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Dynamics of Intermediate-Size Stream Outlets, Northern Oregon Coast

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AN ABSTRACT OF THE THESIS of Ellen Eberhardt for the Master of Science in Geology presented October 21, 1988.

Title: Dynamics of Intermediate-size Stream Outlets,
Northern Oregon Coast.

APPROVED BY THE MEMBERS OF THE THESIS COMMITTEE:

Leonard A. Palmer, Chairman

Richard E. Thoms

Ansel G. Johnson

Bruce W. Brown, Graduate Office Rep.

This study measured and evaluated the relation of coastal foredune morphology to stream beach outlets, and investigated the processes associated with the stream outlet. Intermediate-size streams were studied, and defined as those that flow across the beach most of the year but have no tidal influence. Fifty-four of these streams were found along the northern Oregon coast between the Columbia River and Yaquina Bay. Crescent Lake Outlet, Saltair Creek and Daley Lake Outlet were chosen as study streams for

further investigation.

Significant differences at the intermediate-size stream outlets were found in dune morphology and volume, beach profile and plan form, and in wave and wind processes.

Dune height and volume are less at the outlet, especially on the northern side of the stream, because stream wetting of sand was found to interrupt the dominant northward eolian processes. Stream incision into the upper beach allows storm waves to break farther onto the shore, into the area of dune formation. Flooding hazard is also increased by the stream embankment's focusing of wave energy. Increased deposition at stream outlets appears to increase the lower beach elevation in the surf zone and may cause the observed increase in offshore turbulence near the stream. No significant beach sediment size variation was found.

Increased hazard to development is expected because of reduced dune size, lowered beach face and focusing of storm waves at the stream outlet.

DYNAMICS OF INTERMEDIATE-SIZE STREAM OUTLETS,
NORTHERN OREGON COAST

by

ELLEN EBERHARDT

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
GEOLOGY

Portland State University

1988

TO THE OFFICE OF GRADUATE STUDIES:

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CHAPTER I

INTRODUCTION

The purpose of this study is to measure and evaluate the relation of coastal foredune morphology to stream outlets, and to investigate the processes associated with these stream outlets. The primary orientation is toward collecting data on landforms and processes at "intermediate-size" stream outlets, and analyzing the relations of wave, wind and stream erosion, deposition and transport within this area. Intermediate-size streams have been defined here to include those that flow across the beachfront most of the year and are not influenced by normal tidal changes. It excludes those streams which are under normal tidal influence at their mouths, such as those with estuaries: the Alsea River, Nehalem River, and Necanicum River. It also excludes those streams which percolate through the sand and which rarely, if ever, flow across the beach face.

Little has been published about the intermediate-size stream beach outlet and its materials, processes and landforms. Its impact upon land use risk in Oregon is unknown. In this study, basic observations on intermediate-size coastal streams were made. The questions investigated include:

(1) What are the basic characteristics of intermediate-size stream outlets on the northern Oregon coast?

(2) Do intermediate-size stream outlets modify the location or energy of the swash and surf zone of the beach?

(3) Do intermediate-size streams modify the beach face?

(4) Do beach sediments have special properties of size and distribution at intermediate-size stream outlets?

(5) Are eolian processes of the beach and foredune modified by the presence of an intermediate-size stream?

(6) Are coastal foredunes reduced in height or volume adjacent to intermediate-size streams?

(7) Do intermediate-size streams generate a "reduced protective value for coastal development due to conditions of the beach and dune morphology" (OLCDC, 1986)?

Interactions between the dynamic geologic processes of land and sea create a constantly changing coastal environment. Commonly, coastal areas of great concern to land-use planners are those where fluvial processes are involved, such as estuaries and deltas. Erosion and progradation along many coastlines have been a concern to many beachfront property owners. As the coastal zone becomes more developed, the need for research into the interactive processes occurring there increases. The effects of intermediate-size stream outlets on such developments are not known.

This research was prompted by a recent study done under the direction of the Oregon Land Conservation and Development Commission (1986), which stated a need for more information on which to base land-use decisions in the areas affected by these streams.

LOCATION

The reconnaissance study area is located along 210 kilometers (130 miles) of Oregon coastline between the mouth of the Columbia River and Yaquina Bay (Fig. 1). Localities reconnoitered are at the mouths of all accessible intermediate-size streams located on U.S.G.S. 7 1/2-minute quadrangle maps (Appendix A). These sites are generally on long sandy beaches accessible by secondary roads which cross both public and private land.

The three streams chosen by the criteria listed on p. 20 for more extensive study out of 54 reconnoitered lie in Tillamook County along two major stretches of coastline. Two of these are Crescent Lake Outlet and Saltair Creek, located near and in the town of Rockaway Beach, respectively. Crescent Lake Outlet is at Manhattan Beach State Wayside, and Saltair Creek is at SE 6th St. near Twin Rocks. Crescent Lake Outlet drains Lake Lytle and Crescent Lake, while Saltair Creek drains the Clear Lake basin. The

Figure 1. Location map of field area, northern Oregon coast.

third, Daley Lake Outlet, is located approximately 8 kilometers (5 miles) north of Neskowin, at Camp Winema, and drains Daley Lake.

The two northern streams at Rockaway Beach lie between the major headlands of Neahkahnie Mountain and Cape Meares, and between the major estuaries of Nehalem Bay and Tillamook Bay. Daley Lake Outlet is tucked between the headlands of Cape Kiwanda and Cascade Head, and lies between Nestucca Bay and Neskowin Creek.

PRIOR INVESTIGATIONS ON THE NORTH OREGON COAST BEACHES AND DUNES

Little, if any, specific work has been focused around intermediate-size streams outlets on coastlines. Related coastal investigations include the following papers and publications.

W.S. Cooper's (1958) regional reconnaissance of the coastal sand dunes of Oregon and Washington is a landmark work, providing baseline data studies along these beaches. He mentions the area studied here, the area between Tillamook Head and Heceta Head, as Region II. Twenty-seven percent of that area has dunes, and 8 out of 10 significant dune localities in the area are related to river mouths. The localities of the study sites investigated in the current study were designated by Cooper as Locality 6 -

Rockaway and Locality 11 - Neskowin Creek (Daley Lake). He generally mentions the dune areas, but not streams associated with them.

James Stembridge (1975) inventoried shoreline changes along the Oregon coast and noted that there has been confusion regarding shoreline changes in the Rockaway Beach area. He concluded that slow progradation of the coastline combined with frequent storm damage caused this confusion. The area near Daley Lake was represented as being non-erosional, one of the most stable of the Oregon's beaches.

Beaches and Dunes of the Oregon Coast, published by the Soil Conservation Service in 1975, is a general inventory of coastal beach and dune areas, and includes descriptions and examples of dune classifications. It addresses each county separately, and includes maps of each dune type in the area.

The U.S. Department of Agriculture Soil Conservation Service (1975) inventoried data and interpretations about beaches and sand dunes of the Oregon coastal zone. It included sections on the dune resources of each coastal county, as well as explanations of resource use and map interpretation. It is a good general resource for studying the coastal sand dunes of Oregon, and includes maps of active, stabilized and older dunes.

N.A. Aguilar-Tunon and P.D. Komar (1978) chronicled the annual profile changes of two Oregon beaches

approximately 56 kilometers (35 miles) south of the area of present study. Changes in profiles caused by storms, longshore sand transport, tides and coastal winds were related to wave conditions.

David Rankin (1983) did an extensive study of the dunes on Clatsop Plains, directly south of the Columbia River. He addressed the various ages of the dunes in that area through carbon dating of peat and discussed sediment transportation along the Oregon coast as it related to sand dunes.

Evidence for Holocene earthquakes in bedded soils of estuaries along the coast of Washington was found by Brian Atwater (1987). He concludes that great earthquakes originated in the Cascadia subduction zone, and the tsunamis they generated caused anomalous rapid subsidence and also caused sheets of sand to be deposited in estuaries. This provides evidence that rapid coastal subsidence of 0.5 to 2.0 meters (1.6-6.6 feet) occurred at least six times in the past 7000 years. The potential for catastrophic flooding in lowlying coastal areas is therefore present.

The most recent work in the area is the study by the Oregon Land Conservation and Development Commission entitled Rockaway Beach/Nedonna Beach Dunes Management Study (1986). Included in this study is a section from a discussion paper written by Karl Nordstrom of the Center for Coastal and Environmental Studies, Rutgers University, on

the relationship between shoreline erosion and the presence of small coastal streams. It was the only research found that specifically discussed the unique situation of intermediate-size stream outlets. This paper addresses the subjects of stream erosion, wave erosion, depositional processes and shoreline stabilization attempts with respect to stream mouths and the integrity of the nearby foredune. He states that "all shoreline locations at stream mouths are susceptible to greater erosion problems than adjacent shoreline segments" and should receive special management consideration.

Waves and Beaches by Willard Bascom (1980) is a general work on the behavior of waves and beaches under various conditions. Many of the examples contained in this book come from work done on the beaches of Oregon. He mentions the pocket-like nature of the Oregon coast as the classic example of a youthful shoreline, where little time has passed since the last change in sea level. Bascom was involved in the offshore profile survey of coasts in the 1940's using a DUKW, a six-wheeled amphibious vehicle. This remains one of the few studies concentrating on the topography in the surf zone. Much of Bascom's work does not directly relate to the outlet areas studied here; however, it is worth mentioning that he did notice the effect of offshore islands on the nearby beach in reducing

the height of the berm in their lee to enable streams tend to flow into the sea behind the island.

C.M. King's Beaches and Coasts (1972) is a foundation work on the subject area of coastal processes, as well as the more recent work Geographical Variation in Coastal Development (Davies, 1977). Due to the lack of specific information on intermediate-size stream outlets, these generalized works provided information on the processes discussed within the context of the current study.

GEOLOGIC SETTING OF THE NORTHERN OREGON COAST

The physiography of the northern Oregon coast is dominated by the Oregon Coast Range, a broad low mountain range composed of Tertiary volcanics and sedimentary rocks. The coastline runs approximately north-south and at no place are the mountains far from the coast. The narrow zone between the mountains and the sea is occupied by a "strip of terraced nature" (Cooper, 1958). Sedimentary bedrock underlies pocket bays and beaches separated by volcanic headlands.

Present shoreline geomorphology is a result of rock resistance and sea level changes that combined to form various terrace levels paralleling the coastline. Sea level changes can be divided into two types: those associated with worldwide, or eustatic, sea level changes and those resulting from relatively local tectonic or isostatic

changes in the level of the land.

Submergence in the early Pleistocene cut a terrace 458 m (1500 ft.) above present sea level and was followed by uplift, lowering sea level to 91 m (300 ft.) below present and initiating river entrenchment. The next submergence marked the beginning of Pleistocene dune activity, bringing sea level 49 m (160 ft.) above present, drowning river valleys and creating the older yellow and red iron-stained consolidated dunes seen today (Wiedemann, 1974).

In the late Pleistocene a slight emergence occurred, and created a terrace 46 m (150 ft.) above present sea level, which remains covered today with unconsolidated sediments. This is the 30 m terrace of Cooper (1958) that has been warped both up and down in many areas and is no longer continuous. Terraces along the northern two-thirds of the Oregon coast, in comparison to those observable along the southern one-third of the coastline, are obscured by large sand dune deposits or prograding beaches, and were perhaps never formed due to the presence of large quantities of sediment dumped by the Columbia River (Palmer, 1967).

Eustatic sea level changes, those associated with glaciations, have affected the coastal zone of Oregon. After the maximum Wisconsin glaciation, approximately 13,000 years ago, glaciers began to melt and sea level rose from about minus 100 meters to present sea level, stable for approximately the past 3500 years (Rankin, 1983). The

current stand of sea level created the features of the present coastline, with sand dune activity beginning again and peaking from 3000 to 2200 years ago (Rankin, 1983). During a slight resubmergence from 2000 to 1000 years ago, river valleys were again drowned, and those without enough flow to stem the sand dune build-up were ponded and created lakes. Since the last major sea level change, dunes have gone through various cycles of stabilization and rejuvenation depending upon current climatic and shoreline conditions.

In this region, Region II of Cooper (1958), the dunes lie on a downwarped terrace with continuous, narrow dune ridges paralleling the mountain front. Behind these dune ridges lie small ponded lakes. Crescent Lake and Daley Lake are just two examples of many in the area. In other locations, however, terraces are eroded and dunes have not been built. Dissection of these terraces is minor, and they remain relatively intact.

CLIMATE

The Oregon coast lies in a marine temperate zone and is generally wet and cool. Uniform annual temperatures range between 10.5 C.(51 F) at Astoria to 11.0 C.(52 F) at North Bend. Precipitation averages 195 centimeters (77 inches) per year at Astoria and 165 centimeters (65 inches)

per year at North Bend. Two-thirds of this total falls between December and February (Wiedemann, 1974). At Tillamook, in the general vicinity of the study area, annual precipitation averages 230 centimeters (91 inches) per year, and the mean temperature ranges from 2 C.(35.5 F) to 20 C.(68.5 F)(Figure 2).

Gentle northwest winds predominate in the summer, while strong southwest winds bring severe winter storms (Figure 3). Relative humidity averages between 70% and 90% at Astoria (Figure 4).

Shoreline vegetation is dominated in height by the beach pine (Pinus contorta) and Sitka spruce (Picea stichensis), with an understory of salal (Gaultheria shallon) and evergreen huckleberry (Vaccinium ovatum). Sand dunes are covered first by European beach grass (Ammophila arenaria), an introduced species, and later colonized progressively by other grasses, broad-leaf plants, shrubs and, finally, trees.

WAVE CONDITIONS

Measurements of ocean wave conditions in Oregon have been taken and recorded daily off the coast of Newport, Oregon since 1971 by a seismic recording system operated by the Hatfield Marine Science Center. Data collected between November 1971 and June 1975 was analyzed by Komar and others (1976). This wave data is related to waves occurring

TILLAMOOK, OR (# 358494)		CLIMATOLOGICAL SUMMARY										1951-80										45° 27' N 123° 52' W										10 FT.									
		TEMPERATURE (F.)										PRECIPITATION (TOTALS, INCHES)																													
MEANS		EXTREMES						MEAN NUMBER OF DAYS				DEGREE DAYS		*		*		PRECIPITATION (TOTALS, INCHES)				SNOW		MEAN NUMBER OF DAYS																	
DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	RECORD HIGHEST	YEAR	DAY	RECORD LOWEST	YEAR	DAY	90 AND ABOVE	32 AND BELOW	32 AND BELOW	0 AND BELOW	HEATING BASE 65	COOLING BASE 65	*	*	MEAN	GREATEST MONTHLY	YEAR	DAILY	YEAR	DAY	MEAN	MAXIMUM MONTHLY	YEAR	10 OR MORE	50 OR MORE	100 OR MORE													
JAN	48.8	35.5	42.2	69+	76	30	11	74	9	0	0	11	0	707	0	14.87	29.18	53	4.65	65	28	1.2	15.0	69	18	10	5	5													
FEB	52.4	36.8	44.6	73+	68	28	15+	79	2	0	0	8	0	571	0	10.11	22.90	61	3.06	54	19	2	2.5	69	15	7	3	3													
MAR	53.4	35.9	44.6	73+	69	25	18+	60	1	0	0	10	0	632	0	10.43	17.42	61	3.14	74	05	1.4	19.0	51	17	8	3	3													
APR	56.7	38.2	47.5	83	51	11	23+	80	6	0	0	6	0	525	0	6.13	11.22	72	2.92	62	27	.0	.8	75	12	4	1	1													
MAY	60.9	42.3	51.7	87+	53	4	26+	54	1	0	0	2	0	412	0	4.07	8.87	77	1.68	75	03	.0	.0	.0	9	3	0	0													
JUN	64.5	46.6	55.6	91+	70	1	31+	76	3	0	0	0	0	282	0	3.04	6.80	68	4.10	54	16	.0	.0	.0	6	2	0	0													
JUL	67.3	49.0	58.2	102	61	11	34+	56	30	0	0	0	0	211	0	1.29	4.87	74	2.00	74	17	0	0	.0	3	1	0	0													
AUG	68.2	49.4	58.8	93+	72	7	33+	59	9	0	0	0	0	196	0	2.00	6.53	68	1.71	53	24	.0	.0	.0	4	1	0	0													
SEP	68.5	46.7	57.6	97+	79	14	27+	72	27	1	0	0	0	226	0	3.73	7.80	77	2.65	71	02	.0	.0	.0	7	3	1	0													
OCT	63.0	42.4	52.8	88	52	1	22+	71	28	0	0	3	0	378	0	7.64	15.29	55	3.02	55	09	.0	.0	.0	11	6	2	0													
NOV	55.0	38.6	46.9	80+	62	1	17+	55	14	0	0	7	0	543	0	12.52	22.07	73	4.26	75	30	.1	2.0	77	16	9	4	4													
DEC	50.4	37.0	43.7	69	60	22	4+	72	8	0	0	8	0	660	0	15.07	22.41	71	4.92	77	02	1.0	11.0	64	19	11	5	5													
YEAR	59.1	41.5	50.4	102	61	11	4	72	8	1	0	55	0	5343	0	90.90	29.18	53	4.92	77	02	3.9	19.0	51	137	65	24	24													

Figure 2. Climatological survey data from Tillamook, OR, 1951-70 (Ruffner, 1985).

