Establishment of American Dunegrass (*Leymus mollis*) Communities at Upland Dredge Material Disposal Sites for Sand Stabilization and Invasive Plant Species Control

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US Army Corps of Engineers®
Seattle District

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CHAPTER 1. INTRODUCTION

The goal of this study is to determine the most effective methods for establishing American dunegrass communities at upland dredge material disposal sites. This report is a technical reference of successful plant establishment techniques. It is not a hypothesis-tested study. Establishing vegetation on erosive dredge material can aid in sand stabilization and help restore jeopardized native American dunegrass (*Leymus mollis*, formerly *Elymus mollis*) communities. This report documents the results of experimental plots to evaluate different establishment methods, and presents the most effective treatments for establishing American dunegrass on upland dredge material disposal sites. An overview of the ecology of Pacific Northwest sand dunes and background report of the study site are also provided.

Dredging is performed to maintain waterways and harbors used for waterborne commerce and water related industry, shipping, and for new port and marina construction. Dredging in harbors is performed in a variety of ways including mechanical, clam shell, hydraulic pipeline and hopper dredging. The hopper dredge is a self-propelled floating plant which is capable of dredging material, temporarily storing it onboard, transporting it to an in-water disposal area, and discharging it. Five basic dredged material disposal options are possible. Generally, these include: unconfined, open-water; unconfined upland/nearshore; confined aquatic; confined nearshore; and confined upland (USACE, 1995). Of these options, this report focuses on vegetating confined upland disposal sites. Confined upland disposal is defined as disposal of dredge material at, or above, the Mean High Water (MHW) mark. In many instances, upland disposal has resulted in redevelopment or conversion of estuarine and other sensitive shoreline habitats to commercial development (USACE, 2001 & Arden, 2004). However, under some circumstances, upland disposal sites can provide the opportunity for ecologically beneficial uses of dredge material.

Establishing American dunegrass at upland dredge material disposal sites is consistent with recognized Best Management Practices (BMP’s) for dredge material disposal and the Corps of Engineers Environmental Operating Principles (EOP’s). The EOP’s integrate recognized environmental operating principles into the decision-making and project management processes of the Corps of Engineers.

1.1 Purpose

The purpose of this study is to evaluate the most effective methods for establishing American dunegrass communities at upland disposal sites of dredge material. Establishing American dunegrass at dredge material disposal sites will help stabilize the substrate and aid in sand retention by accumulating airborne sands. Sand accumulation triggers the geomorphic processes that establish dunal topography. In addition, establishing American dunegrass deters the establishment of invasive introduced species and aids in the recovery of dwindling American dunegrass communities.

1.2 Need

There is limited literature available on establishing American dunegrass communities on disturbed sites, including upland dredge material disposal sites. Most disposal sites proposed for planting are large in size and generally require large quantities of plant material. In order to protect the federal investment of future revegetation projects, there is a need for data that identifies the most effective planting methods to ensure plant survival and growth.

CHAPTER 2. ECOLOGICAL OVERVIEW OF SAND DUNES

This chapter provides an overview of the geomorphology and biology of Pacific Northwest dune ecosystems. Vegetating upland dredge material can aid in the establishment of natural dunal topography. Plants serve an important function in the morphology of a dune landscape in two ways. First, they can initiate the development of a particular dune form, either by actively interacting with the wind-blown sand, or simply by their presence. Secondly, plants act as stabilizers of sand surfaces by protecting them from the erosive force of the wind (Wiedemann, 1984). Hence, when considering vegetating upland disposal sites, naturally occurring dunes can provide analog sites. Analog sites provide a characterization of plant communities suitable for the specific location of the disposal area.

2.1 Coastal Sand Dune Morphology

Dunes are viewed as great natural laboratories where biological and geological processes can be observed in accelerated action. The coastal sand dune landscape is comprised of a complex mosaic of many dune forms. The dune forms are the basic morphological units making up the coastal dune systems. The dune forms are the result of the interaction of the environmental factors such as sand, wind, water, and plants. Each combination of factors produces unique, identifiable forms that recur over the landscape (Wiedemann, 1984). Wind and sand alone produce the forms for which dunes are known. Water and vegetation are the stabilizers, slowing sand movement and ultimately stopping dune movement (Wiedemann, 1984). There are a number of topographic features which constitute the basis of the various dune systems. These are the foredune, deflation plain, transverse ridge, oblique ridge, and precipitation ridge (Ecology, 2003). Each feature is described briefly below. Figure 2-1 is a diagram showing the relationships of these features in the landscape.

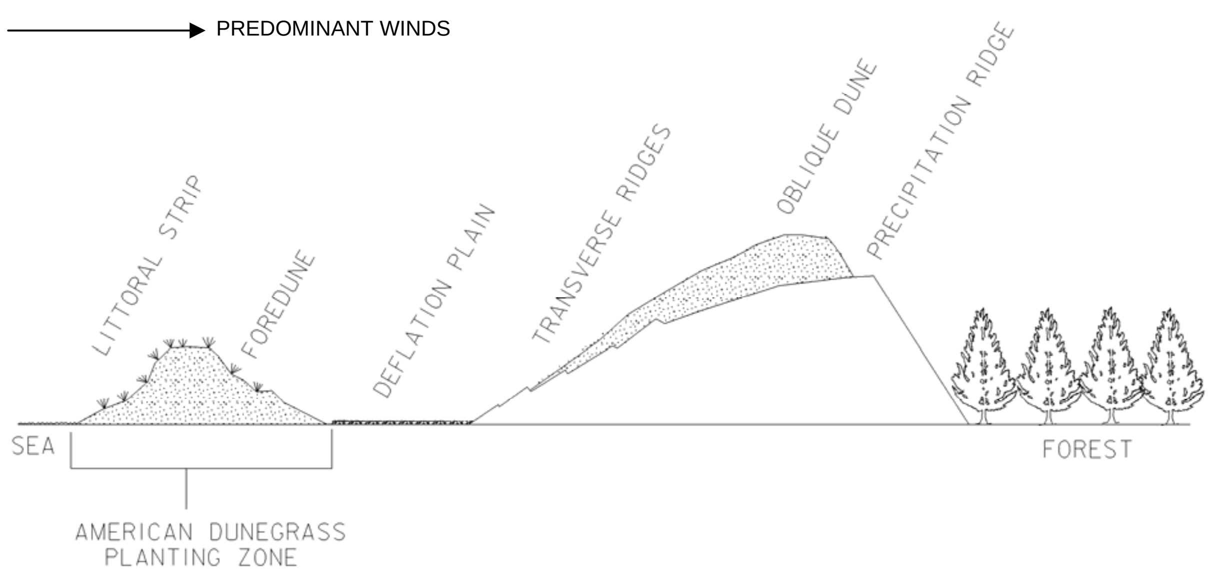


Figure 2-1 Dune Land Features Profile

Foredune
The foredune is the ridge of sand parallel to the beach just above the limit of ordinary wave action. It is formed by the interaction of wind, sand, and vegetation. Plants tolerant of sand burial become permanently established above the high-tide line. Sand transported up from the beach by the wind collects in and around the vegetation, by entrapment and deposition. The plants are able to maintain growth even though buried completely. As the plants continue to grow, a ridge of accumulated sand develops and increases in height (Wiedemann, 1974).

Deflation Plain
The leeward slope of the foredune is very gradual, and as sand removal continues, the moist sand near the water table is eventually reached. At this point, effective sand movement ceases. This is a deflation plain. Deflation plains are found inland from the foredune. Because of the absence of sand movement and the presence of large amounts of water, the deflation plain becomes a favorable habitat for the initiation of wetland vegetation.

Transverse Ridge
Where an extensive area with abundant sand supply and no vegetation occurs, a transverse ridge pattern develops in which the dune crests are oriented generally at right angles. The ridges are about six feet in height, with steep slopes on the lee side and gentle slopes on the windward side.

Oblique Ridge
On very extensive sandy areas, open to the full force of wind regimes, and with an abundant sand supply, massive sand dunes develop that have crests orientated at right angles to the southwesterly winds of winter. Because of their exposure to wind and the activity of sand over their surfaces, the oblique dunes are not likely to become stabilized by vegetation (Cooper, 1958).

Precipitation Ridge
When there is a sufficient sand supply behind the foredune, sand is moved inland by the driving force of the seasonal winds. If an area of vegetation (trees) is encountered, sand begins to accumulate as a ridge in front of the vegetation barrier because the wind is deflected upward, loses velocity, and drops its load of sand (Wiedemann 1974). This ridge will grow in height, depending upon the height of the vegetation. The lee side becomes very steep and sand slips down the face, effectively initiating forward movement of the dune and invades the vegetation (usually a forest in the Pacific Northwest).

2.2 Dune Fauna

Coastal dune systems provide a mix of habitat types including unstabilized sand, grasslands, wetlands, and scrub-shrub communities in a unique association with open-ocean and forested uplands. Although sand dunes themselves are considered unique in the Northwest because of their limited distribution, the wildlife habitat they provide is not necessarily unique (Long Beach, 2000).

Wiedemann (1984) listed 168 species of birds, 31 species of mammals, 10 amphibian species, and 3 reptile species occurring in association with the Pacific Northwest coastal dune ecosystem. These include *generalist* species (an animal species with a large niche breadth) found in coastal forests, sand dunes, interdunal wetlands, salt marsh, beach, intertidal, and open ocean habitats. The list of species utilizing only sand dune habitats is significantly less. Dunes also provide protection for many migratory seabirds and shorebirds from severe storms as they pass along the coast. There have been instances when hundreds, perhaps thousands of birds have either sought shelter on the beach and into the dunes by winter storms (Gabrielson and Jewett, 1940).

2.2.2 Endangered Species

Two federally listed endangered species are associated with dune habitats of the Pacific northwest coast. These include the western snowy plover (*Charadrius alexandrinus nivosus*) and Oregon silverspot butterfly (*Speyereia zerene hippolyta*).

<u>2.2.2.1 Western Snowy Plover</u>

The western snowy plover was listed as a threatened species under the Endangered Species Act of 1973, as amended in March 1993. The primary cause of the western snowy plover population decline is poor reproductive success resulting from loss of nesting habitat. Active nesting colonies have declined as a result of the spread of non-native European beachgrass, urban development, human disturbance, predation, and inclement weather (USACE, 2000).


Courtesy: Bureau of Land Management

The western snowy plover breeds on the Pacfic coast from southern Washington to Mexico, with a center of distribution near the southern boundary of California. Preferred nesting habitat includes sand spits, dune backed beaches, unvegetated beach strands, open areas around estuaries, and beaches at river mouths. Snowy plovers forage on invertebrates in the wet sand and surf-cast macroalgae of the intertidal zone, in sandy areas above high tide, on salt pans, on spoil sites, and along the edges of salt marshes and salt ponds. (USFWS 1993, USFW 2004).

<u>2.2.2.2 Oregon Silverspot Butterfly</u>


Courtesy: University of California, Berkeley

The Oregon silverspot butterfly was historically found along the coastal zone of southern Washington and central northern Oregon. The species is classified as a federally threatened subspecies (WDFW, 1991). Oregon silverspot butterflies are found in coastal salt spray meadows and open field habitats that support the larval host plant, western blue violet (*Viola adunca*). Moderate grass cover found in these open habitats provides shelter for the larvae from wind, rain, and sun. Adult butterflies feed in the meadows on nectar producing herbaceous plants. Open areas used by the butterflies are typically surrounded by a fringe of brush or conifer trees, which provide necessary shelter for adults. In Washington, the butterflies breed in stabilized sand dune communities where violets persist (WDFW, 1991). Limiting habitat factors are availability of salt spray meadow habitat that supports the western blue violet and nearby forest fringe shelter-belts. Both natural and human induced factors contribute to habitat decline for this species.

2.3 Dune Flora

Since almost all types of plant seeds will germinate readily on wet sand it is not uncommon to find a wide variety of seedlings on the dunes in the spring as the new growing season begins. Very few of the seedlings survive however, because they have neither the root system to reach down into the deep, moist sand for water, nor can they tolerate the sand burial that comes later (Wiedemann, 1974). The development of stable plant cover is the function of species which can tolerate sand deposition but which eventually spread over large areas and cover the sand to protect it from movement by wind. Only a few plants thrive in this type of environment. Two of these species include American dunegrass (*Leymus mollis*) and European Beachgrass (*Ammophila arenaria).*

2.3.1 American Dunegrass

American dunegrass, *Leymus (*formerly, *Elymus) mollis* was the dominant grass on dunes immediately adjacent to the ocean until the introduction of European beachgrass, which is now the more abundant species (Wiedemann, 1984, Pojar & Mckinnon, 1994). American dunegrass traps airborne sands that accumulate around the plant base. The sand accumulation triggers both horizontal and vertical rhizomatous growth.

American dunegrass *Leymus mollis (Courtesy: Lewis & Clark Herbarium)*

2.3.1.1 Species Description and Current Range

American dunegrass is a common, robust perennial native grass found in coastal dunes and on the edges of gravel beaches from Greenland, eastern arctic and western North America to Asia. It grows in large clumps of ascending, scale-covered rhizomes. Stems are erect, 50-150 cm tall, and have hairs that are rough to the touch. Salt crystals are often found on the leaf surface. Auricles are usually present. Glumes are soft hairy. American dunegrass blooms from June to August. Leaves are very tough, almost woody, dark blue-green, 6-16 mm wide, with prominent veins. Inflorescence is very large, a compact spike, 15-30 cm long, 1-2 cm wide. Spikelets are attached directly to the stalk and paired at each node (Cooke, 1997).

2.3.1.2 Ethnobotany

American dunegrass has been used for weaving fishing gear and baskets. It is used in Japan for making ropes and mats and is also used in decorative paper (Cooke, 1997). Bundles of roots have been used by northwest indigenous tribes to rub the body after bathing, for sewing and tying, and the Kwakiutl have used the leaves with skunk cabbage leaves to line steaming boxes for cooking lupine roots (NPS, 2004).

2.3.2 European Beachgrass

European beachgrass (*Ammophila arenaria)* has been introduced to several continents for the purposes of sand stabilization, and is now internationally recognized as an invasive species. European beachgrass was first planted on the west coast of California in the late 1800's. The primary mode of natural (unplanted) expansion of European beachgrass is vegetative, although plants produce viable seed. Efficient dispersal by seeds or other propagules is a crucial life history feature of this plant. Plant fragments have the potential to survive extensive periods of time in seawater. Once established, European beachgrass develops vigorous root and rhizome systems. Active sand burial stimulates the production of new shoots from rhizomes (Pickart et al. 1998).

