a soil and lawn conditioner.

The County's Wastewater Treatment Division provides wastewater treatment and disposal services to 17 cities, 16 local sewer and/or water districts, and the Muckelshoot Indian Tribe. The system serves about 1.4 million people in King County, southern Snohomish County, and northern Pierce County, transporting and treating about 200 million gallons of wastewater each day. To accomplish this, King County currently operates and maintains three wastewater treatment plants, two combined sewer overflow (CSO) treatment plants, 42 pump stations, and approximately 539 kilometers (335 miles) of sewer lines (Figure 1-1). The West Point Treatment Plant (TP), South Plant (formerly known as the Renton and East Division Reclamation TP), and Vashon Island TP provide secondary wastewater treatment. The average wet-weather flows (based upon average wet season flows from November through April excluding large storms) for the West Point and South TPs are 133 and 115 million gallons per day (MGD), respectively. The maximum capacity (maximum flows that can be handled by the plants for short periods with a portion of the flows receiving minimal treatment) of the West Point, South, and Vashon TPs are 440, 325, and 1.0 MGD, respectively. The Alki and Carkeek CSO Treatment Plants store combined wastewater and stormwater flow and later pump it to the West Point TP or provide the equivalent of primary treatment and disinfection before discharging it to Puget Sound. The South TP outfall discharges at a water depth of 640 feet (ft), the West Point TP outfall at 230 ft, the Vashon TP outfall at 200 ft, the Alki CSO outfall at 143 ft, and the Carkeek CSO outfall at 200 ft.

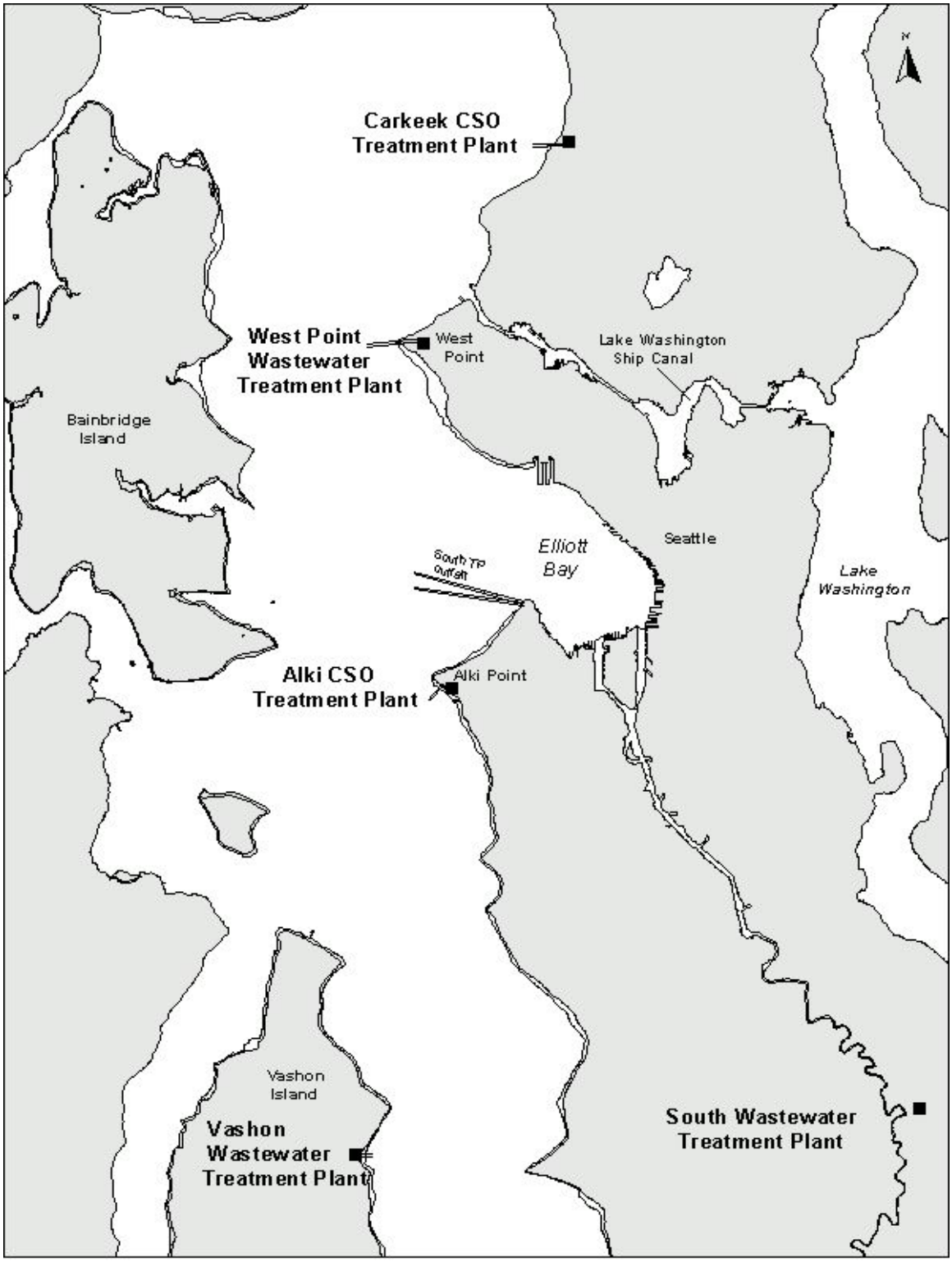

Figure 1-1. King County Wastewater Treatment Plant & Outfall Locations

The West Point TP discharges the largest volume of effluent of the three secondary facilities. In 2002, the average daily discharge rate was 107.1, 74.8, and 0.10 MGD for the West Point, South, and Vashon TPs, respectively. Average monthly wastewater discharge volumes from the two largest TPs are shown for the last 10 years in Figure 1-2, along with monthly total rainfall. The slight decrease in discharge volumes shown in late fall/winter 2000 and 2002 compared to the last several years corresponds to low rainfall amounts, particularly for 2000 which had the lowest recorded rainfall amount (28.7 inches) since 1985. A drier than normal year also occurred in 2002, with a total of 32.1 inches recorded for the year. Effluent discharges peak during times with high rainfall, with January and December having the highest average monthly discharge rates (see Section 3.1 for 2002 rainfall patterns). Average monthly wastewater discharge volumes from the Vashon TP are shown for the last three years in Figure 1-3 along with total rainfall amounts measured at the treatment plant.