Figure 3. Directional data from the Oregon dunes. A. Wind rose. Data from June 1, 1973 through May 31, 1974, from Newport, Oregon, plotted as downwind directions. B. Rose diagram showing sand transport calculated from the wind data plotted in A. The arrow labelled "R" represents the resultant transport by all winds, R' represents the resultant transport by all winds with northerly components, and R" represents the resultant transport by all winds with southerly components. (Hunter and others, 1983).

ASTORIA, OR										CLATSOP COUNTY AIRPORT										PACIFIC										46° 09' N 123° 53' W 8 FT																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
Temperature °F										Normal Degree Days Below 65 °F										Precipitation in inches										Relative humidity pct.										Wind										Mean number of days										Average station pressure mb																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
Normal					Extremes					Heating		Cooling		Normal		Maximum		Minimum		Year		Water equivalent		Maximum		Minimum		Year		Snow, ice pellets		Year		Fastest mile		Wind		Pct. of possible sunshine		Sunrise to sunset		Precipitation		Heavy fog visibility		Temperatures °F		Average station pressure mb																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
Month	Daily maximum	Daily minimum	Monthly highest	Monthly lowest	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year	Record	Year</

NOTE: NORMAL COOLING DEGREE DATA PUBLISHED IN THE 1987 ANNUAL WERE FOR THE 1951-1980 PERIOD.

NORMALS, MEANS, AND EXTREMES TABLE NOTE(S):

- (a) Length of record, years, through the current year unless otherwise noted.
- (b) Based on January data.
- (c) Less than one half.
- (d) Trace.
- BLANK entries denote missing or unreported data.
- NORMALS - Based on record for the 1951-1980 period.
- MEANS - Length of record in (a) is for complete data years.
- EXTREMES - Length of record in (a) may be for other than complete data years.
- WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
- FASTEST MILE WIND - Speed is fastest observed 1-minute value when direction is in tens of degrees.
- Means and extremes above are from existing and comparable exposures. Extremes have been exceeded at other sites in the locality as follows:
- Precipitation: Maximum monthly : 36.07 in Dec. 1933. Maximum in 24 hours: 6.98 in Jan. 1919.
- Temperature: Highest: 101 in Jul. 1942.
- Speedfall: Maximum monthly : 27.3 in Jan. 1910.

Figure 4. Climatological survey of normal and extremes, Astoria, OR, 1951-80 (Ruffner, 1985).

offshore in 12 m (40 ft) of water.

Winter wave breaker heights averaged 4.5 m (14.8 ft.), while significant storm wave height were 7 m (23 ft.). In the summer months, breaker heights averaged a little over 1 m (3.3 ft.) with significant storm wave heights of 4 m (13.1 ft). "Significant wave height" is defined as the average of the highest one-third of the waves measured over a span of time (Komar and others, 1976). They show the yearly pattern in significant wave breaker heights in 1972-1973 (Figure 5).

The offshore gradient along Rockaway is 1:110 and near Daley Lake it is 1:105 (Greene, 1973 from Stembridge, 1975). This can be compared with the relatively gentle offshore gradient off the Washington coast of 1:254, and a gradient two to four times steeper than that of Washington off the coast of California (1:50-100)(Palmer, 1967). The coast of Oregon is under the influence of a semidiurnal tidal cycle, with two high tides and two low tides in each 24 hour period.

The Oregon coast is a cool, very wet, steep, mountainous coastline characterized by pocket bays and beaches with basalt headlands. High wave energy forms medium- to coarse-grained beaches and dunes which distribute river sediment originating in volcanic mountains. Housing development on younger beaches and dunes is jeopardized by active coastal changes. Intermediate-size streams are a part of the processes in need of further understanding.

Figure 5. Significant wave breaker heights and periods measured at Newport during July 1972 through June 1973. Each datum point gives the average for one-third month. The dashed lines give the maximum and minimum breaker heights during those one-third month intervals (Komar and others, 1976).

CHAPTER II

METHODS

Basic data on materials, physical dimensions and active geologic processes at intermediate-size coastal stream outlets was collected by reviewing reference materials and through field investigations and measurements. Reference material included topographic maps and aerial photo mosaics, which provided data on stream locations and historical changes at the stream sites.

(1) Reconnaissance data collection was done to provide background on the basic characteristics of the intermediate-size stream outlet parameters of size, distribution, location and geomorphic setting. Topographic maps provided much of the data, but on-site visits to all accessible streams in the study area provided data and enabled documentation of site conditions not apparent on maps and aerial photos. This information was used to select specific sites for further study.

(2) Video photography taken during this study and existing Oregon State Highway Division aerial photo mosaics of stream outlets document the surf and swash zone and its characteristics at each study site.

(3) Beach face morphology was surveyed by a series of

beach profiles to determine landforms and any modification of the beach face due to the presence of a stream outlet. Local bench marks were established to provide repeatable reference measurements for this study, and for long-term reevaluation by later investigations. Stream discharges and erosion/deposition rates were measured as they related to erosion on the beach face.

(4) Sediment samples were taken and size analysis done to determine what variations may be attributable to the effects of intermediate-size stream outfall processes.

(5) Sand traps were set up and monitored to determine possible modification in eolian transport due to the presence of an intermediate-size stream outlet.

(6) Traverses of the dune crests adjacent to intermediate-size stream outlets were taken to document foredune height.

(7) Oregon State Highway Division aerial photo mosaics and references were consulted to determine past threats to coastal development near these intermediate-size stream outlets. The interaction of geologic processes considered during this study was also used to evaluate land use risk at these areas.

RECONNAISSANCE TECHNIQUES

To provide a background for more detailed studies, a preliminary reconnaissance survey of the northern Oregon

coast was done. This included map and field identification of intermediate-size streams, site visits and comparisons for selection of streams for more detailed measurement. Map analysis provided data on drainage basin dimensions.

Original reconnaissance of the streams was done to identify possible study sites. This was done through personal observation using notes and 35mm black-and-white photography. Stream outlets were located with the assistance of U.S. Geological Survey 7-1/2 minute quadrangle maps (Appendix A). Names reflecting nearby natural or man-made features were given to designate those streams with no names on the U.S. Geological Survey maps.

The distance to the south from the mouth of Columbia River of each stream was measured in coastline kilometers, using a opisometer (map wheel), for ease in identification and to allow relative location. Drainage area in square kilometers was calculated to allow comparisons with other research.

Selection and determination of sites suitable for study were based first upon the accessibility, then upon the presence of active sand dunes, and finally upon the degree to which human activities have interfered with normal geologic processes. The selection of these streams provided a sample of those that cross active dunes and are least impacted by human activities.

A simple classification scheme to aid site selection was created during this study. The degree of human impact was determined by the classification system shown in Table I.

TABLE I
CLASSIFICATION OF STREAM OUTLETS BASED ON THE
PRESENCE OF MAN-MADE STRUCTURES

Classification	Criteria
1	No man-made structure present nearby
2	Bridge across stream mouth
3	Culvert directs streamflow OR Rip-rap directs streamflow on one side Barriers to log movement in place
4	Concrete retaining wall OR Wooden retaining wall OR Rip-rap on both sides OR Significant asphalt work

This classification takes into account most of the man-made barriers to natural stream flow and course present along this stretch of coastline. The effect of human impact upon the intermediate-size stream outlet areas was considered crucial to the choosing and evaluation of stream outlets because each geologic process may be significantly altered by human activities and structures. No attempt was made to scientifically discern relative human impacts upon beach and stream processes, as this study is not aimed

toward that end, but rather uses it as a means of finding suitable study streams. The goal was to select streams that were least disturbed by human impact and which had active foredunes on both sides. Examples of each classification type are shown in Figure 6.

The selection of streams for detailed investigations was followed by documentation of the morphology, material distribution, changes through time and measurement of active processes at these selected study locations.

FIELD MEASUREMENTS

Video

Documentary videotapes of stream outlet interaction with surf and swash were taken at all three study sites. Time and date of each video was recorded on the video image. Videotapes were made and edited with the assistance of a Panasonic Commerical/Industrial video recorder on loan from Portland State University's Television Services. Aerial photo mosaics were obtained from the Oregon Department of Transportation. Three sets from each site, dating back approximately 20 years, were studied for modification of the swash zone on a large scale.

Topographic Profiles

Topographic data was collected using a Brunton compass, clinometer, 50-foot (15.2 m) measuring tape and 6-

(A)

(B)

Figure 6. Examples of stream classification (see Table I) based on the presence of man-made structures. (A) Class 1, Red Rock Creek, (B) Class 2, Canyon Creek, (C) Class 3, Fall Creek (I), (D) Class 4, Austin Creek.

(C)

(D)

Figure 6. continued.

foot (1.8 m) rod marked in tenth-of-a-foot intervals. At Daley Lake Outlet, a transit was used to shoot longer distances. This method was chosen for the accuracy it afforded on seemingly flat beaches where few obvious breaks slope could be discerned. It was crucial that the methods chosen allow work in wet and blowing weather conditions on the winter beach, permit rapid measurement between tidal cycles, and minimize the number of field assistants necessary. This surveying method was adapted from K.O. Emery (1961) with the substitution of a clinometer for leveling.

Elevation profiles were surveyed along lines roughly parallel (N 60 E) and perpendicular (N 30 W) to the shoreline trend, measured at 6-foot (1.8 m) intervals in the dunes and upper beach, and at 12-foot (3.6 m) intervals along the lower beach (Figure 7). The lines perpendicular to the shoreline trend were surveyed from the highest point on the dune profile to the swash zone at lowest tide. Lines parallel to the shoreline trend were chosen to run roughly along the dune crest. This particular layout was selected for two reasons: first, it enabled the accurate, closely-spaced measurements necessary for documenting the subtle slope changes; and second, three parallel profiles could be done at a stream during one tidal cycle. The major problem with this method is that large areas between the profiles chosen remain unsurveyed. An effort was made to survey the

Figure 7. Generalized scheme for taking beach profiles parallel and perpendicular to the shoreline trend.

profiles nearest the stream channel at the lowest part of the tidal cycle, making them longer in order to detect any anomolous landforms at the surf/swash zone opposite the stream outlet.

Data collected from surveying was entered into a database management system (DBASE III+) and run through a graphics program (GOLDEN GRAPHICS). After a rough topographic map was created by computer, a smoothed version was done by hand. Due consideration was given to the computer's tendency to create illusory topographic lines and to ignore obvious features that were not detected in the survey.

Due to the lack of stable bench marks in the area, local assumed bench marks ("zero points") were established at each locality for future reference. A "zero point" is a location assumed to be at zero elevation for the purpose of the study. Care was taken to steer clear of railroad tracks and buried pipes to avoid their magnetic effect upon the Brunton compass. All survey lines were tied together, and relative elevations were calculated from the zero points.

Topographic maps were drafted at a scale of $1" = 200'$ ($1\text{cm} = 24\text{ m}$) to match the scale of the most recent aerial photo mosaics available.

Stream Discharge

To determine the degree to which these streams modify

the beach face, stream discharge measurements were taken at the mouth of each stream where it breached the dune. These measurements were taken using a method of Dunne and Leopold (1978) by the use of floats without a current meter. This is a quick estimate meant only to roughly quantify the discharge and to compare between the three streams.

Equipment included a measuring tape, meter stick, stopwatch or sweep secondhand and handy pieces of flotsam and jetsam. Eight to twelve velocity measurements were taken across the stream with velocity averaged along a 10-15 foot (3.05-4.59 m) reach of stream. Cross-sections of the stream channel across the beach face between tides were measured.

Sediment Sampling

Sand samples were collected to determine size and distribution of sediment at stream outlets. Locations for sediment sampling were chosen to represent stream sediment, beach sediment and stream outlet sediment (possibly some combination of beach and stream) in and around the stream outlet and to correlate it with present geomorphic process occurring there (Figure 8). A handful of sand (approximately 350-450 grams) was sampled from within 15 cm of the surface to get sand most representative of the present process. At two of the study streams, samples were taken along profile lines to facilitate comparisons with future data.

DUNES

STREAM
CHANNEL OUTLET
AREA

BEACH

SWASH
ZONE

Figure 8. Sand sample areas representing different geologic processes.

In the laboratory the sand samples were treated with 35% hydrogen peroxide for 30 minutes to dissolve most of the organic matter. Very little effervescence was observed during this process. Each sample was rinsed and decanted five times with tap water to wash away the hydrogen peroxide, and dried overnight in an evaporating oven. Sieving was done with 30 grams of original sample, taken at random, using a Ro-Tap shaker and standard 8-in. sieves from 1 to 3 phi at quarter phi intervals for 10 minutes. Sieves were weighed before and after each sample run. The precision of this method appears to be good (reproducible to within 0.05 phi) but the accuracy may underestimate the actual modal intermediate diameter by 10-20% (Blatt and others, 1980). Sand sample data from sieving was plotted by weight on cumulative frequency curves.

Eolian Transport

The transport rate for eolian processes was measured using sediment traps made for this study (Figure 9). Metal coffee cans in graduated sizes were attached to a wooden stake and planted into the sand. Graduated size cans were used for more accurate measurements near the sand surface. No holes or screen were put into the cans. The sand traps were located in the stream-wetted sand approximately 20 ft. (6.1 m) leeward of the stream channel, and in a non-wetted portion of the beach approximately 50 feet (15.2 m) windward

Figure 9. Sediment trap and wind gauge built to measure eolian sediment transport rates.

of the stream channel. Wind speed was measured approximately every five minutes during a forty-five minute period during which time sand was blowing across the beach face. The sand caught in each can of each trap was then weighed to the nearest .01 g, adjusted for the size of each can opening, and the results plotted on a semi-log graph.

Foredune Height and Volume

Foredune height and volume at the stream outlet was compared to adjacent dunes away from the influence of the stream outlet. A profile of the foredune to the south and north of Daley Lake Outlet was roughly measured by surveying the elevation of the highest point on the foredune every hundred feet along the shoreline.

The resultant elevations were plotted along a line allowing comparison of foredune height between stream outlet and non-outlet areas.

Photo History

Aerial photo mosaics provide the most useful tool for synoptic documentation of historical changes in the shoreline, specifically at intermediate-size stream outlets. These changes have been thoroughly described in the Rockaway Beach/Nedonna Beach Foredune Management Study (OLCDC, 1986) for the Crescent Lake Outlet and Saltair Creek study localities in addition to Rock Creek and Watseco Creek/Spring Lake Outlet which were not part of the detailed

study.

The data collection methods involved in this study include general reconnaissance to determine the basic characteristics of intermediate-size stream outlets, video documentation of surf and swash processes, beach face and foredune surveys, sediment sample analysis, eolian transport rate determination and historic comparisons with aerial photos.

CHAPTER III

RESULTS

General and localized data was collected throughout this study to define the physical parameters of intermediate-size stream outlets. Analysis of the data included organization, listing and plotting of measurements into tables, graphs, maps and diagrams. Computational processing included computer analysis. These manipulations and organization of the data into more readable and comparable forms were done to facilitate the interpretation of information and to make the data available for comparison with data to be acquired in the future.

RECONNAISSANCE AND SITE SELECTION

In the reconnaissance area, located on the Oregon coast between the Columbia River and Yaquina Bay, 54 streams were found to fit in the intermediate-size category (Figure 10)(Table II). Intermediate-size streams have been defined here to include those that flow across the beach front most of the year and are not influenced by normal tidal changes. It excludes those streams which are under normal tidal influence at their mouths, such as those with estuaries: the Alsea River, Nehalem River, and Necanicum River. It also

Figure 10. Location map of streams visited during reconnaissance of field area. Numbered squares correspond to U.S.G.S. quadrangle maps listed in Appendix A. Study stream are underlined. Scale 1" = 4.2 miles.

Figure 10. (cont.)

Figure 10. (cont.)

TABLE II

INTERMEDIATE-SIZE STREAMS WITH CORRESPONDING
DRAINAGE AREAS, HUMAN IMPACT AND PRESENCE/ABSENCE OF
FOREDUNES AT THE STREAM OUTLET

STREAM NAME	DRAINAGE AREA (km ²) (1)	HUMAN IMPACT (2)	DUNE PRESENCE (3)
** QUADRANGLE: TILLAMOOK HEAD			
INDIAN CREEK	1.30	1	.F.
CANYON CREEK	5.92	2	.F.
** QUADRANGLE: ARCH CAPE			
CLAYTON CREEK	0.45	1	.F.
RED ROCK CREEK	0.84	1	.F.
FALL CREEK (I)	1.81	3	.F.
AUSTIN CREEK	0.79	4	.F.
ASBURY CREEK	5.35	3	.F.
ARCH CAPE CREEK	11.71	1	.F.
N. SHORT SAND*	0.75	1	.F.
S. SHORT SAND*	0.71	1	.F.
SHORT SAND CREEK	18.55	2	.F.
** QUADRANGLE: NEHALEM			
CRESCENT LAKE OUTLET	7.03	3	.T.
** QUADRANGLE: GARABALDI			
ROCK CREEK	2.24	4	.F.
SALTAIR CREEK	0.43	3	.T.
WATSECO CREEK	9.65	2	.T.
** QUADRANGLE: NETARTS			
CAPE MEARES*	0.45	1	.F.
LARSON CREEK	0.86	1	.F.
SHORT CREEK	5.33	3	.F.
BAUGHMAN CREEK	0.73	1	.F.
FALL CREEK (II)	4.33	1	.F.
** QUADRANGLE: SAND LAKE			
CAPE CREEK	1.56	1	.F.
ROVER CREEK	3.83	2	.F.
ALLEN CREEK	0.64	2	.F.

