1. Introduction

1.1. Location of the Study Area

No Name Slough is a freshwater to estuarine channel located in the southeast part of the Padilla Bay watershed in Skagit County, Washington. Together with its upland creek tributaries and a local system of agricultural drainage ditches, No Name Slough drains a watershed of about 2,780 acres. This watershed is part of the greater Padilla Bay/Bay View watershed that drains into Padilla Bay, one of America's 26 designated National Estuarine Research Reserves.

1.2. Policy Background

Section 319 of the federal Clean Water Act requires states to identify water bodies, which, without control of non-point source pollution, cannot attain applicable water quality standards. In response to this federal mandate, the Washington Department of Ecology funded local initiatives to identify and rank such water bodies and to develop action plans for addressing non-point source pollution. In 1988 the Skagit County Watershed Ranking Committee ranked the Padilla Bay/Bay View watershed as Skagit County's second highest priority for management of non-point source pollution (Skagit County Watershed Ranking Committee 1988). In response to the high priority ranking, the Skagit County Department of Planning and Community Development and a committee of stakeholders developed the Padilla Bay/Bay View Watershed Non-point Action Plan (Padilla Bay/Bay View Watershed Management Committee 1995). This plan recommended several activities for controlling non-point source pollution in the watershed, including the No Name Slough watershed.

A related provision of the federal Clean Water Act is Section 303(d) requires states to identify water bodies that do not attain the relevant water quality standards. Further, states must develop plans for limiting the total point source and non-point source pollution discharges to such water bodies, in order that water quality standards can be attained. No Name Slough is identified in Department of Ecology's 1998 303(d) listings as a water body that, without control of pollution, cannot attain the State of Washington Water Quality Criteria for temperature and fecal coliform bacteria (Department of Ecology 1998). Department of Ecology's revised 303(d) listing includes dissolved oxygen and fecal coliform (Department of Ecology 2004). The Department of Ecology has not formulated a plan for regulating "total maximum daily loads" of pollution in No Name Slough for to meet State water quality parameters (i.e. temperature, dissolved oxygen and fecal coliform).

At the mouth of the No Name Slough watershed lies the Padilla Demonstration Farm, a publicly-owned institution set up to provide education and research opportunities related to minimizing the impacts of agricultural non-point pollution on the waters of the State of Washington. More specifically, over the past ten years, Padilla Demonstration Farm research efforts have focused on improving annual cropping practices to improve water quality and fish habitat in the slough and Padilla Bay. An agricultural advisory committee representing local resource management organizations, farmers, and other landowners determines the Padilla Demonstration Farm's general policies for research and operations. In response to the 303(d) listing of No Name Slough and other recent regulatory developments, the agricultural advisory committee has agreed that programs for improving water quality in the watershed should integrate solutions for improving agricultural drainage as well.

2. Watershed Delineation

2.1. Boundaries

The characterization project area, No Name Slough watershed, is a 2,788-acre sub-basin of the 22,970 acre Padilla Bay watershed that drains into Padilla Bay on the western edge of Skagit County, Washington (Figure 2.1). The No Name Slough watershed extends approximately three miles in a north to south orientation, is about two miles wide, and is bounded by the Padilla Bay watershed sub-basins of Bay View to the west, Joe Leary to the north, Big Indian Slough to the east and south, and Little Indian on the south. The No Name watershed was defined by standard watershed delineation techniques using topography and field investigations to identify areas that affect flow direction.

2.2. Topography

The topography of the No Name watershed ranges from mean sea level to 220' above MSL (NGVD29) and has primarily three distinguishing topographic features: the flats, the Bay View Ridge, and the No Name Creek ravine coming off of the ridge (Figure 2.2). Topographic ridges, peaks, and other characteristics of land relief define the boundaries of the watershed.

3. Land Use

3.1. Relevant Historical Land Use

Native American habitation in the general Padilla Bay – Skagit Delta area is documented as far back as 5,000 years ago (Weisberg and Riedel 1991). Spanish explorers first traveled through the Padilla Bay area in the 1790s and European settlers arrived in the 1850s. By 1900, most of the Bay View Ridge had been logged-off and the original salt marsh areas were diked and reclaimed for very productive farmland.

Collins and Sheikh 2003 mapped the pre-settlement vegetation of the Skagit Deltas from historic records. The lower section of the No Name Watershed is included on Collins' map because it was once a northern lobe of the Skagit River. In the historic maps the flats area of the watershed was primarily estuarine emergent wetland with scrub shrub wetland along the base of the forested uplands. Figure 3.1 is an 1886-87 composite of a topographic map (T-sheet) and a nautical chart. The T-sheet shows grassland on the inland side of the dike and salt marsh on the outside of the dike. Some features of interest on this map are Otto Kelso's farm and nearby cemetery, as well as the access road around the base of the ridge. The post office that was once the center of the village of Padilla was situated on land that is now the Washington Department of Ecology's Padilla Demonstration Farm. The post office and a bridge that once crossed Indian Slough are marked on Figure 3.1.

The mouth of No Name Slough apparently has receded inland since the original diking was done. There was enough salt marsh outside the No Name dike that at one time an old barn stood there. It is generally believed that the ground surface elevation of the flats inside the dike has subsided since the area was originally reclaimed. See Appendix 1 for aerial photographs of the watershed taken in 1937, the 1940's and 1966, which show the changing land uses during those decades.

3.2 Existing Land Use

Ninety-seven percent of the land use in the No Name Watershed is categorized as Agricultural, Rural/Agricultural, or Rural/Woodlot. Commercial/Industrial makes up the other 3% with less than 1% in Mobile Home Park or lakes and ponds (Table 3.1). These categories and area estimates are based on the 1993 data incorporated into the Padilla Bay/Bay View Watershed Non Point Action Plan (Padilla Bay/Bay View Watershed Management Committee 1995).

Table 3.1
Land use categories, acreage, and percent of watershed in each land use category for No Name Watershed (1993).

Land use	Area (Acres)	Percent of Watershed
Agriculture	626	22
Rural/Agriculture	1271	46
Residential-Single	14	1
Rural/Agriculture	1021	37
Vacant/Open Space	236	8
Rural/Woodlot	798	29
Commercial/Industrial	87	<3
Lakes/Ponds	3	<1
Mobile Home Park	3	<1
Total	2788	100

Land use on the flats is entirely in annual crop commercial agriculture (22% of the watershed) producing vegetables, seeds, grains, potatoes, or silage corn (Figure 3.2). The Padilla Bay Demonstration Farm (see description in Chapter 1.2 and location on Figure 3.2), located on the agricultural flats, is used for work with the agricultural community to develop management practices to reduce sediment loading to the streams and sloughs. Between the agricultural land on the flats and the bay is the 2.2-mile Padilla Bay Dike-Top Trail managed by Skagit County Parks and Recreation.

Ninety-six percent of land use on the ridge was either Rural/Agriculture or Rural/Woodlot in 1993. Rural/Agriculture is defined as a mixture of small-scale farms, pastures, hay fields, and rural-density single-family residences. Therefore 1993 land use categories of Residential-single, Vacant/Open Space, and Rural/Agriculture have been combined for this summary as a single Rural/Agriculture land use category. Small-scale farms on the ridge support approximately 370 cattle and 75 horses (SCD data collection Spring 2003). Rural/Woodlot land uses are areas of second-growth forest and since 1993 many of these areas have been converted to cleared residential lots.

There is currently no sanitary sewer service in the No Name watershed. There were about 180 septic sites mapped within the No Name watershed (Figure 3.2) in 1993. Over the past decade more septic sites have been installed.

The commercial and industrial areas in the watershed are located along Farm to Market Road and Include PACCAR Inc. Truck Testing, a pallet mill, and the Puget Sound Energy utilities substation.

3.3 Impervious Surfaces

Impervious surfaces are compressed soils or sealed surfaces such as rooftops, sidewalks, roads, and parking lots that prevent infiltration of precipitation into the soils. This in turn affects the water quality, quantity, and velocity of runoff into streams and ditches. Detrimental effects such as stream enlargement and widening, erosion, down cutting, decreased channel stability, and embeddedness begins to occur in watersheds with 10% or greater impervious cover (Schuler 1994).

Impervious surface areas in the No Name watershed were delineated in a Geographic Information System (GIS) from 2002 aerial photography (Figure 3.3). Areas included as impervious were roads (not including gravel areas), rooftops, and driveways. The impervious surfaces were calculated for each of the 13 sub-basins in the watershed (Table 3.2).

The No Name Watershed had only 5% impervious surface in 2002. However, the PACCAR Area and the Lower Marihugh Road sub-basins were already at greater than 10% impervious surface area and the effects are discussed in chapter 6.

Table 3.2.
Estimates of impervious surface area, total sub-basin area, percent impervious area per sub-basin and for entire watershed (2002).

Sub-basin	Acres of Impervious	Total Sub-basin Acres	Percent Impervious
Northern Flats	1.3	201.6	0.6
Southern Flats	3.1	445.8	0.7
Port Area South	2.4	188.7	1.3
Lower Creek	3.9	166.2	2.3
Port Area North	2.9	101.8	2.8
Northeast	6.5	199.2	3.3
Upper Creek	9.2	201.5	4.6
Wilson Road Uplands	18.6	344.0	5.4
Southeast	8.7	122.4	7.1
Middle Creek	12.7	146.6	8.7
Southwest Ridge	22.2	244.5	9.1
Lower Marihugh Road	17.9	172.8	10.4
PACCAR Area	33.9	253.0	13.4
Total	143.3	2788.3	5.1

3.4 Jurisdictional Boundaries and Zoning

Figure 3.4 shows an overlay of key jurisdictional boundaries and Comprehensive Plan Zoning that affect current land use in the No Name Watershed. These include land managed by the Port of Skagit County, jurisdictional boundaries of the local diking and drainage districts, Skagit County Parks Dike Top Trail, and Padilla Bay National Estuarine Research Reserve Demonstration Farm. Table 3.3 lists the zoning designations from the July 2000 Comprehensive Plan as amended in 2003, acreage per category, and percent of watershed covered by each. The Agricultural designation (1 unit per 40 acres) is located entirely within the jurisdiction of Drainage and Diking District 12 and Diking District 19 and will likely see the least change due to development pressures, but may experience changes due to work undertaken by the Diking Districts to protect farmlands from increased runoff from the upland areas. The Urban Growth area located east of Farm to Market Road and south of the parcels along Josh Wilson Road is primarily within the Airport Environs Zone and is slated for heavy industrial special uses and Bay View Ridge Industrial development pending a Bay View Ridge sub area plan. The Airport Environs zone are areas in which land uses must be compatible with the impacts of aircraft utilizing the Skagit Regional Airport (Skagit County Code Section 14.16.210).

Rural Reserve (1 unit per 5 acres) accounts for the majority of open space pasturelands and hay fields in the watershed. The Rural Intermediate (1 unit per 2.5 acres) are areas where there are existing low to medium density development. The Rural Resource (1 unit per 10 acres) area is presently in forested or agricultural landuse and contains one of the most pristine sections of the No Name Creek. Rural Village (1 unit per acre) is located on the west side of Walker Road on the outskirts of the town of Bay View and it includes the mobile home park.

Table 3.3
Land-use zoning designations, area, and % of watershed in No Name Watershed (2003).

Zoning	Area (Acres)	Percent of Watershed
Agriculture	618	23
Rural Intermediate	301	11
Rural Resource	181	6
Rural Reserve	1016	36
Rural Village	55	2
Urban Growth Area	617	22
Total	2788	100

4. Soils of the No Name Slough Watershed

The USDA Soil Survey of Skagit County identifies ten soil types in the No Name watershed (Soil Conservation Service 1989). These can be grouped into two general categories: 1) glacial till soils in the upland (Bellingham silt loam, Bow gravelly loam, Hoogdal silt loam, Norma silt loam, Skipopa silt loam, Terric Medisaprists) and 2) the agriculturally more important silt loam soils on the flats (Skagit silt loam, Sumas silt loam, and Tacoma silt loam). Figure 4.1 shows the locations of the various soil types. Tables 4.1 and 4.2 list relevant physical characteristics of each.

Table 4.1
Location and characteristics of No Name Slough soil types

Terrace Soil #	Soil name	Slope	Hydrologic group	Drainage/Irrigation/Septic Tank Absorbtion fields	Depth (In.)	USDA texture
10	Bellingham Silt loam	0-3%	D	Severe: wetness,percs slowly	0-9"	Silt loam
					9-60"	Silty clay, clay, silty clay loam
16	Bow gravelly loam	0-3%	D	Severe: wetness,percs slowly	0-7"	Gravelly loam
					7-17"	V. gravelly loam, v. gravelly silt loam
					7-17"	Clay loam, silt loam, silty loam
					31-60"	Silty clay loam, silty clay, clay
17	Bow gravelly loam	3-8%	D	Severe: wetness,percs slowly	0-7"	Gravelly loam
					7-17"	V. gravelly loam, v. gravelly silt loam
					7-17"	Clay loam, silt loam, silty loam
					31-60"	Silty clay loam, silty clay, clay
67	Hoogdal silt loam	8-15%	C	Severe: wetness,percs slowly	0-6"	Silt loam
					6-17"	Silt loam, silty clay loam
					17-60"	Silty clay, clay
102	Norma silt loam	0-3%	D	Severe: ponding	0-11"	Silt loam
					11-45"	Loam, gravelly sandy loam
					45-60"	V. gravelly sandy loam
124	Skipopa silt loam	0-3%	D	Severe: wetness, percs slowly	0-8"	Silt loam
					8-16"	Silt loam, silty clay loam
					16-60"	Silty clay, silty clay loam, clay
143	Terric Medisaprists	0-2%	D	Severe: ponding, percs slowly	0-17"	Muck
					17-60"	Silt loam, silty clay, silty clay loam
Floodplain						
123	Skagit silt loam	0-1%	D	Severe: wetness	0-12"	Silt loam
					12-50"	Silt loam, silty clay loam
					50-60"	Silt loam, v. fine sandy loam
136	Sumas silt loam	0-2%	D	Severe: wetness, poor filter	0-6"	Silt loam
					6-16"	Silt loam, silty clay loam
					16-60"	Gravelly sand, sand, coarse sand
142	Tacoma silt loam	0-2%	D	Severe: wetness, percs slowly	0-9"	Silt loam
					9-33"	Silt loam, v. fine sandy loam
					33-60"	Silt loam, silty clay loam, clay

Table 4.2
Location of No Name Slough soil types

Terrace Soil #	Soil name	Depth (In.)	Permeability (In./hr)	H20 capacity (In.)	Soil Type	Grass (non-irrigated) tons	Pasture AUM	Corn silage tons	Peas tons	Wheat Bu
10	Bellingham Silt loam	0-9"	0.2-0.6	0.30-0.40	Saturated	2.5	6	n/a	n/a	n/a
		9-60"	0.06-0.2	0.15-0.20						
16	Bow gravelly loam	0-7"	0.6-2.0	0.15-0.20	Till	2.5	6	n/a	n/a	n/a
		7-17"	0.6-2.0	0.10-0.17						
		7-17"	0.2-0.6	0.19-0.21						
		31-60"	0.06-0.2	0.15-0.19						
17	Bow gravelly loam	0-7"	0.6-2.0	0.15-0.20	Till	2.5	6	n/a	n/a	n/a
		7-17"	0.6-2.0	0.10-0.17						
		7-17"	0.2-0.6	0.19-0.21						
		31-60"	0.06-0.2	0.15-0.19						
67	Hoogdal silt loam	0-6"	0.6-2.0	0.19-0.21	Kitsap	n/a	7	n/a	n/a	n/a
		6-17"	0.6-2.0	0.19-0.21						
		17-60"	0.6-2.0	0.14-0.17						
102	Norma silt loam	0-11"	0.6-2.0	0.19-0.21	Saturated	3.5	5	n/a	n/a	n/a
		11-45"	2.0-6.0	0.10-0.14						
		45-60"	2.0-6.0	0.07-0.09						
124	Skipopa silt loam	0-8"	0.6-2.0	0.30-0.40	Kitsap	4	8	n/a	n/a	70
		8-16"	0.6-2.0	0.20-0.30						
		16-60"	<0.06	0.15-0.20						
143	Terric Medisaprists	0-17"	0.6-2.0	0.30-0.40	Saturated	n/a	n/a	n/a	n/a	n/a
		17-60"	0.06-0.2	0.13-0.16						
Floodplain										
123	Skagit silt loam	0-12"	0.6-2.0	0.19-0.21	Saturated	5	12	24	2.2	90
		12-50"	0.6-2.0	0.19-0.21						
		50-60"	0.6-2.0	0.19-0.21						
136	Sumas silt loam	0-6"	0.6-2.0	0.19-0.21	Saturated	4.5	10	22	2	80
		6-16"	0.6-2.0	0.18-0.20						
		16-60"	6.0-20	0.05-0.09						
142	Tacoma silt loam	0-9"	0.6-2.0	0.25-0.35	Saturated	4.5	9	25	1.5	80
		9-33"	0.2-0.6	0.20-0.30						
		33-60"	0.2-0.6	0.19-0.21						

4.1 Soils of the Uplands

Over half of the total area in the upland terraces of the No Name Slough watershed consist of Bow gravely loam soil. This very deep, somewhat poorly drained soil is formed in glaciolacutrine material and gravelly glacial drift mantled with volcanic ash. According to the USDA Soil Survey, this soil type typically has a surface layer of dark brown gravelly loam 7 inches thick. The upper 10 inches of the subsoil is dark brown very gravelly loam, the next 14 inches is grayish brown clay loam, olive gray silty clay, and light olive gray silt loam, and the lower part to a depth of 60 inches or more is olive gray silty clay. In some areas the surface layer is gravelly silt loam or black gravelly loam about 9 inches thick, and in some areas the subsoil is loamy.