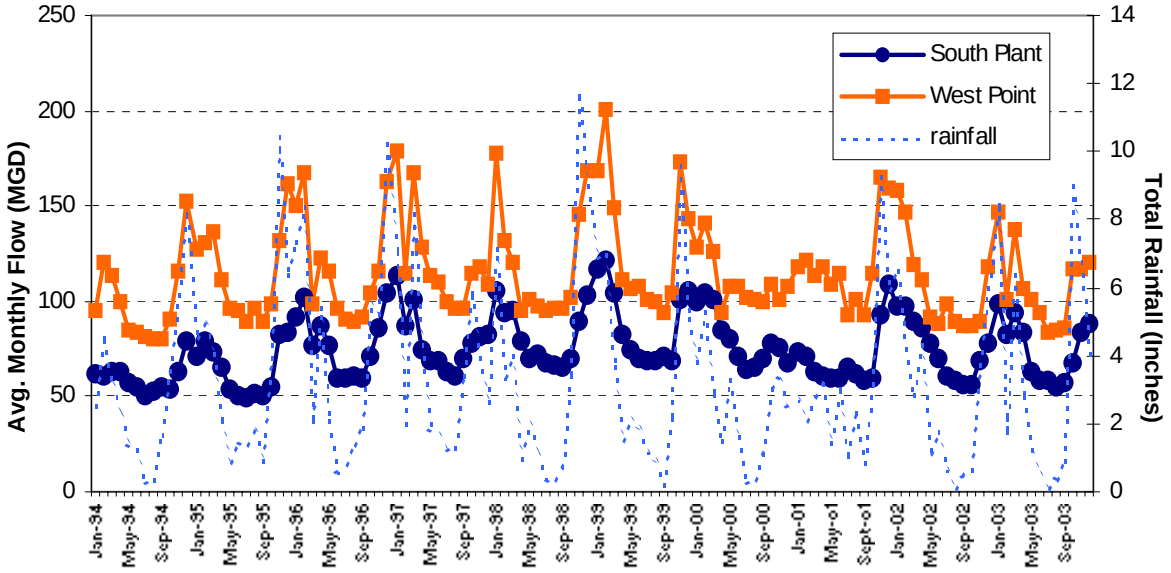

Figure 1-2. Average Monthly Flow from South Plant and West Point TPs and Total Monthly Rainfall (at SeaTac) Between 1994 and 2003

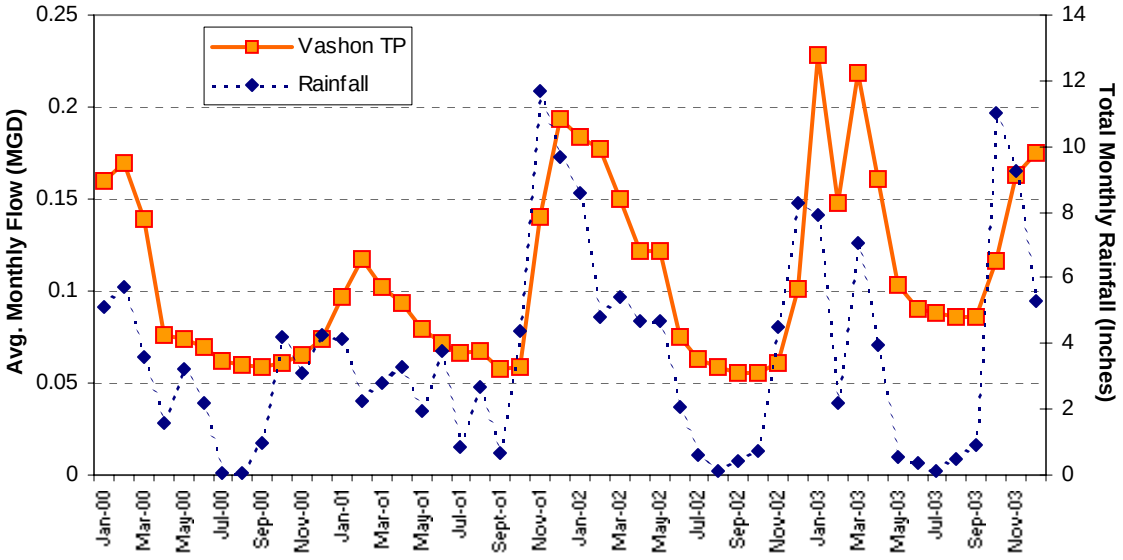

Figure 1-3. Monthly Average Vashon TP Flows and Total Monthly Rainfall (measured at the Vashon TP) Between 2000 and 2003

During 2002, the Alki CSO storage and TP had a total of two discharge events, one in January and one in February. The volume discharged per event was 13.36 and 1.0 MG, respectively. In 2003, there were four discharge events; one in January (8.35 MG), one in March (2.7 MG), one in October (23.43 MG), and one in November (21.76 MG). The Carkeek CSO storage and TP had a total of four discharge events in 2002, one in January, two in February, and one in December. The discharge volumes per event were 7.83, 0.19, 2.03, and 0.4 MG, respectively. In 2003, there were five discharge events at Carkeek; one in January (1.7 MG), two in March (1.5 MG and 0.28 MG), one in October (11.3 MG), and one in November (11.86 MG). In 2003, there were significant rain events in October and November, which are discussed in more detail in Section 3.1.

King County took over operation of the Vashon Island TP in November 1999. The plant previously discharged effluent to a water depth of about –40 feet below mean lower low water (MLLW) through a 1,300 foot outfall pipe located on the east side of Vashon Island south of Point Beals. The County is in the process of planning and constructing a new facility as the current treatment plant is undersized to handle peak wastewater flows. The new treatment facilities include a newly constructed longer outfall pipe that discharges effluent to a water depth of about –200 ft MLLW. The new outfall became operational in early spring 2005.