European beachgrass *Ammophila arenaria(Courtesy: TNC 2004)*

European beachgrass *Ammophila arenaria(Courtesy: M. William 2003)*

2.3.2.1 Species Description and Current Range

European beachgrass is an erect perennial with flowering stems up to 1 m tall. The stems are tufted from scaly, tough, rhizomes that spread horizontally and vertically. The leaf blades are rough, fibrous, and in-rolled to a sharp point. They are 2-4 mm wide when flattened, without auricles, and 10-15 mm broad. Ligules are 10-33 mm. The outer surface of the blade is smooth and grayish-green without distinct ribs; the inner surface is whitish and closely ribbed. The spikelets are 1-flowered 10-15 mm long, the lemma of the single flower 1-3 mm shorter. Flowering occurs from May to August. Mature fruits are dispersed in September. Seeds germinate the following spring, however viability of seeds is low. Reproduction is primarily vegetative by rhizomes (Wiedemann, 1987). European beachgrass is distinguished from the native dunegrass species, American dunegrass (*Leymus mollis*) that has flat, wide, more bluish-green blades, narrower ligules, and a spike inflorescence (TNC). American beachgrass (*Ammophila breviligulata*) is a similar Atlantic coast species that can co-exist with European beachgrass. The species is distinguished from European beachgrass by having very short (about 3mm long) stiff ligules.

European beachgrass dominates coastal dune habitats from the central California coast to northern British Columbia. Its genus name, *Ammophila*, means "sand lover," because this species is so highly adapted to colonize shifting sand. It is present in all coastal and Puget Sound counties throughout its range. The northern extent of its range, in British Columbia, is not limited by climate, rather the lack of suitable dunal habitat where cliff-like fjords meet the shoreline.

2.3.2.2 Impacts to Communities and Native Species

European beachgrass is the most pervasive exotic plant species currently threatening coastal dunes on the west coast of the U.S (Pickart, 1997). The plant is capable of trapping windblown sands very effectively because of it's robust above ground growth. The accumulation of sand at the plant crown triggers aggressive growth. European beachgrass is almost perfectly adapted to a very precise set of habitat conditions. Within that habitat it has no competitors and essentially no predators or diseases. Environmental conditions along the northwest coast of North American are almost perfect for its establishment and spread.

Impacts of European beachgrass to coastal sand dune ecosystems include its ability to displace entire native plant communities, and also significantly interferes with the natural dynamics of dune systems (Pickart, 1997). In addition, areas heavily infested with European beachgrass threaten habitat for the Western Snowy Plover, a federally listed species. Dunes that form under cover of native dune plants have low slopes perpendicular to the beach. The foredunes are low and rise above the beach with a gentle slope. When European beachgrass communities are established, more windblown sands accumulate around the plants on the foredune. Thus, dune structure changes by forming a higher foredune resembling a virtual "wall" of monotypic vegetation. As the dunes increase in height and the normal ocean breeze diminishes behind the dunes, a new microclimate develops.

2.3.3 Sub-dominant Dune Flora

The foredune is typically dominated by European beachgrass and/or American dunegrass. However, many sub-dominant plant species may also occur in and around the mounds caused by American dunegrass and European beachgrass. Sub-dominant plants may not all occur together, and may only comprise one or two additional species (Wiedemann, 1974). The assemblage of these species, characterize the foredune plant community. The plants within the foredune, show many characteristics which enable them to survive the hardships of their environment. Seashore bluegrass (*Poa macrantha*) and large-headed sedge (*Carex macrocephala*) both have large seeds which are easily caught up and spread by the wind. These plants also have a very vigorous system of underground stems. Beach pea (*Lathyrus japonicus*) and beach silver-top (*Glehnia leicarpa*) both have large seeds, and have stems that can come up through many feet of sand. The seedlings in particular can send long roots deep into the sand to provide a good supply of water for the developing plants. The beach morning-glory (*Convolvulus soldanella*) spreads rapidly by means


Rocket *Cakile edentula*
tesy: Eleanor Saulys 2001

of prostrate stems extending over the surface of the sand. Other plants of this community include the prostrate woody beach knotweed (*Polygonum paronychia*), American sea rocket (*Cakile edentula)*, with very small purple flowers, large seed pods and thick stems and leaves; beach pea (*Lathyrus japonicus*), a plant that looks similar to the common garden pea and coastal strawberry (*Fragaria chileonsis)*.


Beach pea *Lathyrus japonicus*
Courtesy: WA Native Plant Society

CHAPTER 3. PROJECT VICINITY

Grays Harbor is located at the mouth of the Chehalis River about 45 miles north of the Columbia River and 110 miles south of the entrance to the Strait of Juan de Fuca. (Figure 3-1). The harbor is 15 miles long and 11 miles wide. On the ocean side, the estuary is enclosed by two long spits, Point Brown along the north, and Point Chehalis on the south. Two convergent rock jetties, North Jetty and South Jetty, extend seaward from the spits, constricting the harbor entrance width to about 6,500 feet (Figure 3-2). The purpose of the jetties is to confine tidal currents to obtain scouring velocities for navigation in the Bar and Entrance channels (USACE, 1997).

3.1 Study Location

The study site for monitoring American dunegrass establishment methods is located at the South Jetty Breach Fill at Grays Harbor, Washington (3-3). The South Jetty Breach Fill is located along the shoreline of Half Moon Bay in southwestern Grays Harbor, adjacent to Westhaven State Park in Westport, Grays Harbor County, Washington (T16N, R12W, Section 1). Driving directions to the site from Aberdeen, Washington are as follows. Turn left on H Street proceeding west on Highway 105 for 18 miles. Turn right off Highway 105 on West Spokane Avenue. Proceed towards Westport on Spokane Avenue to the sign for Westhaven State Park (immediately before the city wastewater treatment plant). Follow the drive to the parking area. The study site is located immediately west of the parking lot.