According to the USDA Soil Survey, permeability of this Bow soil is slow. Available water capacity is high. Effective rooting depth is limited by a perched water table that is at a depth of 6 to

18 inches from November to May. Runoff is slow and the hazard of water erosion is slight. Because of its wetness and potential to shrink and swell, it is poorly suited to house site development without engineered treatment such as draining and backfilling with imported gravel and other soils. Likewise, the slow permeability and wetness limits the soil's suitability for septic tank drain fields. The use of interceptor drains, additional topsoil placed over the absorption field and longer absorption lines helps compensate for these limitations.

A second major soil type found in the central part of the upland terrace area in the No Name watershed is Skipopa silt loam. This very deep, somewhat poorly drained soil is formed by loess and volcanic ash underlain by glaciolacustrian sediment. It typically has an 8-inch surface layer of organic duff and dark brown silt loam. Subsoil typically is 8 inches of silt loam underlain by over 4 feet of grey or olive silty clay, with lenses of sand in some areas (Soil Conservation Service 1989). Areas of Skipopa silt loam typically have a perched water table at a depth of 12 to 24 inches from October to June; runoff and permeability is slow. Like Bow gravely loam, the Skipopa soil type is poorly suited for septic tanks drain fields. Because of the perched water table, trees are frequently subject to wind-throw.

Boring logs for two piezometers installed in 2002 in areas classified as Bow gravely loam soil generally conformed to the USDA soil survey description, with the exception that they had silt clay loam in the uppermost layer (see Figure 4.2). Boring logs in areas classified as Skipopa silt loam conformed to the USDA survey description (Figure 4.2). While both major soil types in the upland terrace area are described as having low permeability, the piezometer monitoring data (Table 5.1) suggests that the actual permeability varies somewhat over relatively small areas due to localized conditions.

4.2 Soils of the Flats

The majority of the soils on the flats are classified as either Sumas silt loam or Skagit silt loam (Figure 4.1). Typically the surface soils consist of about 6 inches of very dark grayish brown silty clay loam underlain with a very dark grayish brown silty clay loam. The upper 3 inches of the underlying material is gray silt loam. The next 14 inches is gray loamy sand, and the lower part to a depth of 60 inches or more is dark gray coarse sand. In some areas the surface layer is silty clay loam.

According to the USDA Soil Survey, permeability of these two soil types is moderate in the upper part and rapid in the lower part. Available water capacity is high. Areas affected by tides are moderately saline. Effective rooting depth is limited by a perched water table that is at a depth of 12 to 36 inches from November to April. Runoff is very slow and the hazard of water erosion is none. Flooding is rare in areas protected by dikes; however, this soil is subject to frequent long periods of flooding in areas not protected by dikes. This unit is well suited to use as cropland if dikes and drainage systems are maintained.

Boring logs for eight piezometers installed in 2002 in areas classified as Sumas silt loam and Skagit silt loam generally conformed to the USDA soil survey description in the top 12 inches (i.e. the soils within the plough zone), but showed wide variability in lower strata (See Figure 4.2). Several borings contained well-defined layers of clays, sand, and peat within the top 6 feet of the soil column. These alternating layers of very low and high permeability form confining layers for percolation of freshwater from above or salt water intrusion from below. Because of this wide variability in sub-surface soil characteristics below the plough zone, the generalized properties described in the USDA Soil Survey (See Table 4.1 and 4.2) may not necessarily be valid for deeper soils at any given particular location on the flats.

4.3 Soil Salinity on the Flats

Padilla Bay National Estuarine Research Reserve has conducted limited analysis of nutrient and soil conductivity characteristics of soils at the Department of Ecology Padilla Demonstration Farm. For the range of soil conductivities measured at the Padilla Demonstration Farm, conductivity can be related to soil salinity concentration by the rough approximation of 1.0 micromhos/cm conductivity to 0.47 mg/l (i.e. parts per million) sodium chloride salt (Black, Black Soil Testing, 2004 personal communication). Thus, a soil conductivity of 4.0 mmhos/cm equates to salinity concentration of roughly 1.9 mg/l sodium chloride.

Soil cores from the top 10 inches from eight different areas at the site had a median soil salinity of 1.0 mmhos/cm, with a range of 0.6 mmhos/to 6.4 mmhos/cm (Bulthuis 1997). The lowest salinity concentrations were found in the field adjacent to the south bank of No Name Slough (0.6 mmhos/cm) and at the southern end of the site near the weather station (0.7 mmhos/cm). The highest concentrations of salinity were detected in soils located near the two remnant sloughs on the southern end of the site (6.4 mmhos/cm) as well as at some isolated locations where winter ponding occurs in the northern end of the site (2.2 mmhos/cm) (Bulthuis 1997).

Yields of many crops are restricted at salinities greater than 4 mmhos/cm, while yields of very sensitive crops may be restricted at salinities greater than 2 mmhos/cm (Maynard and Hochmuth, 1997). Crop “yellowing” was noted in the areas where the highest soil salinities were measured in Padilla Bay National Estuarine Research Reserve’s study (Bulthuis 1997), suggesting that elevated soil salinity may hinder crop yields in these specific areas.

5 Geohydrology

At least two groundwater systems occur within the No Name Slough watershed. A partially confined aquifer occurs at the approximate elevation of sea level and a seasonal perched water table occurs on the flats.

5.1 Confined Aquifer

A review of well drilling logs on record with the Department of Ecology indicates that water supply wells in the watershed typically tap a production aquifer with static water level ranging from between about 10 feet above to 10 feet below mean sea level. The aquifer is located in sand, sand–gravel, or gravel-clay strata, which are confined from above by a clay stratum. The well logs do not extend deeply enough to determine the presence of a confining bottom stratum. Figure 5.1 shows locations of selected water supply wells from Department of Ecology's well log database. Figure 5.2 shows driller well logs of these wells located on two transects across the watershed. Based on the available well log data, it is inferred that the confined aquifer flows towards the south and southwest (towards the flats) at gradients ranging from 0.002 to 0.01 feet/feet. Figure 5.2 also illustrates the static water level relationship among the wells.

A typical published hydraulic conductivity for the sand-gravel-clay soils found at the static water level in the well logs is 10^3 meters per second (Freeze and Cherry 1979). Assuming this hydraulic conductivity value, the velocity of groundwater flow in the confined aquifer can be estimated by Darcy's law. From the well log data, the product of the hydraulic conductivity and the aquifer gradient ranges from $(10^3)(0.002) = 2 \times 10^6$ m/sec to $(10^3)(0.01) = 1 \times 10^5$ m/sec, which equates to 0.6 to 2.8 feet per day. Recharge to the confined aquifer is probably from infiltration of precipitation.

5.2 Perched Water Table

As part of the study, twelve sets of piezometers were installed in the lower part of the No Name watershed. The piezometers were used to measure the seasonal change in the elevation of the shallow (perched) water table, the seasonal change in the water table's salinity concentration, and the influence of Padilla Bay's tide stage on water table elevation at selected sites. The piezometer sets consisted of imbedded PVC pipe grouped in two transects running inland from the bay shore dike in the flats and a third transect running perpendicular to the upland creek just north of Bay View Road. Figure 5.3 shows the locations of the piezometers. Boring logs for each piezometer, which illustrate the soil horizons and depths at each location, are included in Figure 4.2.

Upland Area

Piezometers No. 9A, 9B, 10, and 11 were installed to depths of 3 to 4 feet below ground surface in the upland bordering No Name Creek. Piezometers No. 9A and 9B were installed at the edge of a pasture within 100 feet of the creek, at the top of the steep ravine in which the creek runs. Piezometers No. 10 and 11 were installed in forested areas about 300 and 800 feet east of the creek, respectively. Monthly water surface elevation monitoring data for the period December 2002 to December 2003 for these piezometers is shown in Table 5.1.

At the upland pasture piezometers the water surface elevation varied from 0.40 feet above ground surface elevation (gse)[1] to 2.13 feet below gse from October to May. The piezometers were dry during the summer months (i.e. water surface elevation was more than 3.0 feet below ground surface). The water table responded quickly to precipitation: after one of the driest summers on record, the water table rose to 0.69 feet below gse in Piezometer 9B within ten days of the first substantial autumn rains. This suggests that the clay soil horizon effectively confines the upper, perched water table. A slug test conducted at Piezometer No. 9B during November 2003 estimated a soil hydraulic conductivity in the shallow clay-gravel stratum of about $3x10^6$ m/sec with a soil porosity of 0.51.

The water table elevation responded more slowly to changes in precipitation at the upland forest piezometers. At these, the water table fell gradually from about 0.5 feet below gse in March to below the bottom of the well (3.5 feet below gse) by June, and did not rise into the well again until December, even though both are located adjacent to wetland areas. This slower response is probably attributable to greater permeability of the soil, as well as, perhaps, the effect of increased soil moisture-uptake by the forest vegetation. The piezometers near the creek are located in Bow gravelly loam, while the ones in the forest are located in Skipopa silt loam. Apparently there is enough difference in soil permeability to cause significant variability in water retention capacity. This suggests that the soil in the upland part of the No Name watershed is not uniformly impermeable clay, but rather exhibits variations in permeability over relatively small areas.

Flats

In the flats, piezometers were used to measure the seasonal change in the elevation of the shallow (perched) water table, the seasonal change in the water table's salinity concentration, and the influence of Padilla Bay's tide stage on water table elevation at selected sites. Each set of piezometers was installed at two depths: about 30 inches ("shallow") and 6 feet ("deep"). The depth of the shallow piezometers was assumed to be just below the root zone of crops grown on the flats (Soil Conservation Service 1989).

Seasonal Water Table Elevation

<u>Transect No. 1</u>: The seasonal water table gradient measured in Transect 1, which runs from the sea dike to the toe of the hill below Bay View Road, differed from the gradient measured in Transect 2, which runs from the pumphouse along the slough past Bay View-Edison Road. Along Transect 1, typical wet season water table elevations ranged from 0.9 feet above mean sea level (MSL)[2] at the toe of the hill to 0.7 feet below MSL at the dike. The range of wet season gradients measured from January 2003 to December 2003 was 0.0004 to 0.001 feet/feet. During August and September, the water table gradient reversed itself, with elevations ranging from more than 4 feet below MSL at the dike to more than 6 feet below MSL closer to the toe of the hillside. The data suggest that during summer, the tides in the bay influence on the shallow water table more than runoff from upland areas. (Tidal affects are discussed below.) Table 5.1 lists piezometer-monitoring data.

[1] PZ No. 9B is located in a natural swale that contained standing water during some wet weather sampling events.
[2] NGVD 1929, as referenced to Semrau and Lisser's 1993 survey BM No. 80-70-B.

Table 5.1

Summary of Shallow Aquifer Water Surface Elevation Monitoring Data

Transect 1							**WSE (Ft. above MSL)**					
PZ No.	**Transect Dist. (Ft.)***	**GSE (Ft. MSL)**	**1/9/03**	**3/6/03**	**4/14/03**	**5/15/03**	**6/9/03**	**8/12/03**	**10/14/03**	**10/24/03**	**11/14/03**	**12/9/03**
Shallow Piezometers												
1 ditch	40	-3.01	-1.80	_	_	-2.41	-2.41	-3.21	-2.81	-2.35	-2.73	-1.71
1	50	0.69	-0.98	-0.78	-1.00	-2.03	<-2.48(dry)	<-2.48	-1.76	-0.83	-0.98	-0.74
2	400	0.99	0.24	_	0.72*	-1.33	-1.73	<-1.71	-1.67	0.72	0.55	0.55
3	1070	1.14	-0.22	1.50	0.42	-1.27	<-1.30(dry)	<-1.30	<-1.30(dry)	0.30	0.85	1.35
4	2100	2.89	0.56	0.66	0.56	0.66	<0.64(dry)	<0.64	<1.1 (dry)	0.66	0.61	0.93
Gradient			0.00073	0.00069	0.00074	0.0013				0.00071	0.00076	0.0008
Deep Piezometers												
1 ditch	40	-3.01	-1.80	_	_	-2.41	-2.41	-3.21	-2.81	-2.35	-2.73	-1.71
1	50	0.69	-0.95	-0.90	-1.00	-1.75	-2.30	-2.65	-0.70	-0.52	-0.70	-0.32
2	400	0.99	-0.11	_	0.09	-1.06	-1.56	<-4.4	-2.23	-0.21	-0.06	0.11
3	1070	1.14	-0.20	-0.77	0.35	-1.50	-4.42	-6.16	-4.67	-2.02	-1.37	-0.87
4	2100	2.89	0.47	0.74	0.84	0.34	-0.31	<-1.36 (dry)	<-0.3 (dry)	0.29	0.50	0.79
Gradient			0.0011	0.00078	0.00088	0.001	0.00095			0.00039	0.00059	0.00054
Transect 2												
Shallow Piezometers												
6 slough	630	-4.24	-1.90	_	-1.75	-2.5	-2.43	-3.24	-2.80	-2.26	-2.78	-1.63
5	100	0.79	-1.90	-1.75	-1.85	<-2.55(dry)	dry	<-2.6	dry	-1.87	-2.10	-1.67
6	490	-0.73	-1.2	-0.97	-0.97	-2.17	-3.62	-3.30	-3.29	-1.32	-1.42	-1.21
7	1790	-0.66	-1.70	-1.59	-2.79	-2.29	-2.44	<-2.5	<-2.5 (dry)	-2.04	-2.27	-1.49
8	4300	1.74	_	-0.4	-0.2	-0.64	-1.4	<-1.5	<-1.5 (dry)	-0.94	-0.91	0.15
Gradient				0.00031	0.00038	0.00044	>0.00028	>0.00025		0.00022	0.00028	0.00043
Deep Piezometers												
6 slough	490	-4.24	-1.90	_	-1.75	-2.50	-2.43	-3.24	-2.80	-2.26	-2.78	-1.63
5	100	0.79	-1.1	-1.17	-1.17	-1.17	-2.52	-3.59	-2.72	-1.55	-0.6	-1.17
12	470	-0.40	-1.17	_	-1.17	-2.37	-2.97	-1.97	-1.67	-0.69	-1.02	-0.77
6	630	-0.73	-1.61	-1.07	-0.91	-0.71	-0.96	-1.33	-1.53	-1.59	-4.13	-3.73
7	1790	-0.66	-1.79	-1.79	-2.69	-2.39	-2.72	-3.67	-3.37	-1.99	-2.19	-1.43
7 slough	1780		-2.25			-2.51	-2.48		-2.83	-2.50	-2.8	-1.7
Gradient			-0.00040	-0.00037	-0.00090	-0.00073	-0.00012	-0.00002	-0.00039	-0.00026	-0.00094	-0.00015

*Distance is measured from the outside toe of the sea dike.

Hydraulic conductivity values of 4.2 x 10^{8} m/sec and 6.1 x 10^{7} m/sec were calculated from field tests conducted at PZ No. 6 and PZ No. 2, respectively, in November 2003. These values are reasonably consistent with published typical values for the soil types present at the shallow water table in the flats (clay/peat at PZ No. 6 and silt/clay at PZ No. 2) (Freeze and Cherry 1979).

Applying these hydraulic conductivity values with measured soil porosity values and the observed range of water table gradients, it is estimated that the shallow ground water moves through the flats in the vicinity of Transect 1 at velocities ranging from 7 x 10^6 ft/day to 3 x 10^4 feet/day.

Transect No. 2: The piezometers in Transect 2 are all located within 30 feet of either No Name Slough or a tributary ditch. Not surprisingly, the variation in water surface elevations measured in the piezometers is strongly affected by the water stage in the slough. In the shallow piezometers, a slight gradient of 0.0002 to 0.0004 feet/feet was measured from east to west along the flats from the point where the upland creek flows into the slough to the pumphouse reservoir. The gradient was slightly greater during the rainy months than in the summer. In the deep piezometers, the gradient reversed itself to -0.00002 to -0.0009 (i.e. west to east). In the deep piezometers, water surface elevation was less dependent on seasonal rainfall (and lack thereof) than on the stage of the slough.

Tidal Influence

The shallow water table at the western edge of the flats, closest to the sea dike, apparently also is influenced by daily variation in tide stage. Water surface elevation was monitored in piezometers No. 1 and No. 6 for part of a spring tide cycle in June 2003. As the tide fell from a high of 8.9 feet to a low of -1.80 feet above mean lower low water (MLLW), the wse in PZ No. 1 (located about 50 feet inland from the outside toe of the dike) correspondingly fell 0.24 feet. The piezometer wse then rose again with the rising tide. The time lag between the tide in Padilla Bay and the response in PZ No. 1 was about 5.5 hours. During this time, the water surface elevation in the ditch inside the dike (located within 10 feet of PZ No. 1) also fell 0.51 feet. At PZ No. 6, located about 630 feet inland from the outside toe of the dike, no response to the rise and fall of the tide was detected.[3]

Salinity Concentration

Salinity was measured in the piezometers in Transects No. 1 and 2 each month during 2003. In general, the salinity of the water table in the flats varied according to the distance from the sea dike. Table 5.2 summarizes the salinity monitoring data. The complete set of salinity data is included in Appendix 2.