(1) Area of drainage basin

(2) Classification of impact (Table I)

(3) .F. = No dunes present

.T. = Dunes present

* Stream name not present on U.S.G.S. maps

TABLE II

INTERMEDIATE-SIZE STREAMS WITH CORRESPONDING
DRAINAGE AREAS, HUMAN IMPACT AND PRESENCE/ABSENCE OF
FOREDUNES AT THE STREAM OUTLET
(continued)

STREAM NAME	DRAINAGE AREA (km ²) (1)	HUMAN IMPACT (2)	DUNE PRESENCE (3)
** QUADRANGLE: NESTUCCA BAY			
SEARS LAKE OUTLET	0.59	3	.T.
MILES CREEK	2.57	1	.F.
DALEY LAKE OUTLET	4.51	2	.T.
** QUADRANGLE: NESKOWIN			
NESKOWIN CREEK	29.36	3	.T.
CHITWOOD CREEK	1.35	1	.F.
CLIFF CREEK	2.67	1	.F.
TWO ARCHES*	0.37	1	.F.
LOGAN CREEK	1.68	3	.T.
** QUADRANGLE: LINCOLN CITY			
SHILO INN*	0.53	3	.T.
D RIVER	25.11	4	.F.
DLAKE*	0.56	4	.F.
BALDY CREEK	1.49	4	.F.
** QUADRANGLE: DEPOE BAY			
SCHOOLHOUSE CREEK	13.87	1	.F.
FOGHERTY CREEK	13.87	4	.F.
BOILER BAY*	1.11	1	.F.
PIRATE COVE*	0.17	1	.F.
DEPOE BAY*	0.33	1	.F.
OTTER CREST*	0.35	1	.F.
** QUADRANGLE: NEWPORT NORTH			
N. OTTER ROCK*	0.24	1	.F.
S. OTTER ROCK*	1.01	1	.F.
JOHNSON CREEK	2.98	1	.F.
SPENCER CREEK	20.49	3	.F.
WADE CREEK	10.23	3	.F.
COAL CREEK	2.87	3	.F.
MOOLACK CREEK	6.05	3	.F.
SCHOONER CREEK	3.00	4	.F.

(1) Area of drainage basin

(2) Classification of impact (Table I)

(3) .F. = No dunes present

.T. = Dunes present

* Stream name not present on U.S.G.S. maps

TABLE II

INTERMEDIATE-SIZE STREAMS WITH CORRESPONDING
DRAINAGE AREAS, HUMAN IMPACT AND PRESENCE/ABSENCE OF
FOREDUNES AT THE STREAM OUTLET
(continued)

STREAM NAME	DRAINAGE AREA (km ²)	HUMAN IMPACT	DUNE PRESENCE
	(1)	(2)	(3)
N. AGATE BEACH*	0.13	1	.F.
S. AGATE BEACH*	0.86	1	.F.
LITTLE CREEK	4.18	4	.F.
BIG CREEK	14.23	4	.F.
NYE CREEK	1.48	4	.F.

- (1) Area of drainage basin
 (2) Classification of impact (Table I)
 (3) .F. = No dunes present
 .T. = Dunes present
 * Stream name not present of U.S.G.S. maps

excluded those streams which percolate through the sand and rarely, if ever, flow across the beach face. Such streams do not generally appear on the U.S.G.S. topographic maps used in this study (Appendix A) and do not appear to significantly affect the nearby dune structure and continuity.

The drainage basin size of intermediate-size streams measured off maps ranged from .13 sq. km. (.03 acres) to 29.36 sq. km. (7.25 acres) averaging 4.69 sq. km. (1.16 acres). Nine streams were identified on maps but were inaccessible and were not measured or considered further. The other 45 were visited, observed and photographed. Foredunes were present at eight (15%) sites. Out of 54 sites, twenty-six (48%) without human structures received a rating of 1 on human impact, 5 sites (9%) received a 2, 13 sites (24%) received a 3, and 10 sites (19%) rated a 4 for their high degree of human impact and development.

Streams located during reconnaissance were screened for their suitability for study relative to the presence or absence of dunes, and the degree to which human activities have interfered with normal geologic processes. Selection of three streams for more detailed investigation was done to allow greater definition of materials, processes, rates of change and landforms.

Site Selection

Crescent Lake Outlet, Saltair Creek and Daley Lake Outlet were chosen for in-depth study due to the relative lack of human interference in the natural stream flow, the larger discharge, the presence of well-developed active foredune for some distance on either side of the stream and the absence of major obstructions along adjacent coastline.

Crescent Lake Outlet is located at Manhattan Beach State Wayside and flows approximately 3 meters (10 ft.) beneath both railroad and highway bridges before crossing the beach face. No regulation of flow occurs either into or out of the lakes that supply its water. Rip-rap shores up the railroad bed to the north of the outlet for a distance of approximately 122 m (400 feet). Concrete pilings beneath the railroad bridge provide a barrier to log pileup in the stream outlet (Figure 11). Discharge is great enough to provide flow across the beach except when periods of low rainfall coincide with the presence of a berm, allowing ponding of stream water. An active foredune exists both north and south of the stream outlet, but has been minimally impacted by past human development. This stream outlet is approximately 11 kilometers (7 miles) from the nearest major headland along the coastline.

Saltair Creek is laterally constrained at its outlet by both highway and railroad bridges approximately 1.5 meters (5 feet) above stream level. Stream flow is not

Figure 11. Crescent Lake Outlet, Rockaway, OR
March 25, 1987

regulated during periods of either high or low flow and during this study was always observed to be flowing. It has been confined by riprap to a channel extending west approximately 45.7 meters (150 feet) from the bridges. Active foredunes have been artificially graded to the north of this location, and those to the south appear relatively intact (Figure 12). The stream is located approximately 3.22 kilometers (2 miles) south of Crescent Lake Outlet, and is at least 11 kilometers (7 miles) from the nearest headland.

Daley Lake Outlet has all the appearances of being the least influenced of all locations in terms of human activities. It is constrained by a small road bridge back in the dunes at the outlet of the lake (Figure 13). No riprap or asphalt of any kind is in place, nor any other human structure. Similar to Crescent Lake Outlet, it flows across the beach when the discharge is high enough and when no berm is ponding the water. No flow constraints are in place.

A special situation occurs at this outlet due to a beach modification plan undertaken by Camp Winema, the property immediately adjacent to the site. The caretaker of the camp reported that he periodically "straightens" the stream channel on the beach face 3-5 times a year (Figure 14) using a bulldozer. It was related that the straightening of the channel was done to maintain stream flow across the beach and allow fish to enter the lake. It

Figure 12. Saltair Creek, Rockaway, OR. March 26, 1987.

Figure 13. Daley Lake Outlet, Neskowin, OR. February 9, 1987.

Figure 14. Bulldozing activity at Daley Lake Outlet, October 1, 1987.

is evident that this action is also taken to maintain a viable foredune in front of the camp, as the stream has a tendency to flow northward and cause or allow dune erosion. Evidence of this modification activity is obliterated by wind and waves, and is visible only on the uppermost beach, or not at all. Because of the rapid rate at which the area seems to erase evidence of bulldozing, study of this stream was continued and assumed to be valid.

Active foredunes are present for 610 m (2000 ft.) north and 1524 m (5000 ft.) south of this outlet. The nearest major headland is located eight kilometers (5 miles) south of Daley Lake Outlet.

SURF AND SWASH MODIFICATION AT OUTLETS

Video photography and aerial photo mosaics were evaluated to document possible modification of surf or swash at intermediate-size stream outlets.

Video pictures show increased turbulence and wave focusing in the surf zone at intermediate-size stream outlets in contrast to the relatively straight wave-angle of a continuous shoreline. As waves approach the beach they often focus at the stream area, eventually meeting from the sides to create turbulence.

Aerial photos show bulges in the surf line occurring all along the shoreline. The presence of an intermediate-size stream outlet does not always indicate the presence of

a bulge or other abnormality in the surf zone during calm conditions when the photos were taken. Surf bulges occur along about 30-50% of the shoreline. At intermediate-size stream outlets, 33% of the photos show a bulge in the beach, 44% show a straight surf zone, and 22% show an indentation in the beach. This data shows no significant difference in surf bulges when comparing intermediate-size stream outlets with non-outlet beaches. The intermediate-size stream does not appear to form a change in the surf zone topography as shown by wave patterns in aerial photo mosaics.

BEACH FACE MORPHOLOGY

Beach profiles and topographic maps were created to help to define beach-face morphology and to document landforms for each of the three intermediate-size study streams: Crescent Lake Outlet, Saltair Creek and Daley Lake Outlet. Data collected in the spring of 1987 is listed in Appendix B.

Profiles at Crescent Lake Outlet

Four beach profiles were taken at Crescent Lake Outlet on March 24-25, 1987 (Figure 15). Three profiles were measured perpendicular to the shoreline trend while one ran parallel. Two of the perpendicular profiles were taken north of the stream, and one to the south. The "zero point" for this location was the top of the west rail on the corner

Figure 15. Location of profiles taken at Crescent Lake Outlet, March 24-25, 1986. Photo Jan. 1984. Scale 1"=200 ft. (1 cm = 24 m).

of the railroad bridge.

The profiles for Lake Crescent Outlet are shown in Figure 16. The slope of the profile closest to the stream channel (#2) is .013 meters per meter, approximately .009 meters per meter (40%) less than that of the other two profiles (Table III). These profiles can be compared in Figure 17. The profile nearest the stream is lower in absolute elevation near the upper part of the beach and higher near the surf zone than the other two profiles.

A topographic map created from combining the profiles at each location is shown in Figure 18. Crescent Lake Outlet cuts the largest embayment of the three stream areas, 500 ft. (154 m) behind the front of the foredune and 1055 ft. (321 m) along the shoreline trend. The total area of beach/dune affected is 263,750 sq. ft. (24,529 sq. m). The width of the stream flow near the swash during the time the profile measurements were taken on March 24, 1987, was 520 ft. (158 m).

Profiles at Saltair Creek

The four beach profiles were taken at Saltair Creek on March 25-26, 1987, and are shown on Figures 19 and 20. Three were parallel to the shoreline trend, while one was perpendicular to the shoreline trend. Two of the profiles were north of the stream, while one was to the south. The "zero point" for this location was the intersection of the

Figure 16. Profiles 1 - 4, Crescent Lake Outlet. Scale 1" = 200'. Arrows indicate intersection with other profiles.

Figure 16. continued.

Figure 16. continued

TABLE III
STREAM PROFILE SLOPES IN METERS PER METER

Crescent Lake Outlet

Profile 1	.021
Profile 2	.013*
Profile 3	.022

Saltair Creek

Profile 5	.035
Profile 6	.026*
Profile 7	.032

Daley Lake Outlet

Profile 9	.023
Profile 10	.012*
Profile 11	.014
Profile 12	.019

*profile nearest stream channel

Figure 17. Comparison of Profile 1-3, Crescent Lake Outlet. Scale 1" = 200'.

Figure 18. Topographic map of Crescent Lake Outlet.
Scale 1" = 200'. Contour interval = 1 ft.

Figure 19. Location of profiles taken at Saltair Creek, March 25-26, 1987. Scale 1" = 200 ft. (1 cm = 24 m). Photo Jan. 1984.

Figure 20. Profiles 5 and 6, Saltair Creek. Scale 1" = 200'. Arrows indicate intersection with other profiles.

Figure 20. continued. Profiles 7 and 8, Saltair Creek.

west edge of the railroad track and the south edge of SW 6th St.

At Saltair Creek, the slope of the Profile #6, nearest the stream channel, is .026 meters/meter, approximately .006 meters/meter (20%) less than the slope of the adjacent profiles (Table III). These profiles are compared in Figure 21. The profile nearest the stream is lower than the adjacent profiles at the upper end and higher in elevation at the surf zone. However, the slope in the lowest section near the swash zone appears to be the same in all profiles, .026 meters/meter.

The topographic map created from these profiles is shown in Figure 22. Saltair Creek is the smallest in area of influence of the streams studied. It appears to directly influence 460 ft. (140 m) of shoreline, extending 300 ft. (91 m) behind the front of the foredune, or approximately 69,000 sq. ft. (6,417 sq. m). The stream channel meandered 65 ft. (20 m) wide. across the midline of the beach.

Profiles at Daley Lake Outlet

Five beach profiles were taken at Daley Lake Outlet on April 26-27, 1987 (Figures 23-24). Four were taken perpendicular to the shoreline trend and one was parallel. Two were taken north of the stream and two south of it. The "zero point" for this location was the top of the roadbed at the northwest corner of the bridge crossing the stream at

Figure 21. Comparison of Profiles 5-7, Saltair Creek. Scale 1" = 200'.

Figure 22. Topographic map of Saltair Creek.
Scale 1" = 200'. Contour interval = 1 ft.

Figure 23. Location of profiles taken at Daley Lake Outlet, April 26-27, 1987. Scale 1 inch = 200 ft. (1 cm = 24 m). Photo January 1984.

Figure 24. Profiles 9-10, Daley Lake Outlet, April 26, 1987. Scale 1" = 200'.

Figure 24. continued. Profile 11, Daley Lake Outlet.

Figure 24. continued. Profile 12, Daley Lake Outlet.

Figure 24. continued. Profile 12, Daley Lake Outlet.

the outlet of the lake. No significant human impact is apparent. When the profile data was taken in this area, no visible sign of bulldozing was present and the stream was relatively straight.

At Daley Lake Outlet, the slope of the upper portion of the profile nearest the stream (#10) is the lowest in the area, at .012 meters/meter (Table III). This is approximately .011 meters/meter (50%) less than the profile taken further away from the stream outlet. At the end of profile #10, the slope actually becomes positive - goes "uphill". The four profiles can be compared in Figure 25.

A topographic map of this area is shown in Figure 26. Daley Lake Outlet has the second largest area of influence, approximately 1119 ft. (341 m) along the beach and 400 ft. (122 m) behind the main dune line. The total area affected is approximately 223,800 sq. ft. (20,813 sq. m). Direct influence of the stream channel is approximately 40 ft. (12 m) in width across the upper and middle beach face. The mouth of the stream is crossed by a small bridge quite far back in the dunes.

In all these profiles, the lowest slope was that nearest the stream.

Non-Stream Outlet Profiles

The stream beach profiles can be compared to non-stream beach profile slopes from other areas along adjacent

Figure 25. Comparison of Profiles 9-12, Daley Lake Outlet.

Figure 26. Topographic map of Daley Lake Outlet. Scale 1" = 200 ft. Contour interval = 1 ft.

coastline (Figure 27). To the north at Straub State Park on Nestucca Spit, three profiles taken have slopes of .059 meters/meter, .027 meters per meter and .087 meters per meter, or an average slope of .058 meters per meter. Offshore rip channels, identified by deep water with few breakers, were present at this location and may have a bearing on the slope differences. One profile was taken at Neskowin to the south with a slope of .040 meters per meter.

Stream Discharge

Stream discharge measurements were taken to compare each stream and its erosive power. Crescent Lake Outlet had a discharge of 0.32 cubic meters per second (11.3 cubic feet per second) on March 18, 1988 on a sunny day after a week of fairly dry weather.

The discharge measurement was 1.01 cubic meters per second (35.68 cubic feet per second) at Saltair Creek on December 11, 1987, directly after a heavy rainfall when the discharge was abnormally high. Daley Lake Outlet had a discharge of 0.26 cubic meters per second (9.18 cubic feet per second) on March 18, 1988, on a sunny, dry day.

The cross-sections of the Daley Lake stream channel on the beach are shown in Figures 28-29. Two sets were taken, one on June 6, 1987 and one on March 18, 1988. Both were taken between high and low tide during the day. On June 6, the upper parts of the stream channel were eroded between

Figure 27. Profiles 1-2, Straub State Park. Scale 1" = 200'.

Figure 27. continued. Profile 1, Straub State Park. Profile 3, Neskowin, OR.

Figure 28. Stream channel modification in one tidal cycle, Daley Lake Outlet.
 - - - High tide, — Low tide.

CROSS-SECTION 1
DALEY LAKE OUTLET
3/18/88
Total Change = +1.32 sq. ft.

CROSS-SECTION 3
DALEY LAKE OUTLET
3/18/88
Total Change = - 0.61 sq. ft.

CROSS-SECTION 2
DALEY LAKE OUTLET
3/18/88
Total Change = - 0.73 sq. ft.

Figure 29. Stream channel modification between one high and one low tide, Daley Lake Outlet.
- - - High tide, — Low tide.

CROSS-SECTION 4
DALEY LAKE OUTLET
3/16/88

Total Change = +3.10 sq. ft.