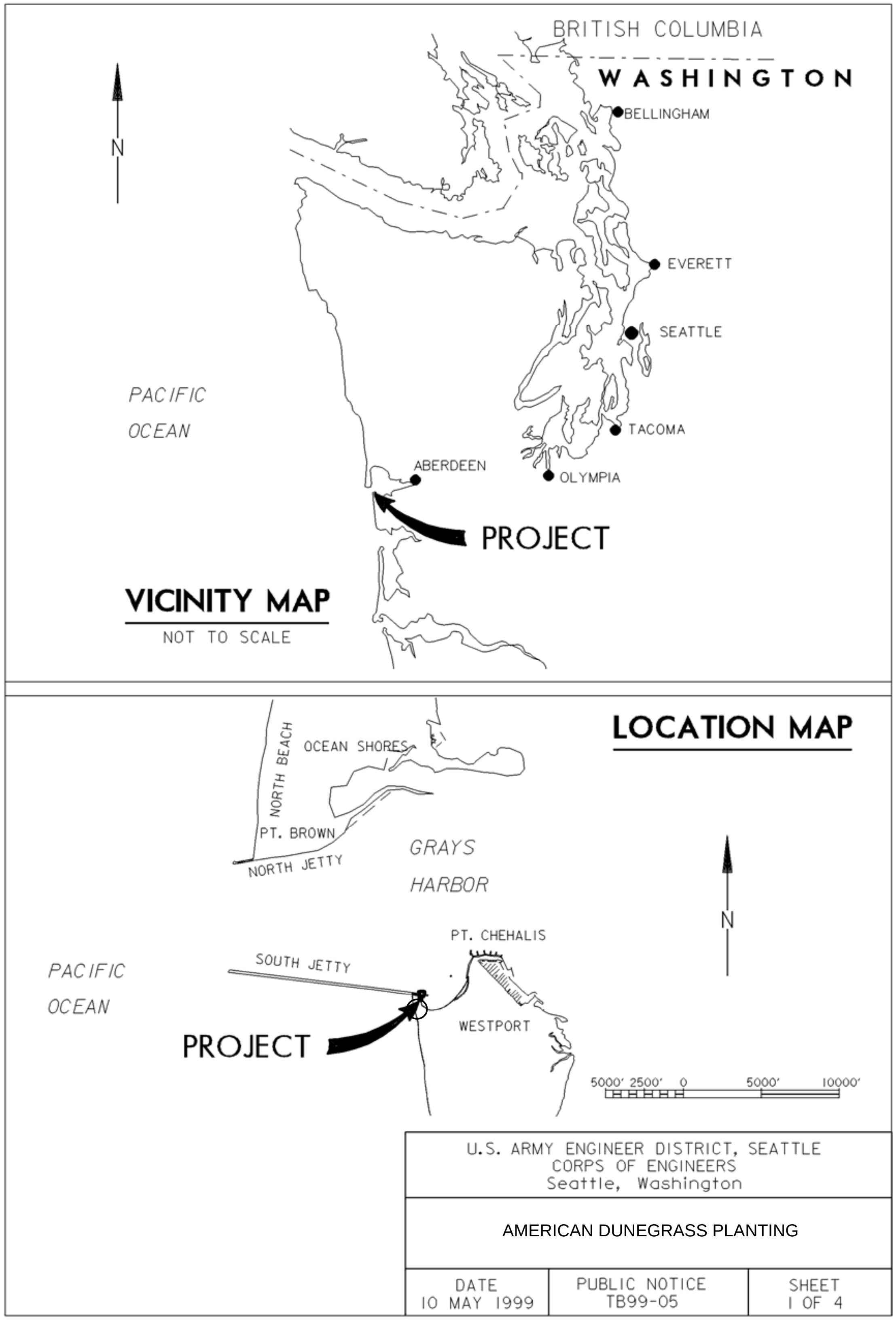


Figure 3-1. Project Vicinity & Location Map

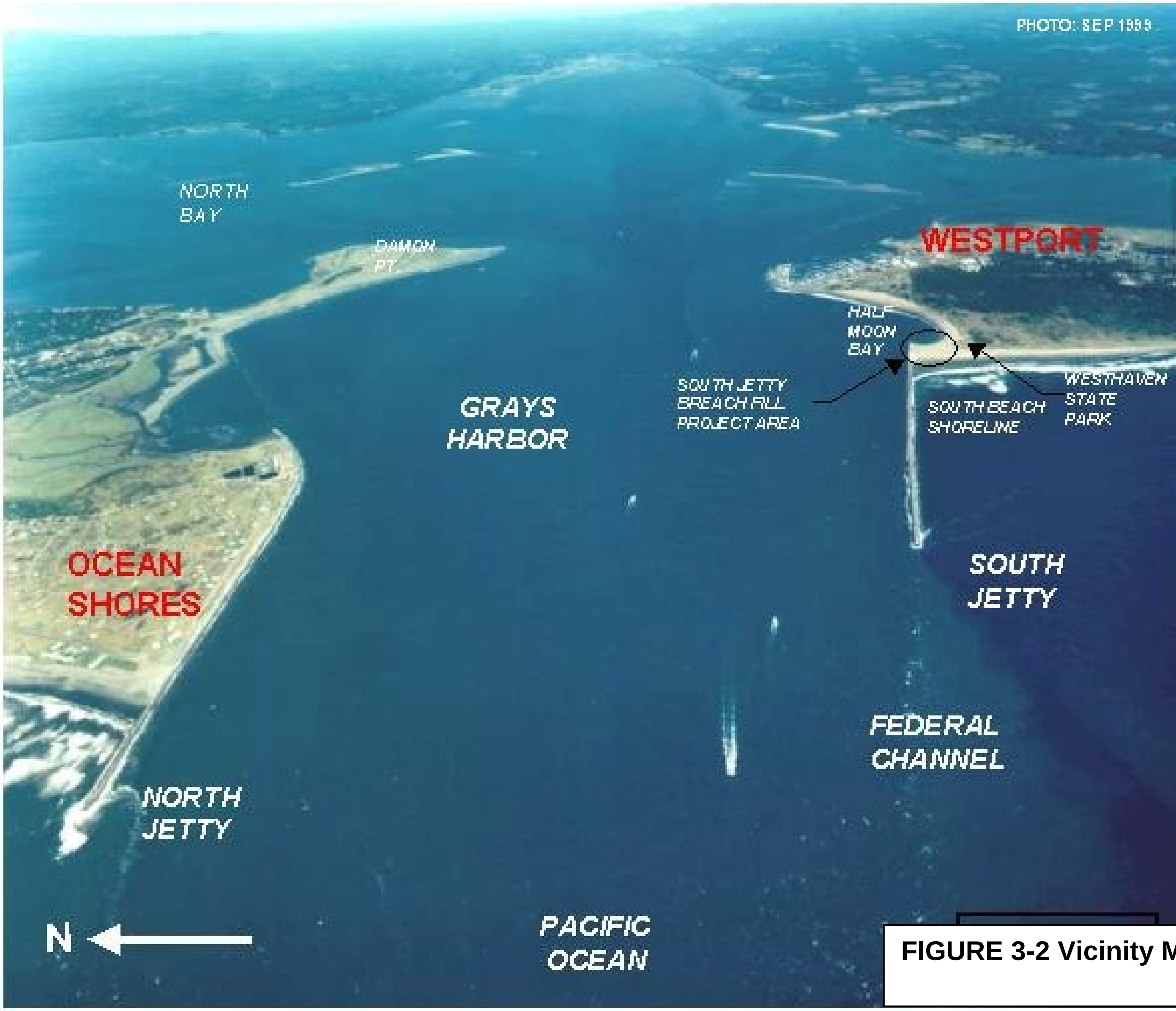


FIGURE 3-2 Vicinity Map

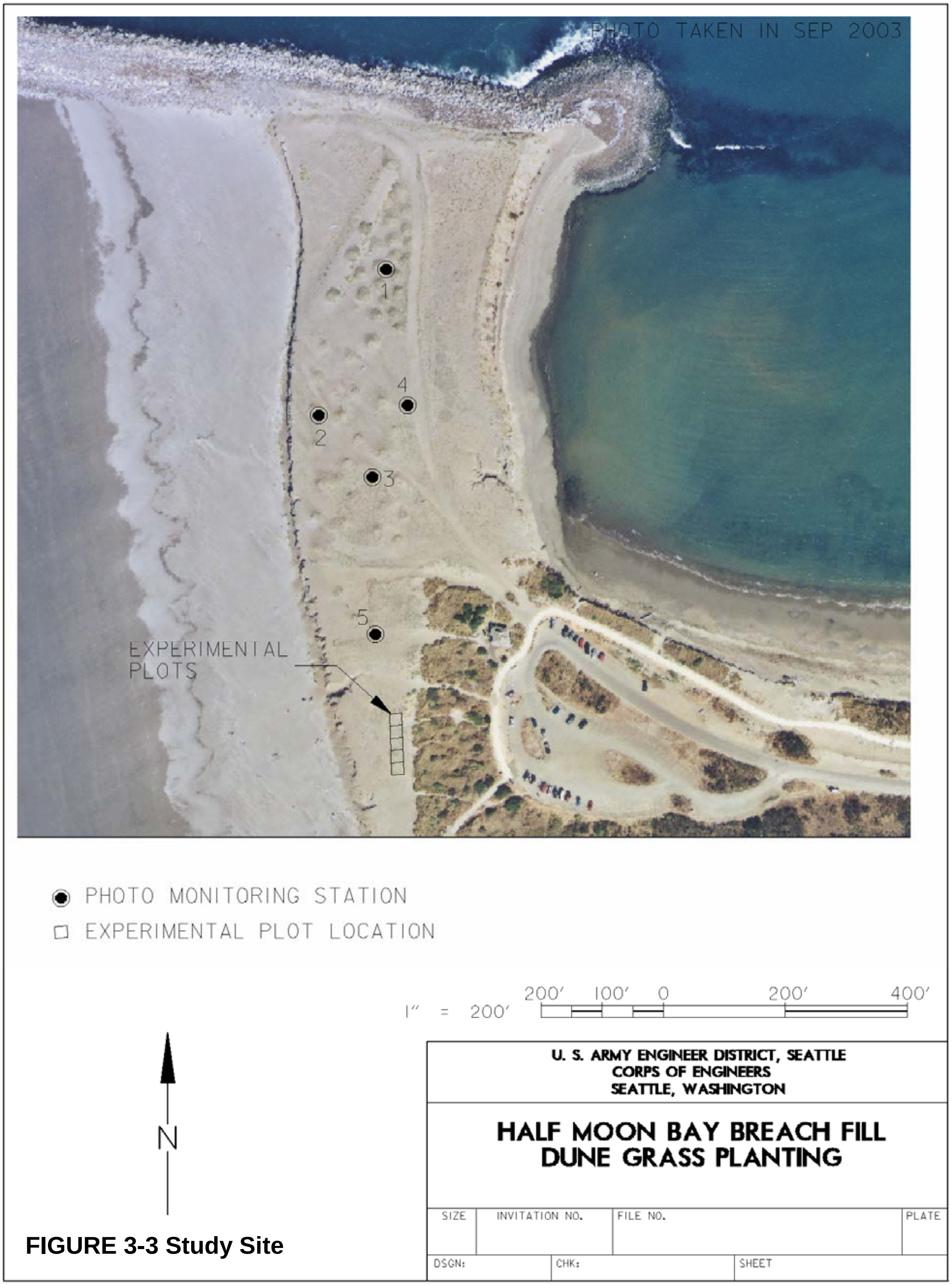


FIGURE 3-3 Study Site

3.2 Background

Persistent erosion of the shoreline at the landward end of the South Jetty has resulted in a series of maintenance actions implemented by the Seattle District - Army Corps of Engineers (Corps). The shoreline to the west and south of Point Chehalis has undergone major changes since jetty construction between 1898 and 1917 by the Corps. The jetty is a barrier to northerly long shore drift, and by 1904 South Beach had advanced 3,000-feet to the west. During much of the 20^{th} Century, the shoreline advanced or retreated depending on the condition of the jetty structure; when the jetty was in a deteriorated condition, sand was able to pass over or through the jetty and nourish Pt. Chehalis and South Beach shoreline would erode. However, since the 1960's a long-term trend of erosion along the South Beach shoreline has been apparent. Since 1967, South Beach has seen recession rates ranging from 2 to 62 feet per year (USACE, 2003).

Erosion of the shoreline and overtopping by storm waves at the landward end of the south jetty resulted in the formation of a breach between the jetty and the adjacent South Beach shoreline during a winter storm in December 1993. The breach widened rapidly, exposing the landward end of the jetty and eroding portions of Westhaven State Park. Within six weeks, the breach was approximately 500 feet wide. Local officials, alarmed by the formation of the breach, expressed concern about further erosion at the breach site and impacts to City of Westport public facilities, including a wastewater treatment plant, municipal well, and sewer outfall. The breach was also determined to be a potential threat to the stability of the south jetty, and there was concern that the breach could cause adverse impacts to the maintenance of the navigation channel.

In March 1994, the Department of the Army directed Seattle District to fill the breach between the South Jetty and the adjacent South Beach shoreline. In late fall 1994, at a cost of $4 million, the breach was filled with approximately 600,000 cubic yards of material dredged from the Grays Harbor and Chehalis River navigation channel. The breach fill was an interim measure to help protect the south jetty, the navigation channel and local beaches until an acceptable long-term solution could be implemented. At the time of placement, the breach fill was expected to have a life of five to ten years.

In 1997, the Corps released a study which evaluated various alternatives and selected a long-term plan to protect against another breach. The *Long Term Maintenance of the South Jetty at Grays Harbor, Washington* (USACE, 1997) report confirmed that continued erosion of the shoreline adjacent to the South Jetty, if left unchecked, would result in the formation of a permanent breach between the South Jetty and the adjacent South Beach. The selected alternative consisted of an extension of the South Jetty to meet the existing Point Chehalis revetment, combined with periodic beach nourishment with sand in half Moon Bay. This plan was to be constructed in two phases: (1) a buried 1,900-foot southward extension of the existing Point Chehalis revetment; and (2) a 2,500-foot eastward extension of the South Jetty across Half Moon Bay. The Point Chehalis revetment extension was constructed between November 1998 and March 1999 (USACE et al. 1998). In accordance with the inter-agency mitigation agreement for the extension project, the entire revetment was buried under 2 to 3 feet of sand and a beach nourishment stockpile was created so that sand eroded by winter storms is replaced and the toe of the structure remains buried. Material dredged during navigation channel maintenance is periodically used to replenish the stockpile of sacrificial material.

By 1999, State of Washington resource agencies, City of Westport, and other public interests had serious concerns related to environmental and recreational impacts associated with the proposed South Jetty extension. In addition, surveys indicated that the breach fill material was eroding more slowly than originally anticipated. Therefore, the jetty extension project was deferred and a modified plan to extend the life of the breach fill was developed. The new plan consisted of three elements: (1) construction of a wave diffraction mound to maximize wave refraction-diffraction, thereby reducing wave-induced erosion of the shore in the western portion of Half Moon Bay adjacent to the jetty; (2) a gravel/cobble transition beach designed to slow erosion of the breach fill directly adjacent to the south side of the jetty, and to eliminate the dangerous 8-foot high scarp that had formed in that location; and (3) major repair work on the inner (landward) end of the jetty structure so that it is better able to withstand the undermining effects of any future breaches and to help reduce wave-caused erosion of the unprotected portion of Half Moon Bay. However, the scope of the transition gravel/cobble protection was reduced by approximately two-thirds and 250 –feet of the remnant south Jetty removed/lowered as agency mitigation requirements for constructing the diffraction mound.

Between December 1999 and February 2000, the wave diffraction mound was constructed and 11,600 cubic yards of 12-inch minus rounded cobbles and gravels were placed on the adjacent beach. The South Jetty rehabilitation work occurred in late 2001 and early 2002. Severe storms during November and December of 2001 caused overtopping of the South Beach Shoreline directly south of the jetty. The temporary construction haul road used to transport armor rock as part of the South Jetty repair project was breached and the three large rainwater runoff gullies, each about 5 feet deep, cut through the narrow strip of land remaining. In January 2002, it was necessary to make urgent repairs to relocate the haul road. At this time, an additional 16,100 cubic yards of 12-inch minus cobbles and gravels were placed along the western shore of Half Moon Bay to extend the transition gravel/cobble protection to reduce severe end –cutting erosion of the South Jetty breach fill (Arden, 2003).

Between 1996 and 2001, an estimated 70,000 cubic yards of fill material eroded from the breach site. In 2002, the Corps placed an additional 135,000 cubic yards of dredged material and sculpted the landscape in an attempt to mimic the surrounding dunal environment (Appendix A – Sand Placement and Cross-Section Diagrams). Following earthwork activities, approximately 50,000 culms of American dunegrass plantings were installed to aid in stabilization of the dredge material, accumulate airborne sands, and deter the establishment of invasive plant species. American dunegrass was planted on approximately 3-acres of the project area. The Corps recognizes that events brought on by natural cycles (wave erosion) will undoubtedly alter the constructed dune profile. In this regard, areas prone to wave erosion or future disturbance for maintenance activities were either not planted or planted sacrificially.

CHAPTER 4. METHODS

4.1 Experimental Plots

The purpose of the experimental plots is to determine the most effective treatments for survival and growth of American dunegrass on future phases of this project, or future upland dredge material disposal sites. Five (5) experimental plots were established on 14 November 2002. The plot locations are in the southeast portion of the disposal site (Figure 3-3). The plots are twenty (20) by twenty (20) feet in size, and located adjacent to each other in a north to south orientation on the created foredune. Plots were measured with a hand-held tape with each plot corner numbered for surveying. Three (3) of the plots described below have plants placed on 15-inch centers. Planting was accomplished with clam shovels (18-inch narrow blade). The point of the shovel is driven six to eight-inches in the sand, then the handle pushed forward to expose a hole. The culms (the individual stems with root material) are placed in the hole and gently "tamped" by the installer's foot (ADNR, 1994). To aid in an exact placement of plant material, a large rake-style apparatus was constructed. The "rake" was dragged across the plot with large nails centered 15-inches apart on a 2" x 4" x 8'. The rake resulted in a criss-cross pattern locating planting locations on exactly 15-inch centers.

4.1.1 Plot 1: 15-inch center w/ N

The Plot 1 treatment evaluates if the application of nitrogen affects plant survival or above ground growth. Microtopography was also monitored to determine the effectiveness of vegetation trapping airborne sands. The topography data is compared with clustered plantings (Plot 4) for comparison of sand accumulation.

Single culms were placed on 15-inch center with a nitrogen application. A total of 144 plants in twelve (12) rows of twelve (12) plants were installed. After planting, Evergreen (®) Sulfate of Ammonia 21-0-0 nitrogen was applied in granular form as a top dressing throughout the plot. The recommended quantity was reduced by 50% as the recommended quantity application is for lawn and garden purposes. The pure nitrogen (N), without phosphorous (P) or potassium (K), was applied since coastal air contains quantities of P and K sufficient to inoculate soils (Clayton 1972, Art et al 1974, Van der Valk 1974). Ample precipitation occurred following N application as forecasted.

In order to determine plant survival, all 144 plants were inspected for living reproductive shoots the following season. If no living shoots were observed, the plants were considered dead. Productivity estimates were made to observe differences in growth and vigor. Aboveground biomass of 10% of the plants in each plot was harvested on 14 August 2003. The length and width of all living plant material was measured. Dead culms and leaves from the previous year planting were omitted. Topography was measured with a Trimble MS 750 Real-Time Kitomataic (RTK) Global Positioning System (GPS) on 9 September 2003 and 22 June 2004.

4.1.2 Plot 2: 15-inch center w/o Nitrogen

Plot 2 tests differences in plant survival and growth when no nitrogen is applied. Plot 2 followed the same installation and monitoring procedures as Plot 1, however no Nitrogen was applied.

4.1.3 Plot 3: Control (Do Nothing)

No planting or nitrogen application occurred in the control plot. The control plot is meant to portray site conditions without planted vegetation. Monitoring included identification and cover of volunteer pioneer species and changes in microtopography as recorded by GPS.

4.1.4 Plot 4: 15-inch center, clusters of 3 Plants

Plot 4 evaluates the differences in plant survival or growth when individual culms are planted in clusters. Plot 4 followed the same planting and monitoring procedures as Plot 2 (15-inch center without Nitrogen), however three (3) individual culms were placed per hole, instead of one (1). Changes in microtopograpy as a result of sand accumulation were recorded by GPS.

4.1.5 Plot 5- Broadcast seed

The Plot 5 treatment evaluates the effectiveness of establishing American dunegrass from broadcast seed. An additional greenhouse experiment was conducted to determine if germination rates differed from a controlled greenhouse environment to that in the field. American dunegrass seed was purchased from Inside Passage Seed Company in Port Townsend, Washington. Seed was collected from naturally occurring dunegrass communities on Indian Island, Jefferson County, Washington, where fertile seeds are documented (Forest, 2002). Two (2) ounces of dry seed was mixed with wet sand into the consistency of cake batter. The material was dropped in clumps on the plot and raked evenly across the surface. A S75® single-net straw blanket with lightweight photodegradable polypropylene netting was placed over the plot to prevent loss of seed from wind exposure. The netting was secured with twelve-inch metal staples. No nitrogen was applied. An additional two (2) ounces of seed was spread in four (4) flats at a greenhouse. Monitoring was performed at plot 5 on 14 August 2003 by visually estimating percent cover of germinated seed.

4.2 Soil Analysis

Soil samples were collected from the project site and sent to the University of Massachusetts Soil and Plant Tissue Testing Laboratory for analysis. The goal of the soil testing is to determine if soil properties differed significantly from that in a naturally occurring dune, and if potential differences could contribute to plant survival or growth success. The dredge material was analyzed for pH, Nutrients, Organic Matter, Texture and Soluble salts. Reference dune soil properties were obtained from literature.

4.3 Volunteer Planting Event

Following earthwork and grading activities of the 2002 dredge material placement, the site was planted with American dunegrass. The 2002 American dunegrass installation was performed primarily by volunteers overseen by biologists experienced in volunteer revegetation projects. Volunteers included local businesses, non-profit environmental organizations, students, and local residents. Over the course of two days, volunteers installed approximately 50,000 dunegrass culms throughout approximately 3-acres. A paid prison crew provided one-day labor following the volunteer event to complete the planting.