The wastewater and CSO treatment plants discharge treated effluent directly into Puget Sound marine waters. The Clean Water Act states that all wastewater collection and

treatment facilities that discharge effluent into surface waters are required to have an NPDES permit. In Washington, the Washington State Department of Ecology (Ecology) administers the permitting process by delegation from the U.S. Environmental Protection Agency. NPDES permits set limits on the quality and quantity of wastewater that is discharged at each facility. The NPDES permit for the West Point, Carkeek, and Alki TPs was reissued in 2003 and expires in 2008. The South Plant NPDES permit expired in 2002 and was administratively extended until the renewal was issued in 2003. The current Vashon Island TP NPDES permit expired in 2001 and was renewed in 2002. The individual treatment plant NPDES permits can be reviewed at the following website http://www.ecy.wa.gov/programs/wq/permits/northwest_permits.html.

1.2.1 Brightwater Treatment System

The King County Wastewater Treatment Division is making major improvements to its sewage treatment system as part of an approved long-term plan. These improvements are necessary in order to contend with rapid population growth and support the division's mission to protect public health and the environment. One such improvement is the Brightwater Treatment System which includes a new treatment plant, associated conveyance pipes, and a marine outfall in Puget Sound.

A new treatment plant is necessary as the current regional wastewater system will reach capacity by 2010 due to rapid growth in both King and Snohomish Counties and failure to have sufficient capacity in place when needed could lead to problems, such as public health issues. The Brightwater siting process began in 2000 as it takes at least a 10-year period to locate a suitable site, and to design and build the required facility and support structures.

King County conducted an extensive four-year siting process that began by considering over 100 potential sites. Subsequent phases of the process narrowed the number of sites under consideration. An environmental review process was conducted on three system alternatives. A Final Environmental Impact Statement (EIS) was issued on November 19, 2003 that evaluated the potential impacts and possible mitigation measures for the Brightwater system. On December 1, 2003 the King County Executive decided that the regional Brightwater Treatment System would be located northeast of Woodinville. The Brightwater facilities are being located in the north part of the area served by the regional system in order to handle population growth in north King County and south Snohomish County. The outfall will discharge treated wastewater into Puget Sound offshore of Point Wells at a water depth of just over 600 ft.

1.3 Other Puget Sound Discharges

There are several types of anthropogenic inputs that enter Puget Sound marine waters. A brief description of the major inputs is provided below. Discharge locations for marine wastewater treatment plant outfalls in Puget Sound are shown in Figure 1-4. Figure 1-5 shows discharge locations within King County for wastewater treatment plant, CSO, and stormwater discharges.

1.3.1 Wastewater Treatment Plant Effluent

There are both primary and secondary wastewater treatment plant discharges into Puget Sound originating from city, county, tribal, federal, and privately operated wastewater treatment facilities. In 2002 and 2003, King County operated 5 wastewater/stormwater treatment plants and there are 50 other permitted wastewater facilities with discharges to Puget Sound, excluding facilities on the outer coast and north of Admiralty Inlet. Discharge volumes and discharge distance offshore vary dependent upon the capacity of the facility. King County's wastewater treatment plant outfalls, which are located 2,800 (Vashon TP), 3,600 (West Point TP), and 10,294 (South TP) feet offshore, are located the furthest offshore of all Puget Sound outfalls, with the exception of the Kimberly-Clark marine outfall in Port Gardner, which is located 2,700 feet offshore.

1.3.2 Combined Sewer Overflow Discharges

CSO discharges consist of untreated sewage and stormwater occurring when sewers have reached their capacity during heavy rainfall events. Between the late 1800s and 1940s in the City of Seattle, engineers designed combined sewer systems to convey both sanitary sewage and stormwater runoff in a single pipe to the nearest receiving body of water. In the early 1950s, most sewer systems were built as separated systems which conveyed sewage in one pipe and stormwater runoff in another pipe. In the late 1950s, treatment plants were built to treat wastewater. Combined sewer systems still exist in portions of older cities, including Seattle. Figure 1-5 shows locations of King County and City of Seattle CSOs in western King County. All the CSOs within King County are centered around Seattle, as this is the oldest part of the sewer system that has not yet been separated. Wastewater and stormwater from other parts of King County are collected and conveyed to treatment plants for treatment before being discharged. In 2002/2003 King County operated two CSO treatment plants that provide primary treatment before the effluent is discharged into Puget Sound. In 2005, King County began operation of two new CSO TPs, the Elliott West CSO Storage and Treatment Facility and the Henderson/MLK CSO Storage and Treatment Facility. There are also CSOs in other counties within Puget Sound, but the outfall locations were not available for this report.

