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Pacific Northwest National Laboratory
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King County Nearshore Habitat Mapping Data Report: Picnic Point to Shilshole Marina

D. L. Woodruff
P. J. Farley
A. B. Borde
J. S. Southard
R. M. Thom

March 2001

Prepared for
King County Department of Natural Resources
under a Related Services Agreement
with the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Pacific Northwest National Laboratory
Richland, Washington 98382

EXECUTIVE SUMMARY

King County has initiated environmental studies on the northern King County and southern Snohomish County portion of the nearshore environment of Puget Sound to support the siting of a new wastewater treatment plant outfall and the King County Wastewater Treatment Division Habitat Conservation Plan. The primary objective of our study was the development of accurate maps of nearshore habitat resources within the Snohomish/King County study area. As such, the results of the study provide a critical basis for assessment of the aquatic habitats and fisheries resources within the nearshore zone (defined as +1 m to –30 m mean lower low water [MLLW]) between Shilshole Marina in Seattle and Picnic Point, slightly north of Edmonds. The depth range was designed to cover all low intertidal and shallow subtidal habitats, including potential rockfish habitat. Our report documents methods used to map the nearshore environment and presents georeferenced maps and summary tables of substrate, vegetation, fish, and macroinvertebrates.

Twenty-two contiguous kilometers of nearshore habitat were mapped within the overall study area during the fall of 1999 using a combination of side scan sonar and underwater-video technologies. The study area was divided into 12 subareas (A through L) for ease of data collection and processing. All data were collected along predetermined survey track lines and linked to a global positioning system. Side scan sonar data and underwater video footage were postprocessed to develop geographical information system map layers of eelgrass (*Zostera marina*), substrate type, total macroalgae, kelp (*Nereocystis luetkeana*), and *Ulva* spp. In addition, map layers including fish and macroinvertebrate species and selected macroalgae were developed from the video data.

A total of 144 km of video data and 1033 hectares of side scan-sonar data were collected during the survey. The dominant substrate type was sand, occurring in 90% of the study area. A mixed coarse substrate that included gravel, shell hash, and/or cobble occurred to a much lesser extent (9% of the study area) and was generally noted close to shore with a few exceptions. Very little rocky habitat occurred in the study area. Eelgrass occurred to some extent in all subareas, covering approximately 260 hectares, (23% of the study area). Eelgrass was found to a depth of –7 m MLLW with dense coverage (80 hectares) usually associated with a steeper slope, and moderate or patchy coverage (126 hectares) associated with a shallow slope. Sparse eelgrass coverage (50 hectares) was usually found on the inner (shallow) or outer (deep) edges of denser eelgrass meadows. Kelp occurred infrequently (2.6% of the study area) with the exception of several areas, including the Edmonds Underwater Marine Park where its extensive presence prohibited mapping. Approximately two thirds of kelp coverage occurred in mixed coarse substrate with the remaining occurring in sand, usually located on the outer fringes of eelgrass meadows. *Ulva* spp. was present in all subareas, generally in close association with eelgrass, along with numerous other species of macroalgae not specifically identified in the video transects.

Fish species recorded by video were categorized based on their schooling and non-schooling behavior. A total of 775 sitings of non-schooling fish were recorded along transects oriented perpendicular and parallel to shore. Estimates of total schooling fish ranged between 16,000 and 27,000. Predominant schooling species were tubesnout

(*Aulorhynchus flavidus*), found primarily in eelgrass habitat, and shiner surfperch (*Cymatogaster aggregata*), found in open sand locations. Flatfish and ratfish, the most common non-schooling fish species, were generally found in sand. Very few rockfish and lingcod were observed; those present occurred on sand. Predominant benthic macroinvertebrates recorded by video included sea anemones (*Metridium* spp.), orange sea pens (*Ptilosarcus gurneyi*), and various sea stars. These occurred principally in open sand habitat.

This study is the first to provide complete coverage maps of major nearshore benthic habitats over a large area of Puget Sound. The combined use of side scan sonar and underwater video provided an effective tool for mapping the nearshore environment of the study area in Puget Sound. Side scan sonar provided high spatial resolution and accuracy for development of eelgrass habitat and substrate maps. The underwater video provided excellent groundtruthing of the sonar data, as well as a dataset of fish, macroalgae, and macroinvertebrate locations spatially referenced to habitat type. These data will be further analyzed and used in future studies related to the north treatment facility marine outfall siting study process.

Acknowledgements

Funding for this study was provided by King County Department of Natural Resources under a Related Services Agreement with the U.S. Department of Energy under Contract DE-AC06-76RLO 1830. A mapping effort of this magnitude could not have been successful without the continued support and extra effort put forth by a number of individuals. In particular, we would like to acknowledge the program management support, technical assistance, and thoughtful review comments throughout the duration of this project by King County DNR personnel, including Debra MacLellan Williston, Randy Shuman, Jim Brennan, and Kent Hale. We would also like to acknowledge the exceptional video support of Jim Norris (Marine Resources Consultants) and Sandy Wyllie-Echeverria (University of Washington). Thanks are also given to Blythe Barbo and Heida Deifenderfer for editorial assistance and Eileen Stoppani for secretarial support.