Plant material was procured from Westlake Nursery in Westlake, Oregon. Individual culms cost between 19 and 21 cents. The collected culm is approximately 24 to 36-inches in length, and about the diameter of a marking pen. When culms are planted, the above ground portion of the stem is (semi) dormant. The green leaves die back shortly after transplanting and the new growth emerges from the nodes the followings spring (ADNR, 1994). The nursery obtained a license from the U.S. Forest Service to collect American dunegrass culms from dune communities at the Oregon National Dunes. A condition of the license is that the material will be collected in an environmentally sensitive manner. Plants are physically pulled from the sand which stimulates vigorous re-growth and does not eradicate the communities in any way (Evanow, 2004). Licensed plant collectors are supervised by U.S. Forest Service and the collection sites are also monitored annually.

Corps contract specifications for the plant order addressed the following specifications for storage, handling and transport: The plants are to be collected no longer than 10 days prior to delivery. During collection, the plants are to be adequately protected from wind and sun exposure to prevent drying. Plants are to be tied neatly in bundles of approximately 250 plants per bundle. Bundles should not exceed a size or weight that could not be transported by one professional laborer. Bundles are to be stored in a protected cooler at approximately 45 degrees, between the period of collection and delivery. The plants will be transported in a protected vehicle that will not subject the plants to unnecessary wind or sun exposure.

The Corps arranged storage of the delivered plant material at a nearby covered City of Westport sewage treatment facility. Upon arrival, bundled bags were inspected randomly to ensure healthy plant material. Inspection procedures include the following: Leaf color should be inspected. The leaves should be dark blue-green and not pale or yellowish. If so, the plant is lacking nutrients, probably Nitrogen. The leaves should be tough, almost woody (Cooke, 1997). Red or orange spots on the leaves could be an indication of fungal disease. A few spots are acceptable, but if the leaves are covered with it, the plants should be rejected. The base of the leaves should be inspected for insect pests such as aphids. The roots should have nice form, with firm, white growing tips (nodes). If roots and nodes are entirely brown, the plant should be rejected (Buis, 2002). With harvested plants, more concern should be placed on the condition of the roots rather than the top growth. The white nodes at the root are where the new plant growth will occur. A hand lens helps with the plant material inspection.

Prior to arrival of volunteers, the Corps crew leaders transported the material from storage and stockpiled the plant bundles throughout the planting area. When volunteers arrived, crew leaders oriented them to the site and provided a brief demonstration on proper planting techniques. Volunteers worked in groups of two. One person used a clam shovel or spade to make approximately 100 holes in the sand. Holes were 18 to 24-inches on center. The other laborer followed by placing the plant culm (or culms) approximately 6 to 8-inches deep in each hole. The plants do not need to be placed vertically. Culms can be placed in any position and will resume growth, thereby eliminating the need for careful upright planting (Wright 1990a). After placement, the installer softly tamped the sand back with their foot around the plant. The number of individual plants per hole varied, from one to three depending on the installer. Volunteers worked fairly independently for the rest of the day. One Corps crew leader was available for approximately every 10 volunteers. Surplus plant material was heeled into the sand, on-site, in bundles, for installation the following week by a hired prison crew.

Five permanent photo stations were established throughout the volunteer planting zone (See Figure 3-3). Each station was staked and surveyed following earthwork activities. At each station, a single landscape photograph was taken aiming north, south, west and east. The photographic record is to document survival and establishment of the American dunegrass community over time.

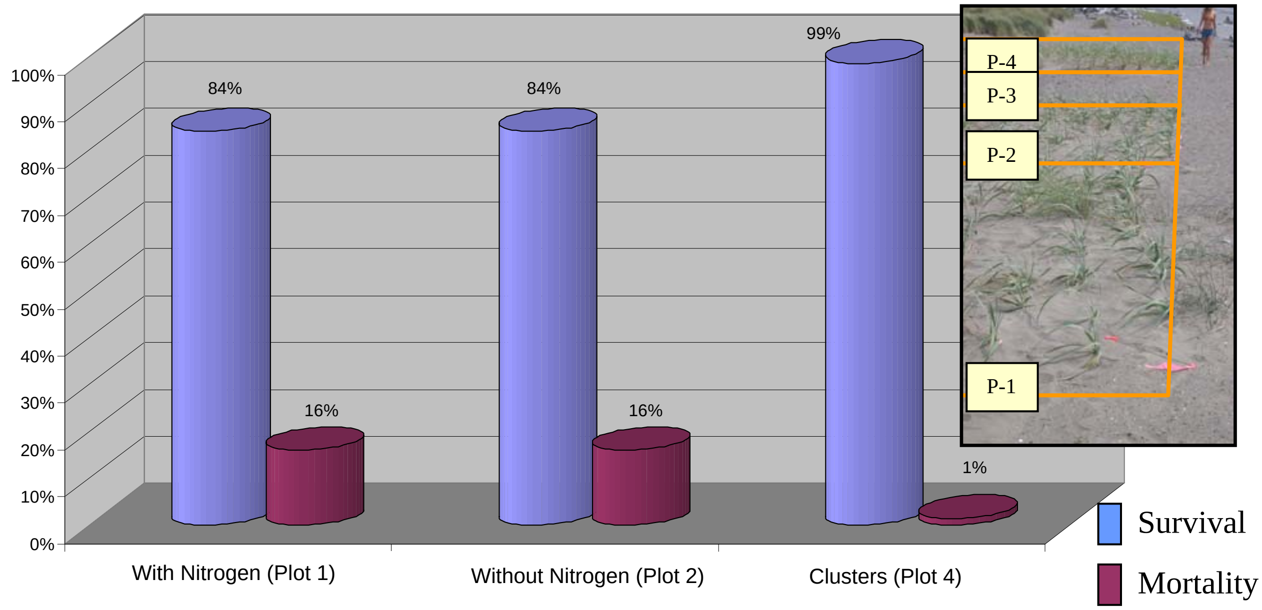
CHAPTER 5. RESULTS

The 2003 monitoring results are presented in Figures 5-1 through 5-5 for each treatment described in section 4.1. Monitoring results are presented for the following:

- Figure 5-1: Plant Survival
- Figure 5-2: Above Ground Biomass
- Figure 5-3: Control
- Figure 5-4: Broadcast Seed
- Figure 5-5: Topography

The soil analysis results and photo documentation of the volunteer planting area is presented following the quantitative analysis.

Figure 5-1 Plant Survival: American Dunegrass, South Jetty Breach Fill, Westport, WA. July 2003



5.1 Plant Survival

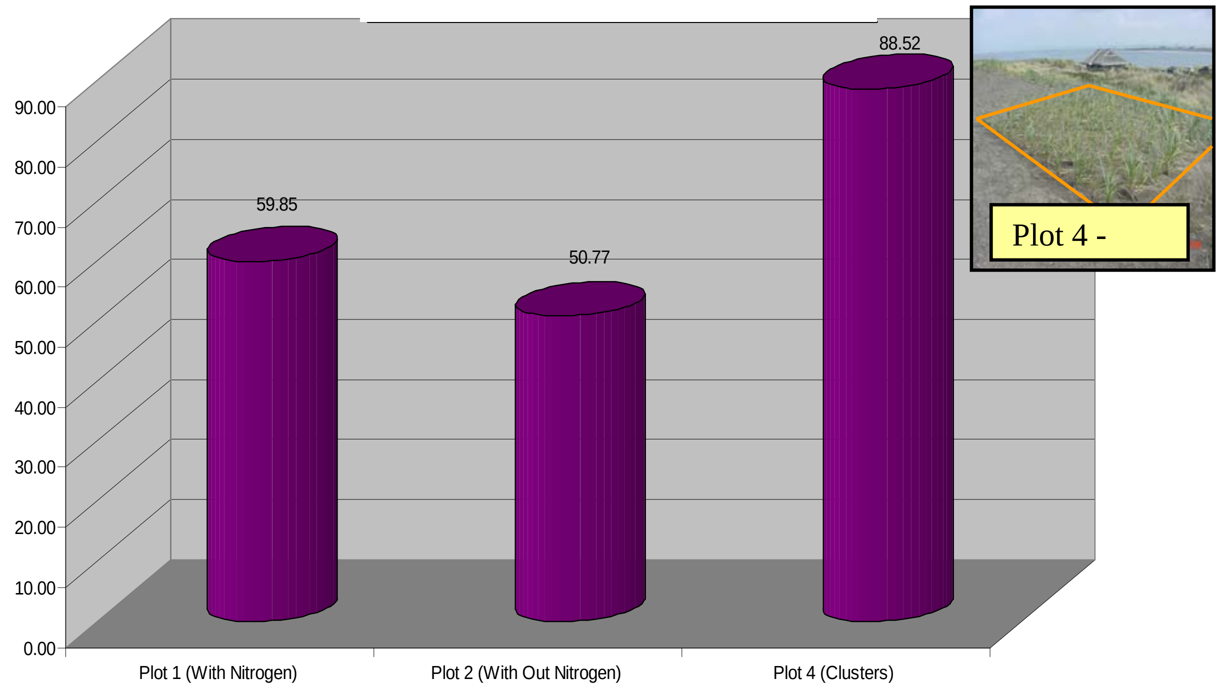
Plots 1 and 2 evaluate if the application of Nitrogen (N) effects plant survival. Plot 4 compares survival of clustered plantings verse individual culms. All three plots experienced an above average, high survival rate. Although many restoration practitioners consider an 80 percent survival rate ambitious, the standard expectancy for plant survival in a restoration or remediation setting is 80 percent (King Co. DDES, 2004). All plots exceeded this expectancy (Figure 5-1). The photo inset depicts plot locations.

Although the literature (Wright, 1990a) states American dunegrass responds to high N fertilizers, the results indicate application of N has no effect on plant survival. Plots 1 and 2 have identical survival rates of 84 percent, only 16 percent mortality occurred. The application of N appears unnecessary as aerosol inputs of nutrients (N, Mg, CA, Cl) in salt spray and fog are high enough that meteroligic inputs meet, or even detrimentally exceed, plant requirements (Clayton 1972, Art et al. 1974, van der Valk 1974). Because of high rainfall and rapid drainage, nutrients, soluble salts, and organic matter are constantly being leached out of the system. These dynamics result in unstable and rapid soil nutrient cycling (Pickart, 1998). The N applied in plot 1 may have quickly leached from the system given the 60-inch (+/-) average annual precipitation for the area. Application of N appears unnecessary considering the dynamic nutrient cycle of a coastal dune system.

The clustered planting of Plot 4 followed the same planting procedures as plot 2 (15-inch centers, no N), however, 3 individual culms were placed per hole. Plot 4 indicates N application does not improve plant survival. Plot 4 experienced a 15 percent higher survival rate then plot 1 and 2 with 99 percent survival. The minor increase in survival of the clustered plantings could be attributed to a competitive relationship of plants when clustered together in a hole.

Figure 5-2. Above Ground Biomass: American Dunegreass, South Jetty Breach Fill, Westport, WA

Average Area (length of blade x width of blade) in sq. cm of the American Dunegrass at Westport, WA July 2003



5.2 Above Ground Biomass

Above ground biomass (plant growth) was monitored to determine if application of N, or clustering individual plant culms, effects growth. Figure 5-2 presents the average area (length x width of each blade) of American dunegrass for plots 1,2, and 4. Ten percent of each plot was harvested for analysis. The plot 4 photo inset depicts abundant above ground growth.

There is an insignificant difference in growth area between plots 1 and 2. Plot 1 (w/ N) experienced a minor 9.08 sq.cm increase in biomass over Plot 2 (w/o N). As with Figure 5-1 (Survival), the N application appears to have no effect on plant growth. This is likely attributed to the rapid nutrient cycling of porous sandy soils (van der Valk, 1974). The November application of N is quickly leached out of the system by precipitation. As plants enter the spring growing season, applied N reserves are absent. At the time of active spring growth, the plants in both plots 1 and 2 are relying on equivalent levels of naturally occurring available nutrients in the soil.

Plot 4 is compared to Plot 2, to test if clustering individual culms in clusters of 3, affects growth. A significant difference in above ground biomass occurs in plot 4 where 3 culms per hole were planted instead of 1. Plot 4 achieved a 37.75 sq. cm increase in biomass over comparison plot 2. Accelerated plant growth is likely attributed to the physiology of American dunegrass. American dunegrass shares similar growth physiology with European beachgrass. European beachgrass attains maximum growth and vigor where sand deposition by wind is greatest (Wiedemann, 1974). It also establishes vigorous root and rhizome systems. Active sand burial stimulates the production of new shoots from vertical and horizontal rhizomes (Gemmell et al. 1953, Greig-Smith 1961). The ability of European beachgrass to withstand up to 1 m/year (3.3 ft/yr) of sand burial contributes to its competitiveness (Ranweell 1972, Barbour et al. 1985). In the absence of fresh sand accumulation, European beachgrass declines in vigor (Marshall, 1965).

Growth of American dunegrass is also stimulated by fresh sand accumulation (Williams, 1980, ADNR, 1994). As depicted in Figure 5-2, clustered plantings have a larger surface area of above ground biomass than a single culm. The greater area of above ground biomass serves to trap airborne sands more effectively than a single culm. Thus, greater sand deposition occurs and results in more aggressive plant growth. Although clustered planting accelerates growth, it should be noted that individual culms also serve to effectively trap smaller quantities of airborne sands. As individual plants mature, their ability to accumulate sand and stimulate growth increases.