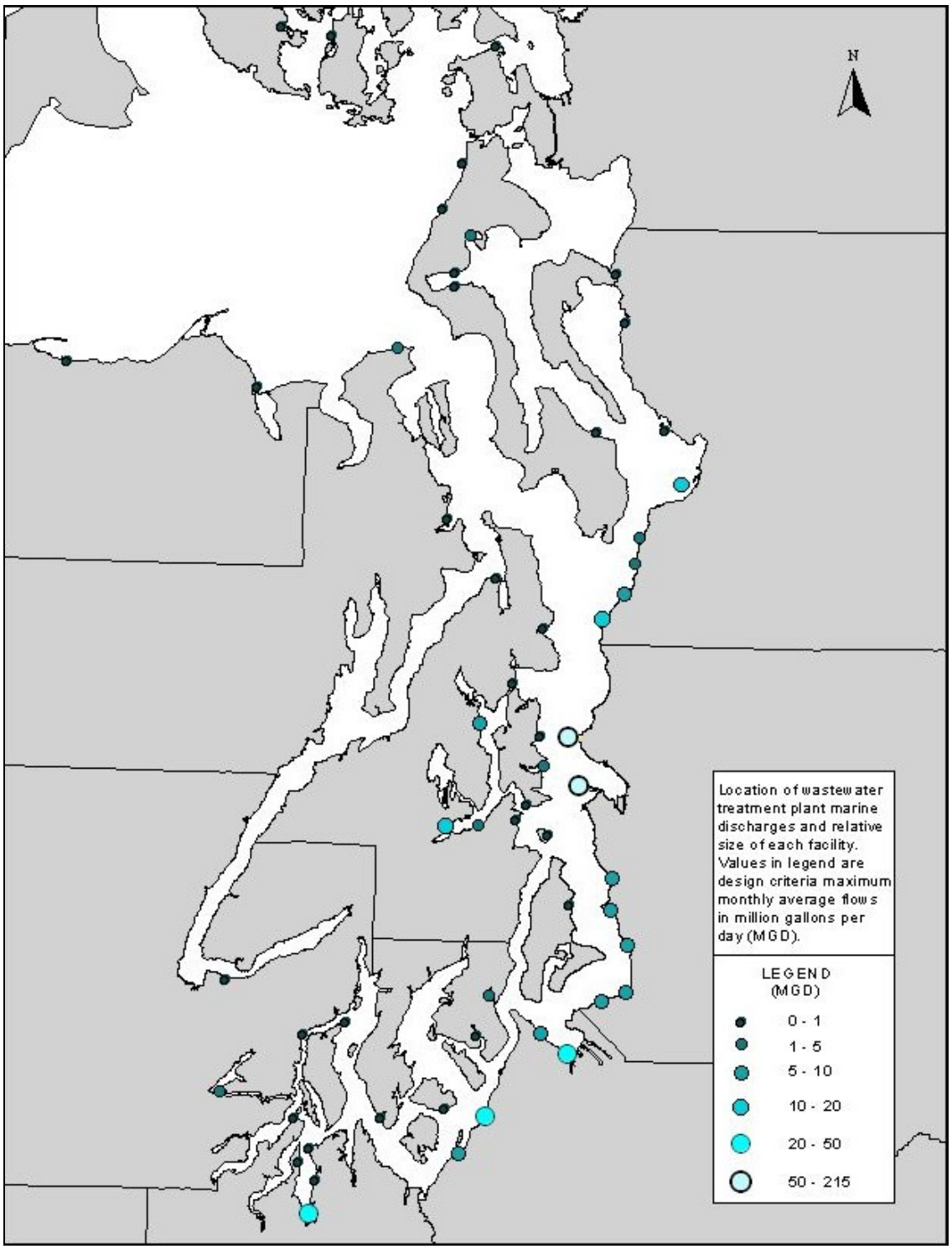

Figure 1-4. Puget Sound Wastewater Treatment Plant Marine Discharge Locations

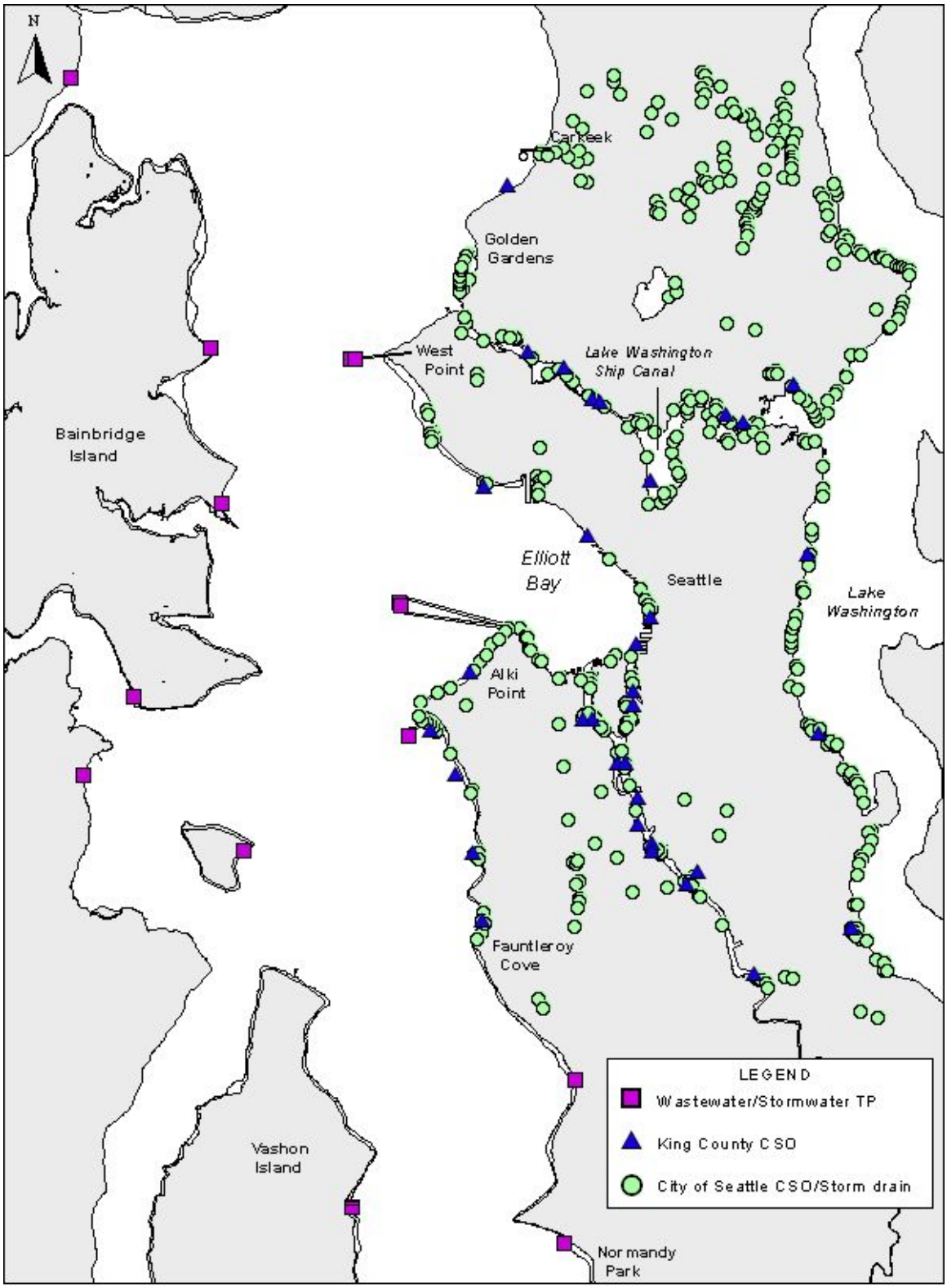

Figure 1-5. Location of Wastewater, CSO, and Stormwater Discharges in Western King County

1.3.3 Stormwater Discharges

Stormwater runoff is the water that flows off surfaces such as paved streets, rooftops, parking lots, and lawns. Stormwater can contain a variety of pollutants, dependent upon the runoff source. For example, runoff from parking lots and streets can contain hydrocarbons from combustible fuel and runoff from lawns and grassy areas can contain pesticides and herbicides. In urban areas, stormwater is collected through storm drains and can then be conveyed in different ways. Stormwater can be conveyed to treatment systems for various types of treatment before being discharged to a receiving water body or directly discharged through a stormwater outfall without receiving treatment. Figure 1-5 shows the location of storm drains and CSOs (which contain some portion of stormwater) within the western portion of King County.