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1.0 INTRODUCTION

King County has initiated environmental studies on the northern King County and southern Snohomish County portion of the nearshore environment of Puget Sound. The purpose of this study is to support the siting of a new wastewater treatment plant outfall and to gather information in support of a King County Wastewater Treatment Division Habitat Conservation Plan for salmon and other species. A fundamental aspect of this study is the development of maps that document the types and locations of aquatic habitats and fisheries resources within the nearshore environment of the study area (see Section 1.2). These maps will provide a critical basis for assessment of the quality of the environment for a variety of aquatic resources including salmonids, crabs, flatfish, geoduck, rockfish, birds and marine mammals. The information could also be used in the development of restoration scenarios for the area.

The primary emphasis of this report is the documentation of methods used to map the nearshore environment in northern King County and southern Snohomish County, as well as presentation of the data collected in the form of maps and summary tables of substrate, vegetation, fish, and macroinvertebrates.

1.1 Objective

The objective of this study is to provide accurate, georeferenced maps of benthic habitats in the study area to assist in the siting of a new wastewater treatment plant outfall and assessment of habitats of endangered, threatened, and economically important species. The mapping was conducted in the fall of 1999 using two complementary techniques: side scan sonar and underwater videography. Products derived from these techniques include geographic information system (GIS) compatible polygon data of substrate type and vegetation cover including eelgrass and kelp. Additional GIS overlays include underwater video track line data of total macroalgae, selected macroalgal species, fish, and macroinvertebrates.

This report provides the details of the methods and a summary of the findings from the study. Copies of the maps are included in this report in an appendix. Digital copies of all maps have been provided to King County along with copies of the videotapes. Specific products provided to King County either in this report or previously are as follows:

1) maps of benthic surface sediment types
2) maps of submerged aquatic vegetation and other features (e.g., pilings, debris piles)
3) estimates of the area covered by each of these features
4) spatial maps of fish and macroinvertebrates observed in the videography
5) a brief written analysis and summary of the information, and
6) an evaluation of the effectiveness of the methods as habitat assessment tools.

1.2 Study Area

The study area covers approximately 28 km of shoreline in the central basin of eastern Puget Sound between Shilshole Marina in Seattle and Picnic Point, located slightly north of Edmonds (Figure 1). The habitat area mapped was approximately 22 linear km of nearshore environment from the water line (ranging between +1 m and +3 m mean lower low water [MLLW]) to a depth of approximately -30 m MLLW. The overall upland environment is varied and includes residential housing, county parks, marinas, and industrial areas with piers extending into the nearshore zone. Most of the shoreline