Table 5.2
Range of Water Table Salinity Data in the flats during 2003

Transect	**Piezometers**	**Distance from Bay Dike** (feet)	**Salinity Range (PSU)*** (Salinity in the Bay is typically 27-30 PSU)	
			Shallow	Deep
	1	50	2.0-20.5	5.1-25.1
1	2	400	2.0-11.7	9.3-21.7
	3	1070	1.3-3.4	0.0-9.3
	5	100	3.8-9.3	0.2-17.3
2	6	630	1.8-3.9	0.5-1.4
	7	1790	0.5-5.8	0.5-10.9

[3] The clay soil at PZ No. 6 has low hydraulic conductivity. It was not determined what relative effect the low-permeability soil had on the lack of response to changing tide elevation, versus the distance from the bay.

*PSU = “practical salinity units” = parts per thousand

The data ranges show a large degree of variability in the salinity of the water table. While in general salinity decreases with increasing distance from the sea dike, proximity to the slough had less of an affect on water table salinity than the permeability of the local soils. For example, both PZ No. 7 and PZ No. 6 are located within 20 feet of the bank of the slough, but PZ No. 7, which is located 1,790 feet inland from the bay, consistently had higher salinity measurements than PZ No. 6, located only 630 feet inland. The impermeable clay soil in which PZ No. 6 is located prevents salt water intrusion from the surface water of the slough, while the much more permeable sand and clay-sand strata found at PZ No. 7 allows intrusion from the slough. This localized and highly variable extent of salt water intrusion is consistent with the relatively wide variation in solid salinity and “yellowing” of crops on the flats reported in Bulthuis (1997). This observation suggests that salt water intrusion, at least in the shallow perched aquifer, is a localized rather than a widespread situation.

5.3 Phreatic Inputs

During winter and spring 2003 several areas of seepage from upland slopes into the tributary creeks and the slough were observed. During the wettest times of the year some of these seeps, such as in the “swale” in which PZ No. 9B is located and several seeps at the toe of the upland area adjacent to the slough, flow with surface water. While the study did not attempt to quantify phreatic inputs into the creek system, it is believed that they represent a small but significant portion of the overall hydrologic “budget” of the watershed, particularly during months of low rainfall.

6 Surface Water Hydrology

6.1 Description of Sub-basins

The No Name Slough watershed drains an area of about 4.3 square miles (2,781 acres). As part of a 2000 hydraulic modeling study, 13 separate sub-basins were identified within the watershed. The sub-basins were delineated based on the local topography and conveyance routes (such as ditches and creeks) within the existing drainage system. Skagit Conservation District and Padilla Bay National Estuarine Research Reserve field-checked the sub-basin delineation in 2003 and adjusted the boundaries slightly to better represent the actual drainage conditions within the watershed. The revised sub-basins are listed in Table 6.1. Figure 6.1 shows the locations of the sub-basins. Relevant hydrologic and land use features of each are summarized below. Wetland features are discussed in more detail in Chapter 6.5.

Table 6.1
Summary of Drainage Sub-basins Within the No Name Slough Watershed

Sub-basin	ID No.	Approx. Area (Acres)	Percent of Total Area
Eastern Drainage			
Northeast	#12	199	7.2%
Wilson Road Uplands	#10	343	12.3%
Upper Creek	#9	169	6.1%
Middle Creek	#8	110	4.0%
Port Area North	#7N	101	3.6%
Port Area South	#7S	188	6.8%
Lower Creek	#6	159	5.7%
Paccar Area	#5	230	8.3%
Southeast	#4	142	5.1%
Flats South of Slough	#3S	446	16.0%
Western Drainage			
Lower Marihugh Road	#1	208	7.5%
Southwest Ridge	#2	292	10.5%
Flats North of Slough	#3N	202	7.3%

Eastern Drainage

Wilson Road Uplands Sub-basin (No. 10)

The upper watershed north of Josh Wilson Road consists primarily of cattle pasture, with some low-density residential development adjacent to Rector Road. Wetland conditions occur in some of the areas that remain forested, including a large forested wetland north of Rector Road. Three surface water drainage patterns are present. Runoff from the forested western half of the sub-basin collects in an emergent wetland and then runs into a ditch through the pasture towards the roadside ditch along Josh Wilson Road. Runoff from most of the center of the sub-basin drains through ditches or swales in the pasture to the Wilson Road ditch. The ditch along the west side of Farm to Market Road picks up runoff from the far eastern side of the sub-basin and conveys it to the Wilson Road ditch system. The road ditches converge in front of the farmhouse at 13757 Josh Wilson Road and flow under the road to form the permanent channel of No Name Creek. These features are shown in Figure 6.2.

Northeast Sub-basin (No. 12)
The northeastern-most corner of the watershed consists of pasture in the north and forest in the south. Most runoff drains into the ditch along the east side of Farm to Market Road. The remainder drains into a ditch along Josh Wilson Road east of the road intersection. Both ditches flow through a 2-foot diameter culvert under the intersection to join the flow from the Josh Wilson Road uplands sub-basin. A manure lagoon and pond associated with the dairy farm at 14435 Josh Wilson Road are located outside of the sub-basin boundaries; runoff from this area drains to Big Indian Slough.

Upper Creek Sub-basin (No. 9)
South of Josh Wilson Road, runoff enters the upper creek sub-basin. Land use in the basin consists primarily of cattle pasture and hay fields, as wells as low density residential development along Marihugh Road and Farm to Market Road. Reach No. 1 of the upland creek's permanent channel begins at the north boundary and runs to a 3-foot diameter culvert under Marihugh Road at the south boundary. Dredge spoil mounds along the west bank indicate that the channel was dredged and straightened at some time in the past. Currently there is a narrow buffer of blackberry, wild rose, and alders on each bank. A farm pond called the Ole Tolum Pond, which lies near the east (left) bank of the creek about 700 feet north of Marihugh Road, receives runoff from swales in the southeast corner of the site. While the gravel creek bed itself runs dry for much of the dry summer season, Tolum Pond retains at least a 0.5-foot water depth year-round.

Other surface ditches and swales run perpendicular to the creek, as shown in Figure 6.2. The most significant of these is the ditch running east from Farm to Market Road on the north side of Marihugh Road. This ditch, which runs for most of the year, originates from a perennially wet area near the intersection of Farm to Market and Marihugh Roads.

Middle Creek Sub-basin (No. 8)
Land use in the middle creek sub-basin consists of a mixture of forest, pasture, and low- density residential development. Reach No. 2 of the creek runs through a meandering channel that gradually deepens into a small ravine as it flows south. Tributaries to the creek in this sub-basin include roadside ditches on the south side of Marihugh Road, a storm sewer outfall from the Marihugh Place subdivision, and two surface swales in open pastureland at the southeast quarter of the sub-basin. Except for some forest clearing and artificial bank hardening at the northern end, the creek corridor is mostly in a natural state, including some stands of large fir and cedar. Two, 3-foot diameter culverts under Bay View Road mark the southern boundary of the sub-basin.

Port of Skagit County Area Sub-basins (Nos. 7 N and 7 S)
Between Farm to Market Road and the northwest runway of Skagit County Airport lies an area of brushy pasture and forest. Parts of this area exhibit wetland conditions. Because this area is the

approach to the airport runway, there is no development on it. Runoff drains west to the ditch along the east side of Farm to Market Road.

About 200 feet north of the intersection with Marihugh Road, this ditch is diverted across Farm to Market Road through a 12-inch culvert. From there, it flows through a ditch on the south side of Marihugh Road into the middle creek sub-basin. The portion of Sub-basin 7 that drains into this diversion culvert is identified as Sub-basin 7 North. Runoff from the rest of the sub-basin (identified as Sub-basin 7 South) continues down the Farm to Market Road ditch to the intersection with Bay View Road, where it runs through an 18-inch diameter culvert under the road and into the lower No Name Creek sub-basin.

Lower Creek Sub-basin (No. 6)
South of Bay View Road the creek flows through a small ravine to the flats. Except for one pasture and some small areas that have recently been logged, nearly the entire sub-basin remains forested. There are some remaining stands of either old growth or very old second growth cedar and fir in inaccessible parts of the lower ravine. Tributaries include the ditch along the south side of Bay View Road (carrying flow from Sub-basin No. 7 South) and at least two small seasonal creeks in the lower ravine. The channel in the upper part of the sub-basin (designated Reach No. 3) is actively incising, resulting in such features as the deep scour pool below the perched Bay View Road culverts, actively eroding hardpan clay banks, and unstable deposition bars of cobble and gravel. The channel midway down the sub-basin (designated Reach No. 4) is more stable, featuring well-developed pool and riffle morphology. At the bottom of the sub-basin, Reach No. 4 flattens out into an extensive wetland of salmon berry and skunk cabbage. Channel morphology in Sub-basin 6 is described in more detail in Chapter 6.3.

There appears to be a topographic divide in the southeast part of Sub-basin 6, from which runoff drains directly into upper No Name Slough either through subsurface seeps or a few ill-defined seasonal surface channels. The drainage from the Paccar area sub-basin also eventually flows into this area. After crossing Farm to Market Road, outflow from the Paccar area sub-basin is constricted into one 2-foot diameter culvert and a rock-lined creek channel. A few hundred feet downstream, the creek spreads out into a large scrub-shrub wetland, where some portion of the flow is absorbed, while the rest eventually drains into the east fork of the slough through subsurface seeps and at least one small surface channel. Portions of the upslope (right) bank of the slough in this area are lined with dredging spoil mounds, which tend to isolate the wetland from the slough.

Paccar Area Sub-Basin (No. 5)
This sub-basin primarily drains the land occupied by Paccar. Land use includes the Paccar complex of buildings, lawns, and paved parking areas, Paccar's truck test track, and surrounding forestland. Runoff from developed areas of the sub-basin runs through a storm drain system to a pond, where it is treated by settling and biofiltration, and then discharged to a ditch along the east side of Farm to Market Road.[4] The ditch crosses the road in two 2-foot diameter culverts, and then flows into Sub-

[4] The Paccar pond is designed primarily as a stormwater treatment facility and secondarily as a stormwater detention facility. Flow through the outlet is regulated by a system of orifices. At normal flow conditions, the pond does not store a significant amount of water. At high flows (apparently on the order of a 1-year storm event and higher), the capacity of the orifices is exceeded and flow backs-up temporarily in the pond.

basin 6 through a natural creek channel at the 12734 Farm to Market Road property. Runoff from undeveloped land upslope from the Paccar driveway drains to the Farm to Market Road ditch, where it is intercepted by three culverts and drained across the road directly into Sub-basin No. 6. These features are shown in Figure 6.2.

Southeast Sub-Basin (No. 4)
Sub-basin No. 4 consists of the Port of Skagit County land in the southeast corner of the watershed that do not ultimately drain through Sub-basin No. 6. Most of the land is currently forested and includes extensive forested wetlands. The Port reportedly plans to develop a portion of this sub-basin in the future. Some of the runoff from this area drains through ditches along Ovenell Road. The rest runs through two natural stream channels. All ditches and stream channels converge at a pair of culverts under Farm to Market Road and then run through a 30-inch culvert on the "pallet mill" facility to join the east fork of the slough on the flats.

Southern Flats Sub-basin (No. 3S)
This sub-basin includes all of the area lying between No Name Slough and the boundary of the Little Indian Slough watershed. While the land generally slopes very slightly to the west, there are localized low points where runoff tends to pond up on a regular basis. Drainage patterns are determined primarily by the maintenance of the local system of remnant estuary channels, agricultural ditches, and seasonal v-ditches. All of these ditches and remnant estuary channels ultimately discharge to the No Name Slough pump station reservoir, either directly or through a ditch along the inside perimeter of the Padilla Bay dike. These features are shown in Figure 6.2

The divide between Sub-basin No. 3 and the Little Indian Slough drainage basin is ill- defined and tends to shift back and forth depending on seasonal v-ditching, the periodic dredging of ditches and the sloughs, and the maintenance of tidegates. Because of the shallow grade (and in some places, reverse grade) of No Name Slough and the ditches, storm runoff tends to pond-up in the low-lying northeast corner of this sub-basin (Dahlstedt property) for weeks at a time during typical rainy seasons, which shortens the length of the farming season in that area.

Western Drainage

While all runoff from the eastern side of the watershed ultimately drains to either the creek or the upper reaches of No Name Slough, runoff from the western side of the watershed drains directly to the lower slough and the northern flats area. Within the western drainage are three sub-basins.

Lower Marihugh Road Sub-Basin (No. 1)
This sub-basin is bounded by the divide between Sub-basin No. 9 in the east, Marihugh Road in the south, and the divide between the Bay View watershed in the north and west. Land use consists primarily of medium density residential, as well as some pasture area in the upper (east) area. The majority of the runoff in the area is collected by rock-lined road ditches along Marihugh and Walker Roads, and runs to a 2-foot culvert under Bay View-Edison Road to the northern flats area. Another culvert located a few hundred feet north drains a smaller area occupied by a mobile home park.

Southwest Ridge Sub-basin (No. 2)
This sub-basin includes the remainder of the upland area in the western side of the watershed. Land use is a mixture of forest, pasture, low-density, and medium-density residential. Runoff is collected

in road ditches and drains under Bay View-Edison Road to the northern flats area through a total of ten culverts. The culverts, which appear to carry the most flow, are the ones at the bottom of Bridgeview Way and at the intersection of Bay View Road, both of which are 18 inches in diameter. Runoff drains from the land uphill of Egbers-Kalso Road through three culverts as well as by direct overland flow to the flats.

Northern Flats Sub-basin (No. 3N)
All runoff from the western side of the watershed eventually flows into the northern flats sub-basin. This sub-basin includes all of the flat cropland lying north of No Name Slough and inland from the Padilla Bay dike. Like the southern flats sub-basin, drainage patterns are determined by the maintenance of the ditch and tidegate system. The system includes ditching along the entire perimeter of the area, permanent cross-ditches and seasonal v-ditching, and several tidegates, including a cluster at the mouth of No Name Slough and others under the dike to the north. Water level in the slough is controlled by two pump stations located at its mouth.

6.2 Flow

Local hydrology conditions, including seasonal flooding of low-lying farm fields, are a function of the quantity, intensity, and timing of runoff from each of the sub-basins within the No Name Slough watershed. Based on a hydrologic modeling study completed in 2000 and field monitoring in 2002 and 2003, typical apportionments of runoff flows from each sub-basin during various rainfall conditions have been developed.

Hydrologic Modeling

In 2000, Padilla Bay National Estuarine Research Reserve hired Northwest Hydraulic Consultants (NHC) to develop quantitative models of runoff from the watershed and water storage capacity in the No Name Slough system (Northwest Hydraulic Consultants 2000). Using land-use and soils data from available documentation, NHC calculated the effective impervious area of each sub-basin, then used EPA's HSPF model to calculate runoff expected from 2-year, 10-year, 25-year, 50-year, and 100-year storm events. Table 6.2 is a summary of NHC's modeling results:

Table 6.2
Summary of HSPF Flow Frequency Estimates **(cfs)**

Location (Sub-basin)	2-Year Storm	10-Year Storm	25-Year Storm	50-Year Storm	100-Year Storm
Lower Marihugh Rd	6.2	12.4	16.2	19.3	22.5
Middle Creek*	21.0	35.5	41.7	45.9	49.9
E. Fork of Creek**	21.9	33.4	39.6	44.3	49.1
All Upland Area	46.5	81.9	101.4	116.6	132.3
Entire Watershed	49.5	91.3	115.3	134.2	154.0

*All area upland of Bay View Road
**Flow from the Paccar area and southeast sub-basins

Flow Monitoring

In order to calibrate the modeling results with actual runoff conditions within the watershed, actual stream flows were monitored at several locations in the watershed between November 2002 and December 2003. Stream gauge stations were installed at the outlet of the middle creek sub-basin (located 100 feet downstream of the Bay View Road culverts), the outlet of the lower Marihugh Road sub-basin (located at the inlet of the Bay View-Edison Road culvert) and in the pump station reservoir near the mouth of No Name Slough. These installations used a pressure transducer to continually measure the depth of water at the station. Flow rates were correlated with water depth data at each station by directly measuring flows during selected storm events and comparing the data to the water depth record for the same time period. Stream flows also were measured directly at culverts, ditches, and channel sections at selected locations in each of the sub-basins during a representative range of rainfall and runoff conditions. The location of the flow measuring stations (starlogger sites) is shown in Figure 7.3. The following text summarizes the stream gauging and direct flow measurement results.