Figure 29. continued.

one high and one low tide, while the lowest cross-section prograded. Erosion of sand was 1654 cubic feet (46.3 cu. m) while deposition was 206 cubic feet (5.7 cu. m). Total sand lost during one six-hour period between high and low tides equaled approximately 1548 cubic feet (43.3 cu. m) along approximately 425 feet (129 m) of stream channel. On March 18, the upper sections both eroded and prograded, but the cross-section nearest the swash prograded. The amount of sand added in this case was 484 cubic feet (13.5 cu. m) over a 600 feet (183 m) reach of stream channel.

These two profile examinations show that the stream channel gets deeper and sometimes wider in the middle beach on an out-going tide, while the lowest section of the stream progrades (Figure 30).

SEDIMENT SIZE ANALYSIS

Sediment analysis was done to discern any difference in grain size due to the presence of an intermediate-size stream on the beach. At all locations, no statistically significant difference was found between the average sand grain size, the percentage less than 5% or less than 95%, standard deviation of the samples, skewness or kurtosis.

At each location, samples from within the creek channel, near the creek channel and away from the creek channel were taken. Thirty-one samples were sieved. Six samples were taken at Crescent Lake Outlet on

Figure 30. Sketch of stream channel erosion and deposition in one tidal cycle.

March 24, 1987. Seventeen samples were taken at Saltair Creek, six on March 26, 1987 and eleven on December 11, 1987. Eight samples were taken at Daley Lake Outlet on November 11, 1986. The locations of the samples are shown on maps included in Figure 31. Sand grain size distribution obtained from sieve data is shown in Appendix C.

Sieve data were plotted by weight on cumulative frequency curves (Appendix D). Comparisons of various granulometric measurements are made in Table IV. The samples were taken in the spring and winter of 1987. The largest median grain size sand in all size intervals was that taken from Crescent Lake Outlet. It also has the smallest standard deviation. The first sample taken at Saltair Creek had the smallest sand in all size fractions, and the largest standard deviation.

EOLIAN DEPOSITION MODIFICATION

Eolian transport at one stream outlet was measured by the use of sand traps. The weight of sand caught in each portion of the trap is given in Appendix E. This data was plotted on a semi-log curve in Figure 32. As the height above the beach increases, the amount of sand caught decreases exponentially on both sides of the stream. The intermediate-size stream outlet trapped eolian sand which crossed the outlet area. A 97% reduction in eolian sand transport was measured from the upwind to the downwind side

Figure 31. Location of sand samples taken at all stream outlets. North is to the left.

TABLE IV
GRANULOMETRIC STATISTICS OF
SAND SAMPLES

CRESCENT LAKE OUTLET
3/24/88

Sample Number	D 5%	D 50%	D 95%	Standard Deviation	Skewness	Kurtosis
3241	1.90	2.23	2.72	0.27	0.23	0.77
3242	1.80	2.05	2.44	0.19	0.18	1.09
3243	1.98	2.32	2.77	0.27	0.10	0.45
3244	1.94	2.21	2.70	0.25	0.28	0.84
3245	1.86	2.24	2.68	0.25	0.09	0.94
3246	1.87	2.19	2.71	0.26	0.25	0.91

SALTAIR CREEK
3/26/87

Sample Number	D 5%	D 50%	D 95%	Standard Deviation	Skewness	Kurtosis
3261	1.76	2.13	2.98	0.36	0.40	0.80
3262	1.73	2.07	2.59	0.26	0.20	2.38
3263	1.87	2.21	2.82	0.29	0.27	0.98
3264	1.76	2.16	3.03	0.37	0.35	1.11
3265	1.86	2.18	2.77	0.30	0.36	0.74
3266	1.97	2.43	2.92	0.30	-0.02	0.81

GRANULOMETRIC STATISTICS

SALT AIR CREEK

12/11/87

Sample Number	D 5%	D 50%	D 95%	Standard Deviation	Skewness	Kurtosis
12111	1.86	2.16	2.74	0.26	0.31	0.96
12112	1.41	2.25	2.97	0.35	0.24	0.84
12113	1.73	2.14	2.73	0.30	0.20	0.95
12114	1.79	2.13	2.71	0.29	0.22	0.92
12115	1.78	2.08	2.69	0.29	0.43	0.90
12116	1.78	2.16	2.91	0.35	0.62	0.91
12117	1.85	2.18	2.80	0.30	0.27	0.88
12118	1.82	2.16	2.70	0.27	0.21	0.93
12119	1.77	2.04	2.72	0.32	0.45	0.84
121110	1.75	2.07	2.65	0.27	0.26	1.03
121111	1.75	2.08	2.66	0.27	0.27	1.02

GRANULOMETRIC STATISTICS

DALEY LAKE OUTLET

11/1/86

Sample Number	D 5%	D 50%	D 95%	Standard Deviation	Skewness	Kurtosis
1118	1.65	2.02	2.56	0.26	0.15	1.22
1119	1.61	1.96	2.50	0.23	0.02	1.56
11110	1.51	1.93	2.35	0.23	-0.04	1.21
11111	1.37	1.90	2.37	0.27	-0.08	1.28
11112	1.56	1.95	2.46	0.24	0.02	1.41
11113	1.51	1.91	2.31	0.23	-0.03	1.51
11114	1.61	1.98	2.51	0.24	0.08	1.45
11115	1.56	1.93	2.36	0.22	-0.01	1.30

Figure 32. Weight of sand caught in sand traps
at Daley Lake Outlet on March 19, 1988
at 3:30 pm with wind gusts 8–15 knots per hour.

of the stream outlet channel area on the beach.

The moisture content of the beach sand near a stream outlet was observed in all cases and at all stream outlets to increase toward the stream. No measurements on the moisture content were taken, but through observation it was noted that the width of this moist sand is equal to the stream channel on the upper beach, and approximately 2-3 times the width of the stream channel on the lower beach.

The effect this moisture has on eolian transport can be recognized in both the sand trap data and in still photographs. In Figure 33 the white portion of the beach is sand blowing, or saltating, along the beach. The darker portion is the wet sand that is not blowing. In all cases, the stream appears to halt the movement of most of the sand blowing near the surface by catching it in the water.

FOREDUNE CREST PROFILE

A foredune crest height longitudinal profile was measured along a portion of coastline between Nestucca Bay and Neskowin (Figure 34) to determine whether the presence of a stream modifies the foredune. It measured the foredune height relative to the position of the stream outlet. The foredune height at the stream outlet was lower in all but one location along the stretch of coastline measured.

Four locations south of the stream outlet had dunes which were stripped down to the level of the upper beach and

Figure 33. Examples of a stream halting eolian sediment transport. Watseco Creek. In the top figure, wind is blowing from left to right. In the bottom figure, wind is blowing out of the page.

(A)

(B)

Figure 33. (A) Sand trap apparatus collecting sand.
(B) Sand collecting on the windward side of the stream channel.

Figure 34. Foredune crest height profile, Daley Lake to Neskowin, March 19, 1988

were bare of vegetation. One of these low areas, or "washovers", was north of the outlet. A washover for purposes of this discussion is a low place where the integrity of the foredune has been compromised by a breach possibly due to wave erosion. The washovers are narrower and higher than the stream outlet. Washovers to the south appear to be filling in as a result of sand stabilization fence emplacement.

Between Neskowin and Daley Lake Outlet four washovers were located. Two of these were measured off aerial photo mosaics and were determined to be 60,000 sq. feet (5580 sq. m) and 5,000 sq. feet (465 sq. m).

The foredune south of Daley Lake Outlet, measured from aerial photo mosaics, varies in width from 100-200 feet (30-60 m) and is approximately 10-15 feet (3-4.5 m) high. The volume along a 500 foot (152 m) stretch of beach would be approximately 1,125,000 cubic feet (31,500 cu. m). In the area of influence around Daley Lake Outlet the foredune is approximately 50 feet (15 m) wide and 4 feet (1.2 m) high, so along a 500 foot (152 m) stretch of beach the volume would be 100,000 cubic feet (2,800 cu m). This shows that the volume of foredune sand at stream outlets is 9% of the volume of foredune sand away from stream outlets.

HISTORICAL CHANGES

Aerial photos provide the most useful tool for

observing historical changes in the shoreline, including intermediate-size stream outlets (Figures 15,19 and 23). These changes have been thoroughly described in the Rockaway Beach/Nedonna Beach Foredune Management Study (LCDC, 1986) for the Crescent Lake Outlet and Saltair Creek localities, in addition to changes in adjacent Rock Creek and Watseco Creek/Spring Lake Outlet.

In aerial photos studied in the LCDC report, between 1939 and 1964, there was over 200 ft. (61 m) of landward foredune erosion on the north side of Crescent Lake Outlet, and between 1939 and 1977 as much as 230 ft. (70 m) of landward foredune erosion was measured. Some seaward foredune accretion between 1964-1979 occurred but was negated by later landward foredune erosion. The south side of Crescent Lake Outlet has experienced at least 150 ft. (46 m) of seaward foredune accretion since 1939, but was relatively stable between 1964-1984. The foredune management study indicates that continued flooding of the north side of the outlet by ocean waves is expected due to the low, poorly developed foredune. The south side will remain relatively stable because of the lack of windblown sand for seaward foredune accretion and the lack of storm wave erosion from the northwest.

Foredunes both north and south of Saltair Creek are the lowest of all study sites. To the north, they become

lower in elevation toward the creek, while to the south, they have been graded. It was reported by LCDC that in the periods of 1966-1970 and 1977-1984, there was about 40 ft. (12 m) of landward foredune erosion north of the creek. Seaward foredune accretion in that area since 1939 has been up to 300 ft. (91 m). After the emplacement of a "rubble rock dike" at Saltair Creek sometime between 1953 and 1966, seaward foredune accretion up to 1970 was 200 ft. (61 m) (50 ft/year)(15.2 m/year). The average seaward foredune accretion rate since 1970 has been 5.7 ft/year (1.7 m/year). South of the creek shoreline landward foredune erosion was 30-40 feet (9-12 m) along 300-400 feet (91-122 m) of shoreline. On the south side of the creek there was almost no net seaward foredune accretion from 1939 to 1966, and from 1966-1970 (after emplacement of the dike) there was up to 30 feet (9 m) of seaward foredune accretion. From 1970 to 1977, the seaward foredune accretion rate has been approximately 5.7 feet/year (1.7 m/year), the same as on the north side. The foredune management study indicated that both landward foredune erosion and seaward foredune accretion are greater on the north side than the on south side.

Daley Lake Outlet appears to have been relatively stable in the period between 1965-1984. From photos examined in this study, landward foredune erosion between 1965-1973 of approximately 50 feet (15 m) at the north end

of the area of stream influence was replaced by seaward foredune accretion between 1973-1984. Directly south of the stream outlet the foredune has stabilized and strengthened through vegetation growth but little seaward foredune accretion or landward foredune erosion can be documented. This stream has historically had a strong tendency to meander. The present policy of artificial straightening was developed to counteract this.

CHAPTER IV

DISCUSSION

The basic measurements of intermediate-size streams are summarized and discussed within this chapter. At intermediate-size stream outlets three major geologic processes are acting and interacting:

1. Marine processes (waves and tides),
2. Fluvial processes (stream), and
3. Eolian processes (wind).

Human impact must be considered, in addition to geologic processes. In coastal zones it is difficult to separate the effects of each process and to identify its relative importance. The following discussion addresses separately each objective stated in the purpose of this study, and the consequences of the processes on the sediment budget of the area.

Interpretation of data collected during this study allows characterization of coastal areas influenced by intermediate-size stream outlets and provides a basis for discussion of the processes influencing them. Comparison of the measurements and data obtained with those expected from local knowledge and published literature is done to examine the questions stated in the purpose.

BASIC CHARACTERISTICS OF INTERMEDIATE-SIZE STREAMS

Fifty-four intermediate-size streams are scattered in a relatively even pattern along the northern Oregon coast (see Figure 10), not including areas of spits and estuaries. Locations of intermediate-size streams are on relatively impermeable resistant rocks of headland basalt and lithified sand terraces. They are sparse around areas of underground water flow, as in areas of permeable sand spits. When these streams flow across beach sand, it is often due to the presence of a higher water table ponded behind the foredune in the form of a lake.

There is a large range of drainage basin sizes (see Table II) in intermediate-size stream basins. In the three study streams, drainage basin size was not necessarily related to discharge. This is probably due to differences in percolation rates at each location. Drainage basin size ranged from 0.13 sq. km. (.03 acres) to 29.36 sq. km. (7.25 acres), averaging 4.69 sq. km. (1.16 acres). Stream frequency averaged 3.8 streams/kilometer (2.3 streams/mile) in 210 kilometers (130 miles) of coastline.

Human influence at the different stream outlets varies drastically and generally seems to depend upon the degree of housing or resort development in the area. Many of the uninfluenced streams are smaller and adjacent to undeveloped lands. They are not forced into artificial channels or

protected in any way from the forces of waves and tides. The three streams that flow across Short Sand Beach at Oswald West State Park are good examples of relatively uninfluenced streams. A total of 24 streams fell into this category.

Many of the largest coastal developments and those most attractive to vacationers are located near the larger stream outlets. Lincoln City is centered around the D River, Nye Beach (Newport) around Nye Creek, and Rockaway Beach around Rock Creek. Ten streams fell into this category. A historical perspective shows that the earliest settlements along the coastline were built near these streams, a source of fresh water. As the areas grew and developed, public pressure to provide safety for homes and businesses from ocean and stream flooding increased. More attempts were made to control the forces of tides and waves at these outlets.

MODIFICATION OF THE SWASH AND SURF ZONE AT STREAM OUTLETS

Examination of surf and swash at intermediate-size stream outlets determined no identifiable anomaly between that at the stream mouth and apparently random surf and swash lines. Surf and swash as observed in person, documented on videotape, and observed in photo mosaics was no different between outlet and non-outlet beaches. It was

not possible to recognize changes in the intermediate-size stream areas which were significantly different from the apparently random modification of surf and swash along the stretch of coastline adjacent to the study streams.

Differences in the actions of waves may occur at high tides and under storm conditions at these intermediate-size stream outlets. All documentation in this study was done at low to medium tidal levels, with no observations made during storms or extremely high tides. High tides would be expected to fill the embayment present at intermediate-size stream outlets with water due to the low to absent foredune in these areas. Extreme high tides and high waves would encounter reduced resistance and increase wave penetration and run-up.

Nordstrom (1986) postulated that as the tide rose, incoming waves would be funnelled out the stream channel due to the presence of a berm and the more efficient shape of the channel (Figure 35).

The action of waves at intermediate-size stream outlets at low tide indicates the presence of an offshore topographic anomaly. In many cases, waves were observed to focus at the stream outlet. They also broke further from shore than along non-stream beach segments, indicating that the offshore beach profile was higher. Waves interact with streamflow at all times, although at lower tides the

Low tide.

Intermediate tide.

High tide

Figure 35. Effect of waves and currents on stream embayments at different stages of the tide (Nordstrom, 1986).

velocity of the stream in the swash zone is so small that the interaction is negligible.

Studies done with tracer grains (Ingle, 1966) compare the predominant paths of sand grains on planar foreshore-inshore slopes under different surf conditions (Figure 36). Diagram C shows the normal observed pattern of sand movement on Oregon coastal beaches as recognized in this study. Turbulence at the confluence of stream current and surf was documented on videotape. Because the stream discharges are significantly smaller than the amount of energy provided by the waves, turbulence may be the only manifestation of the stream versus wave confrontation.

MODIFICATION OF BEACH FACE BY INTERMEDIATE-SIZE STREAMS

Beach profiles at stream outlets indicate a consistently lower beach slope near the stream outlet than along adjacent uninterrupted non-stream stretches of beach (see Table III). The absolute elevation of the beach at or behind the foredune is lower near the stream outlets than along adjacent non-stream stretches of beach.

Several variables affect beach slope (Komar, 1976). The most important is sediment grain size. Coarser grain sizes indicate steeper slopes. The data indicates that the sediment size is the same across the entire small stream embayment and along adjacent beaches. This, then, is not

 DOMINANT AND SECONDARY PATHS OF TRACER GRAINS
ON THE FORESHORE SLOPE

 PATH OF TRACER GRAINS WITHIN AND IMMEDIATELY
SHOREWARD OF THE BREAKER (PLUNGE) ZONE

 PATH OF TRACER GRAINS SEAWARD OF THE BREAKER
ZONE

Figure 36. Block diagrams illustrating the predominant paths or vectors of tracer-grain movement on planar foreshore-inshore slopes under the three most commonly encountered surf conditions. A. Grain movement under surf conditions where longshore-current velocity and wave motion exert an equal influence. B. Grain motion under the influence of a high-velocity longshore current (a velocity greater than 2.0 ft./sec). C. Grain motion where longshore-current velocity is less than 1.0 ft./sec and the onshore-offshore motion of passing waves controls grain movement. The three diagrams represent a qualitative average of all tests performed on planar slopes. (Ingle, 1966).

the reason for the lowered beach slope at the stream outlet.

The next variable is wave energy. The greater the wave steepness (relationship of wave height to wave length) the lower the beach slope (Komar, 1976). In this study, the wave energy was assumed to be constant at and along a stretch of beach on either side of the intermediate-size stream outlet. However, if there were indeed an offshore anomaly such as a delta or trough, as is suggested by Nordstrom (1986), the waves could be diverted by refraction at the stream outlet compared to a straight stretch of beach.