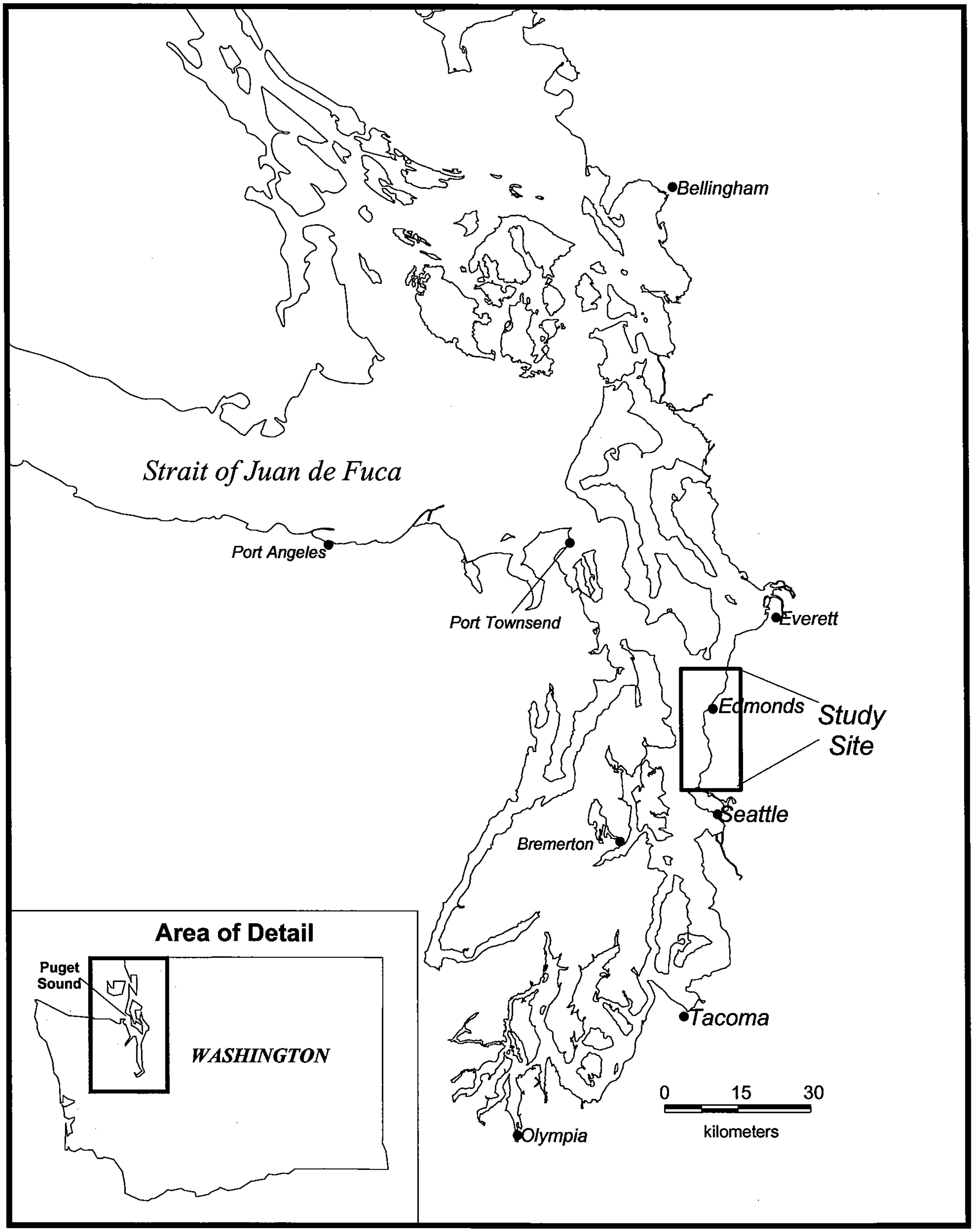

Figure 1. Location of study site in Puget Sound, Washington.

has been altered by the railroad construction at the base of moderately steep bluffs. Several areas within our study site were excluded from the mapping effort for logistical reasons, including the Edmonds Marina, the Edmonds Ferry dock and the Edmonds Underwater Marine Park. For ease of field collection and data reporting, we divided the study site into 12 discrete areas labeled A through L from the north to the south (Figure 2). Areas ranged from less than one kilometer to approximately 3 km in length.

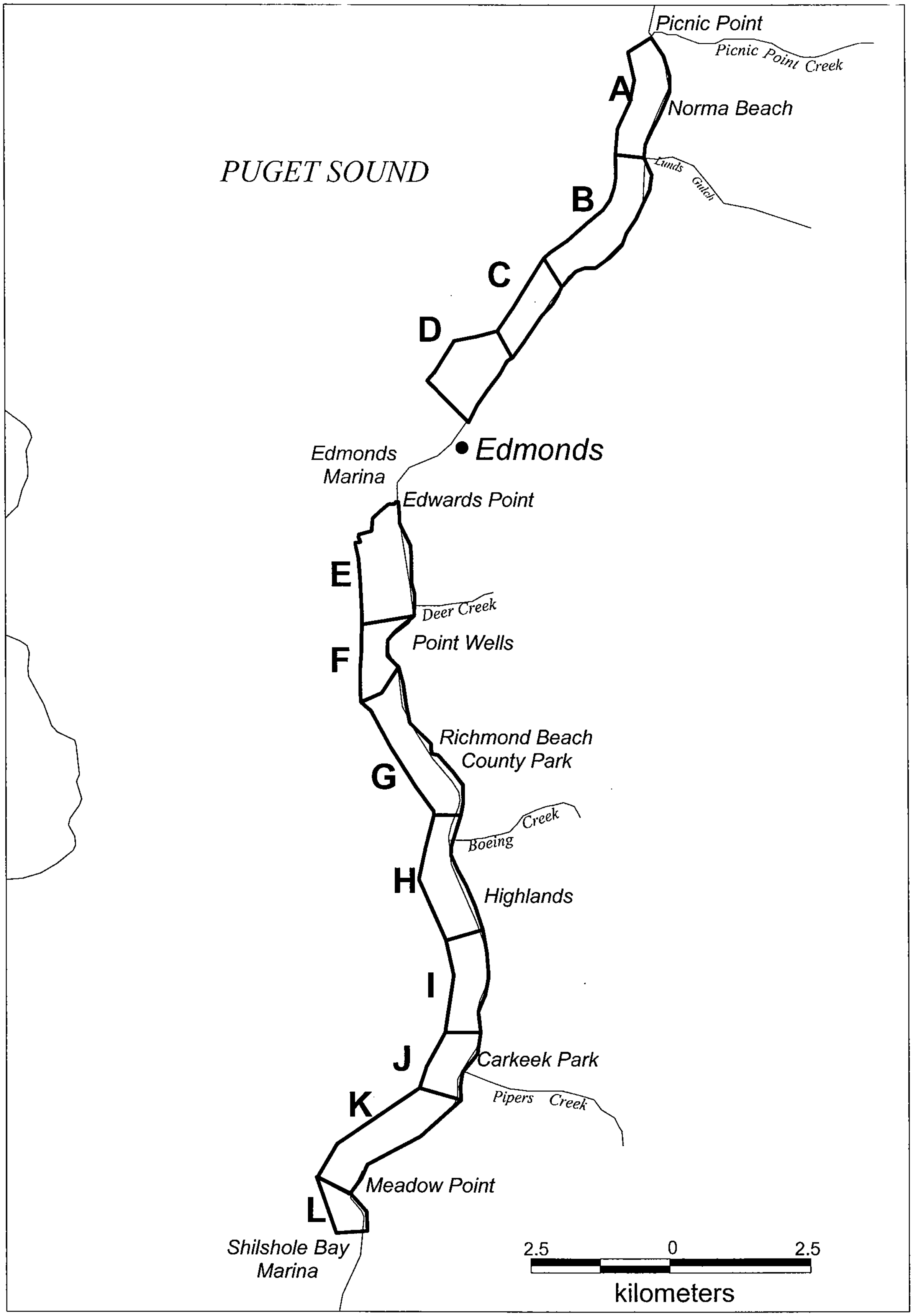

Figure 2. Locations of study Areas A-L within the Puget Sound study site.