In 1987, the Clean Water Act was amended to require certain industries and municipalities to have a NPDES permit for stormwater discharges. The EPA stormwater regulations for Washington State established two phases for the stormwater permitting process. Phase I NPDES permits have been issued to cover stormwater discharges from certain industries, construction sites over five acres, and municipalities with a population over 100,000 people. King, Snohomish, and Pierce Counties, the City of Seattle, and the City of Tacoma are all covered under the Phase I municipal stormwater NPDES permit. The municipal stormwater permit requires the implementation of a Stormwater Management Program, which includes a plan to reduce the discharge of pollutants through discharge of stormwater, reduce impacts to receiving water, and eliminate illegal discharges. The Phase II regulations expanded the requirements for stormwater permits to all municipalities located in urbanized areas and construction sites between one to five acres.

1.4 Sampling Area

King County's sampling area is located within the Puget Sound Main Basin, extending south to just east of Maury Island in East Passage and north to Edwards Point. Elliott Bay, a large urban embayment which includes the City of Seattle waterfront, is also located within the County's monitoring area. All but two sites sampled in 2002 and 2003 were located in marine waters. One brackish site was located in the Lake Washington Ship Canal directly west of the Ballard Locks and a freshwater site was located in Piper’s Creek. All but seven sampling sites were located within King County waters. The other seven sites were located in Snohomish County waters.

In 2002, the Marine Outfall Siting Study (MOSS) sampling area extended along the eastern nearshore from Mukilteo State Park south to Shilshole Bay. The MOSS study area includes sampling sites in both King and Snohomish Counties.

1.4.1 Sampling Area Characteristics

Puget Sound is a fjord-like estuary that extends approximately 230 kilometers (km) in a north-south direction and is bordered by the Olympic mountains to the west and the Cascade mountain range to the east. Puget Sound consists of a series of underwater valleys and ridges (called basins) and submerged hills (called sills). Sills impede the flow of water in and out of the Sound and also induce vertical mixing as water moves over the sill. The Sound consists of four major interconnected basins, including the Main (Admiralty Inlet and the Central Basin), Whidbey, Southern, and Hood Canal Basins. The Whidbey Basin is not a basin in the geological sense; its southern boundary is an arbitrarily chosen line running from Possession Point on Whidbey Island across the channel to Picnic Point in southern Snohomish County.

Water from the Pacific Ocean enters the Sound primarily through Admiralty Inlet and secondarily through Deception Pass. The area where Possession Sound and Admiralty Inlet join with the Main Basin is referred to as the Triple Junction. The Main Basin, with depths greater than 280 m, is shielded at the northern entrance to the Sound by the Admiralty Inlet Sill which impedes the exchange of deep waters. However, the Sound has near-oceanic salinity throughout the year and is supplemented with cold, nutrient-rich, low-oxygenated deep oceanic water upwelled off the Washington coast during the late summer months.

Puget Sound has an average depth of 106 meters (m) and contains approximately 168 billion cubic meters of water. The average tidal range is 3.7 to 4.3 m and an average water volume exchange of 8 billion cubic meters occurs with each tidal cycle (King County, 1994). A mixed semi-diurnal tide, which is characterized by two unequal high tides and two unequal low tides occurring each day, dominates the tidal pattern within Puget Sound. These relatively high water exchange rates are conducive to maintaining overall favorable water quality conditions in Puget Sound.

Many complex factors influence water quality in Puget Sound, including human activities, water currents, and physical, biological, and chemical processes. Offshore water samples consistently indicate good water quality. However, nearshore sediments tend to accumulate contaminants from industrial and urban processes. Sediment carried in runoff from land plays a much greater role in Puget Sound's water quality than in most marine areas. Being surrounded by hills, lakes, and rivers in an urbanized area with substantial rainfall gives the Sound a multitude of complex sediment sources. The predominant sediment sources are from river transport and bluff erosion. The twelve largest rivers entering Puget Sound contribute approximately 1.8 million cubic meters of sediment annually. Their suspended sediment load is highest during winter and early spring when heavy seasonal precipitation from storms erodes soil from the surrounding lowlands. Sediment sampling generally shows the highest levels of organic chemicals are found in nearshore areas of Elliott Bay, where urban runoff from storm drains, industrial sources, and nonpoint sources is the greatest.

Puget Sound marine waters were affected in 1997/1998 by El Niño (a warming episode of Pacific Ocean waters) conditions. The strong 1997/1998 El Niño event was followed almost immediately by a weak to moderate La Niña event (a cooling episode of Pacific Ocean waters) that lasted through 1999. This resulted in a drier than normal year for 2000, however, essentially normal conditions were re-established in 2001. In 2002/2003 a mild El Niño event occurred in the Pacific Ocean. The El Niño developed in the summer of 2002 and dissipated in April of 2003. This El Niño event was milder than the very strong 1997/1998 event, likely due to the influence of the Pacific Decadal Oscillation (PDO). The PDO is a cyclic phenomenon similar to an El Niño /La Niña warming and cooling event but on a much larger scale and lasting decades rather than months. The PDO index describes a pattern of sea surface temperatures in the Pacific Ocean that shifts between warm and cool phases every 20 to 30 years. The PDO was in a warm phase affecting the strong 1997/1998 El Niño and has since been in a cool phase. This cool phase likely tempered the 2002/2003 event and prevented a strong El Niño from forming. La Niña conditions were not observed in 2003 following the El Niño event, as was seen with the previous 1997/1998 El Niño event.