Another variable is the level of the water table on the beach. The greater the water content, or the higher the water table, the flatter the beach slope expected (Komar, 1976). When water from an incoming wave, or foreswash, is allowed to percolate into the beach, the backswash has significantly less power. Sand brought up onto the beach by the incoming swash will be more actively deposited on dry beaches.

When the beach is saturated, the energy of the incoming swash will move sand sizes equal to the energy of the backswash minus frictional drag (Komar, 1976). Stream water at intermediate-size stream outlets causes a near-surface water table, saturates the beach, and causes the backswash to be stronger at those areas. Intermediate-size stream outlet areas thus move more sand offshore than along

comparably drier stretches of adjacent non-stream beach.

Stream processes are most demonstrably involved in lowering the beach profile near intermediate-size stream outlets. These stream processes act much the same on the beach as they do inland. They function by eroding, transporting, and depositing sediment, and changing channel course through time in response to imposed conditions. Possibly because of the erodibility of the grain size and uniformity of beach sands involved, these processes occur rather quickly on the shore. The stream processes can be easily recognized even by the casual observer where coastal streams flow across the beach.

Erosion of the beach face by streamflow between high and low tides was found to be significant. There is measurable widening of the stream channel and lowering of the stream level in absolute elevation (see Figure 30). The magnitude of this erosion is dependent on channel characteristics, sediment size and the stream discharge, which is affected by precipitation, lake levels and tide levels at a particular time.

Peak streamflows are many times greater than normal discharges, and may significantly impact the shape of the stream outlet. The slope of the beach profile nearest the stream was the lowest of all the beach profiles measured at each location, and stream erosion may be partially

responsible for this lowering. Peak streamflows intensify this effect.

A study done for the City of Rockaway (HBE, 1976) cited storm runoff for Saltair Creek as being 3.68 cubic meters per second (130 cubic feet per second) for a 10 year frequency storm, and 4.53 cubic meters per second (160 cubic feet per second) for a 25-year frequency storm. At Crescent Lake Outlet, the 10-year frequency storm produces a discharge of 7.36 cubic meters per second (260 cubic feet per second) and the 25 year frequency storm run-off has a flow of 9.06 cubic meters per second (320 cubic feet per second).

Transportation of sand eroded by the stream was documented on videotape. Normal seaward transportation of sand by backwash is enhanced by continuous streamflow across the swash zone during high tides when the stream flows fast enough to erode its channel. At low tides, streamflow on the lower beach is slowed as the channel widens, water percolates and sediment is deposited. The discharge is related to the amount of precipitation, the lake level, sea level, and the beach groundwater level.

Progradation, by sediment deposition in the surf and swash zone, is more difficult to measure because it is not visible. Between each tidal cycle, the stream channel below the surf is filled in or levelled. Small sand bars move about in the middle of the stream channel, particularly on

the lower beach at low tide. However, net erosion occurs in the stream channel of the upper beach on an outgoing tide, while the eroded sand transported across the beach face by the stream deposits either directly into the swash zone or else off-shore.

During the lowest tides, a sandbar-like form was often observed. At Daley Lake Outlet a channel of water separated the beach from an offshore island of sand. The bar-like form offshore may well be (1) a berm that has moved there for the winter, and will move back onshore in the summer (Komar, 1976) or (2) the delta proposed by Nordstrom (1986). The presence of an offshore delta in the breaker zone has been hypothesized by Nordstrom (1986), and the low sand bar exposed directly shoreward of the stream mouth on the lower beach at low tide at Daley Lake Outlet hints that some landform similar to a delta may be present. Deposition of sand in the swash zone was observed when the stream channel deposited upon encountering the swash.

Nordstrom (1986) also observed the deflection of streams to the north or south, and attributed it to the buildup of sand by longshore drift (Figure 37). This view assumes that a berm exists at the time the stream is deflected and that the stream flow is not able to cut through the berm. In this investigation, stream deflection to the north by berm was observed both at Crescent Lake

Figure 37. Mechanisms for widening of embayment by deflection and diversion of the stream (Nordstrom, 1986).

Outlet and Daley Lake Outlet. However, Saltair Creek had maintained its flow perpendicular to the shoreline trend each time it was observed during this study. When the stream profiles were measured in the spring, the only hint of a berm was on the south side of Daley Lake Outlet. Yet Daley Lake Outlet was flowing straight across the beach, perhaps due to the bulldozer grading. Crescent Lake Outlet was also straight.

It is possible that eolian sand deposition on the windward side of a stream could deflect the stream. That could also allow wave berm build-up by decreasing erosional velocity due to deflection of the stream.

During higher tides, when the stream is still confined to its channel, waves were observed to take advantage of the lower elevation in the channel area by actually flowing preferentially into the channel and out to the sea instead of directly back down the beach slope from whence it came. This increases channel discharge and scour, and maintains the lower slope of the beach area. Nordstrom (1986) drew a series of diagrams depicting this tidal/wave interaction at stream embayments (see Figure 35).

During a low tide, waves encounter the lower beach surface at the stream channel and they focus surf at the stream mouth where there is less resistance. As the tide comes in, this focusing increases until the waves actually

meet each other from each side. It is at this time that turbulence begins to occur. The beach near the stream is below the level of the adjacent beach, and waves find it easier to push up the stream mouth than up the steeper beach. During the highest tides during a storm, waves follow the stream channel and actually break out of it into the embayment surrounding the stream mouth.

SEDIMENT PROPERTIES AT INTERMEDIATE-SIZE STREAM OUTLETS

Sediment size is an indicator of the hydraulic mechanisms which transport and sort it, as well as the rock from which it was derived and the length of time and distance of transport since it has become loose sediment.

Sediment analyses of grain size in beach and stream samples collected for this study show that the samples are statistically indistinguishable from each other. This indicates that one geologic process is dominant in this system. Sand size combined with beach slope indicate a high energy beach processes. Eolian sediment from dunes could be statistically distinguished from sand samples collected on the beach. However, stream sediment could not be distinguished from beach sand collected outside of the influence of the stream outlet. Therefore, it is concluded that marine processes sort all sediment in the beach/fluvial system and overshadow any influence of the stream.

MODIFICATION OF EOLIAN PROCESSES BY THE PRESENCE OF STREAM OUTLETS

Eolian, or wind, processes play a tertiary role in the intermediate-size stream outlet system. Wind moves sediment only during dry or windy periods. Dry sand requires less wind to move it (Cooper, 1958), perhaps as little as 4 knots, while moist sand was observed to require strong winds of at least 10 knots. Eolian transport measured in this study found that sand transport is much greater on the windward side of the stream channel and that the stream channel traps sand movement across it. The leeward side of the stream has a greatly reduced sediment source area.

Most winter storms and strong winds along the Oregon coast blow out of the southwest while the calmer, steadier summer winds blow from the northwest (see Figure 3). Cooper (1958) stated that most inland movement of beach sand onto the dune takes place during the summer months when the sand is dry. However, Hunter and others (1983) calculated that, assuming dry conditions, the amount of sand moved during the winter months (November through March) was 90% of the total cubic meters of sand deposited (Figure 38). Wet sand in the swash zone or stream channel is held by water and not moved by the winds. Observation during winter high-velocity wind storms demonstrates that beach sand is transported

CALCULATED EOLIAN SAND TRANSPORT, ASSUMING DRY CONDITIONS, FROM JUNE 1, 1973, TO MAY 31, 1974

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Winds with northerly components													
Resultant amount	1.5	1.3	0.8	1.1	2.2	1.9	5.2	2.3	1.4	0.4	1.8	0.7	18.6
Resultant direction	242	130	158	163	170	174	173	172	173	159	123	152	168
Consistency ratio	0.62	0.90	0.94	0.95	0.96	0.99	0.99	1.00	1.00	0.95	0.91	0.81	0.87
Winds with southerly components													
Resultant amount	27.8	13.7	22.1	6.5	2.5	2.1	0.0	0.4	6.6	4.7	22.7	21.5	131.2
Resultant direction	24	30	30	22	27	29	27	19	16	23	27	27	26
Consistency ratio	0.96	0.93	0.97	0.95	0.99	0.96	0.67	1.00	0.99	0.98	0.96	0.92	0.96
All winds													
Resultant amount	26.7	13.1	21.7	5.8	1.5	1.2	5.1	2.0	5.3	4.4	22.5	21.1	117.2
Resultant direction	22	31	22	37	87	91	173	167	21	27	30	29	32
Consistency ratio	0.85	0.82	0.91	0.72	0.31	0.35	0.98	0.74	0.6	0.84	0.88	0.87	0.74

Note: The amount of sand transport is in cubic metres of deposited sand crossing a metre width of ground surface. The resultant direction is the direction toward which sand is being transported, in degrees. The consistency ratio is the resultant amount of sand transport divided by the total amount transported by winds of all appropriate directions (for example, the consistency ratio for transport by winds with northerly components is the resultant amount of transport divided by the total amount transported by winds ranging from easterly through northerly to westerly).

Figure 38. Calculated eolian sand transport assuming dry conditions, from June 1, 1973 to May 31, 1977 (Hunter and others, 1983).

agressively even when wet. Rankin (1983) has shown wind generated cusps on ancient dunes aligned SW to NE, recording active winter wind eolian transport.

It is the damp or moist sand, neither completely wet or dry, which is important in the context of intermediate-size stream outlets. Whether the water is flowing across the beach or percolating through the sand, an abnormal amount of moist sand is present at these stream outlets compared to adjacent beaches. Moist or damp sand has a certain cohesive force acting between the sand grains due to the presence of small amounts of water. Wind power can overcome these cohesive forces, however, and stronger winds move even damp sands. The amount of movement is in inverse porportion to saturation.

Cooper (1958) noted that damp sand is moved by gusts of wind and that the rate of removal is rapid. He pictures this very phenomenon (see Figure 33). A similar situation found during the reconnaissance portion of this study at Asbury Creek and the Watseco Creek Outlet localities points to the fact that the stream actually does halt most of this movement. During Twenhofel's field work collecting sand samples on the Oregon coast (1946), he noticed this movement of beach sand by wind and its subsequent deposition on the windward margin of streams, both on the beach and in the stream water. He postulated that this sudden build-up of sand may cause deflection of the stream in the direction of

sand may cause deflection of the stream in the direction of the wind. In this study, it was found that the stream channel can be filled on the windward side about 1 foot per hour in a ten knot wind with a damp beach. This is not enough to cause stream diversion during one tidal cycle. However, stronger winds or a longer period of time may have a larger affect on channel diversion.

MODIFICATION OF FOREDUNES BY THE PRESENCE OF STREAM OUTLETS

The foredune around intermediate-size stream outlets was found to be lower and have less volume: at the stream outlet channel itself, the foredune is absent. A foredune profile from Neskowin to Nestucca Bay (the area near Daley Lake Outlet) was measured for this study, and the lowest area near the stream was documented. There were also other low areas in the dune not associated with stream outlets. These may be due to the past storm wave washover episodes and are currently filling in.

The dune profile is particularly low on the north sides of Crescent Lake Outlet and Daley Lake Outlet (see Figures 17 and 25).

Sand movement in sand dunes is accomplished by eolian transport and is retarded by streams. Therefore, dunes on the leeward (north) side of streams are malnourished compared to those on the windward side of streams. Strong winds

accompany storms from the southwest in the winter. Hunter and others (1983) suggest that most eolian sand movement takes place in the winter months. The trend will be toward deflection of streams to the north and possible dune erosion. Sand dunes on the north side of the stream outlet are lower due to the lack of a dry sediment supply.

Nordstrom (1986) assumed that the intermediate-size stream embayment would fill in by windblown sand, though it would not receive its full potential of sediment due to the sand trapping by moist sand along the stream. He also observed that the bays are traps for logs, and that logs create sediment traps for sand, rebuilding the dunes within the embayment. Few logs were found concentrated in the stream embayments studied, but log jams were found in many stream mouths. The major exception to this rule is Watseco Creek/Spring Lake Outlet just north of Tillamook Bay where drift logs totally cover the area in and around the stream outlet.

REDUCED PROTECTIVE VALUE OF LAND NEAR INTERMEDIATE-SIZE STREAM OUTLETS

Flooding and erosion of coastal property is of great concern to land owners and planners, and the coastal community. Land along low-lying coastlines is subject to flooding, erosion and wave overtopping during periods of

storms, especially those with extremely high tides. One of the purposes of this study was to document geomorphic features and processes which may contribute to the increased risk of flooding and erosion along coastlines where the beach and foredunes provide the main protection from the sea.

The size of beach and dune deposits is directly related to the stability of the shoreline. It is assumed that the alluvial beaches are in a state of equilibrium between factors including wind, waves, available sediment supply, tides and human impact. The size of the beach and dunes is a measure of the balance between continually variable sediment transport and supply. The natural beach in equilibrium is in a state of variable erosion and accretion.

For the property and structures along the beach, the volume of beach and dune sand free and available for erosion is directly proportional to the resistance of the site to property damage during storms. Both the sand available for erosion and the dune resistance to wave overtopping provide "storm insurance" to properties.

Intermediate-size coastal streams are common along the northern Oregon coast. However, they are generally very small, and many do not create any embayment in the coastline. The major effect these stream outlets have on shore and beach land-use is the stream erosion of lithified

sand terraces and depression of beach topography. This depression reduces wave resistance, and waves quickly remove any material deposited from upstream erosion or landsliding. Those streams that do form embayments are along coastlines with well-developed foredunes that can be eroded by a single strong storm or a closely spaced series of storms. Unlike lithified sand terraces, foredunes contain loose sand that is readily removed by storm waves.

Any variation in wave form or sediment erosion and transportation can change the relative risk to property.

1. The study of wave patterns in this research was inconclusive regarding any possible offshore topographic anomaly focusing or dissipating wave energy.

2. The beach face provides some protection for the foredune because waves that break on beaches instead of dunes expend their energy there instead of against the foredune. During storms or periods of high tides, the lowered beach face at the intermediate-size stream outlets allows the waves to run unimpeded farther back into the beach and foredune area and break directly up against the foredune.

3. The height and volume of the foredune has often been used as a measure of protection from wave erosion. With diminished foredune height at intermediate-size stream outlets, especially on the north side in northern Oregon,

land protection is also diminished.

4. Flooding behind the foredune has been a problem at intermediate-size stream outlets. Historically, the clogging of lake outlets by sand and drift logs deposited from a storm has flooded Rockaway Beach (Stembridge, 1975), where several times logs were carried across the railroad tracks onto Highway 101 (OLCDC, 1986). Rising lake levels due to the build-up of sand at Daley Lake also caused flooding problems in Camp Winema.

SEDIMENT BUDGET

Sediment enters the beach through three processes: (1) minor stream deposits, (2) waves, and (3) windblown sand. Sediment grain sizes indicate that sediment input from ocean waves predominates. Waves can be seen depositing on the beach as the rising tide fills the channel of the stream outlet. The original source of the beach sediment has not been defined by this investigation. Longshore drift may be supplying sand in transit along the coast, or the waves and tides may simply be redistributing it between deep and shallow water each seasonal cycle and reforming or levelling the planar beach slope. Windblown sand can be seen as it blows into the study area.

Sediment leaving the beach system moves through the same three processes: stream, waves, and wind. The stream removes beach sand on each outgoing tide. Some of the sand

is redistributed onto the lower beach, and the rest goes out in the swash zone. The wind blows sand downwind on the leeward side of the stream and out of the system. Storm waves, with their great energy each winter season, erode the sand and redeposit it offshore in a berm or storm-profile (Komar, 1976). If the seasonal wave removal exceeds sand supply the beach will erode to rock or to larger-size sediment, such as cobbles, too big to be eroded by the waves.

In this study, at low water and non-stormy times, the intermediate-size stream outlets of the Oregon coast were observed to erode the upper beach during each low tide. During this tidal cycle, the stream transported the eroded sand into the swash and surf zone.

Wind was observed depositing on the windward side of the stream channel, moving the stream channel edge downwind. Groundwater levels may alter the stream flow and the erodibility of the beach but were not investigated. Human impacts, such as beach grading, can modify the beach face considerably yet may not be apparent following wind and surf reshaping of the beach.

Swash and surf processes fill and smooth the stream-cut channel at high tide and that the stream repeats its channel erosion with each low tide cycle. Persistent erosion by the streams maintains the lower channel area

across the beach at stream mouths in spite of the continuing attempts of surf and swash to obliterate such variations along the beach.

The small dune volume on the north side of stream outlets was probably caused by stream trapping of eolian sand from dominantly southerly storms.

The low beach level and much reduced foredune volume and height at intermediate-size stream outlets is persistent. All intermediate-size streams demonstrate lower beach, reduced foredune, and a triangular stream outflow cut into the upper beach.

Although the relative amount of sand movement by the stream is small compared to that moved by the surf and swash, the beach face is continually modified by the stream.

CHAPTER V

CONCLUSION

Intermediate-size stream outlets have a set of geologic processes operating and interacting through time.

(1) These outlets are common along the northern Oregon coast. They vary widely in drainage basin size, but are generally located away from large stream mouths and estuaries. Eight of the 54 sites identified were in the midst of active foredunes. Stream outlets near developed communities are often constrained through human interference. Others, located in relatively remote or undeveloped sections of coastline, have remained in their natural state.