Stream Gauge Results/Rating Curves

The hydrographs for lower Marihugh Road and middle creek sub-basins have a sharply-defined, sudden peak and gradual tail-off patterns that occur within a few hours of significant rainfall events. This hydrograph pattern indicates that that natural storage capacity in upland areas is quickly exceed during rain events, at least during the winter and spring months when the ground is saturated. This pattern occurs despite the fact that there is relatively little impervious surface (i.e. pavement and other development) in the upland areas. The range of flow rates recorded at the Lower Marihugh Road and middle creek gauging stations ranged from winter baseline flows of 0.3 cubic feet per second (cfs) and 1.6 cfs respectively to peaks during a heavy rain event in November 2003 of 10.4 cfs and 39.2 cfs, respectively[5]. Unit hydrographs for the two gauging stations are shown in Figures 6.3 and 6.4.

In contrast to the upland hydrographs, the hydrograph for the slough in the flats is most strongly influenced by the tide and pumping of the tidegate reservoir. In January of 1999 the water depth at the pumphouse near the tidegate illustrates the influence of the tidegate (Figure 6.5). Depth fluctuated twice a day with the tide from January 1 to 7, 1997 when there was little or no rainfall (Figure 6.5). On January 9 and 10, about one and a half inches of rain fell, and almost an inch on January 14th. Following the rain, the water depth at the pumphouse increased to over 1 m above an arbitrary datum compared to daily high of about 0.25 m during January 1 to 7 (Figure 6.5). The highs and lows from January 11 to 14 reflect tidal opening and closing of the tidegates, pumping of water over the tide gates, and water flowing off the watershed to the tidegate reservoirs (Figure 6.5). By the 16th of January, water height returned to pre-rainfall conditions and fluctuated with the twice-daily tides (Figure 6.5). While the response to tide and pumping is most pronounced at the pumphouse reservoir, it is observable, to a lesser extent, throughout the length of the slough on the flats.

[5] This rain storm approximated a 10-year rain event.

Table 6.3.
Summary of Stream Flow Monitoring Data and HSPF Model Predictions

Date	Rainfall	Subbasin 10&12		SB 12, 10, 9, 8, & 7		Subbasin 4&5		Subbasin 1		Subbasin 2		Total
	(inches)*	Q (cfs)	% of total	Q (cfs)	% of total	Q (cfs)	% of total	Q (cfs)	% of total	Q (cfs)	% of total	Q (cfs)
nhc Q2yr	1.35			21.0	42.8%	21.9	44.6%	6.2	12.6%			49.1
nhc Q10yr	2.25			35.5	43.7%	33.4	41.1%	12.4	15.3%			81.3
nhc Q25 yr				41.7	42.8%	39.6	40.6%	16.2	16.6%			97.5
29-Jan-03	0.17	0.56	6.3%	2.96	33.1%	4.09	45.7%	1.01	11.3%	0.89	9.9%	9.0
21-Feb-03	0.47	6.65	20.2%	21.43	65.0%	5.56	16.9%	2.81	8.5%	3.15	9.6%	33.0
25-Mar-03	0.00	0.36	25.4%	0.92	64.8%	0.30	21.1%	0.16	11.3%	0.04	2.8%	1.4
26-Mar-03	0.11	0.79	33.6%	1.54	65.5%	0.50	21.3%	0.20	8.5%	0.11	4.7%	2.4
31-Mar-03	0.34	0.67	11.6%	4.37	75.7%	0.55	9.5%	0.55	9.5%	0.30	5.2%	5.8
3-Apr-03	0.28	_	_	8.15	71.6%	3.24	28.4%	_	_	_	_	11.4
6-May-03	0.00	0.01	3.0%	0.08	24.2%	0.11	33.3%	0.14	42.4%	0.00	0.0%	0.3
17-Oct-03	0.50	0.30	14.5%	0.59	28.5%	1.35	65.2%	0.01	0.5%	0.12	5.8%	2.1
20-Oct-03	0.64	1.23	9.6%	2.52	19.7%	8.32	64.9%	1.12	8.7%	0.86	6.7%	12.8
18-Nov-03	1.06	18.31	26.3%	33.99	48.9%	13.58	19.5%	16.18	23.3%	5.82	8.4%	69.6
9-Dec-03	0.00	1.02	31.2%	2.37	72.5%	0.65	19.9%	0.08	2.4%	0.17	5.2%	3.3
27-Jan-04	0.41	9.75	25.0%	27.52	70.6%	5.32	13.6%	3.16	8.1%	2.98	7.6%	39.0
Avg. percent			18.8%		53.3%		30.0%		12.2%		6.0%	
Median percent			17.0%		61.2%		21.2%		8.7%		6.7%	

*rainfall measured at the Padilla Demonstration Farm rain gauge during the previous 24 hours.

Direct Flow Measurements

Thirteen direct flow monitoring stations were set up at key culverts, ditches, and stream cross sections throughout the watershed. The locations of each are shown in Figure 6.2. Stream flow was measured at these locations by means of various direct measurement techniques during a wide range of runoff conditions ranging from heavy spring rains, early summer base flow, essentially dry conditions during one of the driest summers on record, and the November 2003 heavy rainfall event. Table 6.3 is a summary of the runoff data from eight key sub-basins. A complete record of the monitoring data is included in Appendix 2.

The runoff monitoring data show how the total flow from the watershed is apportioned among the various sub-basins during different rainfall conditions. The average percentage of the watershed's total flow coming from each upland sub-basin during a year of monitoring is shown in Table 6.4.

Table 6.4
Apportionment of Runoff by Sub-basin during 2003 Monitoring

Sub-basin	**Percent of total upland land area**	**Avg. percentage of total watershed flow**	**Range of percentage of total watershed flow**
Wilson Road Uplands and Northeast Sub-basins (No. 10 and 12):	25.3%	18.8%	3.0% to 33.6%
Port Area Sub-basins (No. 7N and 7S)	13.5%	13.5%	1.8% to 27.9%
All sub-basins upstream of Bay View Road (Nos. 7, 8, 9, 10, and 12)	51.8%	53.3%	19.7% to 75.7%
"East Fork" (Sub-basins No. 4 and 5)	17.4%	30.0%	9.5% to 65.2%
Lower Marihugh Road (No. 1)	9.7%	12.2%	0.5% to 42.4%
Southwest Ridge (No. 2)	13.6%	6.0%*	0.0% to 9.9%

*Flows measured from two culverts of a total of twelve.

There is a large degree of variability in the flow apportionment. The variability apparently is due to differences in "initial abstraction" (i.e. the ability of the land to absorb and store precipitation) among the various sub-basins. This absorption capacity depends on such factors as the amount and quality of vegetation cover, amount of impervious surface, presence of ditching or other conveyance channels, soil type, and the degree of saturation of the soil.

While each of these factors affects the timing and intensity of runoff from the No Name Slough watershed, it appears that three are the most significant. First, the monitoring data show that in general, there is little runoff from the first rains of the fall until the soil in the watershed is saturated. While rainfall in the 24 hours preceding the October 7, 2003 and October 17, 2003 sampling events was 0.45 inches and 0.50 inches, only 0.3 cfs and 2.1 cfs, respectively, of runoff was measured for all sampling locations. During some late spring and summer monitoring events, the small amount of flow that was measured in the upper watershed (Sub-basin 12) was entirely absorbed into the soil of the creek channel in Sub-basin 8, so that at the lower end of the sub-basin (at Marihugh Road), the creek bed was dry.

By comparison, a 0.47-inch 24-hour rainfall preceding the February 21, 2003 monitoring event produced 33.0 cfs of runoff from the watershed. The sharp difference is most likely due to the soil being saturated in February but not in October, after a very dry summer. While the summer "baseflow" (i.e. flow in the creek system between rain events) is essentially zero, the winter baseflow was observed to be between 1.5 to 3.0 cfs.

The second key factor affecting timing and intensity of runoff is the relative level of development in a sub-basin. The two most developed areas in the watershed are the northern part of Sub-basin 2 (and in particular, the Bridgeview Way subdivision) and Paccar in Sub-basin 5. At these locations, runoff is more effectively collected and routed away than at other less-developed areas, where more of the runoff is allowed to absorb into the soil or runoff by overland flow. Table 6.5 compares runoff measured from these locations with their relative land areas and shows that they contribute a disproportionate share of runoff to the watershed's overall hydrology.

Table 6.5
Runoff from Bridgewater Estates and the Paccar Corporation Technical Center

Location	**Percent land area relative to entire upland area**	**Percent runoff flow relative to entire upland area**[6]	**Percent of October runoff**	**Percent of Winter Runoff**[7]
Bridgeview Way (Sampling Loc. 2N)	1.4%	3.6%	4.8%	3.8%
Paccar Tech. Center (Sampling Loc. 5)	10.7%	25.8%	57.5%	13.0%

The disproportion is even greater in October, when the soil in less-developed sub-basins is soaking up a higher portion of the rainfall that would otherwise run-off.

A third factor that has significant effect on the quantity and timing of runoff in the watershed is Paccar's stormwater treatment pond. Paccar's pond does not store stormwater, but instead releases it at a controlled rate through a system of orifice outlets. The pond's ability to attenuate the runoff from Sub-basin 5 is obvious at down-stream monitoring stations. During winter rain storms after the ground was saturated, the percentage of runoff from Sub-basin No. 5 relative to the entire watershed averaged about 13.0%, compared with the average contribution of 25.7% the rest of the year. This reduced contribution of flow to the overall watershed hydrology during peak runoff events is due to the temporary storage/flow regulation capacity of the pond.

Runoff Apportionment Ratios

The variability in the quantity of runoff compared with size of each sub-basin can be expressed as a ratio of percent of total runoff to percent of total watershed land area. Table 6.6 shows the ratios for key sub-basins.

[6] The figure is the average percentage from all sampling events during the 2003 study.
[7] Average runoff measured for rain events on 2/21/03, 11/18/03, 12/9/03, and 1/27/04.

Table 6.6
Ratio of Percent Runoff to Percent of Watershed Land Area for Selected Sub-basins

Sub-basin	**Runoff Apportionment Ratio**
Northeast (No. 12)	0.81
Wilson Road Uplands (No. 10)	0.84
Port Area (Nos. 7N and 7S)	1.04
Upstream of Bay View Road (No. 12, 10, 9, 8, 7)	1.03
Paccar Area (No. 5)	**2.39**
Southeast (No. 4)	0.64
Lower Marihugh Road (No. 1)	**1.31**
Southwest Ridge (No. 2) (2 of 14 culverts)	0.44
Bridgewater Estates subdivision only	**2.24**

Sub-basins No. 1 and No. 5 are the only sub-basins that have a ratio that is substantially larger than 1.0, meaning that their contribution to the overall runoff from the watershed is greater than their relative land area. Although the ratio that was calculated for Sub-basin No. 2 is small, it is skewed because only flows from two of the fourteen culverts in this sub-basin were monitored. Data was collected from a single culvert that drains the approximately 30 acres of the Bridgewater Estates subdivision.

Comparison of Field Data with Modeling Results

Table 6.3 (above) shows a comparison of the field data for apportionment of flows from selected sub-basins with the apportionments estimated by the 2000 hydrologic modeling study. For Sub-basin No. 1, the relative apportionment estimated by the model is more or less consistent with the average apportionment calculated from field monitoring. The model underestimated the actual apportionment for the watershed upstream of Bay View Road. The model overestimated the apportionment from the "east fork" sub-basins (No. 4 and 5), probably due to the fact that it did not consider the effect of flow regulation in the Paccar stormwater pond during high runoff conditions.

While the model's predictions for the relative apportionment of runoff from the various sub-basins was reasonably consistent with field monitoring data, the field data suggest that the model underestimates that actual volume of runoff from the watershed during peak runoff conditions. The field measurements taken during heavy rainstorms on February 21, 2003 and November 18, 2003 are illustrative, as shown in Table 6.7.

Table 6.7
Comparison of Selected Sub-basins with HSPF Model Predictions (cfs)

Rain Event	2-year storm event	Feb. 21, 2003	10-year storm event	Nov. 18, 2003
24-hour rainfall	**1.35”**	**0.47”**	**2.25”**	**1.06”**
Sub-basin				
Upstream of Bay View Road (Nos. 12, 10, 9, 8, & 7N)	17.3	15.8	29.0	32.3
East Fork (Nos. 4 & 5)	21.9	5.6	33.4	13.6
Lower Marihugh Rd (No. 1)	6.2	2.8	12.4	16.2
Entire Upland Area	46.5	33.0	81.9	69.6

In both cases, the 24-hour rainfall was significantly less than the rainfall for a statistical 2-year and 10-year storm event, yet the measured runoff approached the model’s runoff predictions. In reality, the actual runoff from the watershed probably exceeded the runoff predictions for two reasons. First, the monitoring stations account for only runoff that drains through major culverts and/or the creek channel, and not overland flow or minor culverts. Second, the HSPF model did not account for flow regulation in the Paccar stormwater pond, resulting in an over-estimate of Sub-basin No. 5’s contribution of the total watershed flow. The monitoring results from the February 21 and November 18 storm events suggest, therefore, that during peak runoff conditions, when the watershed’s soil is already saturated, HSPF runoff modeling underestimates the actual runoff from the watershed.

6.3 *Channel Morphology*

There are three principle types of channel morphology in the No Name Slough watershed: drainage ditches in upland areas, relatively natural creek channels, and the maintained slough and agricultural ditches on the flats.

Drainage Ditches

Maintained drainage ditches run along both sides of virtually all the roads within the watershed. Ditches in which water velocities are high enough to erode the banks are armored with rock. For example, the lower Marihugh Road ditch, which is steep and conveys a large quantity of runoff, is the most heavily armored in the watershed. Lower gradient ditches are typically unlined. The Skagit County Public Works Department dredges sediment and vegetation from the unlined ditches along the two major arterial roads in the watershed, Josh Wilson Road and Farm-to-Market Road, approximately each year, typically in the spring. There are also several unlined ditches through pasture and forest areas that connect to either roadside ditches or directly to the creek. The naturally occurring tributary of the "east fork" of the slough on the Mann property (Sub-basin No. 6) is armored with rock and concrete rubble and is morphologically more like a ditch than a natural creek channel.

Natural Creek Channels

Creek channel with varying degrees of natural morphology occurs on the main tributary of No Name Slough from the south side of Josh Wilson Road (Sub-basin No. 9) to the confluence with the slough's east fork at the downstream end of Sub-basin No. 6. The creek channel can be divided into four reaches of distinct morphology.

In Sub-basin No. 9, between Josh Wilson and Marihugh Roads, Reach No. 1 of the creek is a straightened, dredged channel with a bank full width of about seven feet and a bank full depth of about two feet. The channel gradient in this reach is approximately 0.012 feet per feet (1.2%). The channel substrate consists of medium gravel over clay hardpan.

After flowing under Marihugh Road, Reach No. 2 of the creek runs through an entrenched, meandering channel that gradually deepens into a small ravine as it flows south through Sub-basin No. 8. The channel gradient in this reach is approximately 0.017 feet per feet (1.7%), with typical bank full widths of 12 feet to 15 feet and bank full depths of 1.5 to 2.0 feet. A few small pools and riffles have developed in the vicinity of debris jams. The channel substrate is primarily hardpan clay with local deposition of gravel and cobble up to ten inches in diameter at point bars and debris jams. Sediment deposition is greatest in the vicinity of the inlets of the two, 3-foot diameter culverts under Bay View Road, which mark the downstream end of this reach. While the morphology is somewhat variable, in general Reach No. 2 can be classified as a "G4c" Rosgen type (Rosgen 1996). The channel is actively incising, which results in scouring of the hardpan clay banks and bed for most of the reach. A short section of the right bank about 500 feet downstream of Marihugh Road is armored with rock rip rap.

South of Bay View Road, Reach No. 3 of the creek enters a steep, forested ravine in Sub-basin No. 6. While the morphology characteristics vary in particular locations, in general the morphology is consistent with an entrenched Rosgen "G4c" classification. Typical bank full widths range from 10 to 18 feet and bank full depths range from 1.0 to 1.8 feet. The approximate channel gradient from the Bay View Road culverts to start of the flatter, fourth reach about 1,700 feet downstream is approximately 0.017 feet per feet (1.7%), with a channel sinuosity averaging about 1.18.

This reach has well-defined pools and riffles, particularly in the vicinity of large woody debris that naturally span the channel. The channel substrate ranges from bare clay hardpan that has been swept clean of sediment to well-defined gravel and cobble bars at meanders and upstream of woody debris jams. A small, seasonal tributary enters the main channel on the left (east) bank about 1,250 feet downstream of Bay View Road. Based on measurements of the bank full cross section, slope, and Manning's roughness coefficient at a representative riffle in this reach, it is estimated that the reach has a bank full flow capacity of about 22 cfs.[8]

[8] For comparison, the 2000 HSPF hydrologic modeling estimated the flow in this reach during a 2-year storm event to be 21 cfs.

Reach No. 4 of the upland creek runs about 1,200 feet from where the ravine begins to widen and flatten out to the confluence with the east fork of the slough at the outlet of Sub-basin No. 6. This reach is characterized by an entrenched channel meandering through a wider valley bottom of mature cedar, fir, and alder. In several places old- growth tree trunks span the creek, forming shaded pools and sand and gravel bars. The channel slope is about 0.1 feet per feet (1.0%) with low bank full width to depth ratios, resulting in an overall G4c "Rosgen" morphology classification. A seasonal tributary joins the left bank about 600 feet upstream of the confluence with the east fork. Downstream of the tributary, the valley flattens out into a skunk cabbage and salmonberry wetland, where the channel has a sandy substrate and lower gradient.