2.0. METHODS

The methods discussed in this section include a description of the field survey design and instrumentation used to collect the habitat assessment data (i.e., the navigation system, side scan sonar, underwater video, bathymetry and diver surveys). The data analysis component includes a description of the video post processing methodology, the associated classification scheme and codes used, quality assurance and quality control of the video data, and integration of the side scan sonar and video data into GIS map products.

2.1 Field Collection

A majority of the survey was conducted on the 28' *R/V Strait Science*, a vessel owned and operated by the Pacific Northwest National Laboratory (PNNL). Surveys were conducted between October 6, 1999 and November 14, 1999. Navigation survey software and a global positioning system (GPS) were coupled to a side scan sonar system and an underwater video platform (used at separate times) to collect spatially referenced data for nearshore habitat mapping. Figure 3 shows a schematic of the system; a description of the components is discussed below. A portion of the survey (underwater video data collected along track lines perpendicular to shore) was conducted by Marine Resource Consultants (MRC) of Port Townsend, using the *R/V Brendan D II.*

2.1.1 Survey Design and Navigation System

The baseline tidal datum used for this study was MLLW. Mean high water (MHW), 10.06' above MLLW at 47°48.8' N and 122°23.0' W, was digitized into twelve sub-areas (Areas A – L) from 7.5-minute USGS topographic maps. These digitized shoreline files were imported into HYPACK Hydrographic Survey Software and used as