(2) Waves and tides were observed to be the dominant processes in this study. Tides provide a changing sea level which allows waves to shape the beach by erosion and deposition. Modification of waves at intermediate-size stream outlets was not proven, although constant wave focus at stream outlets and the landward slope found in profile suggest further study is needed in the area of surf profiling. Although waves move landward contrary to streamflow, the greater magnitude of energy in the waves overpowers stream flow. Streamflow does create more

turbulence in the landward wave energy.

(3) Dune and beach deposit volume is reduced at intermediate-size stream outlets. If the volume of the beach deposit and of the foredune is proportional to the relative coastal resistance and protection from storm waves, then the intermediate-size stream embayments have as little as half the resistance to coastal erosion. Beaches at intermediate-size stream outlets are wider and have a lower slope (.025 meters/meter) than those not affected by the presence of stream outlets (.054 meters/meter). The lower slope is probably due to a higher water table that enhances wave backwash energy and erosion of the upper beach by the stream. The stream increases erosion by flowing across the relatively steep beach face and redistributing sediment from the upper to the lower beach. The location of the stream channel that moves around on the beach may be dependent on beach berm deflection, wind deflection, or to channel interference by humans.

(4) Sediment grain size was not found to be variable in this study. All the beach and stream sand sampled was statistically similar in median size and at 5%, 50% and 95% fraction sizes. Standard deviations, skewness and kurtosis were also statistically similar. The similarity in median sediment size between the streams was probably due to the fact that only areas with appreciable dunes were studied. It was concluded that sediment contribution from the stream

was small and that marine processes dominate sediment size.

(5) Eolian processes modified by the presence of intermediate-size streams have caused reduced size of foredunes in the area around the stream outlet. Wind also causes some stream deflection. Windblown sand was found to be trapped by stream water at the stream mouths. This builds up the windward edge of the stream and deflects it slightly downwind. Most strong storm winds come from the southwest and move a great deal of sand. At least two of the three streams studied here are often deflected northward.

(6) The presence of intermediate-size stream outlet embayments combined with the lowered beach slope and greatly reduced foredune is expected to allow storm waves and tsunami waves to break much further up into what would normally be the foredune area. This may cause increased energy to be focused on the embankments around the stream outlet, may carry logs up into the stream, and may create increased flooding behind the dune in those locations. A greater landward transport of wave energy creates a much greater erosion and flooding hazard to human developments in the area.

Other non-stream related embayments in the foredune are present along the coastline. These embayments appear to be wave washovers. They occur approximately 6 per km (4/mile) from Neskowin to Daley Lake Outlet. The foredune embayments can be as large as stream embayments but are

expected to be ephemeral features, eroding and filling in again. They may be due to the presence of rip currents, which are often seasonal features. Stream embayments are always fixed at the stream outlet. Washovers are not affected by the high water table of stream flow and so sand would accumulate within them.

Along the Oregon coast, land on the north side of an intermediate-size stream appears to be much more vulnerable to stream erosion and subsequently to wave erosion and flooding. Eolian sand from the southwest trapped by the stream probably reduces foredune sand nourishment on the north side of intermediate-size stream outlets.

Further investigations into intermediate-size stream outlets should study:

1. Offshore profiles near the stream outlet. This would determine if a delta exists in deeper water and, if so, the permanence of such a feature and how it influences wave patterns.

2. Observation and documentation of the behavior of waves in the stream outlet area during a very high tide large storm.

3. Recording stream discharges daily or weekly over the course of a year, and the condition of the beach berm at those times. This would be very useful in estimating the likelihood of significant storm or tsunami damage during various seasons.

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APPENDIX A

U.S. GEOLOGICAL SURVEY 7 1/2-MINUTE QUADRANGLE
MAPS USED FOR STREAM RECONNAISSANCE

U.S. GEOLOGICAL SURVEY 7 1/2-MINUTE QUADRANGLE
MAPS USED FOR STREAM RECONNAISSANCE

1. Arch Cape, Oreg. Provisional Edition 1985 (4)
2. Depoe Bay, Oreg. Provisional Edition 1984 (12)
3. Devil's Lake, Oreg. Provisional Edition 1984 (15)
4. Dolph, Oreg. Provisional Edition 1985 (14)
5. Garibaldi, Oreg. Provisional Edition 1985 (6)
6. Gearhart, Oreg. 1949 (photorevised 1973) (2)
7. Lincoln City, Oreg. Provisional Edition 1984 (11)
8. Nehalem, Oreg. Provisional Edition 1985 (5)
9. Neskowin, Oreg. Provisional Edition 1985 (10)
10. Nestucca Bay, Oreg. Provisional Edition 1985 (9)
11. Netarts, Oreg. Provisional Edition 1986 (7)
12. Newport North, Oreg. Provisional Edition 1984 (13)
13. Sand Lake, Oreg. Provisional Edition 1985 (8)
14. Tillamook Head, Oreg. 1949 (photorevised 1973) (3)
15. Toledo North, Oreg. Provisional Edition, 1984 (16)
16. Warrenton, Oreg.-Wash. 1953 (photorevised 1984) (1)

() refer to quadrangle locations in Figure 10

APPENDIX B

PROFILE DATA FOR STUDY STREAMS

CRESCENT LAKE OUTLET

SALTAIR CREEK

DALEY LAKE OUTLET

PROFILES 1-3
CRESCENT LAKE OUTLET

PROFILE 1	PROFILE 1	PROFILE 2	PROFILE 2	PROFILE 3	PROFILE 3
DISTANCE	ELEVATION	DISTANCE	ELEVATION	DISTANCE	ELEVATION
0.00	-3.27	0.00	0.00	0.00	0.00
6.00	-3.27	3.99	-0.31	55.36	-8.00
12.00	-3.43	9.96	0.29	61.06	-7.80
17.97	-4.03	15.84	-0.91	67.04	-9.67
23.92	-4.83	21.84	-2.11	73.04	-10.17
41.92	-5.13	27.83	-2.41	78.86	-10.27
59.92	-5.23	33.83	-2.57	84.86	-8.83
77.92	-5.23	39.82	-2.97	90.86	-8.85
95.92	-4.98	45.82	-3.30	96.86	-8.77
113.92	-4.93	51.82	-3.12	102.86	-8.77
119.92	-4.98	56.99	-7.17	108.86	-8.62
125.92	-4.60	62.95	-7.89	114.86	-8.62
131.91	-4.38	68.90	-8.66	132.86	-8.62
137.91	-4.33	74.88	-9.12	138.86	-5.92
143.91	-4.20	80.88	-9.34	144.01	-9.64
149.89	-3.76	86.88	-9.39	149.98	-10.02
155.80	-2.74	92.87	-9.66	155.98	-10.60
161.29	-5.16	98.87	-9.80	161.98	-10.78
167.29	-5.42	104.85	-9.91	167.98	-10.93
173.28	-5.70	110.84	-10.43	173.98	-11.08
179.28	-5.79	116.84	-10.33	179.98	-11.23
185.24	-7.27	122.84	-10.41	185.97	-11.53
191.23	-6.93	128.84	-10.36	191.97	-11.61
197.23	-9.89	134.00	-10.42	197.97	-11.77
203.08	-9.14	140.84	-10.21	203.97	-11.93
208.99	-9.02	146.84	-10.24	209.97	-12.17
213.90	-8.10	152.84	-10.24	215.96	-12.24
219.88	-8.53	158.84	-10.27	221.95	-12.50
225.88	-8.77	164.84	-10.39	227.94	-12.77
237.70	-10.58	170.84	-10.19	233.93	-13.04
243.63	11.48	176.84	-10.33	239.92	-13.41
249.61	-12.03	182.84	-10.35	245.91	-13.78
255.60	-12.37	188.83	-10.65	251.91	-14.08
261.60	-12.57	194.33	-13.05	257.91	-14.26
267.60	-12.65	200.32	-13.34	263.91	-14.30
273.59	-13.07	206.32	-13.45	269.91	-14.35
279.58	-13.41	212.32	-13.64	275.91	-14.53
285.58	-13.63	218.32	-13.69	281.91	-14.77
291.57	-13.96	224.32	-13.74	293.91	-14.99

PROFILES 1-3
CRESCENT LAKE OUTLET

PROFILE 1 DISTANCE	PROFILE 1 ELEVATION	PROFILE 2 DISTANCE	PROFILE 2 ELEVATION	PROFILE 3 DISTANCE	PROFILE 3 ELEVATION
297.57	-14.07	230.32	-13.76	305.91	-15.04
303.56	-13.82	236.32	-13.76	317.91	-15.19
309.52	-14.48	248.32	-13.90	329.91	-15.37
315.52	-14.76	260.32	-13.94	341.91	-15.59
321.97	-15.46	272.32	-14.02	353.91	-15.79
327.44	-16.06	284.32	-14.07	365.90	-16.07
333.44	-16.16	296.32	-14.30	377.89	-16.42
339.44	-16.18	308.32	-14.55	389.89	-16.78
345.44	-16.28	320.32	-14.79	401.89	-16.78
351.44	-16.30	332.32	-15.07	413.89	-17.38
357.44	-16.35	344.32	-15.27	425.89	-17.66
363.44	-16.42	356.32	-15.47	437.89	-17.94
369.44	-16.38	368.32	-15.57	449.89	-18.26
375.44	-16.40	380.32	-15.74	461.89	-18.48
381.44	-16.35	392.32	-15.89	473.88	-18.78
387.44	-16.47	404.32	-16.04	485.87	-19.18
393.44	-16.48	416.32	-16.20	497.85	-19.53
399.44	-16.48	428.32	-16.36	509.86	-19.78
405.44	-16.48	440.32	-16.56	521.86	-20.13
411.44	-16.58	452.32	-16.71	533.85	-20.45
417.44	-16.70	464.32	-16.89	545.84	-20.83
423.44	-16.82	476.32	-17.09	557.83	-21.23
429.44	-16.97	488.32	-17.28	569.82	-21.63
435.44	-17.07	500.32	-17.53	581.81	-22.08
441.44	-17.19	512.32	-17.73	593.80	-22.43
447.44	-17.35	524.32	-17.93	605.80	-22.78
453.44	-17.52	536.32	-18.13	617.80	-23.08
459.44	-17.64	548.32	-18.28	629.80	-23.36
465.44	-17.79	560.32	-18.48	641.80	-23.64
471.44	-17.97	572.32	-18.68	653.80	-23.92
483.43	-18.35	584.32	-18.86	665.80	-24.12
495.42	-18.72	596.32	-19.06	677.80	-24.36
507.41	-19.07	608.32	-19.16	689.80	-24.61
519.41	-19.41	620.32	-19.36	701.80	-24.83
531.40	-19.81	632.32	-19.56	713.80	-25.01
543.39	-20.17	644.32	-19.76	725.80	-25.25
555.38	-20.57	656.32	-20.01	737.80	-25.49
567.38	-20.91	668.32	-20.31	749.80	-25.69
579.38	-21.17	680.32	-20.56	761.80	-26.01

PROFILES 1-3
CRESCENT LAKE OUTLET

PROFILE 1 DISTANCE	PROFILE 1 ELEVATION	PROFILE 2 DISTANCE	PROFILE 2 ELEVATION	PROFILE 3 DISTANCE	PROFILE 3 ELEVATION
591.38	-21.45	692.32	-20.78	773.80	-26.17
603.38	-21.69	704.32	-20.88	785.80	-26.32
615.38	-21.99	716.32	-21.10	797.80	-26.47
627.38	-22.29	728.32	-21.25	809.80	-26.57
639.38	-22.51	740.32	-21.43	821.80	-26.67
651.38	-22.69	752.32	-21.63	833.30	-26.85
663.38	-22.89	764.32	-21.78	845.80	-26.95
675.38	-22.94	776.32	-21.94	851.80	-27.19
687.38	-23.01	788.32	-21.99		
699.38	-23.07	800.32	-22.11		
700.38	-23.12	812.32	-22.27		
723.38	-23.20	824.32	-22.48		
735.38	-23.30	836.32	-22.70		
747.38	-23.50	848.32	-22.88		
759.38	-23.70	860.32	-22.98		
		872.32	-23.16		
		884.32	-23.31		
		896.30	-23.49		
		908.32	-23.65		
		920.32	-23.73		
		932.32	-23.93		
		944.32	-24.07		
		956.32	-24.15		
		968.32	-24.23		
		980.32	-24.33		
		992.32	-24.45		
		1004.32	-24.55		
		1016.32	-24.60		
		1028.32	-24.70		
		1040.32	-24.80		
		1052.32	-24.92		
		1064.32	-25.02		
		1076.32	-25.12		
		1088.32	-25.22		
		1100.32	-25.36		
		1112.32	-25.46		
		1124.32	-25.54		
		1136.32	-25.59		
		1148.32	-25.64		
		1160.32	-25.64		
		1172.32	-25.69		
		1184.32	-25.71		
		300.32	-14.51		

PROFILES 4
CRESCENT LAKE OUTLET

PROFILE 4 DISTANCE	PROFILE 4 ELEVATION	PROFILE 4 DISTANCE	PROFILE 4 ELEVATION	PROFILE 4 DISTANCE	PROFILE 4 ELEVATION
0.00	0.00	472.19	-13.07	831.89	-18.20
4.28	-0.44	478.19	-13.07	843.89	-18.35
9.48	-0.65	484.19	-13.02	855.89	-18.39
25.17	-2.54	490.19	-13.26	867.89	-18.33
41.52	-3.80	496.19	-13.36	879.89	-18.35
53.89	-3.00	502.19	-13.30	891.89	-18.40
65.65	-1.20	508.19	-13.37	903.89	-18.47
89.52	-2.40	514.19	-13.50	915.89	-18.51
97.82	-2.35	520.19	-13.43	927.89	-18.56
106.65	-3.48	526.19	-13.56	939.89	-18.60
122.94	-3.90	532.18	-13.81	951.89	-18.60
135.04	-4.20	538.18	-13.96	963.89	-18.70
153.14	-4.55	544.15	-14.51	975.89	-18.78
171.22	-3.70	549.89	-16.25	987.89	-18.88
189.11	-3.25	555.89	-16.35	999.89	-18.94
207.70	-3.70	561.89	-16.35	1011.89	-18.98
222.50	-3.95	567.89	-16.44	1023.89	-19.10
230.59	-5.40	573.89	-16.48	1027.89	-19.19
243.48	-5.90	579.89	-16.51	1033.89	-19.33
256.88	-6.00	591.89	-16.59	1039.89	-19.33
275.08	-6.60	603.89	-16.79	1045.88	-19.65
289.17	-5.90	615.89	-16.96	1048.88	-19.60
320.45	-7.90	627.89	-17.11	1051.88	-19.50
337.75	-8.20	639.89	-17.18	1054.88	-18.52
357.74	-6.10	651.89	-17.20	1057.88	-18.05
388.58	-8.10	663.89	-17.20	1063.42	-16.67
394.58	-8.15	675.89	-17.32	1075.68	-15.75
400.33	-9.85	687.89	-17.44	1087.68	-15.70
406.27	-10.70	699.89	-17.54	1099.68	-15.48
412.24	-11.25	711.89	-17.62	1111.68	-15.43
418.23	-11.65	723.89	-17.72	1123.68	-15.37
424.22	-11.94	735.89	-17.77	1135.68	-15.19
430.21	-12.29	747.89	-17.85	1142.68	-15.04
436.21	-12.49	759.89	-17.89	1154.68	-14.88
442.21	-12.33	771.89	-17.84	1166.68	-14.78
448.21	-12.35	783.89	-17.99	1178.68	-14.48
454.21	-12.30	795.89	-18.04	1190.68	-14.23
460.20	-12.60	807.89	-18.07	1202.68	-14.01
466.19	-12.97	819.89	-18.10	1214.68	-13.95

PROFILES 4
CRESCENT LAKE OUTLET

PROFILE 4 DISTANCE	PROFILE 4 ELEVATION	PROFILE 4 DISTANCE	PROFILE 4 ELEVATION
1226.68	-13.93	1543.55	-5.82
1238.68	-13.89	1549.57	-4.00
1250.68	-13.79	1555.54	-5.34
1262.68	-13.64	1561.54	-5.29
1274.68	-13.49	1567.53	-4.97
1286.68	-13.29	1573.52	-4.67
1298.68	-13.27	1579.52	-4.50
1310.68	-13.02	1585.51	-4.80
1322.68	-12.87	1591.50	-4.55
1334.68	-12.82		
1346.68	-12.47		
1358.68	-12.35		
1370.68	-12.11		
1382.68	-11.85		
1394.60	-11.63		
1400.67	-11.28		
1406.67	-11.05		
1412.66	-10.75		
1418.65	-10.35		
1424.63	-9.87		
1430.60	-9.32		
1436.56	-8.66		
1442.54	-8.16		
1448.50	-7.48		
1454.48	-6.98		
1460.46	-6.47		
1466.13	-4.52		
1472.04	-5.54		
1478.01	-4.95		
1483.98	-5.55		
1489.98	-5.35		
1495.97	-5.04		
1501.96	-4.79		
1507.78	-6.45		
1513.74	-5.54		
1519.74	-5.49		
1525.67	-4.59		
1531.66	-4.29		
1537.57	-5.35		