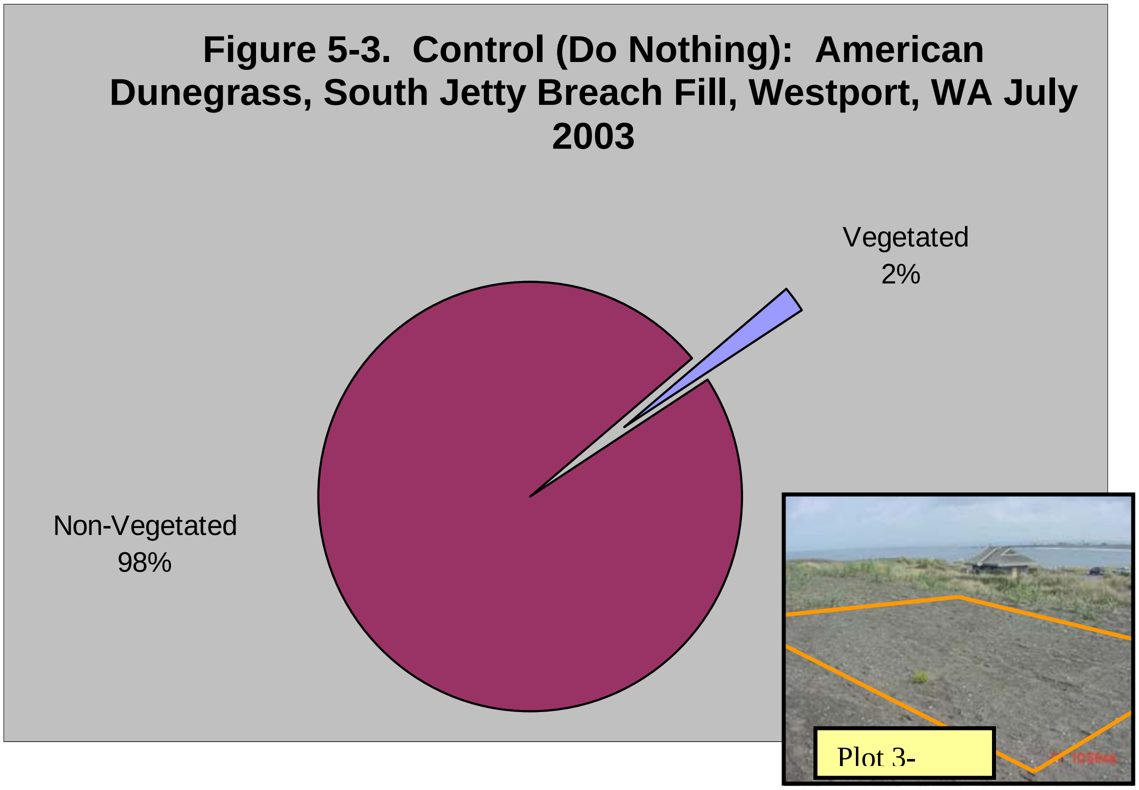


Figure 5-3. Control (Do Nothing): American Dunegrass, South Jetty Breach Fill, Westport, WA July 2003

5.3 Control (Do Nothing)

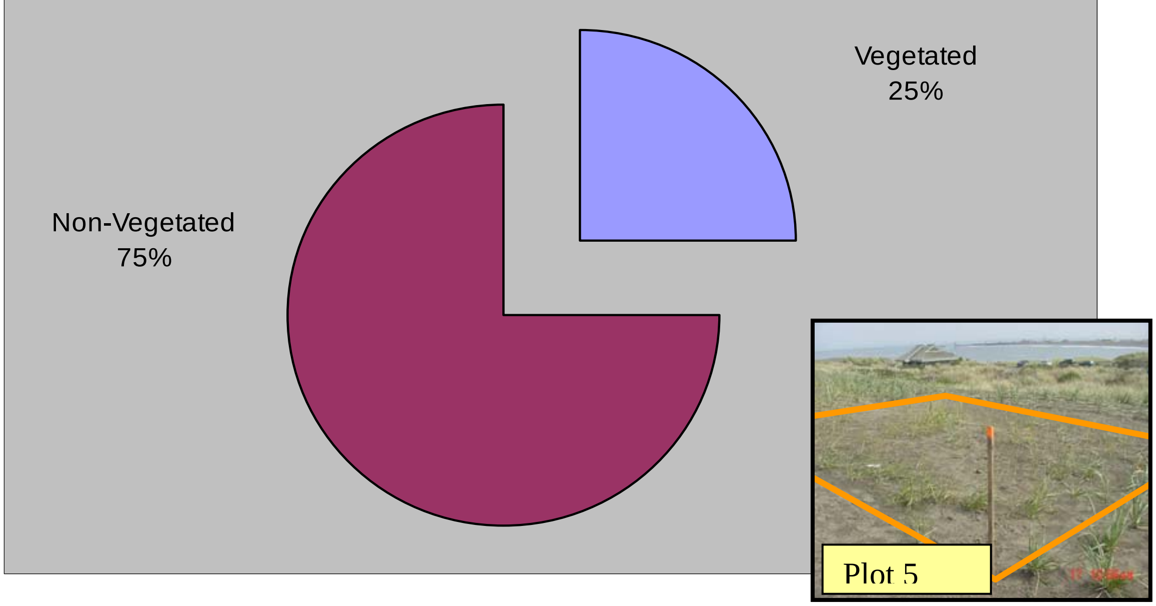
The Control plot documents conditions if no vegetation was installed following upland dredge material disposal. Presence of volunteer vegetation and changes in topography were monitored. Of particular interest is the natural establishment of either the target species, American dunegrass, or the invasive species, European beachgrass.

Figure 5-3 indicates only 2 percent vegetative cover in the control plot at year-1. The photo inset visually portrays the vegetated area. Only 2 individual plants were recorded, salt rush (*Juncus lesueurii*) and American searocket (*Cakile edentula*). Salt rush is a very common rush in coastal systems. American sea rocket, a succulent, occurs commonly in beaches and adjoining dunes (Wiedemann, 1974). The remaining 98 percent of the plot is unvegetated.

The control plot indicates minimal volunteer regrowth occurs without the planting of vegetation. It should be noted however, that photo monitoring (Station 1 through 5) and anecdotal observations throughout the volunteer planting area, indicate volunteer species occur more commonly. Included in the assemblage of observed volunteer species (listed in section 5.7.1) is occasional occurrence of European beachgrass. American dunegrass colonization has not occurred. This is likely due to the fact that, unlike American dunegrass, European beachgrass is capable of dispersal by seed or other propagules (Pickart, 1998). The exposed sandy dredge material is an ideal substrate for seed germination from the surrounding landscape dominated by European beachgrass.

Photo monitoring indicates where American dunegrass is planted, European beachgrass is nearly absent. Whereas, in unplanted or sparsely planted areas, European beachgrass colonization is more common. Monitoring results in the volunteer planting zone indicates planting of American dunegrass deters the establishment of European beachgrass.

FIGURE 5-4. BROADCAST SEED: AMERICAN DUNEGRASS, SOUTH JETTY BREACH FILL, WESTPORT, WA JULY 2003



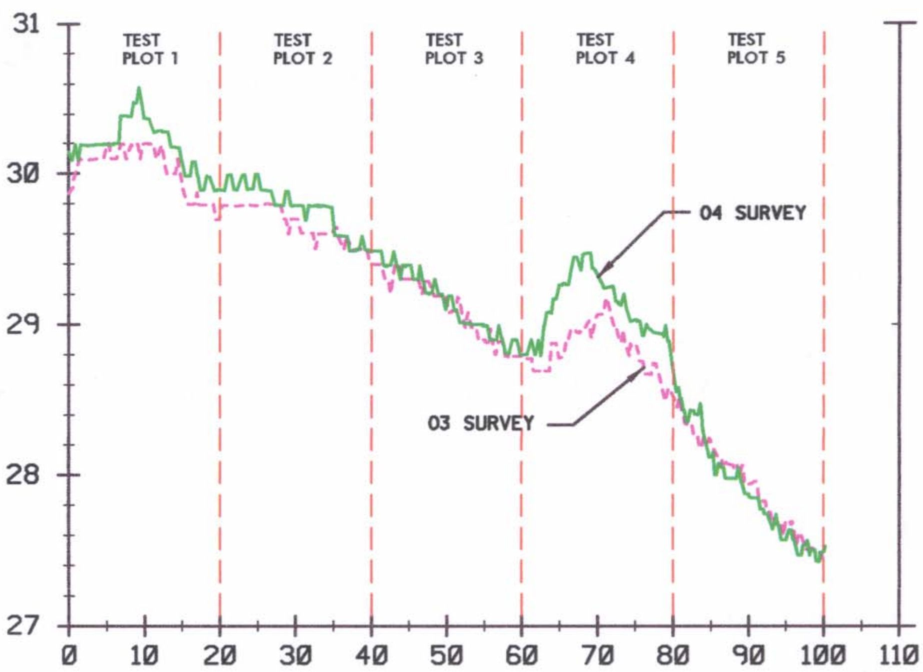
5.4 Broadcast Seed

The broadcast seed plot was established to document effectiveness of vegetating upland dredge material by seed. A broadcast seed treatment, if deemed effective, could provide a cost-effective and low-labor intensive method for establishing dunegrass vegetation. Figure 5-4 depicts the percent cover of American dunegrass germination one year following application. A 25 percent cover of germinated American dunegrass was estimated. No other volunteer species were present. In the greenhouse experiment, four flats of American dunegrass seed were planted. The planting medium was a standard potting soil. Seeds were sewn on the surface and covered with a shallow (<1/4-inch) layer of potting soil. The percentage rate of germination was qualitatively compared to germination rates in Plot 5. The four flats germinated 20 days following seeding. By 18 September, each flat was densely covered with American dunegrass seedlings.

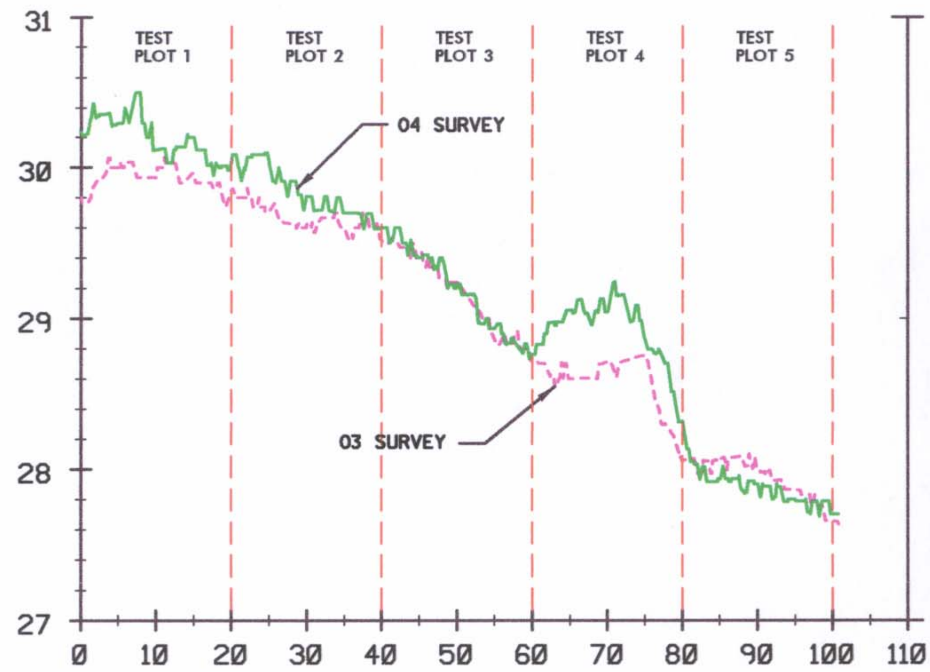
American dunegrass is not known for being a species with either high seedling vigor or exceptional germination percentages for its seed. A 50 percent germination for seed is considered acceptable (ADNR, 1994). Studies in the Aleutians indicate sexual reproduction is very low or non-existent in American dunegrass. This could be attributed to the poor ovary maturation that contributes to poor seed fertility, or perhaps synergistic factors (Williams, 1980). The Plot 5 data, as well as the greenhouse experiment, indicate the seed obtained for the study is indeed fertile. Robust germination occurred in the greenhouse flats with partial germination throughout the twenty square foot area of plot 5. It should be noted, however, that although 25 percent cover was established in plot 5, most of the germinated plants in plot 5 did not survive through the winter of 2003. Low survival rate is likely contributed to the harsh physical environment at the study site. The study plots are exposed to the direct winds of the Pacific Ocean and had no artificial irrigation through the first growing season. The germinated grasses are somewhat delicate and could likely not endure this physical environment. The grasses in the controlled greenhouse environment that weren't exposed to the on-site conditions maintained a high survival rate.

Germination of broadcast American dunegrass seed may not be an efficient method for establishing a dunegrass community. The seed is known to have low seedling vigor with low germination percentages. In addition, it appears as if the germinated grasses have difficulty surviving the harsh growing environment of a coastal zone. Plot 5 was exposed to direct Pacific Ocean winds. Germinated seedlings may have greater long-term survival if planted on the leeward side of the foredune where some wind protection is provided.

Figure 5-5: Topography Cross-Sections. American Dunegrass, South Jetty Breach Fill, Westport WA, 2003 & 2004 Comparison



TEST PLOT CROSS SECTION A
NTS

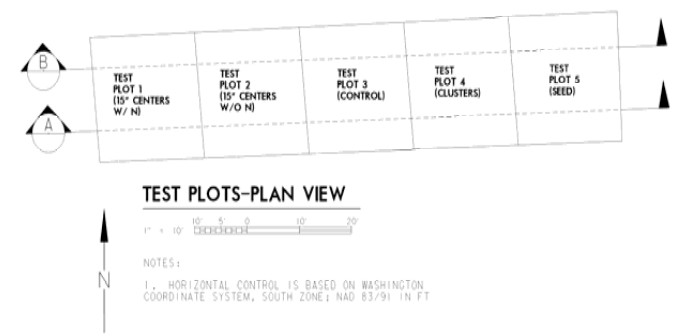


TEST PLOT CROSS SECTION B
NTS

NOTE:

1. VERTICAL EXAGGERATION ON CROSS SECTIONS IS 20:1

2. VERTICAL CONTROL IS BASED ON NOS MLLW IN FT



5.5 Topography Cross-Sections & Elevation Differences

One of the goals of planting upland dredge material is to aid in sand retention. If one of the treatments retains sand more effectively, it should be noted for future consideration of planting. Microtopography within the experimental plots was monitored to determine the quantity of sand accumulation under the various treatments. It is speculated that a greater quantity of above ground biomass will capture and retain airborne sands more effectively than individual culms.

Figures 5-5 compares the cross-sectional changes in topography and elevation difference between years 1 and 2. The vertical exaggeration is 20:1. Each plot is differentiated for comparison by the vertical slashed line every twenty-feet. Within each plot, data are compared to the comparison year in the same plot boundaries. Elevations aren't compared to other plots, as the study plots are located on a generally descending land profile. Note, that the figure only compares differences between 2003 and 2004, one year after planting. There is no baseline data to indicate study plot topography prior to planting. The deposition of sand under the different treatments was an unexpected result, and not initially included in the study methodologies. The inset indicates a plan view of plot treatments and exact location of transects A and B.