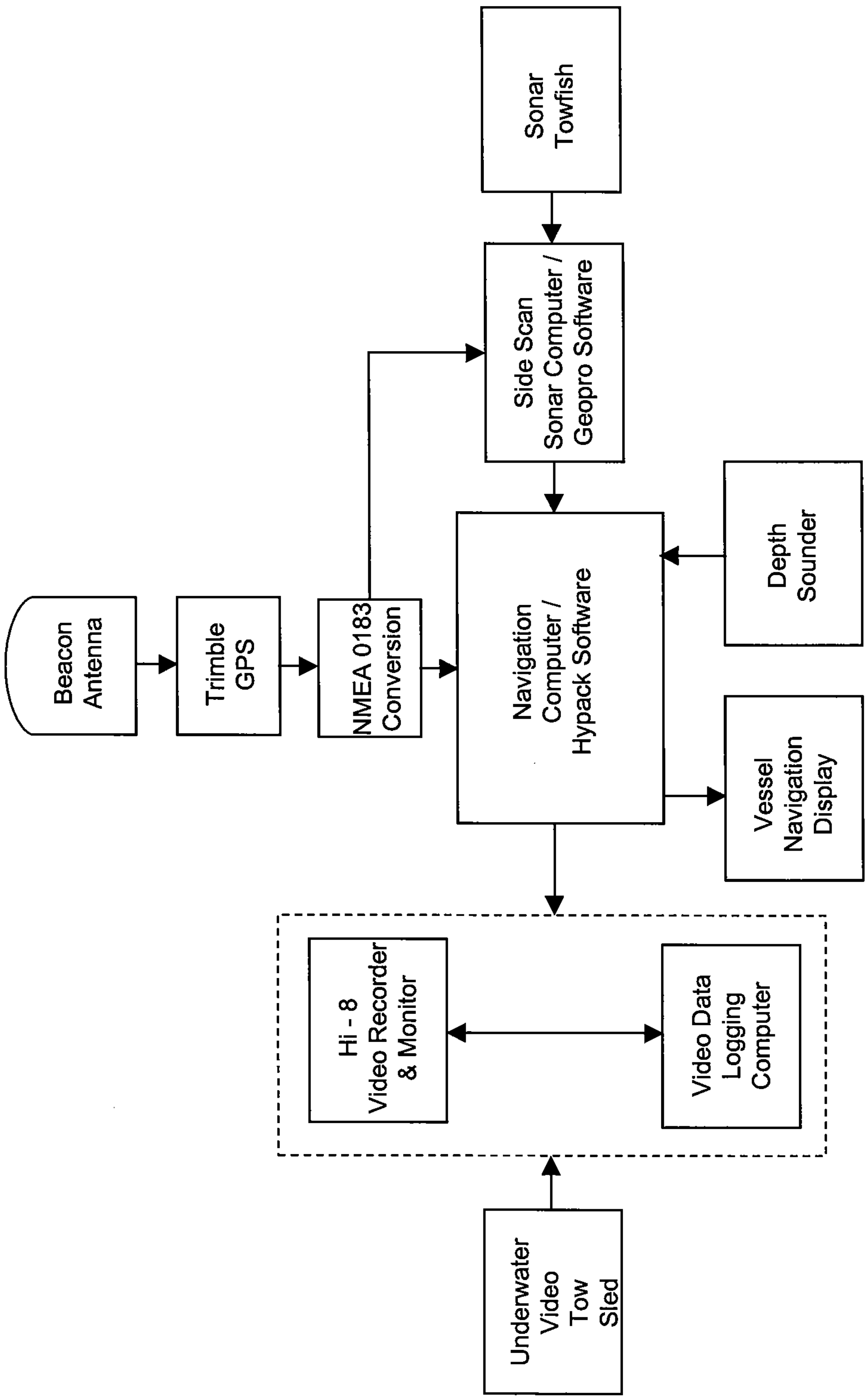

Figure 3. Instrumentation schematic on the *R/V Strait Science*

base templates. Survey track lines were entered in each area following the contour of the shoreline. An initial track line was entered at or just below MHW. Additional track lines were added parallel to the initial track line with an 85 m horizontal separation to a depth of -30 m. When integrated with GPS, this information provided the vessel operator real-time visual reference lines, vessel position, and port and starboard direction indicators for navigation along the survey line.

Position information was provided by a Trimble GPS Pathfinder Pro XRS system that included a 12-channel integrated GPS/Beacon/Satellite Differential receiver and recorded data to an accuracy of ±0.5 m. The GPS antenna was located amidship on the port side of the vessel. The survey software received NMEA0183 format latitude-longitude position information from the GPS and converted this to State Plane Coordinates (Washington State Zone North). The program merged position data with depth data every 1 second and data were recorded on the navigation computer and later post-processed to develop bathymetric records. The navigation computer/survey software also calculated position corrected for layback of the towed video camera based on length of cable out, corrected for catenary and the deck offset. The corrected position data was sent to the video data acquisition system. The side scan towfish offset and layback were entered directly into Geopro software.

2.1.2 Side Scan Sonar Data Collection

A GeoAcoustics LTD dual-frequency, side scan sonar system was used to collect real-time seafloor mosaic data with overlapping edges that were matched to form a continuous image of the bottom profile. The system consists of a tow fish, tow cable, transceiver, and a computer acquisition and control system. The main processing and control system provides the acquisition target analysis and mosaic assembly features. The tow fish and tow cable contain the acoustic transducer array and associated preamplifier, digital electronics, and signal transmission lines.

Digital data from the side scan sonar system were collected along track lines with a separation spacing of 85 m. During the survey, both port and starboard sonar ranges were set at 60 m per channel (or side), which provided approximately 40% overlap of side scan images. One digital (or pixel) sample was taken for every 6 cm of the swath width perpendicular to the track line. Survey speed over ground was generally held at 3 knots or 1.5 m/second. However, this varied slightly depending upon currents and wind speed. Transducer firing rate was 200 ms at 60 m/side range. Assuming 1500 m/s one-way, sound velocity travel time, coverage parallel to track was approximately one pulse every 0.3 m. The theoretical maximum pixel size is 30 cm x 6 cm. The value is dependent on vessel speed and tow fish attitude (heading). Slight variations can occur due to changes in seawater sound velocity characteristics in the survey area such as variations in temperature and salinity gradients.

Side scan sonar data were recorded in two formats. The individual track line data were saved in Society of Exploration Geophysicists (SEGY) format and used for post processing and target analysis. Mosaic images were saved in GeoAcoustics proprietary format and later converted to tiff format for post-processing.

2.1.3 Underwater Video Data Collection

Underwater video footage was recorded along track lines perpendicular and parallel to shore. Sixty-two track line surveys covering the study area were conducted parallel to shore by Battelle, spaced 85 m apart out to a depth of -30 m. The track lines were parallel to and 15 m shoreward of the side scan track lines. Video footage was recorded on Hi-8 mm tape with one to two track lines generally recorded on each hour of video tape. Seventy survey lines were conducted perpendicular to shore by MRC and recorded on VHS tape. Tracklines ranged in depth from +2 m MLLW to approximately -30 m. The specific transect locations for the perpendicular video were predetermined based on consultation with King County. Certain locations were selected to best represent the variety of habitat that might exist based on slope, proximity to creeks, geologic features, and upland features of interest. Several sites were chosen close to docks and piers that would otherwise be difficult to survey with parallel track lines. The remainder of sites were selected in areas E, G, and H.

The underwater video system that Battelle used consisted of a PNNL custom-built aluminum tow sled with a vertical stabilizer and bottom skids to protect the camera system. The camera used was a Super Circuits PC-33-C video camera with a Sony color charged coupled device (CCD) chip and 420 lines of resolution at 0.45 LUX. The lens was a 2.3mm wide angle with an 87-degree field of view. The camera was mounted in a pressure housing with a Plexiglas lens, in an "oblique-looking" orientation on the towsled. An artificial light source was not necessary and visible video footage was obtained down to -30 m. The video camera was towed approximately 1 m to 2 m off the bottom, depending on the type of habitat coverage and the vertical relief on the bottom. Tow speed was generally between 1.5 and 3 knots. This varied according to currents and surface winds, which influenced the speed and direction of travel to a certain extent. The visible video coverage on the bottom varied depending on turbidity in the water column and the depth of the camera off the bottom. Generally, forward looking coverage varied from several meters up to approximately 10 m.