PROFILES 5-7
SALTAIR CREEK

PROFILE 5	PROFILE 5	PROFILE 6	PROFILE 6	PROFILE 7	PROFILE 7
DISTANCE	ELEVATION	DISTANCE	ELEVATION	DISTANCE	ELEVATION
0.00	-1.60	0.00	3.76	0.00	0.00
5.99	-2.01	5.99	3.41	85.00	3.00
11.97	-2.52	11.97	2.91	185.00	2.65
17.97	-2.58	17.90	2.01	214.91	4.95
23.97	-2.53	23.86	1.34	244.82	5.15
29.97	-2.47	29.44	-0.86	274.82	3.55
35.47	-2.50	35.42	-1.49	304.78	2.11
41.97	-2.58	41.41	-1.91	310.60	1.07
47.96	-2.83	47.41	-2.05	316.51	1.94
53.96	-2.96	53.40	-2.42	322.45	2.38
59.96	-3.04	59.40	-2.31	328.43	0.83
65.96	-3.12	65.38	-2.81	334.23	0.29
71.96	-3.10	71.37	-2.96	340.20	-0.82
77.96	-2.99	77.38	-3.04	346.10	-0.27
83.96	-3.01	83.38	-3.09	352.07	0.45
89.95	-2.76	89.38	-3.07	358.03	-0.12
95.92	-3.31	95.38	-3.21	364.02	-1.93
107.90	-3.93	101.37	-3.58	369.66	-4.00
119.86	-4.85	107.36	-3.88	375.29	-5.08
131.84	-5.61	113.35	-4.26	381.19	-5.60
143.83	-6.10	119.25	-5.36	387.17	-5.95
155.82	-6.60	125.24	-5.76	399.16	-6.23
167.82	-6.94	131.23	-6.01	407.16	-6.58
179.81	-7.49	143.22	-6.39	419.15	-6.97
191.78	-8.19	155.21	-6.87	431.14	-7.44
203.76	-8.80	167.20	-7.27	443.13	-7.86
215.75	-9.32	179.20	-7.57	455.12	-8.29
227.72	-10.17	191.19	-7.97	467.11	-8.69
239.70	-10.79	203.18	-8.33	479.10	-9.13
251.68	-11.41	215.18	-8.63	491.09	-9.58
263.66	-12.01	227.17	-9.03	503.08	-10.06
275.64	-12.66	239.17	-9.31	515.07	-10.51
287.63	-13.24	251.17	-9.56	527.06	-10.97
299.62	-13.82	263.17	-9.71	539.05	-11.35
311.61	-14.38	275.17	-9.97	551.04	-11.72
323.60	-14.93	287.17	-10.22	563.03	-12.12
335.59	-15.38	299.17	-10.40	575.02	-12.67
347.58	-15.88	311.17	-10.60	587.01	-13.17
359.57	-16.29	323.17	-10.85	599.00	-13.76

PROFILES 5-7
SALT AIR CREEK

PROFILE 5	PROFILE 5	PROFILE 6	PROFILE 6	PROFILE 7	PROFILE 7
DISTANCE	ELEVATION	DISTANCE	ELEVATION	DISTANCE	ELEVATION
371.56	-16.74	335.17	-11.13	610.99	-14.13
383.55	-17.19	347.16	-11.48	622.98	-14.53
395.55	-17.49	359.15	-11.85	634.97	-15.08
407.55	-17.79	371.15	-12.19	646.96	-15.55
419.54	-18.15	383.15	-12.51	658.95	-15.93
431.43	-18.53	395.15	-12.83	670.94	-16.33
443.43	-18.83	407.15	-13.08	682.93	-16.67
455.43	-19.11	419.15	-13.36	694.93	-17.00
467.43	-19.43	431.15	-13.64	706.93	-17.34
479.43	-19.75	443.15	-13.96	718.93	-17.60
491.43	-20.05	455.15	-14.22	730.93	-17.95
503.43	-20.27	467.15	-14.50	742.92	-18.25
515.43	-20.52	479.15	-14.75	754.92	-18.55
527.42	-20.87	491.14	-15.15	766.92	-18.93
539.42	-21.15	503.13	-15.50	778.91	-19.21
551.42	-21.45	515.12	-15.90	790.91	-19.61
563.41	-21.80	527.12	-16.15	802.90	-19.93
575.40	-22.16	539.11	-16.50	814.90	-20.23
587.39	-22.51	551.11	-16.80	826.90	-20.53
599.39	-22.76	563.10	-17.15	838.90	-20.93
611.39	-22.96	575.10	-17.47	850.89	-21.23
623.39	-23.18	587.10	-17.72	862.89	-21.60
		599.09	-18.12	874.88	-21.88
		611.09	-18.44	886.88	-22.18
		623.08	-18.79	898.88	-22.45
		635.08	-19.11	910.88	-22.70
				922.88	-22.93
				934.88	-23.13
				946.88	-23.33
				958.88	-23.61
				970.88	-23.91

PROFILE 8
SALTAIR CREEK

PROFILE 8 DISTANCE	PROFILE 8 ELEVATION	PROFILE 8 DISTANCE	PROFILE 8 ELEVATION	PROFILE 8 DISTANCE	PROFILE 8 ELEVATION
0.00	-2.53	232.69	-5.88	499.99	-13.19
6.00	-2.41	238.69	-5.99	502.80	-12.13
11.99	-2.11	244.67	-6.47	509.80	-11.98
17.99	-1.97	250.67	-6.56	521.80	-11.83
23.95	-1.30	256.67	-6.63	533.80	-11.60
29.94	-0.95	262.67	-6.65	545.80	-11.33
35.93	-0.53	268.61	-6.72	557.80	-11.13
41.92	-0.17	274.55	-5.87	569.79	-10.75
47.91	0.08	280.55	-6.02	581.79	-10.45
53.84	1.02	286.55	-5.97	593.79	-10.25
59.34	3.42	292.55	-6.08	605.79	-10.01
65.32	2.95	298.55	-6.08	617.79	-9.85
71.31	2.57	304.55	-6.05	629.78	-9.50
77.31	2.59	310.55	-6.10	641.78	-9.19
83.31	2.74	316.55	-6.27	653.78	-8.87
89.27	2.01	322.55	-6.24	665.77	-8.50
95.15	0.83	328.55	-6.39	677.77	-8.25
100.95	-0.69	332.55	-6.56	689.76	-7.70
106.93	-1.14	338.54	-6.97	701.76	-7.45
112.92	-0.87	344.53	-7.34	713.76	-7.30
118.92	-0.70	350.44	-8.39	725.75	-6.88
124.91	-0.35	356.44	-8.31	731.75	-6.74
130.91	-0.57	362.43	-8.59	737.75	-6.76
136.90	-0.86	374.43	-8.72	743.75	-6.67
142.90	-0.79	386.42	-9.27	749.75	-6.48
148.90	-0.98	398.42	-9.57	755.75	-6.33
154.90	-0.76	410.41	-10.02	761.75	-6.24
160.88	-1.26	422.40	-10.42	767.74	-5.95
166.87	-1.62	434.39	-10.77	773.73	-5.70
172.85	-2.06	440.36	-11.35	779.73	-5.55
178.81	-2.74	446.02	-13.35	785.73	-5.42
184.80	-3.11	452.02	-13.36	791.73	-5.25
190.79	-3.39	458.02	-13.39	797.73	-5.20
196.79	-3.57	464.02	-13.43	803.72	-4.94
202.77	-4.09	470.02	-13.48	809.70	-4.50
208.76	-4.43	476.02	-13.41	815.60	-3.42
214.75	-4.71	482.01	-13.71	821.53	-2.51
220.70	-5.47	488.01	-13.76	827.45	-1.53
226.69	-5.73	494.01	-13.63	833.36	-0.49

PROFILE 8
SALTAIR CREEK

PROFILE 8 PROFILE 8
DISTANCE ELEVATION

839.35	-0.22
845.30	-1.00
851.26	-0.34
857.22	0.38
862.96	2.14
868.93	2.71
874.90	3.11
880.90	3.11
886.89	3.41
892.89	3.51
898.86	2.91
0.00	0.00

PROFILE 9-10
DALEY LAKE OUTLET

PROFILE 9 DISTANCE	PROFILE 9 ELEVATION	PROFILE 10 DISTANCE	PROFILE 10 ELEVATION
0.00	5.69	0.00	-6.21
5.92	6.64	5.98	-6.71
11.92	6.49	11.97	-7.05
17.85	5.56	17.94	-7.65
23.71	4.26	23.88	-8.47
29.69	4.71	29.88	-8.68
35.63	3.85	35.88	-8.82
41.63	4.00	41.88	-8.97
47.63	3.90	47.88	-9.13
53.62	4.20	53.88	-9.10
59.61	3.95	59.87	-9.37
65.61	4.09	65.87	-9.57
71.27	6.07	71.87	-9.64
77.25	5.56	77.87	-9.78
83.23	5.11	83.87	-9.78
88.81	2.91	89.87	-9.95
94.69	1.17	95.87	-9.95
100.65	1.06	101.87	-9.92
106.55	-0.04	107.87	-9.95
112.42	-1.29	113.87	-10.15
118.27	-2.64	119.87	-10.12
124.21	-3.47	125.87	-10.19
130.18	-4.02	131.87	-10.27
136.15	-4.59	137.87	-10.35
142.14	-4.92	143.87	-10.43
148.14	-5.16	149.87	-10.47
154.13	-5.48	155.87	-10.53
160.12	-5.73	161.87	-10.69
166.12	-5.95	167.87	-10.75
172.12	-5.98	173.87	-10.78
178.11	-6.30	179.86	-11.08
184.10	-6.65	185.86	-11.20
190.09	-7.01	191.86	-11.21
196.07	-7.51	197.86	-11.22
202.06	-7.87	203.86	-11.33
208.06	-8.03	209.86	-11.44
214.06	-8.25	215.86	-11.62
220.05	-8.55	221.86	-11.77
226.05	-8.77	227.86	-11.87

PROFILE 9-10
DALEY LAKE OUTLET

PROFILE 9 DISTANCE	PROFILE 9 ELEVATION	PROFILE 10 DISTANCE	PROFILE 10 ELEVATION
232.05	-9.00	233.86	-11.97
238.05	-9.19	239.86	-12.03
244.04	-9.47	245.86	-12.11
256.04	-9.62	251.86	-12.11
268.04	-9.92	257.86	-12.17
280.04	-10.22	263.86	-12.17
292.04	-10.53	269.86	-12.26
304.03	-10.94	275.86	-12.22
316.03	-11.24	281.86	-12.28
328.03	-11.54	287.86	-12.33
340.02	-11.94	293.86	-12.39
352.01	-12.41	299.86	-12.40
364.01	-12.74	305.86	-12.48
376.00	-13.09	311.86	-12.57
387.99	-13.46	317.86	-12.63
399.98	-13.90	323.86	-12.67
411.97	-14.34	329.86	-12.72
423.96	-14.77	335.86	-12.82
435.95	-15.23	341.86	-12.84
447.94	-15.63	347.86	-12.90
459.93	-16.03	353.86	-12.94
471.92	-16.40	359.86	-12.84
483.92	-16.70	365.86	-12.88
495.92	-17.00	371.86	-12.91
507.92	-17.22	377.86	-13.03
519.92	-17.50	389.86	-12.98
531.92	-17.65	401.86	-12.96
543.92	-17.87	413.86	-12.94
555.92	-18.09	425.86	-12.94
567.92	-18.24	437.86	-12.93
579.92	-18.40	449.86	-13.08
591.92	-18.54	461.86	-13.09
603.92	-18.67	473.86	-13.29
615.92	-18.85	485.86	-13.30
627.92	-18.92	497.86	-13.38
639.92	-19.07	509.86	-13.50
651.92	-19.22	521.86	-13.56
663.92	-19.39	533.86	-13.71
675.92	-19.59	545.86	-13.85

PROFILE 9-10
DALEY LAKE OUTLET

PROFILE 9 DISTANCE	PROFILE 9 ELEVATION	PROFILE 10 DISTANCE	PROFILE 10 ELEVATION
687.92	-19.87	557.86	-14.02
699.92	-20.10	569.86	-14.22
711.92	-20.25	581.86	-14.27
723.92	-20.42	593.86	-14.42
		605.86	-14.54
		617.86	-14.67
		629.86	-14.88
		641.86	-14.98
		653.86	-15.08
		665.86	-15.24
		677.86	-15.44
		689.86	-15.78
		701.86	-15.83
		713.86	-16.03
		725.86	-16.18
		737.86	-16.38
		749.86	-16.68
		761.86	-16.93
		773.86	-17.18
		785.86	-17.33
		797.86	-17.50
		819.86	-17.75
		821.86	-17.90
		833.86	-18.05
		845.86	-18.32
		857.86	-18.59
		869.86	-18.84
		881.86	-18.99
		893.86	-19.14
		905.86	-19.42
		917.86	-19.65
		929.86	-19.79
		941.86	-19.94
		953.89	-20.05
		965.89	-20.18
		977.89	-20.28
		989.89	-20.38
		1001.89	-20.48
		1013.89	-20.58
		1025.89	-20.43
		1037.88	-20.03
		1049.88	-19.73
		1061.88	-19.55
		1073.88	-19.50
		1085.88	-19.51

PROFILE 11
DALEY LAKE OUTLET

PROFILE 11 DISTANCE	PROFILE 11 ELEVATION	PROFILE 11 DISTANCE	PROFILE 11 ELEVATION
0.00	2.57	231.81	-8.75
6.00	2.80	237.81	-8.97
12.00	2.73	243.78	-9.52
17.93	3.63	249.78	-9.41
23.89	2.94	255.78	-9.66
29.85	2.24	261.78	-9.71
35.57	4.04	267.77	-10.11
41.53	3.34	273.77	-10.25
47.49	2.69	279.77	-10.41
53.49	2.66	285.77	-10.59
59.46	2.03	291.76	-10.85
64.40	-1.37	297.76	-11.06
70.08	-3.30	303.76	-11.21
76.03	-4.08	309.75	-11.59
82.02	-4.47	315.75	-11.79
88.02	-4.82	321.75	-11.95
94.00	-5.13	327.74	-12.20
99.99	-5.47	333.74	-12.33
105.99	-5.52	339.74	-12.49
111.98	-5.84	345.74	-12.67
117.98	-6.03	351.74	-12.82
123.98	-6.06	357.74	-12.99
129.98	-6.26	363.74	-13.15
135.98	-6.43	369.74	-13.29
141.98	-6.61	375.74	-13.16
147.98	-6.75	381.74	-13.11
153.98	-6.76	393.74	-13.09
159.98	-6.95	405.74	-13.09
165.97	-7.23	417.74	-13.06
171.97	-7.23	429.74	-13.02
177.96	-6.97	441.74	-12.97
183.91	-7.75	453.74	-12.95
189.91	-7.88	465.74	-12.80
195.89	-7.38	477.74	-12.70
201.88	-7.78	489.74	-12.52
207.85	-8.34	501.74	-12.46
213.82	-8.98	513.74	-12.41
219.82	-8.88	525.74	-12.36
225.81	-8.63	537.74	-12.26

PROFILE 11
DALEY LAKE OUTLET

PROFILE 11 PROFILE 11
DISTANCE ELEVATION

549.74	-12.22
561.74	-12.17
573.74	-12.11
585.74	-11.96
597.74	-11.80
609.74	-11.74
621.74	-11.69
633.74	-11.60
645.74	-11.66
657.74	-11.76
669.74	-11.98
681.73	-12.38
693.73	-12.68
705.73	-13.00
717.72	-13.35
729.71	-13.76
741.70	-14.31
753.68	-14.96
765.66	-15.61
777.65	-16.11
789.64	-16.55
801.63	-17.01
813.62	-17.40
825.61	-17.81
837.61	-18.09
849.61	-18.38
861.61	-18.65
873.61	-18.89
885.61	-19.14
897.61	-19.38
909.61	-19.63
921.61	-19.83
933.61	-19.98
945.61	-20.18
957.61	-20.35
969.61	-20.55
981.61	-20.70
993.61	-20.73
1005.61	-20.83

PROFILE 12
DALEY LAKE OUTLET

PROFILE 12 DISTANCE	PROFILE 12 ELEVATION	PROFILE 12 DISTANCE	PROFILE 12 ELEVATION
0.00	27.29	222.96	-12.96
2.50	27.15	228.94	-13.45
7.50	27.31	240.93	-13.90
13.37	26.09	252.93	-14.45
19.05	24.17	264.92	-14.55
24.59	21.87	276.92	-14.75
29.81	18.92	288.91	-15.10
35.38	16.68	300.91	-15.34
41.35	15.96	312.91	-15.59
47.27	15.03	324.91	-15.74
53.19	14.06	336.91	-15.89
58.14	10.67	348.91	-15.94
63.69	8.38	360.91	-16.09
69.38	6.47	372.91	-16.23
75.38	6.56	384.91	-16.58
81.23	7.90	396.90	-16.92
87.22	8.20	408.89	-17.30
92.92	6.32	420.88	-17.69
98.75	4.92	432.87	-18.04
104.50	3.22	444.86	-18.41
110.10	1.07	456.85	-18.76
115.85	-0.64	468.85	-19.03
121.66	-2.14	480.85	-19.35
127.51	-3.46	492.85	-19.62
133.39	-4.65	504.85	-19.89
139.29	-5.75	516.85	-20.19
145.25	-6.42	528.85	-20.39
151.21	-7.12	540.85	-20.54
157.17	-7.82	552.85	-20.74
163.12	-8.60	564.85	-20.91
169.09	-9.20	586.85	-21.11
175.17	-9.68	598.85	-21.23
181.05	-10.11	610.85	-21.35
187.03	-10.59	662.85	-21.52
193.02	-10.93	634.85	-21.68
199.01	-11.32	646.85	-21.83
205.00	-11.72	658.85	-22.07
210.99	-12.12	670.85	-22.19
216.98	-12.51	682.85	-22.39