There is also a smaller tributary with natural morphology in the southeast sub-basin (No. 4). This creek originates in extensive forested wetlands on the Port of Skagit County property and flows through mature forest to a roadside ditch opposite the Dahlstedt pallet mill and from there under Farm to Market Road into the upper slough. Unlike the main tributary, this creek channel is not entrenched. Typical bank full widths of four feet, depths of four to six inches, a coarse sand to fine gravel bed, and typical sinuosity of 1.16 result in an overall "C4" Rosgen morphology classification. This stable morphology suggests that the creek is not subject to the erosive "flashy" hydrology that forms the channel of the main tributary.

Dredged Slough

The dredged portion of the slough runs about 9,800 feet from the edge of the flats opposite Ovenell Road to the tidegate outfalls at the Padilla Bay dike. Although the channel is actively maintained by dredging, for much of its length it apparently follows the course of the natural tidal slough that occurred prior to reclamation of the original salt marsh. The gradient of the channel is very low, with the ground surface of agricultural fields dropping only about one foot over its entire course, from about 1.7 feet above MSL (1929 NGVD) to about 0.7 feet above MSL[9]. The slope of the water surface varies with the water surface elevation in the tidegate pumphouse reservoir. A typical gradient measured in October 2003 was a drop of 0.7 feet over a 7,400-foot distance, or 0.01%.

Dredging artificially sets the gradient of the channel bottom. During October 2003, the channel bottom had a net negative (i.e. uphill) slope of about -0.02% between the outlet of Sub-basin No. 4 and the pumphouse reservoir[10], however, this gradient changes somewhat each time the channel is dredged. Upstream of the 4-foot diameter culvert on the Egbers farm, the typical channel bank full width is seven to eight feet, with a sinuosity of about 1.09 (i.e. practically straight). Below the Egbers culvert, the slough has a sinuosity of about 1.35, and gradually widens to a width of about 50 feet at the pumphouse reservoir[11].

Because of its flat gradient, the slough channel has a relatively low flow capacity. Based on field measurements of cross section area and slope, it is estimated that when the pumps at the pumphouse reservoir are not running, flow will begin to overtop the lowest points of the banks at a flow above 18 cfs. Pumping obviously increases the flow capacity of the channel. For example, when the water

[9] Typical elevations. There are some localized areas along the slough where the gse is as low as -0.7 feet above MSL.
[10] The slope direction changed twice over this distance: downhill to a large drainage culvert that bisects Sub-basin 3 South, uphill to the confluence with the creek in Sub-basin No. 6, then downhill again to the pumphouse reservoir.
[11] The slough at the pumphouse reservoir was widened to its present width by dredging in the early 1990s.

surface in the reservoir is maintained at about three feet below MLLW by pumping, the calculated[12] flow capacity of the channel below the confluence of Sub-basin No. 4 is on the order of 30 cfs. Some flooding of farm fields in the eastern part of Sub-basin No. 3 South was observed during February and November 2003 flow monitoring events, when flows in the slough were estimated at 27 cfs and 48 cfs, respectively. During the November monitoring event, at least one of the pumps at the pumphouse reservoir was running, which reduced the amount of bank overtopping that otherwise would have occurred.

6.4 Sedimentation and Erosion

Upper No Name Slough

The distribution of sediment sizes in a typical riffle and depositional bar in the main tributary creek channel below Bay View Road was sampled in order to evaluate the erosion and sedimentation dynamics in upland reaches of the creek. The median (D_{50}) sediment size in the riffle was determined to be 23 mm (coarse gravel) and the largest particle size in a core sample of bar sediment was 70 mm (small cobble). Using the method outlined in Rosgen (Rosgen, 2001), it was determined that the bank full depth and channel slope at the site exceeded that which was required to move the typical bed load (i.e. particle sizes up to 70 mm). Accordingly, high flows have the potential to scour the channel, leading to incision and bank instability.

While a detailed study of channel erosion was not conducted, limited channel cross section monitoring data collected before and after the high flow event of November 18, 2003 are consistent with the conclusion that the channel is actively eroding. The cross sectional area of a straight reach located about 100 feet south of Bay View Road increased by about 0.7 square feet between October 2003 and January 2004. It is assumed that much of the erosion occurred as a result of the high flows during the heavy November 18, 2003 rainfall event.

Visual observations of bank conditions in the middle reaches of the creek show that the outside bank at several meanders and straight runs is eroded vertically or undercut, with some cut faces up to five feet high. Nevertheless, a dense cover of vegetation is intact on the banks along most of the length of the creek. A visual assessment of three representative locations in July 2003 using the USDA Natural Resources Conservation Service (NRCS) “Bank Hazard Erosion Index” (BEHI) method indicated an overall BEHI of “moderate.” Applying Rosgen’s “Modified Pfankuch” evaluation procedure (Rosgen 2001) to these sites resulted in rankings that indicate that the channel has “fair” channel stability for an entrenched channel of this type. It can be concluded, therefore, that although the channel of the middle reaches of the creek is subject to a moderate level of erosion during high flows, its cohesive hardpan clay soils and intact vegetation cover help protect the channel structure.

[12] Capacity calculated with the Manning’s equation using the resulting water surface gradient and a typical cross sectional area and hydraulic radius. Assumes a Manning’s “n” value of 0.04, which is conservative for a ditch in which the weeds are cleared each year.

Dredged Slough

The main source of sedimentation in the slough on the flats is soil eroded from agricultural fields. During wet weather conditions, plumes of highly turbid water can frequently be seen flowing into the slough from permanent ditches and v-ditches on fields with no cover crop. Conversely, the outflows from the upland creek and the creek from the Paccar sub-basin have visibly lower turbidity. During a recent maintenance project, dredging contractors working for DD No. 8 removed about 4.7 cubic feet of sediment from each linear foot of slough (Nelson 2003 personal communication). This quantity corresponds to a depth of about 8" of sediment in the slough bottom. Over a typical four to six-year maintenance rotation, this quantity would accumulate at an average rate of 1.5 to 2.0 inches of sediment per year. On the Padilla Demonstration Farm, a pilot project involving planting a winter cover crop in the v-ditches resulted in over 50% decrease in the sediment loading in runoff entering the slough, compared with runoff from v-ditches with no cover crop (Bulthuis 2001). On the flats, over 75% of the agricultural cropland in the 2003 growing season was placed in cover crops.

6.5 Wetlands

Figure 6.2 shows locations within the No Name Slough watershed that either are listed on the National Wetland Inventory or that, based on field observations, exhibit wetland characteristics. In general, neither the National Wetland Inventory sites nor the field observations have formally been delineated as jurisdictional wetlands, so their inclusion in Figure 6.2 is for general information purposes only.

Wetlands have important hydrologic and wildlife habitat functions. Hydrologic functions include storing precipitation and runoff and then releasing it gradually. In this way, peak runoff flows in the upland tributaries and the slough are attenuated. Likewise, flow in the tributaries is extended further into the summer dry season than it otherwise would be. Wetlands also can serve as areas of groundwater recharge provided that the underlying soil is permeable enough. In the No Name Slough watershed, the low permeability of the soil probably limits groundwater recharge (see Chapter 5). Habitat functions include breeding areas for amphibians and cover for birds, mammals, and other animals.

In the No Name Slough watershed, six wetland areas with large size and/or good habitat quality are particularly valuable. In Sub-basin Nos. 10 and 12, large palustrian forested wetlands located north of Rector Road and east of Farm to Market Road, and large palustrian emergent wetlands located in the pasture east of Farm to Market Road store a large quantity of runoff and release it more gradually than runoff from the surrounding non-wetland areas. In Sub-basin No. 7, the National Wetland Inventory lists extensive palustrian forested and palustrian emergent wetlands. While these were not field-checked during the present study, they also appear to play a significant role in attenuating runoff from the watershed.

Two wetland areas in Sub-basin No. 6 appear to significantly affect the local hydrology. A forested wetland on the west side of Farm to Market Road opposite Paccar serves as the headwaters of a seasonal tributary to lower No Name Creek. South of this, a large palustrian scrub-shrub wetland that has formed at the confluence of the tributary from the Paccar stormwater pond with the upper slough stores a large quantity of water. Disposal of dredge spoils on the right bank of the slough at this location appears to have contributed to the formation of this wetland by “damming” natural runoff patterns.

Finally, in Sub-basin No. 4, there is an extensive palustrian forested wetland that forms the headwaters of the small creek on the Port of Skagit County property. The habitat value of these wetlands is discussed in Chapter 8.

7 Water Quality

Water quality in No Name Slough and tributaries changes over time and in different parts of the slough and creek. Water quality in the creek and roadside ditches on Bay View Ridge differs from the water quality in the slough and agricultural drainage ditches on the flats. Over time, water quality can change daily, with rain events, and seasonally. A variety of completed and ongoing studies have included water quality data on No Name. In this review, water quality data from these studies will be described by parameter (salinity, temperature, etc.) by discussing changes over time (daily, rain event, and seasonal); the spatial differences (mainly Bay View Ridge and the flats); and how these compare with Washington State water quality criteria.

The main studies that will be referenced are:

1) an ongoing (since 1997) weekly water quality study at 15-17 sites in No Name with field instruments (Bulthuis and Dugger 2000);
2) an ongoing (since 1998) biweekly (September – June) Skagit Stream Team study of fecal coliform at four sites (Henry 2003);
3) an ongoing (since 2000) continuous (every 15 minutes) water height and temperature study at four sites (Weinman et al. 2004);
4) a completed (1995-96) nutrient study at one site (Bulthuis 1996b); and
5) an ongoing (since 1996) continuous (every 30 minutes) water quality data sonde study at one site (Bulthuis and Cottrell unpublished data).

Synopses of these studies are included in Appendix 5.

7.1 Water Quality Standards

No Name Slough and both its natural upland tributaries and the ditched channels are "surface waters of the State of Washington" whose water quality is regulated by the Washington water quality standards. Water Quality Standards apply both to natural streams and ditched channels (Washington State 1997, Washington State Attorney General 1969). Specifically, either the Washington Class A Freshwater or Class A Marine Water Quality Criteria apply in No Name Slough depending on salinity (Washington State 1992, WAC 173-201A-030). Characteristic uses for both freshwater and marine Class A water are water supply; stock watering; fish and shellfish rearing, spawning, and harvesting; wildlife habitat; recreation; and commerce and navigation. Selected water quality criteria are presented in Table 7.1.

Table 7.1
Selected Washington State Class A water quality criteria (from Washington State 1997).

Parameter	Class A Freshwater	Class A Marine
Fecal coliform organisms	Not to exceed geometric mean of 100 colonies per 100/ml; no more than 10% of samples may exceed 200 colonies per 100/ml	Not to exceed geometric mean of 14 colonies per 100/ml; no more than 10% of samples may exceed 43 colonies per 100/ml
Dissolved oxygen	Shall exceed 8.0 mg/l	Shall exceed 6.0 mg/l
Temperature	Shall not exceed 18.0°C due to human activities	Shall not exceed 16.0°C due to human activities
pH	Within the range of 6.5 to 8.5	Within the range of 7.0 to 8.5
Turbidity	Shall not exceed 10% over natural background turbidity	Shall not exceed 10% over natural background turbidity
Toxic substances	Shall be below WAC 173-201A-040 numeric criteria	Shall be below WAC 173-201A-040 numeric criteria

The distinction between the marine and freshwater Water Quality Criteria depends on the salinity of the particular waterbody (Washington State 1997):

> *In brackish waters of estuaries, where the fresh and marine water quality criteria differ within the same classification, the criteria shall be applied on the basis of vertically averaged salinity. The freshwater criteria shall be applied at any point where ninety-five percent of the vertically averaged daily maximum salinity values are less than or equal to one part per thousand. Marine criteria shall apply to all other locations; except that the marine water quality criteria shall apply for dissolved oxygen when the salinity is one part per thousand or greater and for fecal coliform organisms when the salinity is ten parts per thousand or greater*. WAC 173-201A-060(2).

In No Name Slough, it is necessary to understand the spatial and temporal variability in salinity in order to determine which Water Quality Criteria apply and in order to understand the sources or causes of fluctuations in other water quality parameters.

7.2 Salinity

Salinity is typically measured as the electrical conductivity of a water sample, which is correlated to the salt concentration of the sample. In estuarine areas the salinity indicates the amount of seawater that is mixed in the freshwater. Salinity of oceanic seawater is typically around 35 (Practical Salinity Units)[13]; Puget Sound roughly averages between 30 to 32 PSU, while Padilla Bay is usually between 27 to 31 PSU (Bulthuis 1996a). At times when a water body is isolated from the sea and evaporation exceeds freshwater inflow, the salinity of the water can be greater than seawater.

Seawater from Padilla Bay may enter No Name Slough via a variety of ways including seepage under or through the dikes, seepage along the outside of tidegates, or low flow through the tidegates

[13] PSU is equivalent to "parts per thousand" (ppt)

when the tidegate doors do not seal completely during high water. It is not known which of these (or other routes) is the main source of salt water entering the slough, but it is clear that salt water does enter the slough on a regular basis.

There is considerable variation in the daily and seasonal salinity of the slough. Figure 7.1 shows hourly variation in salinity at different times in the tidal cycle on the "freshwater" side of the tidegates at the mouth of No Name Slough. For example, during February 27 through March 2, 2003 the salinity varied each day from over 20 PSU (up to 26 PSU) to less than 4 PSU (Figure 7.1). Thus, salinity at this location can vary from fresh to full strength seawater in the same day. In addition to this daily fluctuation there is also a seasonal pattern of salinity at this site. Figure 7.2 shows weekly data collected at the Padilla Demonstration Farm culvert over No Name Slough, about 500 feet upstream of the tidegates, during 1995 around the time of the daytime low tide, when water was flowing out of the tidegates. This is the time of the tide cycle when the water would be expected to have the lowest salinity. Between October and March, the salinity fluctuated between 0 and 20 PSU as rain and low tide brought freshwater to the mouth of the slough. Between April and September, the salinity ranged from about 27 to 31 PSU, which is about the same salinity as in Padilla Bay. These data indicate that for about six months of the year, full strength seawater was moving into and out of No Name Slough with little evidence of mixing by freshwater (Bulthuis 1996b). During the other six months, salinity fluctuated daily and weekly between freshwater and above 2/3 strength seawater.

Salinity also varies along the length of the slough. The variability in salinity at various locations in the flats was measured in two recent studies. Between 1997 and 2000, salinity (and other water quality parameters) was measured each week at 17 sites in the slough, agricultural drainage ditches, and roadside ditches in the upland area (Dugger and Bulthuis unpublished data; Figure 7.3). In 2003, a longitudinal profile of salinity concentrations was measured in the slough during summer low flow and autumn higher flow conditions (Figure 7.4). The data from these studies are presented in Figure 7.5 and Table 7.2. In general, the data show a decreasing trend in salinity the farther upstream in No Name Slough. Salinity extends further upstream in the summer, when there is little or no freshwater flow from the upper watershed (Figures 7.5). Salinities greater than one PSU were measured at some times up the slough as far as the base of Bay View Ridge (Table 7.2, Figure 7.5). Seawater does not extend to the No Name Creek portion on the uplands (Figure 7.5).

The data collected in the weekly water quality sampling project were used to evaluate where Class A Freshwater criteria would apply and where Class A Marine criteria would apply (see above quote from Washington State WAC 173-201A). Water quality site # 5 located near the Egbers culvert was considered close to the dividing point (see Figure 7.3 for site locations). Site # 5 was visited approximately weekly 278 times between January 23, 1997 and April 20, 2004. 61 times the site had too little water to take salinity measurements. Of the 217 measurements, 95% of the salinity values were 1.0 PSU or lower[14]. Thus, the Class A Freshwater criteria would apply at site # 5 (Washington state 1997). The next water quality sampling station downstream is site # 6 at the Padilla Demonstration Farm culvert. At site # 6 the average salinity for the 278 samples was 17.1 and thus the 95% value is well above the 10 PSU, therefore Class A Marine Criteria would apply for all criteria. The dividing line between Class A Freshwater and Class A Marine criteria is somewhere between water quality site # 5 and # 6 on No Name Slough.

[14] Salinity for the remaining 5% of values varied from 9.1 to 29.5 PSU, mainly during late August or September.

Table 7.2
Longitudinal survey of salinity at 14 sites in No Name Slough from the tidegate to Bay View Ridge on September 3 and November 14, 2003. Sample sites are shown in Fig. 7.4. (From Slocum unpublished data).

Site No.	3 September 2003			14 November 2003	
	surface	1" depth	bottom	surface	bottom
bay			26.0	23.7	
1	0.5	14.0	33.5	3.5	18.0
2	1.0	29.0	34.0	4.7	14.1
3	1.0	34.5	34.5	7.1	15.0
4	0.3			2.0	10.0
5	1.3		43.0	2.7	9.0
6	0.7		40.6	0.5	5.6
7	0.1		26.7	0.5	1.2
8	Nd			0.4	Nd
9	Nd			0.3	11.0
10	0.5		5.4	0.1	2.3
11	0.2		15.5	0.2	Nd
12	0.3	10.5	12.2	0.1	1.0
13		6.4	22.5	Nd	Nd
14	0.5		13.3	0.1	0.2

A key location for the spatial variation of salinity in the flats appears to be the large culvert on the Vernon Egbers property, located approximately 5,625 feet upstream from the tidegate outfall (see Figure 7.4). The 1999 and 2003 studies measured salinities in the range of 10 PSU to 22 PSU near this location during the summer dry season. Upstream of the culvert, salinity generally was negligible. Salinities were higher near the bottom of the water column than at the surface, which is consistent with the tendency of less dense freshwater to "float" over the lens of denser salt water. During wet weather, typical salinities at the Egbers culvert were less than one PSU (Fig. 7.5), showing the dilution effect of the greater flow of freshwater from the uplands.