Video data was recorded on a Sony Hi-8 EVO-9500A video recorder and displayed on a Sony video monitor in real time during the survey. The depth of the camera in the water column was adjusted on board the vessel by the winch operator who monitored the video recording on screen. A date, time, and position (State Plane coordinates) stamp was digitally overlaid on the video signal and permanently recorded as part of the tape. This was updated every 1 second. The position information recorded was corrected for layback of the underwater tow vehicle relative to the vessel location. The date, time, and position signal were also recorded on the video data logging computer in an Excel spreadsheet for later post-processing of the video data.

MRC conducted 70 video tows (transects) between Picnic Point and Shilshole Marina that were perpendicular to shore from +1 m MLLW to a depth of -30 m MLLW. Underwater video images were obtained using a SeaCam 2000 underwater camera (DeepSea Power and Light, San Diego, California). The SeaCam uses a Hitachi VK-C150 CCD video camera equipped with a 4.8 mm Cosmicar auto-iris lens. The camera and lens were encapsulated in a Delrin plastic housing; a 250-W underwater light was provided. The camera was mounted in a "down-looking" orientation on a towfish deployed off the stern of the vessel. Deployment methods and data acquisition are described in Norris et al. (1997).

2.1.4 Bathymetric Data

This study was not intended to collect survey-grade bathymetric data. We did, however, record depth data during our side scan operations. An Inner Space

Technologies survey-quality depth recorder with a 5-degree, 100-kHz transducer pole was mounted amidships on the survey vessel *R/V Strait Science*. Depth data along with position information were recorded at 1-second intervals during side scan survey operations and post processed at a later date. A hardcopy of the bathymetry data was also recorded on an electrosensitive strip chart and digital data were collected in HYPACK.

Depth data were also recorded on the *R/V Brendan D II* as part of the video tows conducted perpendicular to shore. Depth was recorded at 2- to 3-second intervals using a 200-kHz or 50-kHz transducer. Depth data were corrected to MLLW manually at 10-minute intervals using predicted tidal heights for Edmonds and Meadow Point.

Depth data were processed in HYPACK for local time and tide difference. These data were then merged with the data collected aboard the *R/V Brendan D II.* Coordinate conversion from latitude/longitude to State Plane was performed in Tralaine software, a commercial conversion utility. After all corrections were incorporated, the data sets were merged in Microsoft Excel as X,Y, -Z format for analysis. A digital copy of the position and depth data for combined perpendicular and parallel track lines (corrected to MLLW) was provided to King County for further processing.

2.1.5 Diver Survey

Battelle conducted a SCUBA survey on November 17, 1999, to visually verify the substrate and habitat types previously observed on the videotapes and sonar imagery, and to assess the positional accuracy of the sonar records.

To verify the substrate and habitat type, two transects (shown in red, Figure 4) were surveyed at the southern end of Area E. This area was selected as representative of