PROFILE 12
DALEY LAKE OUTLET

PROFILE 12	PROFILE 12
DISTANCE	ELEVATION

694.85	-22.54
706.85	-22.66
718.85	-22.81

PROFILE 13
DALEY LAKE OUTLET

PROFILE 13 DISTANCE	PROFILE 13 ELEVATION	PROFILE 13 DISTANCE	PROFILE 13 ELEVATION
0.00	13.69	356.95	-9.47
5.76	12.00	368.95	-9.45
11.73	11.40	380.95	-9.27
17.29	9.15	392.95	-9.17
23.19	8.15	404.95	-8.87
29.15	7.35	416.95	-8.37
35.12	6.80	428.95	-7.90
41.12	6.94	440.91	-6.99
47.12	6.83	452.90	-6.49
53.12	6.69	464.89	-5.94
59.09	6.09	470.88	-5.58
65.07	6.52	476.88	-5.41
71.04	5.90	482.88	-5.24
76.96	4.94	488.88	-5.00
82.30	2.21	494.88	-4.83
87.58	-0.64	500.88	-4.72
93.40	-2.09	506.88	-4.66
99.18	-3.71	512.88	-4.59
105.03	-5.50	518.88	-4.64
117.01	-5.69	524.88	-4.79
129.00	-6.27	530.87	-5.05
140.99	-6.82	536.86	-5.37
152.98	-7.32	542.86	-5.37
164.98	-7.56	548.86	-5.54
176.97	-7.92	554.86	-5.56
188.97	-8.17	560.85	-5.20
200.97	-8.45	566.84	-5.45
212.97	-8.76	572.82	-5.90
224.96	-8.33	578.81	-6.26
236.95	-7.95	584.80	-6.56
248.95	-8.28	590.79	-6.88
260.95	-8.61	596.79	-7.11
272.95	-8.79	602.79	-7.33
284.95	-9.01	608.79	-7.43
296.95	-9.21	614.79	-7.51
308.95	-9.36	626.79	-7.83
320.95	-9.46	638.79	-8.08
332.95	-9.56	650.79	-8.16
344.95	-9.52	662.79	-8.34

PROFILE 13
DALEY LAKE OUTLET

PROFILE 13	PROFILE 13	PROFILE 13	PROFILE 13
DISTANCE	ELEVATION	DISTANCE	ELEVATION

674.79	-8.47	1136.00	-12.66
686.79	-8.62	1148.29	-12.74
698.79	-8.77	1160.29	-12.86
710.79	-9.05	1172.29	-12.91
722.79	-9.21	1184.29	-13.03
734.79	-9.36	1187.69	-13.01
743.29	-9.47	1199.69	-13.15
755.29	-9.53	1211.69	-13.25
767.29	-9.75	1223.69	-13.33
779.29	-9.86	1235.69	-13.40
791.29	-9.98	1247.69	-13.58
803.29	-10.08	1259.69	-13.77
812.29	-10.17	1271.69	-13.92
824.29	-10.28	1283.69	-14.11
836.29	-10.36	1295.69	-14.35
848.29	-10.42	1307.69	-14.58
860.29	-10.50	1314.69	-14.72
872.29	-10.57	1320.66	-15.34
884.29	-10.70	1326.66	-15.35
896.29	-10.80	1332.66	-15.50
908.29	-10.95	1338.66	-15.70
920.29	-11.07	1344.66	-15.68
932.29	-11.22	1350.66	-15.58
944.29	-11.34	1353.66	-15.50
956.29	-11.39	1359.63	-14.90
968.29	-11.39	1371.63	-14.60
980.29	-11.55	1383.63	-14.45
992.29	-11.68	1395.63	-14.24
1004.29	-11.80	1407.63	-14.09
1016.29	-11.90	1419.63	-14.14
1028.29	-12.00	1431.63	-14.23
1040.29	-12.08	1443.63	-14.23
1052.29	-12.19	1455.63	-14.20
1064.29	-12.24	1467.63	-14.15
1076.29	-12.28	1479.63	-14.11
1088.29	-12.35	1491.63	-14.02
1100.29	-12.51	1503.63	-13.97
1112.29	-12.51	1515.63	-13.87
1124.29	-12.61	1527.63	-13.66

PROFILE 13
DALEY LAKE OUTLET

PROFILE 13 DISTANCE	PROFILE 13 ELEVATION	PROFILE 13 DISTANCE	PROFILE 13 ELEVATION
1539.63	-13.39	1910.10	-4.20
1551.63	-13.29	1916.07	-3.58
1563.63	-13.15	1921.75	-1.93
1575.63	-12.93	1927.74	-2.19
1587.63	-12.71	1933.70	-2.84
1599.36	-12.51	1939.56	-4.13
1611.63	-12.26	1945.56	-4.37
1623.63	-12.01	1951.51	-5.15
1635.63	-11.81	1957.41	-4.06
1647.63	-11.65	1963.37	-3.34
1659.63	-11.60	1969.27	-2.27
1671.63	-11.38	1975.01	-0.52
1683.63	-11.19	1980.96	0.29
1695.63	-11.02	1986.88	0.96
1707.63	-10.84	1992.88	1.03
1719.63	-10.60	1998.86	1.49
1731.63	-10.36	2004.85	1.19
1743.63	-10.06	2010.84	0.89
1755.62	-9.66	2016.84	0.98
1767.61	-9.31		
1779.60	-8.95		
1791.58	-8.32		
1803.56	-7.65		
1815.53	-6.80		
1821.45	-5.85		
1827.14	-3.96		
1833.14	-3.84		
1839.10	-3.16		
1845.06	-2.48		
1851.06	-2.37		
1856.73	-0.40		
1862.51	-2.00		
1868.38	-3.63		
1874.35	-3.83		
1880.22	-5.08		
1886.18	-5.81		
1892.18	-5.86		
1898.14	-5.21		
1904.13	-4.94		

APPENDIX C

CUMULATIVE FREQUENCY CURVES FOR

SEDIMENT SIZE ANALYSIS

CRESCENT LAKE OUTLET

SALTAIR CREEK

DALEY LAKE OUTLET

APPENDIX D

SIEVE ANALYSIS DATA ON
SEDIMENT SAMPLES

SIEVE ANALYSIS OF SAND SAMPLES
CRESCENT LAKE OUTLET
MARCH 24, 1987

PHI SIZE CUMULATIVE
PERCENTAGE

** SAMPLE NUMBER 3241

1.00	0.00
1.25	0.00
1.50	0.00
1.75	0.50
2.00	13.10
2.25	52.20
2.50	74.40
2.75	97.90
3.00	100.00

** SAMPLE NUMBER 3242

1.00	0.10
1.25	1.10
1.50	2.30
1.75	2.50
2.00	38.10
2.25	82.80
2.50	96.60
2.75	100.00
3.00	100.00
3.25	100.00
0.00	0.00

** SAMPLE NUMBER 3243

1.00	0.10
1.25	0.20
1.50	0.30
1.75	0.70
2.00	10.80
2.25	45.90
2.50	58.10
2.75	94.40
3.00	98.90
3.25	100.00

** SAMPLE NUMBER 3244

1.00	0.00
1.25	0.10
1.50	0.10
1.75	0.60
2.00	13.30
2.25	55.90
2.50	80.10

SIEVE ANALYSIS OF SAND SAMPLES
CRESCENT LAKE OUTLET
MARCH 24, 1987

PHI SIZE CUMULATIVE
PERCENTAGE

2.75	96.50
3.00	99.10
3.25	100.00

** SAMPLE NUMBER 3245

1.00	0.80
1.25	1.40
1.50	2.00
1.75	3.50
2.00	15.10
2.25	52.00
2.50	81.30
2.75	96.90
3.00	99.10
3.25	100.00

** SAMPLE NUMBER 3246

1.00	0.00
1.25	0.00
1.50	0.00
1.75	0.90
2.00	17.80
2.25	58.80
2.50	81.10
2.75	96.40
3.00	99.50
3.25	100.10

SIEVE ANALYSIS OF SAND SAMPLES
SALTAIR CREEK
MARCH 26, 1987

PHI SIZE CUMULATIVE
PERCENTAGE

** SAMPLE NUMBER 3261

1.00	0.00
1.25	0.20
1.50	0.70
1.75	4.80
2.00	24.80
2.25	59.20
2.50	69.90
2.75	91.10
3.00	96.70
3.25	100.00

** SAMPLE NUMBER 3262

1.00	0.00
1.25	0.00
1.50	0.30
1.75	6.10
2.00	36.90
2.25	81.50
2.50	86.60
2.75	99.40
3.00	99.90
3.25	100.00

** SAMPLE NUMBER 3263

1.00	0.00
1.25	0.00
1.50	0.20
1.75	1.60
2.00	15.70
2.25	55.10
2.50	78.40
2.75	93.20
3.00	98.10
3.25	100.10

** SAMPLE NUMBER 3264

1.00	0.00
1.25	0.20
1.50	1.00
1.75	4.60
2.00	24.60
2.25	59.70
2.50	76.70

SIEVE ANALYSIS OF SAND SAMPLES
SALTAIR CREEK
MARCH 26, 1987

PHI SIZE CUMULATIVE
PERCENTAGE

2.75	88.90
3.00	94.50
3.25	100.00

** SAMPLE NUMBER 3265

1.00	0.00
1.25	0.00
1.50	0.00
1.75	1.40
2.00	16.50
2.25	57.00
2.50	72.20
2.75	94.50
3.00	98.70
3.25	100.10

** SAMPLE NUMBER 3266

1.00	0.00
1.25	0.20
1.50	0.40
1.75	0.80
2.00	6.60
2.25	35.70
2.50	56.60
2.75	87.50
3.00	97.10
3.25	100.20

SIEVE ANALYSIS OF SAND SAMPLES
SALT AIR CREEK
DECEMBER 11, 1987

PHI SIZE CUMULATIVE
PERCENTAGE

** SAMPLE NUMBER 12112

1.00	0.39
1.25	0.80
1.50	1.13
1.75	3.05
2.00	22.99
2.25	50.45
2.50	68.62
2.75	88.59
3.00	95.50
3.25	100.00

** SAMPLE NUMBER 12113

0.75	0.00
1.00	0.17
1.25	0.50
1.50	1.60
1.75	5.52
2.00	32.11
2.25	62.70
2.50	83.14
2.75	95.51
3.00	98.50
3.25	100.00
3.50	100.00

** SAMPLE NUMBER 12114

0.75	0.00
1.00	0.00
1.25	0.00
1.50	0.00
1.75	2.38
2.00	32.09
2.25	64.35
2.50	84.55
2.75	95.93
3.00	98.98
3.25	100.00

** SAMPLE NUMBER 12115

0.75	0.00
1.00	0.48
1.25	0.81
1.50	1.45

SIEVE ANALYSIS OF SAND SAMPLES
SALTAIR CREEK
DECEMBER 11, 1987

PHI SIZE CUMULATIVE
PERCENTAGE

1.75	4.20
2.00	34.71
2.25	67.81
2.50	80.63
2.75	97.32
3.00	99.42
3.25	100.00

** SAMPLE NUMBER 12116

0.75	0.00
1.00	0.00
1.25	0.00
1.50	0.17
1.75	3.23
2.00	30.12
2.25	58.88
2.50	76.82
2.75	90.95
3.00	96.43
3.25	100.00

** SAMPLE NUMBER 12117

0.75	0.00
1.00	0.00
1.25	0.17
1.50	0.50
1.75	2.20
2.00	25.07
2.25	58.11
2.50	79.14
2.75	93.56
3.00	98.40
3.25	100.00

** SAMPLE NUMBER 12118

0.75	0.00
1.00	0.00
1.25	0.00
1.50	0.00
1.75	1.13
2.00	26.31
2.25	62.29
2.50	84.64
2.75	96.42

SIEVE ANALYSIS OF SAND SAMPLES
SALTAIR CREEK
DECEMBER 11, 1987

PHI SIZE CUMULATIVE
PERCENTAGE

3.00	99.15
3.25	100.00

** SAMPLE NUMBER 12119

0.75	0.00
1.00	0.00
1.25	0.00
1.50	0.00
1.75	3.37
2.00	37.17
2.25	69.39
2.50	79.32
2.75	96.55
3.00	99.06
3.25	100.00

** SAMPLE NUMBER 121110

1.00	0.10
1.25	0.62

** SAMPLE NUMBER 12111

1.50	0.98
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** SAMPLE NUMBER 121110

1.75	2.61
2.00	26.45
2.25	62.59
2.50	84.67
2.75	95.27
3.00	98.53

** SAMPLE NUMBER 121111

1.00	0.10
1.25	0.62
1.50	0.98
1.75	2.61
2.00	26.45
2.25	62.59
2.50	84.67
2.75	95.27
3.00	98.53

** SAMPLE NUMBER 121112

1.00	0.10
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SIEVE ANALYSIS OF SAND SAMPLES
SALTAIR CREEK
DECEMBER 11, 1987

PHI SIZE CUMULATIVE
PERCENTAGE

1.25	0.62
1.50	0.98
1.75	2.61
2.00	26.45
2.25	62.59
2.50	84.67
2.75	95.27
3.00	98.53

** SAMPLE NUMBER 121113

1.00	0.10
1.25	0.62
1.50	0.98
1.75	2.61
2.00	26.45
2.25	62.59
2.50	84.67
2.75	95.27
3.00	98.53

** SAMPLE NUMBER 121114

1.00	0.10
1.25	0.62
1.50	0.98
1.75	2.61
2.00	26.45
2.25	62.59
2.50	84.67
2.75	95.27
3.00	98.53

** SAMPLE NUMBER 121115

1.00	0.10
1.25	0.62
1.50	0.98
1.75	2.61
2.00	26.45
2.25	62.59
2.50	84.67
2.75	95.27
3.00	98.53

SIEVE ANALYSIS OF SAND SAMPLES
DALEY LAKE OUTLET
NOVEMBER 1, 1986

PHI SIZE CUMULATIVE
PERCENTAGE

** SAMPLE NUMBER 1118

1.25	0.00
1.50	1.20
1.75	10.90
2.00	45.80
2.25	81.70
2.50	92.90
2.75	98.20
3.00	99.20
3.25	100.00

** SAMPLE NUMBER 1119

1.25	0.00
1.50	1.30
1.75	16.40
2.00	56.70
2.25	90.20
2.50	95.00
2.75	99.60
3.00	99.60
3.25	99.90
0.00	0.00

** SAMPLE NUMBER 11110

1.25	1.00
1.50	4.70
1.75	22.40
2.00	63.30
2.25	92.50
2.50	97.50
2.75	99.80
3.00	99.80
3.25	100.00

** SAMPLE NUMBER 11111

1.25	3.00
1.50	9.00
2.75	28.00
2.00	67.00
2.25	92.00
2.50	97.00

SIEVE ANALYSIS OF SAND SAMPLES
DALEY LAKE OUTLET
NOVEMBER 1, 1986

PHI SIZE CUMULATIVE
PERCENTAGE

2.75	99.00
3.00	99.20
3.25	99.70

** SAMPLE NUMBER 11112

1.00	0.00
1.25	0.70
1.50	3.40
2.75	18.40
2.00	58.60
2.25	90.10
2.50	95.70
2.75	99.90
3.00	99.90
3.25	100.10

** SAMPLE NUMBER 11113

1.00	0.20
1.25	0.90
1.50	0.70
1.75	22.60
2.00	66.00
2.25	93.30
2.50	98.50
2.75	99.90
3.00	99.90
3.25	100.10

** SAMPLE NUMBER 11114

1.00	0.20
1.25	0.50
1.50	2.30
1.75	13.70
2.00	53.10
2.25	87.50
2.50	94.50
2.75	99.20
3.00	99.70
3.25	100.00

** SAMPLE NUMBER 11115

1.00	0.30
1.25	0.60
1.50	3.40

SIEVE ANALYSIS OF SAND SAMPLES
DALEY LAKE OUTLET
NOVEMBER 1, 1986

PHI SIZE CUMULATIVE
PERCENTAGE

1.75	19.00
2.00	63.00
2.25	92.40
2.50	97.20
2.75	99.60
3.00	99.80
3.25	100.00

APPENDIX E

WIND TRANSPORT DATA

DALEY LAKE OUTLET

MARCH 19. 1988

Appendix E
Wind Transport Data
Daley Lake Outlet
March 19, 1988

Height Above Sand (cm)	Weight of Caught (grams)
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** Trap Side Leeward

6.35	4.15
12.70	1.80
19.05	0.70

** Trap Side Windward

6.35	138.00
12.70	8.80
19.05	0.40