Test plots 1 and 2 both were planted with individual culms of American dunegrass planted on 15-inch centers. As discussed in sections 5.1 and 5.2 the application of N had an insignificant effect on survival and growth. Therefore, the amount of above ground vegetated material in plots 1 and 2 is similar (Figure 5.2). Figure 5-5 indicates an overall increase in elevation in both plots between years 1 and 2. Plots 1 and 2 averaged an overall increase in elevation (accumulated sand) between 2003 and 2004 of 1.9-inches. The sand deposition between years 1 and 2 can be attributed to the greater area of above ground growth between year's 1 and 2. An increased area of leaf material occurs as the plants mature. Thus, a greater barrier for sand deposition is created. The sand accumulation at the crown of the plant is known to induce more vigorous growth. Sand accumulation is expected to occur annually, until the plants mature and a somewhat stable equilibrium is created.

Test plot 4 followed the same treatment as Plot 2 (15-inch centers, no N), however, 3 culms per hole were planted. Figure 5-5 indicates the greatest increase in elevation occurred in this plot. Between years 1 and 2, 2. 9-inches of sand deposition occurred. This is attributed to the greater area of above ground biomass. Clusters of 3 plants create more surface area for airborne sand deposition (Figure 5-2). In addition, the greater quantity of sand accumulation induces more vigorous growth of the clustered plants. Test plot 4 indicates the most efficient method of sand retention and deposition is clustering culms to maximize above ground growth.

Test plot 3 is the Control plot, no planting occurred. Figure 5-5 indicates minimal deposition of sand occurs when no vegetation is planted. Between years 1 and 2 an average elevation increase of .64-inch occurred. In addition, surface hardening of the plot was apparent. Surface hardening is likely attributed to uninhibited wind exposure. Hardened sand surfaces can deter germination of desirable volunteer plant species.

Test plot 5 is the broadcast seed plot. After the first growing season, 25 percent of the plot was vegetated with germinated American dunegrass. The grass averaged approximately 6-inches in length, with narrow blades and a delicate leaf texture. As discussed in Section 5.4 most of the germinated seed did not survive through the 2004-growing season. Thus, minimal above ground growth was present for sand deposition. Figure 5-5 portrays elevation differences between 2003 and 2004. The transect A increase in elevation is about neutral, with a minor increase in Transect B. The averaged area of increase between years 1 and 2 is 1.10-inches. This minor increase in elevation could be attributed to the presence of vegetation in the early part of the growing season, as well as the use of the net straw blanket applied for erosion control. Due to the low survival rate and minimal above ground biomass, broadcast seed treatments result in the least effective method of immediate sand deposition. However, unlike the control plot, surface hardening is not apparent.

5.6. Soil Analysis

Soil samples were analyzed to determine the nutrient quality of the dredge material. Dune sands are very poor soils. There is no accumulation of organic matter and nutrient status is very low (Wiedemann, 1984). Because of the high rainfall and rapid drainage, nutrients, soluble salts and organic matter are constantly being leached out of the system. However, as rapidly as many nutrients are leached, aerosol inputs of nutrients are constantly replenishing the soil (Clayton 1972, Art et al 1974, van der Valk 1974). Because of the dynamic nature of nutrient cycling in dune soils, tremendous variability can occur in soil analysis results depending on season, location and weather patterns (University of Massachusetts, 2004). The following results represent soil properties from a combined single sample of dredge material collected on 25 May 2004 at the Westport South Jetty. The material sampled was dredged on 20 October 1995 and stockpiled until May 2002 until it was distributed at the South Jetty Breach Fill site. Data are compared to published reference data from Arcata California dunes.

Soil pH:

Soil pH is a measure of the soils acidity and is a primary factor in plant growth. When pH is maintained at the proper level for a given plant, nutrients are at maximum availability, toxic elements are often at reduced availability, and beneficial soil organisms are most active. Most plants prefer a soil pH between 5.5 and 7.5, and the majority do best in the middle part of this range. The reference site soil pH is 7.1, and that of the dredge material is 7.5. Both soil pH readings are on the higher range of average. However, the average pH is derived from pH levels preferred for common agricultural and horticultural plants.

Cation Exchange Capacity (CEC):

CEC is an important m measure of the soil's ability to retain and supply nutrients. The bulk of this capacity comes in the form of organic matter and clay particles. Very sandy soils, low in organic matter, commonly have CEC's less than 5. The soil analysis of the sandy dredge material has a CEC of 2.7, which is typical of a sandy soil with low organic matter content. Desirable range of organic matter (OM) for most plants is between 4-8 percent. The OM content of the soil sample is 0.3 percent and the reference site data OM content is 0.12 percent. Both samples contain low amounts of organic matter, as expected in a sandy substrate.

Soluble Salts (SS)

Generally, soluble salts (SS) can cause severe water stress and nutritional imbalances in plants. Seedlings are more sensitive than established plants to elevated SS levels and great variation exists between plant species. Most soils have values between 0.08 and 0.50 (University of Massachusetts, 2004). Excessive SS levels can often be corrected by leaching with liberal amounts (2-4 inches) of freshwater. The SS level of the dredge material sample is 0.14 and the reference site data for SS is 0.13. Both samples have nearly the same SS concentration and are within the range of normal for SS.

Nutrients

Table 5.1 presents the results of the soil analysis from the dredge material for Nitrogen (nitrate NO3-N, and ammonium NH4-N), Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg). The data is compared to reference data obtained near Arcata, California (USFWS 1984). Data are expressed in parts per million (ppm).

Table 5.1 Soil Nutrients

Soil Nutrients	Soil Sample-1	Reference Site data
-Ammonium (NH4-N)	1	1
-Nitrate (NO3-N)	12	9
Phosphorus (P)	4	8
Potassium (K)	202	12
Calcium (CA)	277	24
Magnesium (MG)	236	12

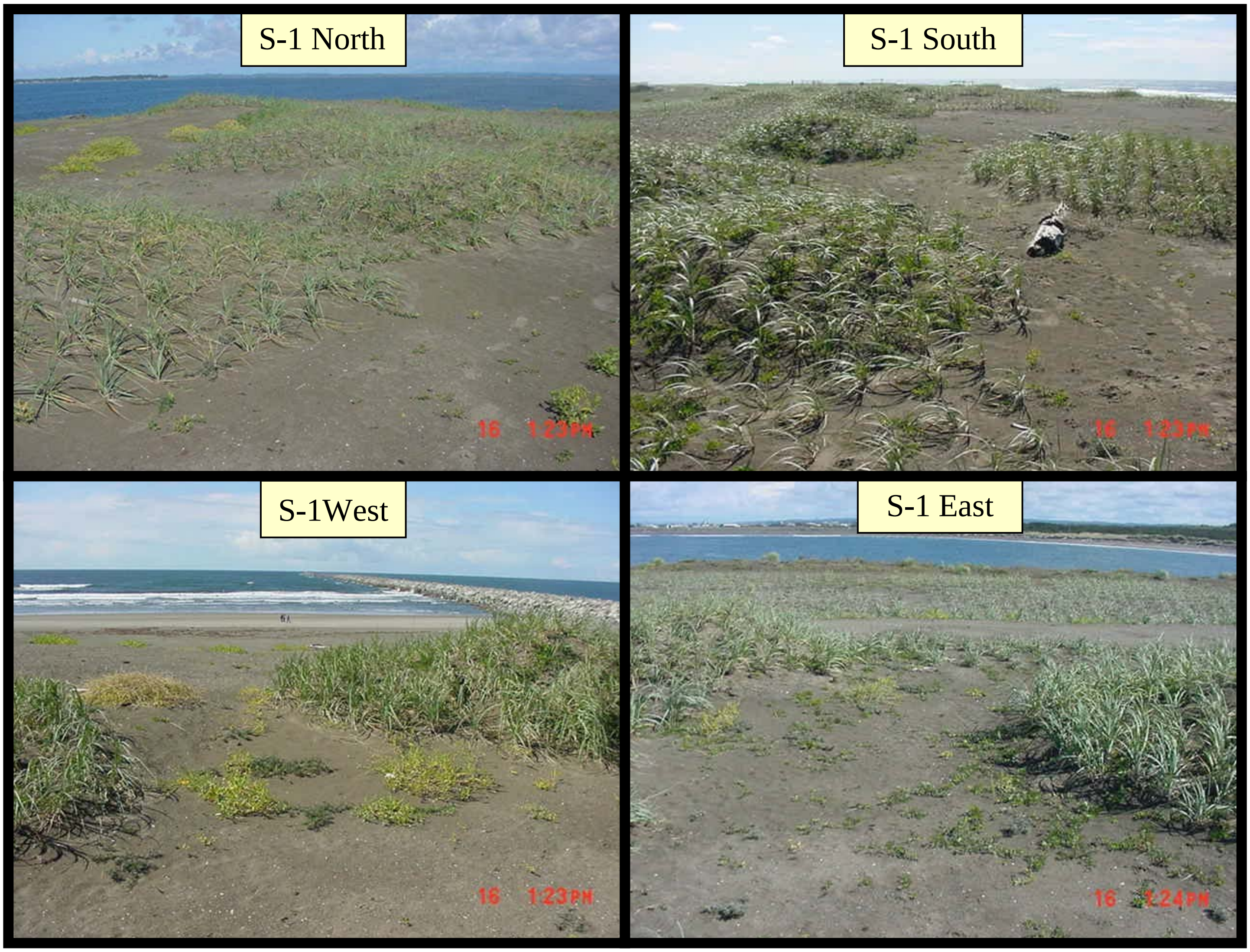
Soil sample 1 is comparable to the reference site data for Ammonium, Nitrate, and Phosophorous. However, concentrations of Potassium, Calcium, and Magnesium are significantly higher for the dredge material sample. This could be attributed to the higher quantity of shell fragments in dredge material. Despite the differences in soil nutrients, soil nutrient status does not appear to be a limiting factor in American dunegrass survival or growth.

5.7 Photo Monitoring Stations

The following Photo Stations 1 through 5 portrays a north, west, south, and east orientation from each photo station in Figure 3-3. Photographs were taken 16 September 2003 following the November 2002 volunteer planting event. All American dunegrass represents new growth following the 2002 planting. Prior to installation, the ground surface had only occasional volunteer species, none of which included American dunegrass. As the following photographs indicate, plant survival of American dunegrass is high. Survival percentages are comparable to the 84 to 99 percent survival rates in the experimental plots. Volunteers placed either 1,2, or 3 culms per hole. The above ground growth reflects these treatments, as more vigorous growth indicates clustered plantings.

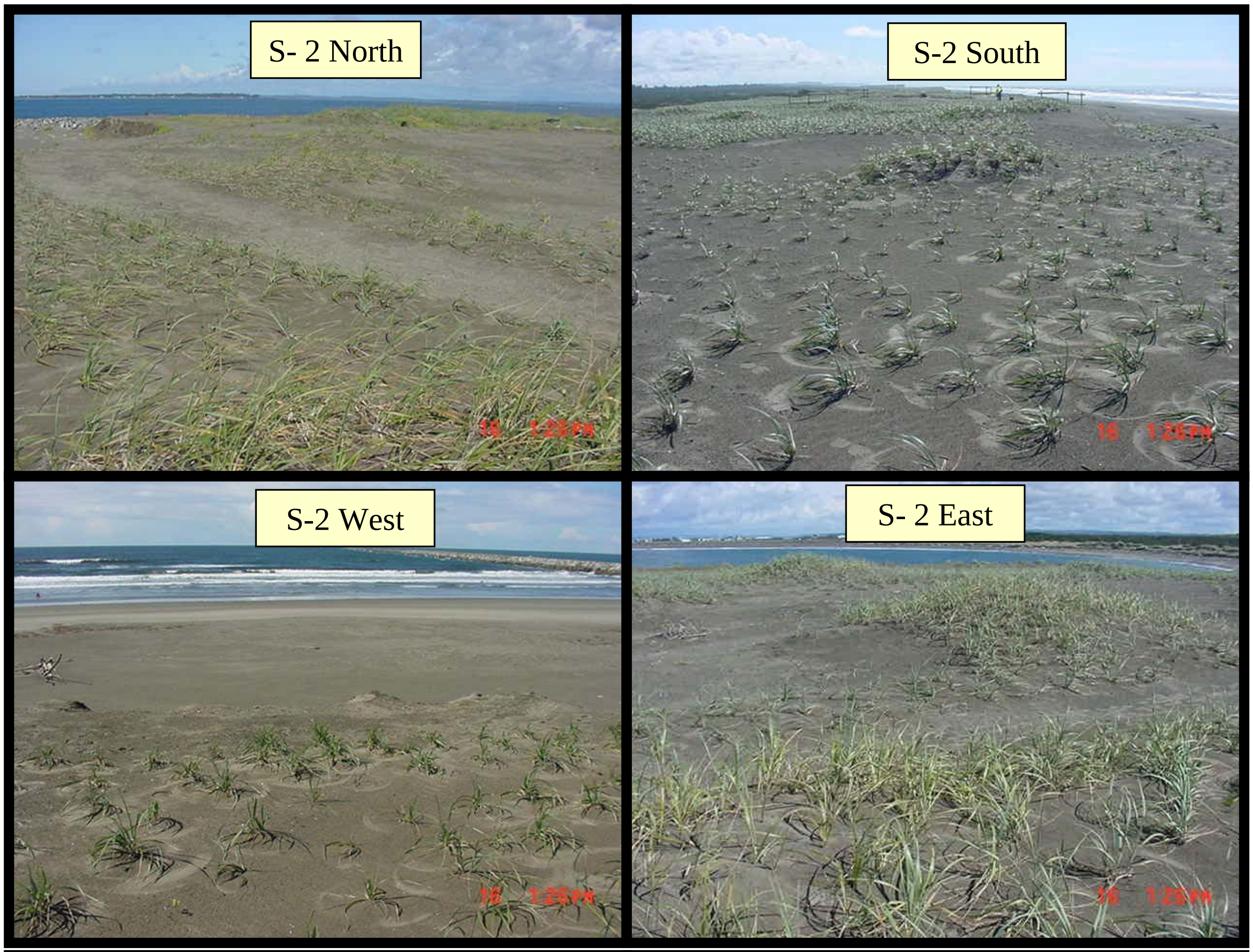
5.7.1 Station 1:

All American dunegrass growth indicates new growth during the 2003 growing season. Photo documentation indicates high survival within planted zones (bare ground was not planted). Note the presence of volunteer species such as European searocket (*Cakile maritima*), beach pea (*Lathyrus japonicus*), seashore lupine (*Lupinus littoralis*) and northern dune tansy (*Tanacetum camphoratum*). European beachgrass infestation was noted in the background of S-1 East where only sparse American dunegrass plantings occurred.