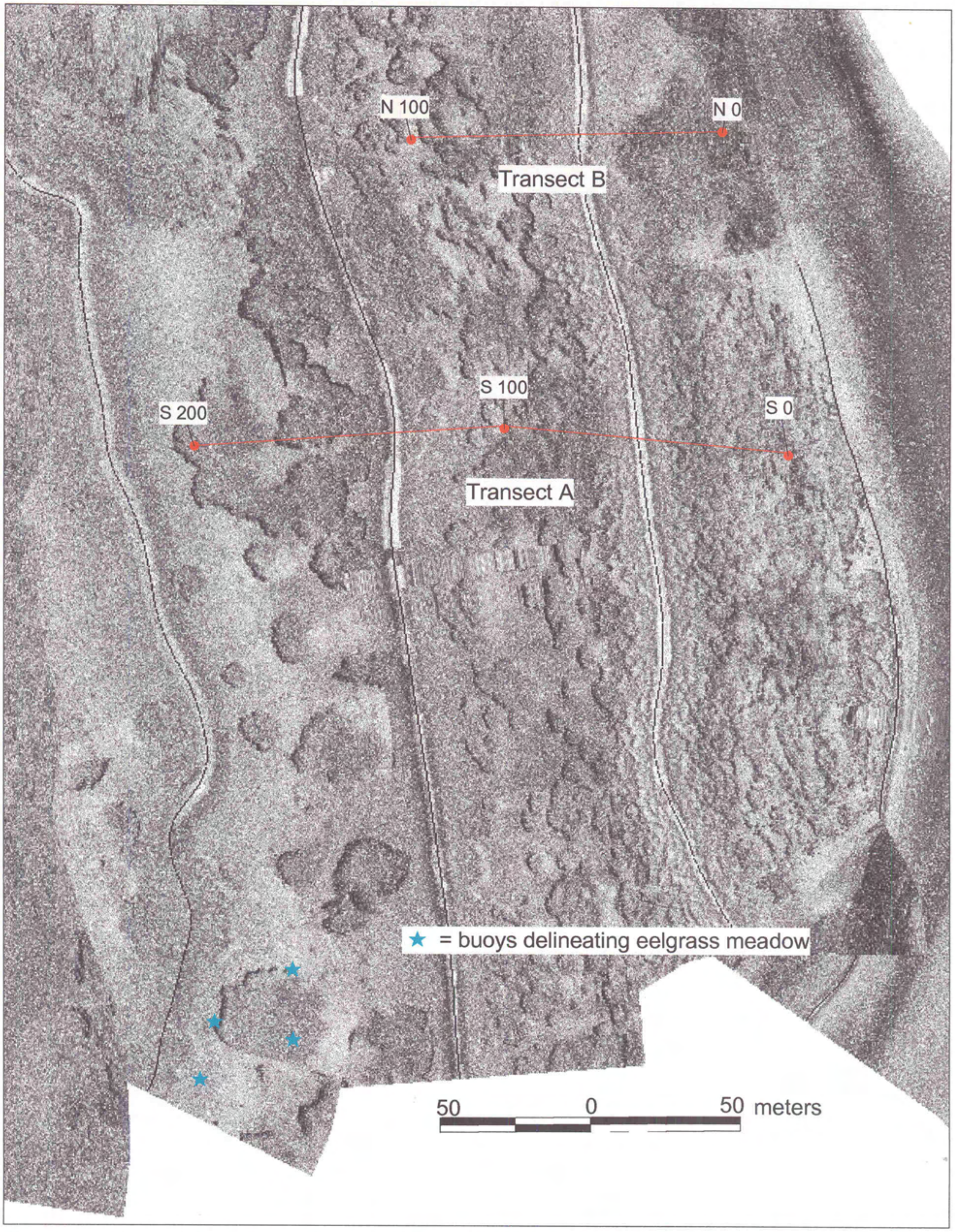

Figure 4. Diver assessment transects and buoy locations at the south end of Area E.

the typical habitat and substrate type found in the study area. The transects were placed perpendicular to shore. Transect A (the southern most transect) was 200 m in length. GPS coordinates were taken at the shoreward, or starting point (S-0) of the transect (0 m MLLW), midpoint (S-100), and endpoint (S- 200) of the transect (-3.5 m MLLW). Transect B (the northern transect) was 100 m in length with GPS coordinates taken at the starting point (N-0) of the transect (-0.5 m MLLW) and endpoint (N-100) of the transect (-2.0 m MLLW). At 10 m intervals along the transect line, divers took notes underwater on visual observations of substrate type, percentage of *Zostera marina* coverage, the type of cover (sparse, dense, continuous, patchy), and information on observed macroalgae and invertebrates. These data were used to verify the video observations and were compared with the final mapped polygons for accuracy.

As a check of the positional accuracy of the side scan sonar record, SCUBA divers located and marked the outer edges of a pre-selected eelgrass meadow with tethered buoys in Area E that had been delineated on the sonar record (Figure 4). The buoy coordinates were then determined using GPS and compared with the sonar record for positional accuracy.

2.2 Data Analysis

Data analysis included post-processing of field records (e.g., video, side scan sonar, visual observations) in a geo-referenced format that was used for the development of GIS maps delineating the substrate type and eelgrass and kelp coverage. The videotapes were further post-processed for macroinvertebrates, macroalgae, and fish, leading to GIS coverages of track lines with georeferenced positions of fauna and flora.

A quality assurance/quality control (QA/QC) assessment was conducted on the post-processed video footage to ensure accurate representations of the data (see Section 3.6)

2.2.1 Videography post processing

There were five primary habitat/species categories that were analyzed on the videotapes:

- substrate
- eelgrass
- macroalgae
- fish
- macroinvertebrates

Each of these primary categories was further subdivided based on distinguishing characteristics representative of the category, such as percentage of cover (eelgrass), substrate type, presence or absence of selected algal species, species identification, size, density and the number of individuals. Details of each classification category are described below.

2.2.1.1 Video Analysis

An Excel spreadsheet captured time and position data every 1 to 3 seconds in the field at the same time the information was captured on videotape. During post-processing, this data was entered into a template containing the header information for the five primary categories and sub-categories (Appendix A.1). As files were post-processed, they were combined for each area to import into GIS mapping software. A post-processing log sheet (Appendix A.2) was completed for each track line file of data, which contained file header information as well as anecdotal notes (e.g., turbidity in the water column, camera off the bottom, missing navigation data).

Video post-processing was conducted in several stages because of the numerous categories of biological and physical data analyzed. Initial post-processing included identification of eelgrass cover, substrate type, several types of macroalgae, and the presence of fish. The identification and enumeration of fish species was done separately as a second phase of post-processing. The final phase included assessment of total macroalgal cover and macroinvertebrate identification.