1.4.2 Oceanographic Characteristics

General Circulation Patterns

The estuarine water circulation in Puget Sound generally consists of a two-layered flow, with incoming saltier oceanic water flowing along the bottom and a fresher, less dense water layer flowing out at the surface. The largest single source of freshwater into Puget Sound is the Skagit River, followed by the Snohomish and Stillaguamish Rivers that all flow into the Whidbey Basin. The Puyallup and Nisqually Rivers are the largest freshwater sources into southern Puget Sound. The largest sources of freshwater input into the Main Basin are the Duwamish River, which flows into Elliott Bay, and water from the Lake Washington Ship Canal. The freshwater flow is driven by freshwater runoff from rainfall and the summer snow melt. Salty, cold dense waters enter Puget Sound at depth through Admiralty Inlet and a portion flows south in the Main Basin while the other portion flows northeast through Possession Sound to the Whidbey Basin. Figure 1-6 shows the net circulation pattern in Puget Sound with the deep incoming water flowing beneath the outflowing upper layer. Water tends to flow faster on the eastern side of the Main Basin near Alki Point and Point Wells and along the western side near Point Monroe and north of Kingston, where major topographic features affect the currents. The deeper, denser waters in the Main Basin often move 5 to 10 times faster than deeper currents in the Whidbey Basin as a result of vigorous mixing at the Narrows (Ebbesmeyer and Cannon, 2001).

The circulation of inflowing and outflowing water is affected by the sills, which provide vertical mixing of the two water layers. An exception to the two-layered flow in the Main Basin occurs in the southern portion around Vashon Island. In this area, the net flow is mainly southward through East Passage, around the southern end of Vashon Island, and then north through Colvos Passage (see Figure 1-6). This effect is caused by

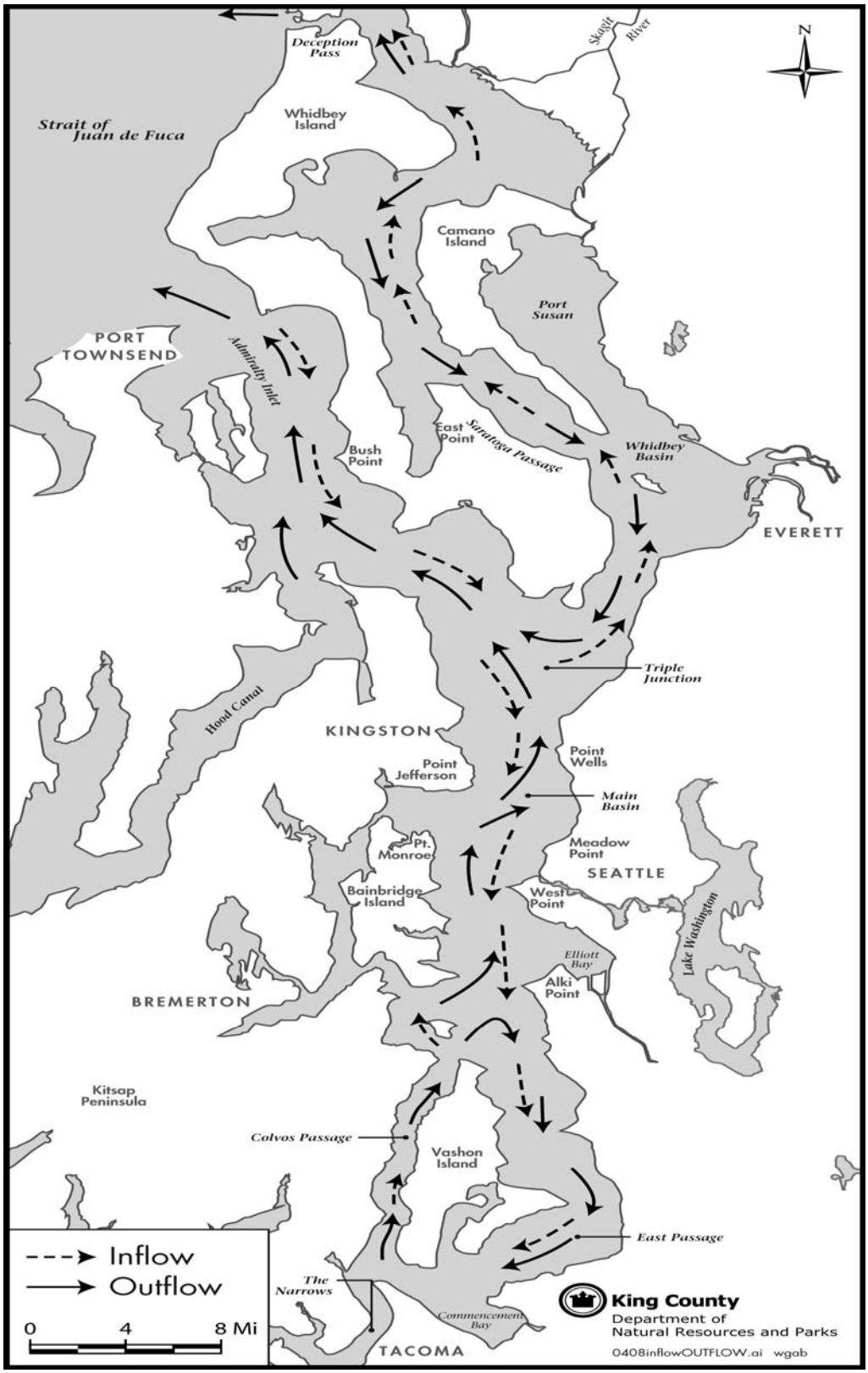

Figure 1-6. Generalized Puget Sound Circulation (from Ebbesmeyer et. al, 2002)

the location of Vashon Island relative to the outflowing water from the Narrows. The outflow from Colvos Passage has a significant effect on surface circulation in the northern portion of the Main Basin (Ebbesmeyer and Cannon, 2001). Water moving northward through Colvos passage is directed across the channel towards Alki Point, where a portion then returns south in East Passage. The other portion flows north toward the triple junction, the area where waters from the Main Basin, Whidbey Basin, and Admiralty Inlet converge.

Winds can cause significant variations in circulation. Southerly winds augment the surface outflowing water and northerly winds can impede and sometimes reverse the surface flow. Bottom water intrusions can also cause significant variations in circulation. Intrusions occur when dense saltwater crosses the Admiralty Inlet sill and replaces deep water in the Main Basin. Bottom water intrusions circulate down Puget Sound at speeds of about 20 centimeters per second (cm/s) near the Admiralty Inlet sill and 10 cm/s along the Main Basin (Ebbesmeyer and Cannon, 2001).