In summary, seawater moves into No Name Slough and in the ditches along the dike with each tidal cycle and periodically extends up the main stem of No Name Slough as far as the Egbers culvert. Seasonally, salinities are higher in the late summer than in winter. The movement of seawater into the slough and its presence in the lower part of the watershed throughout the year has important implications for its characteristic uses (particularly agriculture and fish and wildlife habitat), for its compliance with relevant water quality criteria, for restoration options, and for understanding other water quality parameters.

7.3 Temperature

Like salinity, the temperature of water in the slough and upland tributaries also varies spatially and over time. Over the course of a summer day, temperature can fluctuate more than 5°C at the tidegate reservoir and 3-4°C in the main upland tributary. Figures 7.6 and 7.7 show results of three years of monitoring water temperature at 15-minute intervals at the tidegate reservoir and Bay View Road sampling stations, respectively. In addition, there is a seasonal pattern with daily fluctuations. During summer, daily fluctuations tend to be higher, 3-5°C, than in winter 1-2°C. As expected, there is a strong seasonal trend, with monthly mean temperatures of 4° to 5°C during winter and means of 14° to 20°C during summer, depending on the site (Figures 7.6 and 7.7).

Spatial variation in water temperature is related primarily to location on either the flats or the upland portion of the watershed. The results of the 17-site Weekly Monitoring Study indicate that winter (January – March) water temperatures were similar at all locations on a given day, with a spread of about 7°C over the three month period (Figure 7.8). In contrast, during late summer (July to September), mean temperatures at sites in the upland area were lower and had a lower spread of temperatures than those at sites in the slough and in agricultural ditches on the flats (Figure 7.8).

In order to evaluate whether water in the upland tributaries of the watershed meets the applicable Washington Water Quality Criteria, temperature was measured at the Bay View Road sampling station at fifteen-minute intervals during most of three years between mid-2000 and mid-2003 (Weinman et al. 2004). As shown in Figure 7.6, the maximum temperatures measured at the site were 17°C with mean August temperatures of 15°C. Summer temperatures at this site consistently met the Class A freshwater limit of 18°C. As discussed in Chapter 6, the two reaches of No Name Creek from Bay View Road to the flats are well shaded with a mature canopy of trees, and it is believed that the temperature data from the Bay View Road sampling station are representative of temperature conditions throughout the two reaches.

In contrast, water temperature in the slough and other sites on the flats regularly exceeded the Class A criteria of 16°C for marine water and 18°C for freshwater. Over the duration of the 17-site weekly monitoring study, the mean weekly summertime temperature at sampling Sites 6 and 7 exceeded 18°C (See Figure 7.9). Maximum temperatures at these sites were up to 24° to 28°C (Dugger 2000). At the tidegates, three years of temperature measurements at 15-minute intervals indicated summer daily maxima as high as 29°C and summer monthly means over 20°C (Figure 7.7) (Weinman et al. 2004).

In summary, temperature generally fluctuates widely, both daily and seasonally in the No Name Slough watershed. During summer, the shaded reaches of the upland tributaries have a narrow range of temperature fluctuation and meet the Class A freshwater criteria of 18°C. In the slough and ditches on the flats, daily temperature fluctuations are much greater and temperatures usually exceed both the 16°C marine criterion and the 18°C freshwater criterion during the summer months.

7.4 Dissolved Oxygen

Dissolved oxygen in the water is important for fish, aquatic insects, and other freshwater animals. The concentration of dissolved oxygen is affected by many factors. Temperature and salinity are two of the key factors. As the temperature and salinity of a waterbody increases, the equilibrium (saturation) concentration of oxygen that dissolves in the water decreases. In addition to temperature and salinity, several other factors influence the concentration of dissolved oxygen in a given sample of water. These include respiration by animals and bacteria, photosynthesis by aquatic plants, and the effectiveness of the physical transfer of oxygen from the air. The requirements of various animals for oxygen vary among the animals and among life stages for the same animal. For example, young fish fry often have higher requirements for dissolved oxygen than do adults of the same species.

Dissolved oxygen in No Name Slough fluctuates daily as temperature, salinity, respiration, photosynthesis, and other factors fluctuate. Particularly when there is an abundance of algae in the slough, dissolved oxygen increases as the algae photosynthesize during the day and decrease as the algae, aquatic animals, and bacteria respire at night. As an example, there was a substantial growth of algae near the tidegates in July 2003. Dissolved oxygen measured every half hour increased up to 300% or 20 mg/L during the day, but decreased to 10% (1 mg/L) at night (Figure 7.10). In most studies, dissolved oxygen is measured during the daytime when water samples are collected. Thus, data collected in such studies usually are not representative of the whole day, but of the higher daylight concentrations. Nevertheless, these daylight measurements can indicate seasonal trends, inter-annual variation, and differences among sites and parts of the slough.

Daytime measurements of dissolved oxygen at site # 3 (the creek at Bay View Road) showed a strong seasonal trend with high dissolved oxygen concentrations (greater than 8 mg/L) from late fall to early spring, but daytime summer concentrations falling below 4 mg/L (Figure 7.11). On the other hand, at site # 6 (in the slough on the flats) daytime dissolved oxygen concentration did not vary much over the seasons, nor were concentrations as low as at site # 3. Only once during the 3-year study did the dissolved oxygen concentration fall below 4 mg/L at site # 6 (Figure 7.11). The seasonal trend at site # 3, on Bay View Ridge, may be a reflection of very low surface water flow upstream of site # 3 during summer and phreatic inputs of groundwater (which are usually low in dissolved oxygen). In addition, site # 3 is well shaded and, even during summer; algal growth and photosynthetic rates are probably low. In contrast at site # 6, algae are common in the summer, there is no shading from streamside vegetation, and photosynthesis of the algae would be expected to increase the dissolved oxygen concentrations during the day.

Throughout the slough and creek, daytime dissolved oxygen measurements at 16 sites during the winter months indicated that most of the sites were usually in compliance with the dissolved oxygen water quality criteria of 8.0 mg/l (freshwater) and 6.0 mg/l (marine water) (Figure 7.12). During the summer months, though, most of the sites generally violated the applicable criteria even during the day, with the upland creek and roadside ditches having the lowest concentrations of dissolved oxygen (Figure 7.12).

In summary, dissolved oxygen in No Name Slough fluctuates widely from day to night, particularly during summer, and fluctuates seasonally with the lowest daytime concentrations at the Bay View Road site. In general, No Name Slough and its main upland tributary do not meet the applicable state water quality criteria for dissolved oxygen.

7.5 Fecal Coliform

The presence of fecal coliform bacteria in a water sample is commonly used as an indicator that pathogenic microorganisms might be present in the water, and that, therefore, swimming, direct contact, and eating shellfish from such waters might be a health risk. Fecal coliform bacteria are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease causing) bacteria, viruses, and protozoa that also live in human and animal digestive systems.

Sources of fecal contamination to surface waters include sewage and septage, domestic and wild animal feces, livestock manure, and stormwater runoff from places where manure accumulates. Standard testing does not distinguish between fecal coliform of human origins and those originating in other animals. While the presence of fecal coliforms in a surface water sample does not necessarily confirm any particular source of contamination, it does give a conservative indication that sewage contamination or other waste management problems may be present. In addition to presenting a possible health risk, the presence of elevated levels of fecal bacteria can also be associated with cloudy water, unpleasant odors, and an increased oxygen demand.

A 1994 study conducted as part of the Padilla Bay/Bay View Watershed Action Plan found that fecal coliform bacteria levels in water courses on Bay View Ridge (including some within the No Name Slough watershed) consistently violated the 100 colonies/100 ml geometric mean level stipulated by the Washington Class A Water Quality Criteria for freshwater (Cochrane Consulting 1994). Half of the samples tested exceeded the maximum bacteria counts of 200 colonies/100 ml. The study concluded that bacterial contamination (along with sediment loading and nutrient loading) were problems that needed to be addressed in order to sustain beneficial water uses in the watershed and Padilla Bay estuary (Cochrane Consulting 1994). In the spring of 2002, recreational shellfish harvest at Bay View State Park, located north of the mouth of No Name Slough, was closed due to excessive bacteria levels. Recent tests have detected very high fecal coliform levels around the community of Bay View as well (Skagit County Health Department, unpublished data).

Testing for fecal coliforms directed specifically at No Name Slough has been ongoing since 1998. Trained local volunteers participating in Skagit Conservation District and Padilla Bay National Estuarine Research Reserve “Skagit Stream Team” Program have monitored water quality, including fecal coliform organisms, at four sites in No Name Slough bi-weekly from September to June since 1998. Results of the Stream Team monitoring have detected violations of the fresh water and marine Water Quality Criteria for fecal coliforms on a regular basis from 1999 through 2003 (Henry 2003). While fecal counts vary widely through the year, the counts tend to be highest between November and February, when the ground is saturated and runoff is heaviest (Figure 7.13). This wide variation in bacteria levels is common as bacteria appear sporadically throughout the water column often as clumps.[15]

Even within the wide range of variability, fecal counts measured in the main upland tributary at Bay View Road (NN #2) consistently showed high fecal coliform readings, typically well in violation of state standards (Figure 7.14).[16] Four years of data at this site show an exponential increase in fecal coliform levels. Since the fecal counts are much lower at NN#1 (upstream side of Marihugh Road), the high levels detected at the Bay View Road station (Site NN#2) clearly point to a pollution source between Marihugh and Bay View Roads (Figure 7.14). The data also show a general trend of decreasing in fecal coliform counts in relation to the distance downstream from the uplands (NN#1, NN#2) to the flats (NN#3, NN #4), which is consistent with distance from the probable

[15] This is one of the reasons the State standards rely on the geometric mean of multiple samples.

[16] This was also the same site used in the 1994 Cochrane Consulting study that showed high fecal coliform levels.

contamination source(s) and poorer survival of bacteria in brackish and salt water (Figure 7.14). Even so, the fecal levels at the Egbers culvert (NN#3) frequently violate the upper 10% marine Class A criterion of 43 organisms/100 ml., as well as the marine Class A geometric mean criteria of 14 organisms/100 ml.

The 2002-2003 data shows that the highest average fecal coliform counts in the three Skagit County watersheds monitored by the Skagit Stream Team Program were recorded in the No Name Slough watershed, and that these levels have increased over the past four to five years (Figure 7.15).

7.6 pH

The acidity or alkalinity of water is measured and reported on a pH scale in which 7 is neutral and values below 7 indicate acidity and values above 7 indicate alkalinity. pH has rarely been measured in No Name Slough. In one study pH was measured incidentally at the pumphouse reservoir and at the Padilla Demonstration Farm culvert as part of a datasonde monitoring program. During this study, pH fluctuated slightly on a daily basis similar to dissolved oxygen (Figure 7.10). Where it has been measured, pH in No Name Slough almost always complies with the applicable state water quality criteria.

7.7 Turbidity and Suspended Solids

Turbidity is a measure of the light-scattering material in a given sample of water. Turbidity is directly related to the concentration of dissolved and suspended solids in the water sample. For example, Figure 7.16 shows the relation between turbidity and total suspended solids in samples from No Name Slough.

Turbidity in No Name does not fluctuate on a daily pattern, but does change over a short term and seasonal basis in response to changes in flow. This relation is illustrated by the marked increase in turbidity at the tidegates measured February 12, 1999 (Figure 7.17). When the water depth was slowly increasing as the tidegates were shut and there was little or no flow, turbidity was low. At about 6:00 p.m. the tidegates opened up and the water depth fell in the slough as water flowed out the tidegates. The resulting increased flow velocity in the slough most likely stirred up sediments, so that turbidity increased. When the tidegates shut, the flow slowed and then stopped, the depth began to increase, and sediment settled out of the water, resulting in lower turbidity.

Another cause of short-term change in turbidity is rainfall. On February 21, 2003 about 0.5 inches of rain fell in the Padilla Bay watershed. The turbidity of water in the pumphouse reservoir increased as the sediments and particles stirred up by the stormwater runoff and flow in ditches flowed past the turbidity sensor near the tidegates (Figure 7.1). Rainfall affects seasonal patterns as well as daily and hourly fluctuations. Weekly measurements of suspended solids from April 1995 to April 1996 indicate both the effect of rainfall and the seasonal pattern of low and consistent suspended solids concentrations during summer and early fall, and high and variable concentrations during winter and spring (Figure 7.18).

Like the other water quality parameters, turbidity varies according to location in the watershed as well. Seasonal fluctuations in turbidity were generally smaller at the upland tributary monitoring station than at those on the flats. Figure 7.19 shows weekly turbidity measurements at site # 3 at Bay View Road creek and at site # 6 in the tidegate reservoir. At site # 6 in the flats portion of the slough, turbidities usually were lower in the summer than at site # 3 on Bay View Ridge, and higher in the winter than at site # 3. Thus, seasonal fluctuations are clearer at site # 6 than at site # 3 (Figure 7.19). Likewise, while agricultural ditches, roadside ditches, and the mainstem of No Name Slough had similar turbidity levels during the winter (Figure 7.20), the agricultural ditches had higher and more variable turbidities in summer than did the mainstem (Figure 7.20).

The water in agricultural ditches is mainly runoff from temporary v-ditches that are placed in the fields in the fall and plowed over in the spring. Water flows off of the fields in these v-ditches mainly during rain events (Bulthuis 2001). The concentrations of suspended solids can be quite high in these temporary v-ditches (over 1000 mg/L), which may be a major source of the suspended solids to the floodplain portion of the slough during winter. The planting of winter cover crop was found to significantly reduce (by about 50%) the suspended solids flowing from these temporary v-ditches into the agricultural drainage ditches (Bulthuis 2001).

The Washington Water Quality Criteria for turbidity states that turbidity shall not be raised more than 5 NTU above background turbidity[17]. In No Name Slough, the term “background turbidity” is ambiguous. If measurements of mean turbidity in the main upland tributary are assumed to be the “background turbidity” level, then sites 4, 5, and 6 all violated the criteria during winter of 1999 (Figure 7.20), but all measurements in the slough complied with the criteria during the summer of 1999 (Figure 7.20).

7.8 Nutrients

Nitrogen and phosphorus are important parameters of water quality because algae and other aquatic plants are often limited in their growth by the availability of these two nutrients. High concentrations or supply of nitrogen and phosphorus can result in nuisance blooms of algae in both freshwater and estuaries. Dissolved nutrients were measured in No Name Slough in 1993-94 by Cochrane Consulting (1994) and in 1995-96 by Bulthuis (1996b).

Daily fluctuations of nutrients have not been measured in No Name Slough, but concentrations near the mouth probably fluctuate like Joe Leary Slough with opening and closing of the tidegates (Bulthuis 1996b). Higher concentrations of dissolved nitrogen and lower concentrations of dissolved phosphate would be expected when the tidegates are open and freshwater is flowing down from the upper parts of the watershed (Bulthuis 1996b).

Seasonally, at the mouth of No Name Slough, dissolved nitrogen concentrations (nitrate plus ammonium) were low (near the detection limit) from May to October, but increased to 1 to 2 mg nitrogen per liter as nitrogen after the rain season started in November (Figure 7.21). Dissolved phosphate concentrations, on the other hand, were higher (0.1 to 0.4 mg phosphorus per liter) during May to October, but decreased to less than 0.1 after November (Figure 7.21). This pattern is primarily a reflection of the water sources near the tidegates in No Name Slough. During May to October the water on the “freshwater” side of the tidegates is mainly Padilla Bay water, which is

---

[17] Alternatively, for waters containing background turbidity more than 50 NTU (nephlometric turbidity units), the increase in turbidity shall not be raised more than 10% above background turbidity.

low in dissolved nitrogen, but higher in dissolved phosphate than freshwater in No Name Slough. Thus, during November to April when freshwater flows to the mouth of the slough, dissolved nitrogen increases and dissolved phosphate decreases.

There are no Washington Water Quality Criteria for dissolved nitrogen or phosphorus. However, the growths of filamentous algae that cover the surface and bottom of the lower part of No Name Slough periodically indicate that nutrient loading to No Name Slough is excessive and deleterious to water quality.

7.9 Pesticides and Metals in Slough Sediments

Pesticides that are used to control unwanted plants and animals on residential lots and on commercial fields can run off into surface waters and harm or kill aquatic plants or animals. Similarly, metals from a variety of sources can run off into freshwater and impact aquatic life. While the water of No Name Slough has not been tested for presence of pesticides and metals, limited testing has been done on the slough's sediments. Many types of pesticides and metals tend to adsorb onto sediment particles in the water column and then settle to the bottom of creeks, sloughs, rivers, and estuaries. In one study of sediments collected near the mouth of No Name Slough, there was no indication of high concentrations of chlorinated pesticides or heavy metals. The metals that were detected were at concentrations that reflected the background levels in seawater and the silt and clay sediment of Padilla Bay (Bulthuis and Anderson 1996). Thus, although not measured directly in the water, chlorinated pesticide and metal concentrations in No Name Slough water are probably low and unlikely to significantly impact the plants and animals that are living in the slough.