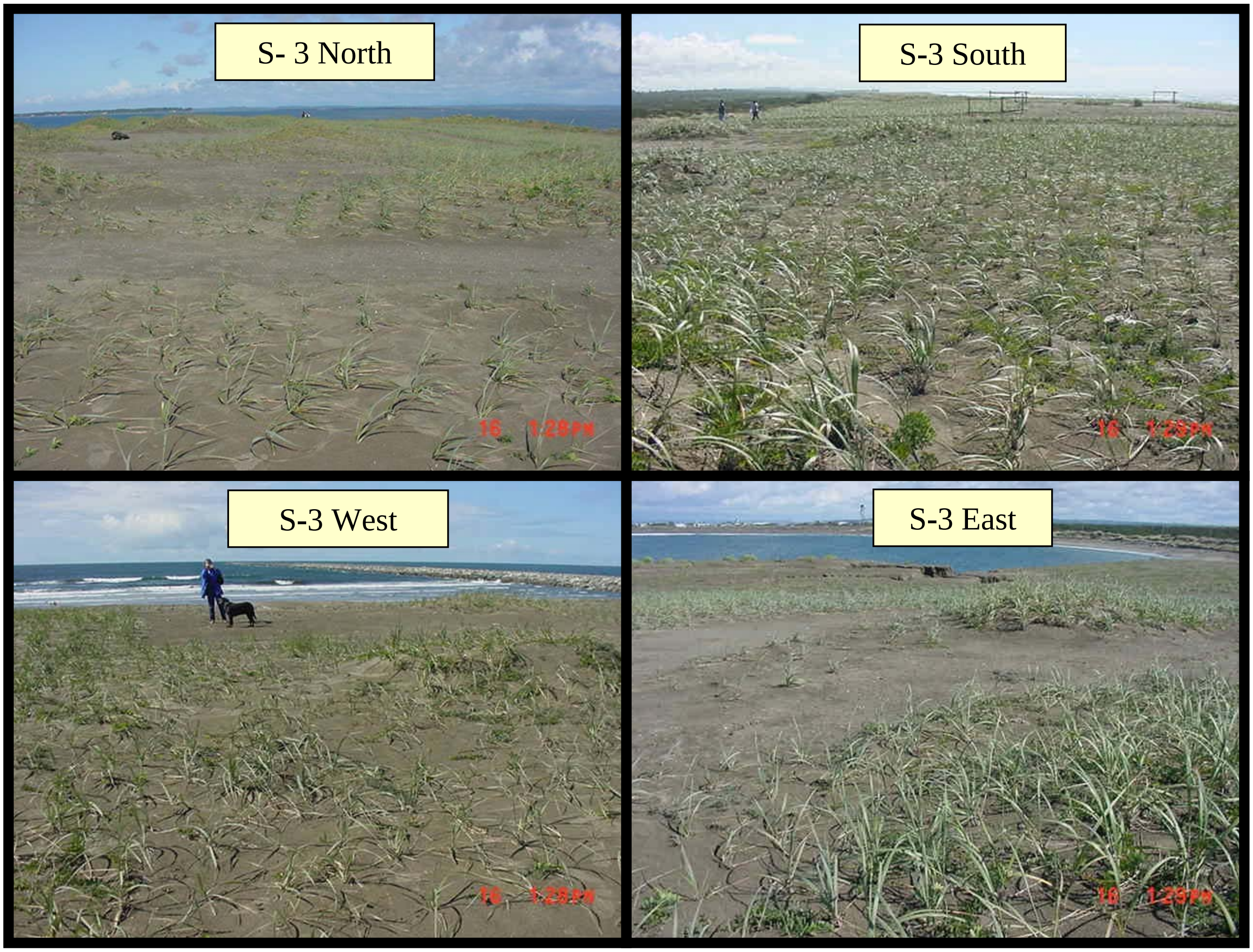
5.7.2 Station 2

Station 2 photos indicate a high plant survival rate and sand deposition around newly emerged plantings. S-2 North, S-2 South and S-2 West all were planted with individual culms of American dunegrass. Note the more vigorous growth in S-2 East where clusters of 3 culms were planted. Foot paths (S-2 North) were left unplanted to guide users to access areas. Station 2 has low occurrence of volunteer species.



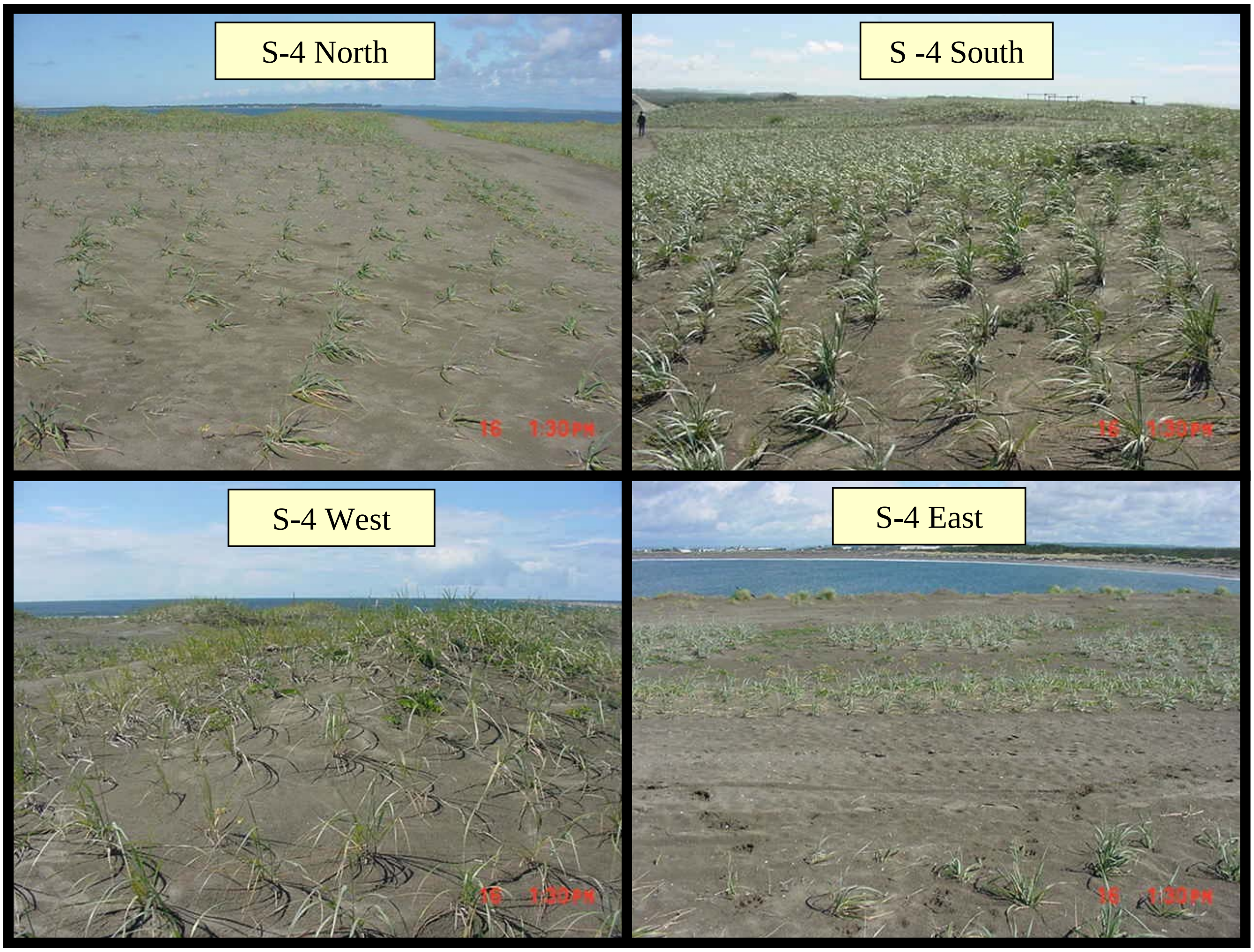
5.7.3 Station 3

Station 3 photos indicate a high survival rate throughout the planting area. Unvegetated areas were not planted. All above ground growth indicates new growth during the 2003-growing season. Some volunteer growth of beach pea is present in the foreground of S-3East and S-3 South.



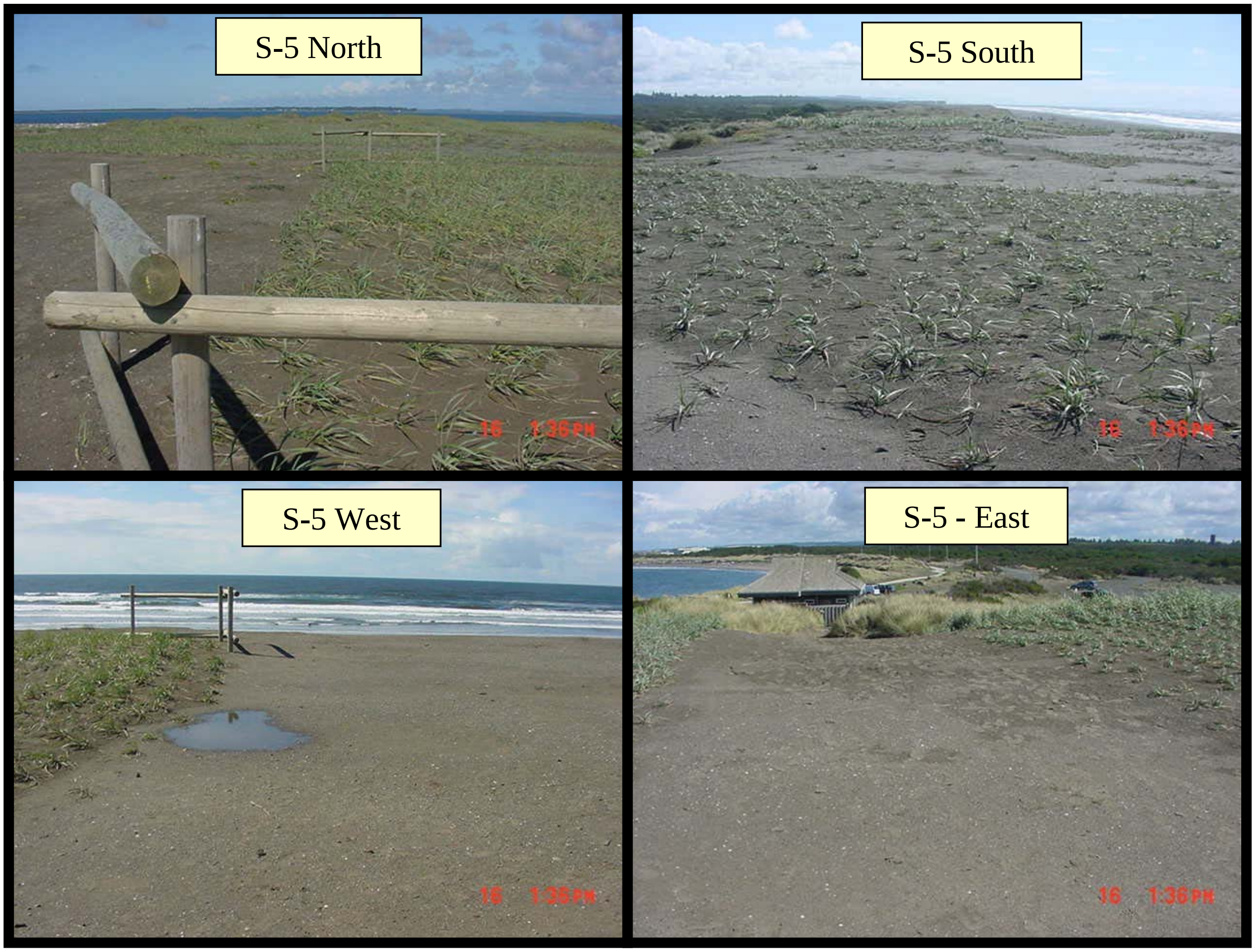
5.7.4 Station 4

Station S-4 North followed placement of individual plants in each hole. Station S-4 South was planted in clusters. Note the vigor of clustered plants. Sand deposition patterns are apparent around plant crowns. In the background of S-4 East, European beachgrass is present. This infestation occurs in the unplanted zone along the east bank of the fill material. This area has since eroded away.



5.7.5 Station 5

Wood fencing was placed strategically to guide users to beach access areas. S-5 West and S-5 East both depict the primary beach access route from the Westhaven State Park parking area. As indicated in Control Plot 3 (Section 5.3) surface hardening, as noted in the perched water surface in S-5 West, occurs when areas are left unvegetated. Note the deposition of sand in S-5 South, compared to the unplanted area in the same picture.



CHAPTER 6. DISCUSSION

The goal of this study is to determine the most effective methods for establishing American dunegrass communities at upland dredge material disposal sites. This report is a technical reference of successful plant establishment techniques. It is not a hypothesis-tested study.

American dunegrass is an optimal plant species for revegetating dredge material. The species is suited to a strictly maritime climate and can thrive in coarse sandy substrates, sand and gravel beaches, and treeless, sea bird islands (Pojar & Mckinnon, 1994). Logistically, these coastal environments are also the most feasible disposal locations for ocean or harbor derived dredge material. Potential project areas for dunegrass revegetation could include a variety of coastal erosion control projects, buried revetments, dredge material islands, and coastal dikes. In addition (despite the origin of the substrate) residences and parks along coastal and Puget Sound shorelines could be encouraged to plant American dunegrass. American dunegrass is often planted ornamentally because of its aesthetic appeal.