The residence time of water in the Main Basin is about 48 days, depending upon the time of year (Babson, 2004).

1.5 West Point Current Meter Study

Current meters were deployed in the vicinity of the West Point TP outfall for a five week period beginning in February 2003 to support the first phase of a tiered approach in assessing and monitoring sediment quality around King County's West Point TP outfall. The objective was to gather data on water movement in the vicinity of the outfall to determine how the movement of these waters may affect physical properties of sediment around the outfall, as well as effluent transport. Results will be incorporated into the sampling design for Phase 2 of the study. It is important to assess currents at, and in the vicinity of, the effluent discharge point due to the role of currents in mixing and distributing the effluent. Currents can also impact seafloor sediments by creating areas of scouring or deposition.

Four Acoustic Doppler Current Profilers (ADCPs) were deployed between February and March 2003. ADCPs lie on the seafloor and measure currents throughout the water column using acoustic pulses that bounce off particles suspended in the seawater. Water velocities are computed by estimating the differential position of the particles between the outgoing instrument pulses and the returning echoes. The current meters were deployed at depths of -760, -295, -260, and -70 ft below MLLW. Current meter locations were chosen to measure both nearshore and deep water currents that may affect effluent transport. Three of the current meters were placed along a transect parallel to the outfall at shallow, moderate, and deep depths (-70, -260, and -760 ft MLLW, respectively). The fourth current meter was placed north of the outfall, in the general direction of the net current flow, at a moderate depth of -295 ft. A five week deployment period was chosen

in order to collect sufficient data to account for tidal variability. A detailed description of the methods and results are provided in *West Point Treatment Plant Marine Outfall Current Meter Analysis* (Nairn, 2004).

Results are briefly summarized in the following discussion. The three ADCP meters placed along a parallel transect aligned with the outfall all showed tidal currents that flowed predominantly in the southwest/northeast directions, corresponding to the semi-diurnal tides. Tidal currents at the offshore station west of the outfall flowed in a more north/south direction. Currents at depths of 100 m and greater had a wider distribution of direction and aligned more towards the southwest/northeast than the currents at shallower depths. The tidal signal is less apparent in the east-west current component at the outfall discharge point, but more so north of the discharge point where the currents appear to be flowing parallel to the shoreline. The 90th percentile current speeds ranged between 30 and 50 centimeters/second (cm/s). The current direction is influenced by the topography of West Point as the shoreline is approached. Slightly to the north of West Point, currents flowed predominately in the along-shore direction.

Mean current directions are useful for understanding the long-term transport of material and are indicative of the overall estuarine flow. Mean currents were determined for each current meter from the first 29 days of recorded data, a period sufficient to average out the tidal variability. Mean current speeds at the 20 m depth were between 7.3 and 10.9 cm/s, dependent upon location, and between 2.4 and 6.3 cm/s at the 60 m depth. At 220 m, the mean current speed was 2.7 cm/s (Nairn, 2004). Figure 1-7 shows the mean near-surface current direction at depths common to three of the meters and Figure 1-8 shows near-bottom current speeds and direction.

Eddies are known to form downstream of headlands. The current meter data suggest that a recirculation pattern characteristic of an eddy exists at West Point. All four meters showed a predominantly southwest current during strong flood (incoming) currents, while during ebb (outgoing) flows, the meter south of the outfall closest to shore did not exhibit a northward flow. During the ebb, the eastern component of the flow north of the outfall and the western flow southeast of the outfall suggest that a clockwise-rotating eddy is formed north of West Point.

Winds affect currents by pushing the surface water downwind, which in turn results in a compensating flow (upwind) at depth. Typically, wind-related effects are seen at timescales of hours to several days as weather systems move through the area. To look at wind effects with the current meter data collected at West Point, data were compared with wind data obtained at the NOAA C-MAN station WPOW1 at West Point. Northerly winds explained 30 to 40% of the north-south current variability at the bottom depths at the deepest meter closest to the main channel (140 to 220m depths) and near the surface (20m depth) at the meter near the discharge point. This agrees with the anticipated outcome that winds tend to drag the surface waters downwind. The compensating flow appears to be occurring below 140 m. Wind driven flows appeared to be up to 10-15 cm/s in the surface layer and 5-10 cm/s at deeper depths (Nairn, 2004).