7.10 Sources of Water Quality Degradation

There are no documented "point sources" of pollution in the No Name Slough watershed. However, there are a variety of "non-point sources" of pollution in the watershed that have the potential to degrade the water quality relative to the Class A freshwater and marine Washington State Water Quality Criteria. In the uplands, non-point sources include stormwater runoff from roads and parking areas, areas where livestock congregate, manure storage areas, and residential lawns. Poorly functioning septic systems are also believed to be a significant non-point source of pollutants. In the flats, runoff from exposed soil on annual crop fields is the main source of non-point pollution. The following preliminary observations can be made regarding potential sources of degradation of selected water quality parameters in the No Name Slough watershed. This is not meant to be a comprehensive list or review of nonpoint pollution sources. Further description of nonpoint sources are discussed in the Padilla Bay/Bay View Watershed Action Plan and the associated water quality review and water quality sampling projects (Padilla Bay/Bay View Watershed Management Committee 1995, Bulthuis 1993, Cochrane Consulting 1994).

Temperature

It is believed that the elevated summer water temperatures in the slough and ditches on the flats are due to lack of vegetation cover, lack of surface water flow from the upland tributaries, and lack of groundwater inflow.

Dissolved Oxygen

The significant seasonal variability in dissolved oxygen in the main upland tributary at the Bay View Road monitoring site may be attributed to several potential factors. First, the very low summer base flow of water in the creek probably consists mostly of phreatic inputs of groundwater, which is typically low in dissolved oxygen. Second, the elevated fecal coliform levels in this reach suggest that it might be impacted by septage. Septage (as well as runoff from confined livestock areas and other non-point sources) typically has high nutrient concentrations. As naturally occurring bacteria in the creek metabolize the nutrients, they consume dissolved oxygen and decrease the oxygen concentration in the water. Third, the greater seasonal variability at water quality site #3 in the uplands compared with site #6 on the flats (Figure 7.11) may be related to the dense vegetation that shades the creek at site #3. At site #5 on the flats, a high supply of nutrients and lack of shade result in excessive growths of algae. These algae produce oxygen during the day (cf. Figure 7.11 when dissolved oxygen was above 200% saturation or greater than 15 mg/L). The weekly water quality measurements are made during the day when the dissolved oxygen concentrations are high at site #6 because of the algal growth.

In contrast, at site # 3, which has good shade from the dense vegetation, nuisance growths of algae do not develop, and the time dissolved oxygen concentrations remain low. Thus the upland site # 3 appears to have poorer water quality than the lowland site # 6 with regard to dissolved oxygen when only daytime weekly water quality measurements are considered.

Fecal Coliform

Extensive testing indicates that the likely source of fecal coliform contamination in the main upland tributary is located between Marihugh and Bay View Roads. There is no significant livestock use in this area and vegetation buffers protect the creek from other runoff sources. Therefore, it is likely that one or more poorly functioning septic systems with connections to the creek are the source of the fecal coliform inputs.

Turbidity

The sources of particulates and suspended sediment that contribute to turbidity in No Name Slough include runoff from roads and other impervious surfaces, erosion of ditches and channel banks, re-suspension of particles and sediments that settled to the ditch and slough bottom, and runoff from fields used for annual crops.

8 Fish and Wildlife Habitat

The No Name Slough watershed contains four general fish and wildlife habitat categories:

1) upland pasture, forests and wetlands,
2) upland creek, and
3) slough and surrounding agricultural fields on the flats
4) connected habitat seaward of the dike.

The following is a description, inventory of common plant and animal species, and evaluation of habitat function and value for each of these general categories.

8.1 Upland Pasture, Forests, and Wetlands

Description

These habitats include undeveloped areas shown in Figure 3.2 and upland wetlands shown in Figure 6.2. Remaining forested areas consist of second-growth Douglas fir, red cedar, and various hardwoods. By the late 1800s, the pasture areas were created by pulling and burning stumps in logged areas. Pastures today contain a mixture of pasture grasses, native grasses, and invasive grasses and herbs. As discussed in Chapter 6.5, wetlands occur in both pasture and forested areas where the hydrology and soil conditions retain surface runoff.

Species Inventory

While no general survey of plants and animals in the uplands of the No Name Slough watershed is documented, a vegetation survey of the adjacent Port of Skagit County lands is probably representative of the No Name uplands as well. The Port property inventory includes 13 species of trees, 25 species of shrubs, 35 herbaceous plants, and 16 species of grasses, rushes, and sedges. Animal species that have been documented include 28 species of small mammals, 12 species of amphibians, 25 species of over-wintering waterfowl, 27 species of nesting birds, and 9 species of migrating birds (MacWhinney and Thomas, 1996). Of particular importance is the habitat provided for endangered, threatened, and otherwise “sensitive” species, including bald eagle, great grey owl, peregrine falcon, and great blue heron. Figure 8.1 shows areas listed for Washington Department of Fish and Wildlife Priority Habitat and Species (PHS) in the watershed.

Evaluation of Habitat Quality

While the upland pasture areas primarily serve for cattle grazing and growing hay, isolated thickets of wild rose and other shrubs probably provide cover for songbirds and mammals like raccoon and deer. Large areas of pasture remain intact, particularly in Sub-basin Nos. 7N, 10, and 9, and the southern part of Sub-basin No. 2. Residential housing development is gradually fragmenting pasture habitat in other sub-basins. Historic ditching affects the hydrology of the pasture areas, which probably has reduced the overall area of upland wetland than occurred prior to settlement in the 19^{th} Century.

Habitat quality in forested areas is gradually improving as the second growth forests mature. Particularly good habitat exists in Sub-basin No. 6, where isolated stands of very large (possibly old-growth) fir and cedar have been noted near the southern reach of the creek. Smaller woodlots in other sub-basins are more fragmented, but still provide decent habitat value, as many of them contain forested wetlands. Due to wetland protection provisions in the *Washington Growth Management Act*, it is probable that habitat conditions in at least some of these smaller woodlots will continue to improve over time, even as the surrounding upland pastures are more intensively developed.

8.2 Upland Creek

Description

The habitat in the upland reaches of the main fork of the creek falls into two categories. Reach No. 1 (from Josh Wilson Road to Marihugh Road), is characterized by a dredged and straightened creek channel bordered on both sides by a narrow thicket of wild rose, blackberry, and young alder trees. Most of the land bordering the creek is pasture. Reaches No. 2, 3, and 4 (downstream of Marihugh Road) contain a moderately incised creek channel running through a forested ravine. North of Bay View Road, (Sub-basin No. 8) about 75% of the land bordering the ravine is open pasture, with the remainder in second-growth forest. South of Bay View Road (Sub-basin No. 6), most of the land is covered by mature second-growth forest.

Species Inventory

Reach No. 1 presently does not support any fish populations. The dense riparian thicket of shrubs and alders probably provides cover for songbirds and small mammals. Tolum Pond, a small, man-made farm pond located immediately adjacent to the creek channel, provides year-round habitat for frogs and small birds.

Reaches No. 2, 3, and 4 support limited fish populations. According to Washington Department of Fish and Wildlife, Coho salmon, cutthroat trout, and resident fish historically used the No Name Slough watershed (Buchanan, WDFW, 1998 personal communication). Coho salmon smolts have been documented in pools as far upstream as Bay View Road (Dugger, 2000). Limited walk-past inventories of fish and wildlife utilization of these reaches were carried out during spring and summer 2003. During one inventory in May 2003, approximately 35 to 40 salmonid fry (species unknown) were observed in pools, particularly in Reach No. 4. By late in the summer, when water levels in the pools dropped due to one of the driest summers on record, no salmonid fry or aquatic invertebrates were observed.

There is little documentation on benthic macroinvertebrate populations in the upland creek. During a walk-past inventory in May 2003, caddisfly and stonefly larva were observed in Reach Nos. 4 and 3. In November 2003, a preliminary survey by Skagit River Steward volunteers found very few benthic macro invertebrates in Reach Nos. 2 and 3. It is speculated that the drought conditions in the summer/fall of 2003 caused insects to retreat deep into the subsurface gravels, thus delaying their reemergence and hatching (Rawthouser, USFS, 2003 personal communication).

Observations of utilization of habitat in at least the lowest two reaches of the creek by terrestrial animals include raccoon and river otter tracks on exposed sand and silt bars and sightings of hawks, bald eagle and coyote in the forest and pastures adjacent to the lower reaches of the creek.

Evaluation of Habitat Quality

Reach No. 1 has little habitat value for fish. There are essentially no riffles or pools, large woody debris, side channels, or other structural features that would provide habitat value. Because dredging has deepened the creek, for all practical purposes it is disconnected from its floodplain. Several drainage and roadside ditches feed into the reach, which results in a sharply peaked hydrograph pattern, and the reach typically runs dry in the summer.

In Reach Nos. 2, 3, and 4, the creek channel and adjacent riparian area contain fish habitat features of varying quality. Features such as riffle and pool channel morphology, large woody debris in the channel, undercut banks, and diverse, mature communities of riparian vegetation are present throughout the three reaches. In general, the frequency and quality of these features increases in relation to the distance downstream from Marihugh Road, with high quality fish habitat present in the relatively inaccessible areas just upstream of the confluence with the east fork. Appendix 4 is a record of a field inventory of habitat features in this reach during May 2003. Figure 8.2 shows photos of habitat features in these reaches.

Three main conditions detract from the otherwise good quality of fish habitat in these reaches. First, the entrenched channel is disconnected from the floodplain over much of its distance. This condition precludes the development of side channels and other "refuges" for fish during seasonal high water flows. In Reach No. 4, immediately upstream of the confluence with the east fork, the channel is somewhat less entrenched, which gives it marginally better connectivity with mature forest and scrub-shrub wetland areas adjacent to the banks.

A second condition that detracts from the fish habitat quality is the sharply peaked runoff hydrograph that characterizes flow in the creek. Due to deforestation and extensive ditching along roads and in pastures in upstream areas, runoff drains very rapidly into the channel. The resulting high flow velocities erode the banks, and stress fish and aquatic invertebrate utilization of the creek. The peaked hydrograph also results in extreme dewatering of the channel during the dry season. By May of some years, flow has ceased in Reach No. 2, and by July, water is only present in pools throughout all three reaches. Consequently, it is likely that aquatic invertebrates and fish can survive year-round only in the pools.

The third major habitat impact in the creek is the set of two, 36-inch culverts under Bay View Road. Scouring at the outlet of these culverts has resulted in a 3-foot drop to the typical water surface elevation of the large scour pool. While a 1998 engineering evaluation determined that the diameter and slope of the culverts do not cause a velocity barrier to fish passage, the 3-foot drop results in a complete barrier to fish passage upstream of Bay View Road (Leonard Budinot and Skodje, 1998).

8.3 Slough and Flats

Description

The slough in the flats includes the dredged and straightened channel from Farm to Market Road (east fork) to the tidegates at Padilla Bay. While most of the land adjacent to the slough is open crop fields, about 2,000 feet of the slough is bordered by forest on the north side and about 1,000 feet has a thicket of wild rose and blackberry along both banks.[18] The flats adjacent to the slough consist entirely of land that was reclaimed from tidal marshes and mudflats in the late 19th century. Diking and drainage infrastructure has converted nearly 62% of the historic tidal wetland area of the Padilla Bay ecosystem into agricultural land. (Collins and Sheikh 2003, Thom and Hallum 1990).

Species Inventory

Limited walk-past surveys of fish and wildlife utilization of the slough were carried out in spring, summer, and fall 2003. Upstream of the Egbers farm road culvert, where the water is unaffected by salt water influence, river otter, frog, great blue heron, hawks and bald eagles were observed. Downstream of the Egbers culvert, the presence of animal life that is associated with estuaries increases with the gradual increase in water salinity. As well as herons, eagles, hawks, and river otter, the lower 1,500 feet supports Dungeness crab, three-spine stickleback, and mud clams. These species also utilize benthic habitat in some of the ditches that drain into the pumphouse reservoir. Washington Department of Fish and Wildlife (Gersib, Department of Ecology, 1999, personal communication) has documented Coho salmon migrating into the slough.

Evaluation of Habitat Quality

The slough on the flats lacks habitat features for fresh water fish. There are no features such as riffles and pools, no in-stream large woody debris, side channels, or other channel structural features. The complete lack of trees and other shade on the south bank and most of the north bank result in elevated water temperatures and reduced dissolved oxygen concentrations in the summer months. Mitigating the generally poor fish habitat features somewhat are extensive scrub-shrub wetlands at the confluence with the creek from Sub-basin No. 5 (Paccar area) and near the confluence with Reach No. 4 of the main fork of the creek; a greater connectivity with the floodplain than in the upland reaches of the creek; and the water storage capacity of the tidegate reservoir, all of which contribute to a more stable hydrology and resulting lower flow velocities than in upland reaches.

Due to its intensive agricultural management, the farm fields on the flats adjacent to the slough provide little natural habitat value for wildlife. Nevertheless, crop residues left in the fields do attract over-wintering trumpeter swans, and tundra swans, and other waterfowl. Ducks and other waterfowl also utilize the pump station pool for resting and feeding.

8.4 Connected Habitat Seaward of the Dike

The ecological value of a habitat typically increases in relation to its proximity to and interconnection with other habitat types (MacWhinney and Thomas 1996). The principle of habitat

[18] This is in the vicinity of the confluence of the main and east forks and immediately upstream of Bayview-Edison Road, respectively.

"interconnectivity" is particularly important in estuary areas, where terrestrial, freshwater, and marine habitats interface. In the Pacific Northwest, the role of habitat interconnectivity is clearly illustrated by the life cycle of salmon, which utilize all three habitats during different stages in their life cycle. While the scope of the *No Name Slough Watershed Characterization* focuses on the watershed landward of the Padilla Bay tidegates, it is important to consider the interconnectivity of its habitats with the key estuarine habitats located seaward of the dikes. The three key estuarine habitats are 1) salt marsh/blind channels, 2) nearshore areas, and 3) eelgrass meadows located adjacent to the dikes.

Salt Marsh and Blind Channels

The salt marsh/blind channel complex includes two isolated remnant sloughs in the agricultural fields south of No Name Slough as well as the land outside of the dikes along Little Indian and Big Indian Slough to the south. This habitat represents 9% of the estimated 153 acres of remaining inter-tidal marshes of Padilla Bay. This area is believed to be representative of a complex system of blind channels and estuarine emergent marshes that once extended from the shoreline into the upland forest. In Appendix 1 is an aerial photo of this system circa 1937.

The elevation for native salt marsh species in Padilla Bay is from about 4 ft to 6.2 feet above mean sea-level (NGVD 1929), and slightly higher from 5 ft to 6.2 feet in the south end of the bay (Bulthuis and Scott 1993). By comparison, the top of the Padilla Bay dike is typically about 8.5 feet above MSL and the elevation of the agricultural fields on the flats ranges from about 0.7 to 1.7 feet above MSL (Slocum, 2002, unpublished data). Salt marsh wetlands are often divided into two habitats based on their elevation and plant communities (Weinman et al. 1984). High salt wetland/estuarine scrub-shrub wetland occurs in areas above mean higher high water (approximate 9 feet above MSL in Padilla Bay). Typical species include tufted hairgrass, Pacific Silverweed, meadow barley and Lyngby's sedge. The upper limits of this area is dominated by shrubs Sweetgale, black twinberry, willow, wild rose, cattails and spirea. Low salt wetlands/estuarine emergent habitats occur in areas below mean higher high water. Key salt marsh plants growing here include pickleweed, arrrowgrass, saltweed, and saltgrass.

A diverse mix of waterfowl and other wildlife typically utilize these wetlands. Crabs, clams, shrimp, marine fish, salmon, eagles, herons, and other birds use tidal sloughs for cover and food. The tidal marshes are home to a variety of invertebrates: nematodes (roundworms), turbellarians (flatworms), harpactacoid copepods (zooplankton), and annelids (worms). The worms are important to the diets of waterfowl and shorebirds, and the zooplankton are of particular importance as a food supply for juvenile and adult fish in the bay (Simenstad 1988).

The salt marsh complex is important for juvenile anadromous fish for many reasons. The juvenile salmon use the shallow areas of the bay for feeding and to escape predators. Recent research has shown that pocket estuaries in Skagit Bay are key habitat areas for juvenile Chinook salmon, sometimes holding twenty times the amount of fish found in other habitats (Beamer et al. 2003). These pocket estuaries are sub-estuaries that form among other places at small creek deltas and are important for food as well as a place where salmon adjust to the higher salinities of Puget Sound in a process called smoltification. Research shows that estuarine habitat is an extremely important part to wild Chinook salmon, and that the lack of this habitat may influence the ability of the salmon to recover (Aitkin 1998).