Revegetating with American dunegrass should be considered where site conditions are deemed appropriate. The vegetation will provide a vital role in sand deposition and deter the establishment of invasive species. American dunegrass establishes well once planted in coastal environments. Assuming installation of culms or containerized plants takes place in fall or spring, watering does not appear necessary as Pacific Northwest coast precipitation is ample. Once planted, American dunegrass spreads readily through robust rhizomatous growth. As discussed below, above ground growth, sand deposition and survival are maximized when clustering plants in groups of 3 (Figure 5-1, Figure 5-2, Figure 5-5). However, if funding or material constraints prohibit clustered plantings, results indicate adequate survival and growth can also be achieved using single culms.

The study results indicate survival and growth is greatest when American dunegrass is clustered in groupings of 3 on 15-inch centers. In the event an individual culm dies, uniform vegetative cover is still established since additional plants in the cluster should survive. Quantity of sand deposition is also maximized under the clustered treatment. Higher survival and growth rates could be attributed to a greater sand deposition rate that accelerates vertical and horizontal plant growth in American dunegrass. Nitrogen application proved to have an insignificant effect on plant survival and growth. This is likely due to the seasonal timing of application. N was applied in November at the onset of the winter rains. Nitrogen was likely leached from the system by the start of spring growth (March and April). If increased growth rates are desired, a spring application of N would make N available during the time of active plant growth.

The experimental plots described in this report are located on relatively flat topography. Within the volunteer planting zone, however, portions of the topography are sculpted in a hummock formation. Anecdotal observations and aerial photographs indicate American dunegrass growth may be more robust on the hummock areas than on the relatively flat surrounding areas. It's difficult to determine if the robust growth is a result of topography or planting technique. Volunteers chose to use single or multiple culms for planting and the dense growth could be a result of clustered plantings. As Plot 4 indicates, greater above ground growth occurs when plant culms are clustered. The less robust growth within the flatter topography, could be a result of only individual culm placement, sparser placement or environmental exposure. Nevertheless, consideration should be given to sculpting the topography to potentially result in more robust growth and in some applications mimic the surrounding dunal topography.

Despite speculation that American dunegrass seeds are sterile, the broadcast seed results in the plot and greenhouse experiment confirm fertile American dunegrass seed is available commercially. However, when considering a broadcast seed application, care must be taken to site the planting area on leeward sides of slopes or areas protected from wind exposure. Germinated plants exposed to direct forces of the wind did not survive through the first growing season. Irrigation may also be necessary.

The control plot and unplanted areas in the volunteer planting zone, have surface hardening and minimal, to no presence of volunteer vegetation. This same condition was observed throughout the entire South Jetty Breach fill since its inception. From 1994 until this planting effort in 2002, virtually no American dunegrass established on this site. Only minimal cover of common weedy species established. Topographic monitoring indicates only minor sand deposition occurs without the presence of vegetation. Unplanted areas are also zones where European beachgrass infestation has occurred. No volunteer American dunegrass was observed anywhere on the site. In the absence of planted vegetation, this short-term study supports no volunteer regrowth of American dunegrass will occur.

Ongoing monitoring of the project area should continue for an additional 4 years (2007). The monitoring program should include continued topography monitoring in the experimental plots. In addition, the photos stations should be monitored annually for qualitative documentation of survival, growth, and volunteer species. Although European beachgrass occurs occasionally throughout the volunteer planting area, dense infestations are developing in unplanted areas where foot traffic does not occur. Maintenance crews, perhaps Washington Conservation Corps or prison crews, should be retained to provide regular control of this species. To deter the further establishment of European beachgrass, a future phased planting should be coordinated to plant unplanted areas that are not in immediate threat of water erosion.

Footpaths were established to guide users to access areas without trampling vegetation. Occasional observations of user use, indicates the majority of visitors adhere to the paths for access. When people deviate from the paths, it is primarily in unvegetated areas. If future monitoring indicates foot traffic is having an adverse effect on plant survival or growth, more restrictive means for controlling human access will be considered.

CHAPTER 7. CONCLUSIONS & RECOMMENDATIONS

The goal of this study is to determine the most effective methods for establishing American dunegrass communities at upland dredge material disposal sites.

7.1 Conclusions

- Plant survival rates under the three different treatments average 91 percent. Preliminary results from the spring 2004 installation indicate comparable survival rates.

- The study results indicate survival and growth is greatest when American dunegrass is clustered in groupings of 3 (99 percent survival). Quantity of sand deposition is also accelerated under the clustered planting treatment.

- For sand retention, plants should be planted 15 to 18-inches, on-center

- Nitrogen application proved to have an insignificant effect on plant survival and growth. If increased growth rates are desired, a spring application of N (instead of fall) would make N available during the time of active plant growth.

- Dredge material nutrient status does not appear to be a limiting factor in American dunegrass survival or growth.

- The control (do nothing) plot has surface hardening and only 2 percent cover of volunteer vegetation. Topographic monitoring indicates only minor sand deposition occurs without the presence of vegetation.

- Unplanted areas of the volunteer planting zone is where European beachgrass infestation has occurred. No volunteer American dunegrass was observed anywhere on the site. In the absence of planted vegetation, study results indicate no volunteer regrowth of American dunegrass will occur.

- American dunegrass may grow more robustly on hummock (sand mounds) topography rather than flat ground. This could be attributed to physical protection from the elements on the leeward side.

7.2 Recommendations

- On-going photo monitoring of the project area should continue for an additional 4 years (2007). The monitoring program should include continued topography monitoring in the experimental plots.

- European beachgrass occurs occasionally throughout the volunteer planting area, however ,dense infestations are developing in unplanted areas where foot traffic does not occur. Maintenance crews, perhaps Washington Conservation Corps or prison crews, should be retained to provide regular control of this problematic invasive species.

- To deter the further establishment of European beachgrass, a future phased planting should be coordinated to plant unplanted areas that are not in immediate threat of water erosion.

- Occasional observations of public use, indicates the majority of visitors adhere to the footpaths for beach access. When people deviate from the paths, it is primarily in unvegetated areas. If future monitoring indicates foot traffic is having an adverse effect on plant survival or growth, more restrictive means for controlling human access will be considered.

- The project area would benefit from educational and interpretive signage. A kiosk with interpretive signs should be constructed at the footpath entrance. The signs could explain the purpose and need for the revegetation project, as well as an overview of coastal dune ecology.

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APPENDIX A: SOUTH JETTY SAND PLACEMENT CROSS-SECTION DIAGRAMS

SOUTH JETTY BREACH FILL

NOTES:

1. CONTOUR INTERVAL IS 2 FEET.
2. HORIZONTAL CONTROL BASED ON WASHINGTON COORDINATE SYSTEM, SOUTH ZONE, NAD83/91.
3. VERTICAL CONTROL BASED ON MEAN LOWER LOW WATER (NOS).
4. TOPOGRAPHY FROM 20 SEP 2001 SURVEY.

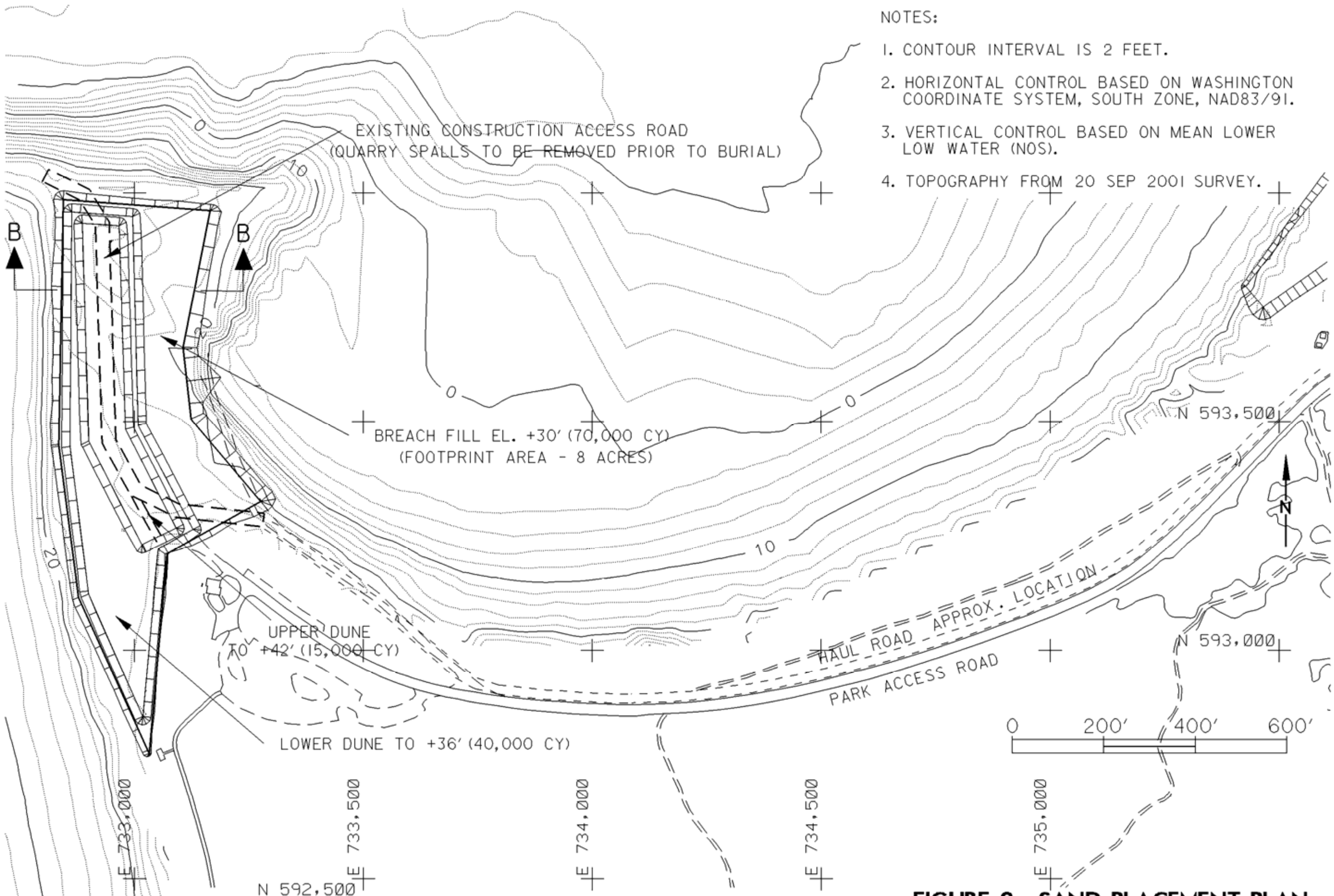

FIGURE 2. SAND PLACEMENT PLAN

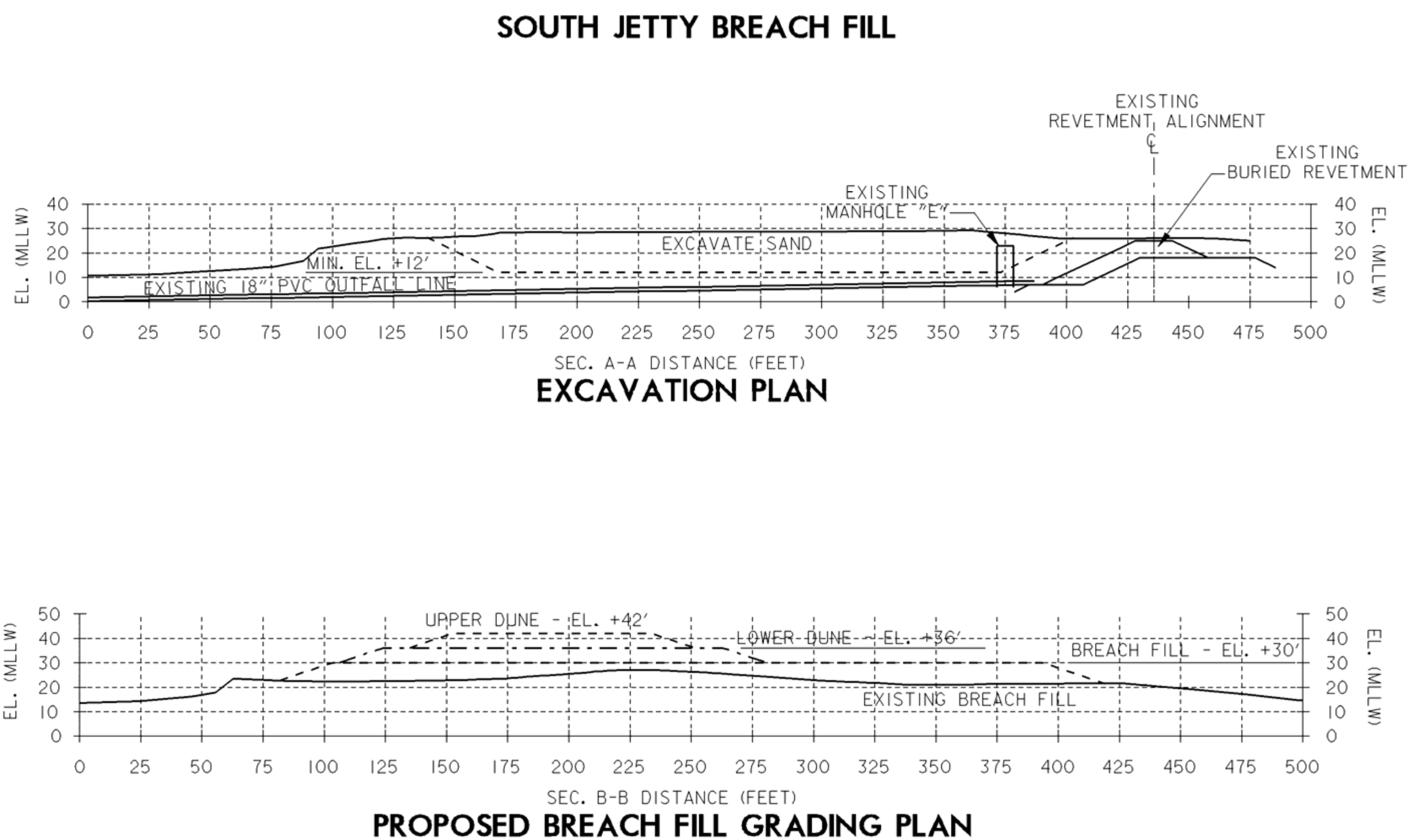

FIGURE 3. CROSS SECTIONS