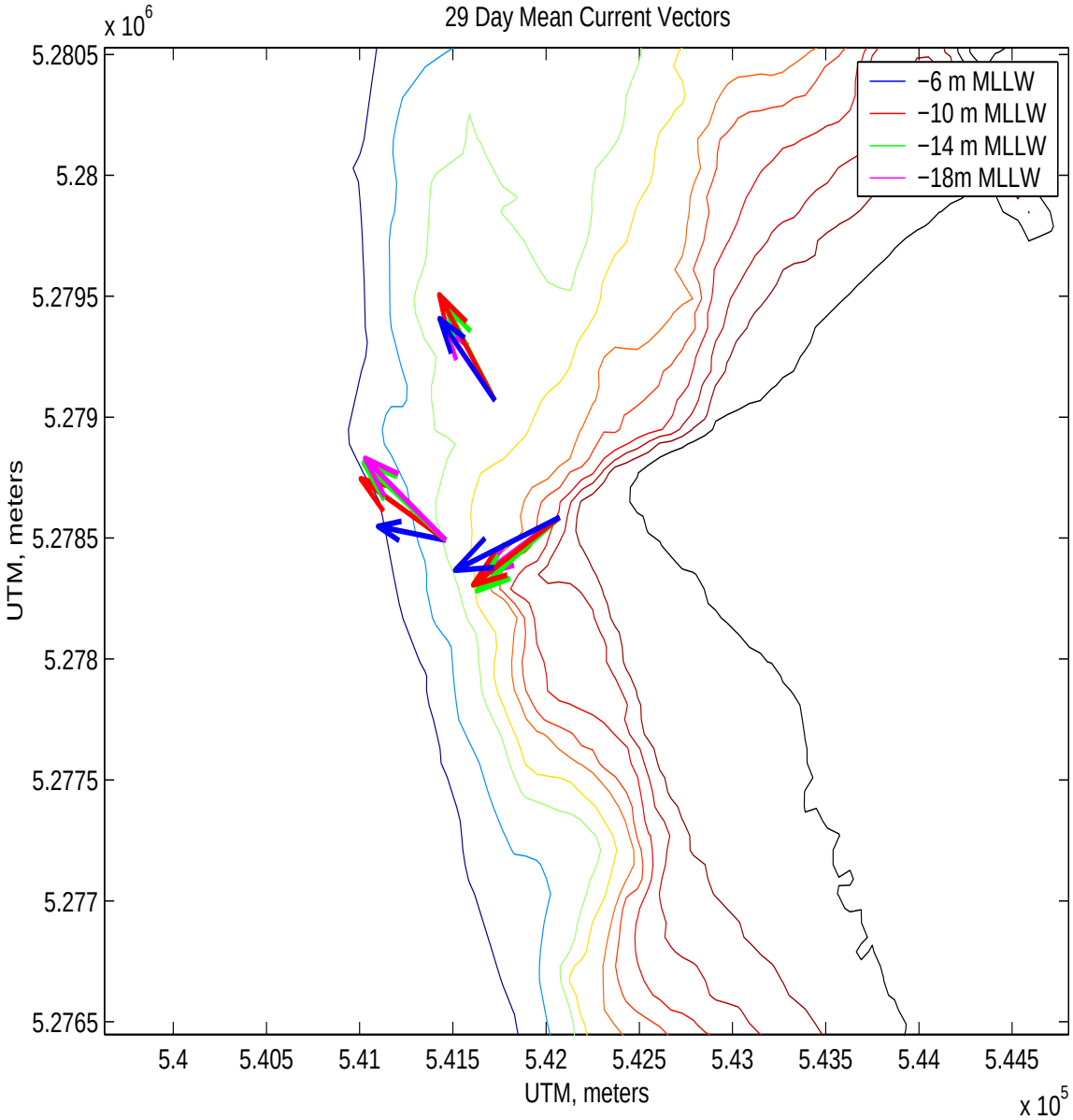

Figure 1-7. Mean Near-surface Current Direction Near West Point

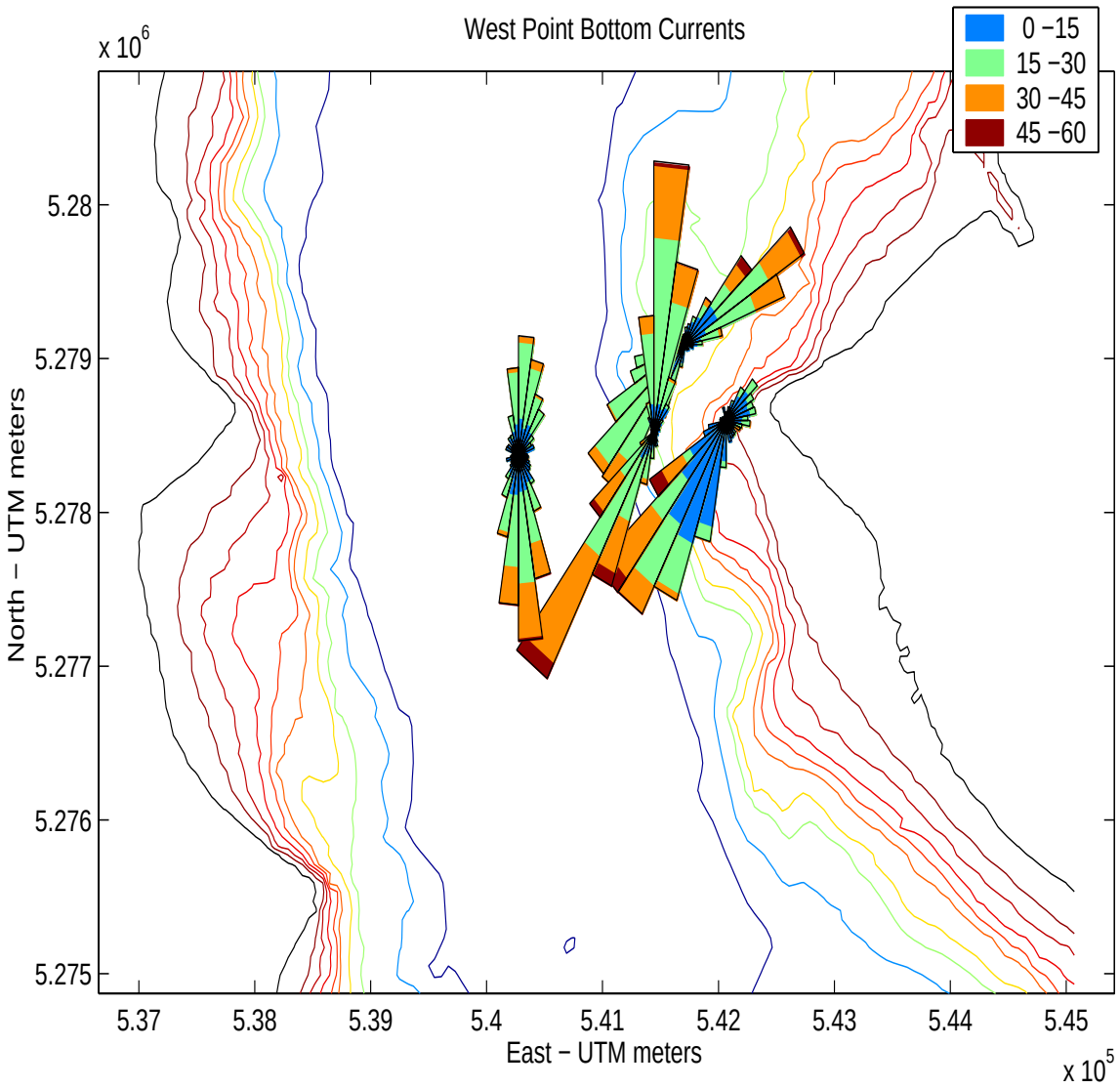

Figure 1-8. Mean Near-bottom Currents Near West Point (cm/s)

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