Near Shore

This habitat area includes the shoreline areas around the mouth of No Name Slough. Nearshore habitat typically includes the land 200 feet landward of the ordinary high-water line to the shallow subtidal zone. In Pacific Northwest nearshore habitats, a soft, complex, well-shaded shoreline offers marine life opportunities for attachment, egg laying, shelter, and grazing, and reduces the scouring of forage fish spawning areas. Of particular concern in Puget Sound and the Straights of Georgia is nearshore habitat for so-called “forage fish.” Species such as Pacific herring, surf smelt, and sand lance lay eggs at different elevations in soft (i.e. sand or gravel) inter-tidal beaches. Likewise nearshore habitat is crucial for juvenile salmonids and other fish species.

Essentially all of the shoreline adjacent to the No Name Slough watershed, as well as 60% of the rest of the Padilla Bay shoreline, is armored with rock or otherwise hardened. This prevents utilization of the near shore area for fish habitat. In addition, shoreline armoring and hardening also prevents the development of natural drainage channels in the mudflats outside of the dikes. Such sub-tidal channels are important refuge areas for animals that use the eelgrass habitats during high tide (e.g. English sole and buffalo sculpin), and that use the channels for certain life stages (e.g. Dungeness and red rock crabs) (Dinnel et al. 1986).

Eelgrass Meadows

Much of the land lying below MLLW in Padilla Bay supports native and non-native eelgrass. The roughly 7,400 acres of eelgrass meadow of the bay represent the largest eelgrass meadow on the west coast of the lower 48 states. Eelgrass meadows are highly productive and supply important food refuge habitat to fish, shellfish, and bird populations (Bulthuis 1996a). As the eelgrass decays it provides the detritus that is the foundation of the ecosystem that supports a highly valuable aesthetic and recreational resource for local residents and tourists.

8.5 Endangered Species Act Functional Criteria / Environmental Baseline Conditions

Using field observations conducted during habitat inventories and hydrologic monitoring in 2003, “environmental baseline conditions” were evaluated with regard to habitat for salmon species regulated under the Endangered Species Act. Environmental baseline conditions for salmon habitat in the upland creek reaches and the lowland slough were evaluated by functional criteria specified in NOAA fisheries guidance. Field data sheets are included in Appendix 4. Table 8.1 summarizes the evaluation of the relative quality of the various habitat features observed in the upland creek reaches and lowland slough. For simplicity, the various types of habitat features are grouped into three categories: physical channel features, biological features, and land use/man made features.

Table 8.1
Summary of Ratings for Environmental Baseline Conditions

Habitat Features	Reach 1	Reach 2, 3, and 4	Slough on Flats
Physical Channel Features	Functioning at Risk	Functioning at Risk	Functioning at Risk
Biological Features	Not Properly Functioning	Functioning at Risk	Not Properly Functioning
Land Use Characteristics	Functioning at Risk	Properly Functioning Condition	Properly Functioning Condition

The summaries of Endangered Species Act functional criteria in Table 8.1 indicate that Reaches 2, 3, and 4 of the upland creek (i.e. between Marihugh Road and the confluence with the east fork in the flats) have the highest quality salmonid habitat in the No Name Slough watershed. Reaches 3 and 4 (below Bay View Road) in particular, because of their relatively remote location and their relatively high quality of large woody debris, pools, riparian vegetation, and other habitat features, offer the best salmon habitat in the watershed. Reach 1 and the lowland slough have been so impacted by dredging and agricultural development that they currently have low habitat value for salmon.

It should be emphasized that this evaluation of environmental baseline conditions is intended as an attempt to assess and understand existing habitat conditions in the No Name Slough watershed. It is not intended as a formal Endangered Species Act Biological Evaluation for the purpose of supporting a particular project proposal.

References

Literature Cited

Aitkin, J.K. 1998. *The importance of estuarine habitats to anadromous salmonids of the Pacific Northwest: a literature review*. US Fish and Wildlife Service: Lacey, Washington.

Beamer, E., A. McBride, R. Henderson and K. Wolf. 2003. *The importance of neo-natal pocket estuaries in Skagit Bay to wild chinook salmon: an emerging priority for restoration*.

Bulthus, D.A. 1993. *Review of water quality data in the Padilla Bay/Bay View watershed.* Washington State Department of Ecology, Padilla Bay National Estuarine Research Reserve: Mount Vernon, Washington. 72 pp. Padilla Bay National Estuarine Research Reserve Technical Report No. 10.

Bulthuis, D.A. 1996a. *Coastal habitats in Padilla Bay, Washington: a review*. 57 pp. U.S. Army Engineers Waterways Experiment Station: Vicksburg, Mississippi. U.S. Army Engineer Waterways Experiment Station, Environmental Impact Research Program, Technical Report EL-96-15.

Bulthuis, D.A. 1996b. *Nutrients and suspended solids in Padilla Bay and its watershed during 1995-96*. 45 pp. Padilla Bay National Estuarine Research Reserve: Mount Vernon, Washington.

Bulthuis, D.A. 1997. *Padilla Demonstration Farm: soil salinity and soil nutrients in December, 1996*. 16 pp. Washington State Department of Ecology, Padilla Bay National Estuarine Research Reserve: Mount Vernon, Washington. Washington State Department of Ecology Publication No. 97-111; Padilla Bay National Estuarine Research Reserve Technical Report No. 18.

Bulthuis, D.A. 2001. *Suspended solids in seasonal V-ditches on annual crop fields in Skagit Valley, Washington: effects of various agricultural trials*. 55 pp. [A report of the Padilla Bay National Estuarine Research Reserve, Washington State Department of Ecology to the Skagit Conservation District in partial fulfillment of Grant No. PB97-02.]. Padilla Bay National Estuarine Research Reserve, Washington State Department of Ecology: Mount Vernon, Washington.

Bulthuis, D.A. and W.C. Anderson. 1996. *Survey for pesticides on the Padilla Bay National Estuarine Research Reserve Demonstration Farm, 1993*. 15 pp. Washington State Department of Ecology, Padilla Bay National Estuarine Research Reserve: Mount Vernon, Washington. Washington Department of Ecology Publication No. 96-121, Padilla Bay National Estuarine Research Reserve Technical Report No. 16.

Bulthuis, D.A. and B.A. Scott. 1993. *Effects of application of glyphosate on cordgrass, Spartina alterniflora, and adjacent native salt marsh vegetation in Padilla Bay, Washington*. 29 pp.

Washington State Department of Ecology, Padilla Bay National Estuarine Research Reserve: Mount Vernon, Washington. Padilla Bay National Estuarine Research Reserve Technical Report No. 7.

Cochrane Consulting. 1994. *Padilla Bay/Bay View watershed water quality study final report*. 59 pp. [Prepared for Skagit County Department of Planning and Community Development and Washington State Department of Ecology Grant Number - G9200187]. Skagit County Department of Planning and Community Development: Mount Vernon, Washington.

Collins, B. D. and Sheikh, A. J. 2003. *Historical aquatic habitat in river valleys and estuaries of the Nooksack, Skagit, Stillaguamish, and Snohomish watersheds, May 1, 2003*. Report to Northwest Fisheries Science Center, National Marine Fisheries Service, P.O. Box 157, 2725 Montlake Blvd. E. Seattle, WA 98112.

Dinnel, P.A., R.O. McMillan, D.A. Armstrong, T.C. Wainwright, A.J. Whiley, R. Burge and R. Bumgarner. 1986. *Padilla Bay dungeness crab, Cancer magister, habitat study*. 78 pp. [Final report to NOAA/MEMD, Washington D.C., Grant No. NA85-AA-D-CZ046]. Univ. Washington, Fisheries Research Institute: Seattle, Washington. Padilla Bay National Estuarine Research Reserve Reprint Series No. 3.

Dugger, P.J. 2000. *Possible water quality and habitat factors influencing the presence of coho salmon and sticklebacks in No Name Slough during summer, 2000*. 12 pp. [An informal report to Doug Bulthuis, Research Coordinator, Padilla Bay National Estuarine Research Reserve.] Washington State Department of Ecology, Padilla Bay National Estuarine Research Reserve: Mount Vernon, Washington.

Freeze, R.A. and J.A. Cherry. 1979. *Groundwater*. Prentice Hall, Inc.: Englewood Cliffs, NJ.

Henry, D. 2003. *2003 citizen monitoring water quality summary: Nookachamps, Samish, & Padilla Bay watersheds, 2002*. [Prepared for the following grants: Samish and Padilla Bay Watersheds Information and Education. Padilla Bay Agriculture BMP Implementation, Lower Skagit Basin Watershed Implementation]. Washington State Department of Ecology: Mount Vernon, Washington, Padilla Bay National Estuarine Research Reserve.

Leonard, Budinot, and Skodje. 1998. *Skagit County Culvert Evaluations Fish Passage Improvement (Task No. 1)* Prepared for Skagit County Washington. Mount Vernon, WA.

MacWhinney, E.J. and J.G. Thomas. 1996. *Indicator value assessment (IVA) of wetland functions at the Port of Skagit County, located in the Padilla Bay/Bay View Watershed, Washington. Mt. Vernon, Washington.* Phase II: Skagit Wetland Inventory Network. Burlington, WA.

Maynard, D.N. and G.J. Hochmuth. 1997. *Knott's Handbook for Vegetable Growers, Fourth Edition*. John Wiley and Sons, Inc.: New York.

Northwest Hydraulic Consultants. 2000. *Padilla Bay hydrology: hydrologic and hydraulic model of the No Name Slough drainage*. 10 pp. [Prepared for Padilla Bay National Estuarine Research Reserve]. Northwest Hydraulic Consultants: Seattle, Washington.

Padilla Bay/Bay View Watershed Management Committee and Skagit County Department of Planning and Community Development. 1995. *Padilla Bay/Bay View watershed nonpoint action plan*. Skagit County Department of Planning and Community Development: Mount Vernon, Washington.

Reiser, D.W. and T.C. Bjornn. 1979. *Habitat requirements of anadromous salmonids*. In: W.R. Meehan, Editor, *Influence of forest and rangeland management on anadromous fish habitat in western North America*. U.S Forest Service General Technical Report PNW-96. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Rosgen, D.L. 1996. *Applied river morphology*. Wildland Hydrology Publishers: Pagosa Springs, CO.

Rosgen, D.L. 2001. A stream channel stability assessment methodology. In: *Proceedings Seventh Federal Interagency Sedimentation Conference*, Reno, NV, Vol. 2: pp. 18-26.

Schuler, T. 1994. *The importance of Imperviousness*. Watershed Protection Techniques 1(3): 100-111.

Simenstad, C.A., J.R. Cordell, R.C. Wissmar, K.L. Fresh, S.L. Schroder, M. Carr, G. Sanborn and M. Burg. 1988. *Assemblage structure, microhabitat distribution and food web linkages of epibenthic crustaceans in Padilla Bay National Estuarine Research Reserve, Washington*. 60 pp. [Final report to NOAA/MEMD Grant No. NA86AA-D-CZ027]. Univ. Washington, Fisheries Research Institute: Seattle, WA. FRI-UW-8813. Padilla Bay National Estuarine Research Reserve Reprint Series No. 9.

Skagit County Department of Planning and Community Development. 1988. *Skagit County watershed ranking project*. Skagit County Department of Planning and Community Development: Mount Vernon, Washington.

Soil Conservation Service, United States Department of Agriculture. 1989. *Soil survey of Skagit County area, Washington*. 372 pp. [In cooperation with Washington State Department of Natural Resources and Washington State University, Agriculture Research Center.] United States Department of Agriculture, Soil Conservation Service.

Thom, R.M. and L. Hallum. 1990. *Long-term changes in the areal extent of tidal marshes, eelgrass meadows and kelp forests of Puget Sound*. 55 pp. University of Washington, Fisheries Research Institute, Wetland Ecosystem Team: Seattle, Washington. EPA 910/9-91-005, FRI-UW-9008.

Washington State. 18 November 1997. *Washington Administrative Code, Chapter 173-201A WAC, Water quality standards for surface waters of the State of Washington*. 18 pp. Washington State: Olympia, Washington.

Washington State Attorney General 1969. *Attorney General Opinion 1969 No. 4: Opinion given to James P. Behlke, Director, Water Pollution Control Commission.* 10 pp. Olympia, Washington. [to be cited as AGO 1969 No. 4]

Weinman, David, Jennifer Linkhart, David Henry, and Douglas A. Bulthuis. 2004. *Short-term fluctuations and seasonal patterns of depth and temperature in No Name Slough, 2000-2003*. Washington State Department of Ecology, Padilla Bay National Estuarine Research Reserve: Mount Vernon, Washington. Padilla Bay National Estuarine Research Reserve Technical Report No. 29.

Weinmann, F., M. Boule, K. Brunner, J. Malek and V. Yoshino. 1984. *Wetland plants of the Pacific Northwest*. 85 pp. [Prepared for U.S. Army Corps of Engineers, Seattle District]. Seattle, Washington.

Weisberg, S. and Riedel, J. 1991. *From the mountains to the sea: a guide to the Skagit River watershed.* North Cascades Institute: Sedro-Woolley, Washington.

Appendices

Appendix 1: Land Use – Historical Photos

Appendix 2: Groundwater/Flow– Supplemental Tables

Appendix 3: Surface Water Hydrology – Supplemental Data Tables

Appendix 4: Habitat – Supplemental Tables and Figures

Appendix 5: Synopsis of the Major Water Quality Studies in No Name Slough

Appendix 1: **Land Use – Historical Photos**

Appendix 2: **Groundwater/Flow– Supplemental Tables**

Appendix 3: **Surface Water Hydrology – Supplemental Data Tables**

Appendix 4: **Habitat – Supplemental Tables and Figures**

Appendix 5: **Synopsis of the Major Water Quality Studies in No Name Slough**

Water Quality Studies in No Name Slough

A short synopsis is provided below for five monitoring projects or studies on No Name Slough from which data were extracted or summarized for this characterization report.

Dugger, Phil, and Douglas Bulthuis, unpublished data. *Weekly water quality sampling at up to 17 sites in No Name Slough*. This project is an ongoing water quality monitoring study in No Name Slough. About 15 sites have been identified where water quality is measured each week. The study began in 1996 and is continuing. During the course of the study a few sample sites have been abandoned and a few others added as data from the monitoring was used to refine the design of the study. At each site, temperature, salinity, conductivity, dissolved oxygen and water depth are measured with field instruments. Over the seven years of the study a variety of YSI field instruments have been used. During 2004, a YSI 85 that measures all of the above parameters (except depth) has been used. In addition a water sample is collected and turbidity measured in the laboratory with a turbidimeter, usually within 24 hours of sampling. A variety of student interns, Washington Conservation Corps, AmeriCorps and volunteers have conducted the monitoring with a turnover every one to two years. In 2000, Phil Dugger checked and corrected obvious errors of all of the 1999 – mid 2000 data and produced a variety of graphs to summarize the data. A selection of these graphs have been slightly modified and included in this characterization report.

Skagit Stream Team. 2003. *Henry 2003 citizen monitoring water quality summary: Nookachamps, Samish, and Padilla Bay watersheds*. Testing directed specifically at the No Name Slough watershed has been ongoing since 1998 by trained local volunteers participating in SCD's and PBNERR's "Skagit Stream Team" Program have monitored water quality, including fecal coliform organisms, at four sites in the No Name Slough watershed bi-weekly from September to June since 1998. Results of the Stream Team monitoring have indicated violations of the fresh and marine Water Quality Criteria for fecal coliforms on a regular basis. Further details of this study can be found in Henry 2003.

Weinman, David, Jennifer Linkhart, David Henry, and Douglas Bulthuis. 2004. *Short-term fluctuations and seasonal patterns of depth and temperature in No Name Slough, 2000-2003*. This project is an ongoing monitoring of water depth and temperature every 15 minutes at four sites in No Name Slough. Sites were established in 2000 and 2001 to provide a basis for estimating flow in No Name and tributaries. At each site a pressure transducer with sensors for height and temperature has been established. Starlogger dataloggers store an instantaneous measurement every 15 minutes and a 15 minute average. Starloggers are checked regularly to insure continuous operation and the data are downloaded each month. Further details of this study can be found in Weinman et al. 2004.

Bulthuis 1996b. *Nutrients and suspended solids in Padilla Bay and its watershed during 1995-96.* In this completed study, water samples were collected weekly near the time of daytime low tide, when maximum flow out of the tidegates would be expected. Total suspended solids, turbidity, inorganic nitrogen, and dissolved phosphate were determined in all samples. Samples were collected weekly from No Name Sough and Joe Leary Slough from April 1995 to April 1996. Further details of this study can be found in Bulthuis 1996b.

Bulthuis, Douglas and Robin Cottrell unpublished data. *Thirty minute water quality data at the No Name Slough tidegates*. This ongoing monitoring project measures water depth, temperature, salinity, dissolved oxygen, pH, and turbidity every 30 minutes with a water quality datasonde. The sonde is exchanged about every 2-3 weeks, cleaned, recalibrated, data downloaded, and redeployed. An instrument was deployed at a fixed depth just above the bottom sediment at the pumphouse on No Name Slough from 1997 through 2002. (During 2003, the instrument was redeployed to a floating position by the Padilla Demonstration Farm culvert over No Name Slough.) Only data collected at the pumphouse is presented in this report. Data from 1996 and 1997 can be accessed via the National Estuarine Research Reserve website: http://cdmo.baruch.sc.edu/. The website includes metadata which give further details about the methods used in this monitoring program.