During post processing, the video monitor screen was divided in half horizontally with a thin line of tape. Eelgrass, macroalgae, substrate type, and macroinvertebrate classifications were recorded from the lower half of the monitor (i.e., closer to the camera). This viewing area ranged between approximately 1.5 and 4.2 square meters for the video transects parallel to shore and slightly less than 1 square meter for the transects perpendicular to shore. This reduced the subjective bias of the observer in classifying data that was a distance from the camera, and also allowed the observer to see what was coming into view before having to make a classification call. By alerting the observer to oncoming changes in categories, it allowed the tape to be stopped and data entered into the spreadsheet before changes occurred.

Fish were analyzed and classified using the entire screen. Since fish are mobile, some species only occurred at a distance and then moved out of the screen's view. This was particularly true for schooling species. Although fish at a distance could not be as readily identified to species, it was felt that these data were important to record to the nearest class.

During post processing, if data gaps were found in the videotape, the corresponding spreadsheet information with the position, time, and date stamp were omitted from further analysis as well. If there were less than or equal to, a 30-second gap in the video observation of the bottom (due to the camera being a significant distance off the bottom), and there were no recorded change in the dominant classifications before and after the gap, the data were determined to be useable. This situation occurred almost exclusively at the deeper depths (close to -30 m MLLW), where eelgrass was not found, and a change in substrate seldom occurred. If there were questions in the determination of a classification, a second independent observer reviewed the classification as well.

2.2.1.2 Classification Scheme and Codes

For each habitat or substrate type, a coded classification scheme was implemented to identify the video observation in a spreadsheet format. The general categories, represented as columns in the spreadsheet, are shown in Table 1. More detailed information indicating the corresponding GIS field header information and definitions is presented in Appendix B.

Eelgrass – Eelgrass (*Z. marina*) habitat was assessed and classified using a modification of a semi-quantitative system used in Chesapeake Bay (Orth et al., 1997) to monitor seagrass coverage annually. This method estimates eelgrass density (percentage of cover) by visually comparing the bed with an enlarged Crown Density Scale similar to those developed for estimating crown cover of trees from aerial photography (Paine 1981). We have modified this system somewhat to accommodate our underwater video data collection method (Table 2).

Table 1. Classification Categories Used for Underwater Video Post-processing

Category	**# of Codes**	**Type of Code**
Eelgrass	4	Density (% cover)
Dominant Substrate	5	> 50% dominant surface cover
Substrate Presence	6	>10% <50% surface cover
Artificial Substrate	9	Man made surface cover
Nereocystis luetkeana	2	Presence/absence
Sargassum muticum	2	Presence/absence
Ulva spp.	4	Density (% cover)
Fish Presence	2	Presence/absence
Fish Species ID	22	Identification
IND[1]/SCH[2]	2	Behavior type
Fish density	4	Density
Number of fish	0 to >100	Total individuals
Macroalgae	4	Density % cover
Sea pen density	4	Density
Invertebrate Presence	2	Presence/absence
Invertebrate Species ID	12	Identification
IND[1]/AGG[3]	2	Behavior type
Invertebrate Density	4	Density
Number of Invertebrates	0 to >100	Total individuals

[1] IND=individual
[2] SCH=school
[3] AGG=aggregate

Table 2. Eelgrass (*Zostera marina*) Classifications

Code	Description
0	0-10%; none to sparse coverage
1	10 – 50%; moderate coverage
2	>50%; dense coverage
3	Edge of dense bed or dense patches

The development of the estimations of eelgrass coverages was based on several inherent assumptions about the video data. Our camera angle of view was oblique when recording video data on track lines parallel to shore. It was not always easy to distinguish edges of dense beds that were closely spaced from contiguous beds. Therefore, "Category 2 - >50%" included dense patches or contiguous beds. If, however, an edge of a dense bed was distinctly visible or a single patch was dominant in the field of view and represented >10% of the viewable area of the bottom half of the screen, then it was classified as "Category 3 – edge" and over-rode Categories 1 and 2". An assumption was also made when operating in deeper water (25 m to 30 m) that eelgrass did not exist at this depth (Thom et al., 1998). These were generally areas where the "30-second gap" rule was employed (see Section 2.2.1.1; an assumption was made that eelgrass was not present and the area was categorized as 0).

Substrate—There were three major categories of substrate type that were classified: Dominant Substrate, Substrate Presence, and Artificial Substrate. The substrate classifications were adapted from *Marine and Estuarine Habitat Classification System for Washington State* (Dethier 1990). Dominant Substrate and Substrate Presence shared the same codes (Table 3) with the exception of shell hash that was added to the Substrate Presence category. Dominant Substrate occupied a majority of the viewable screen (>50%). If a second substrate type was present and identified in the same frame (between 10% and 49%) it was recorded as Substrate Presence. The category codes range from 2 through 7. Originally, Code 1 was mixed fines; however, because of the difficulty distinguishing between sand and mixed fines in the video, it was incorporated into Code 2 - Sand.

Table 3. Dominant Substrate and Substrate Presence Classifications

Code	Description
2	Sand—0.6-4mm. What appears visually to be sand and mixed fines
3	Gravel—Small rocks or pebbles, 4-64mm diameter
4	Mixed Coarse—consisting of cobbles, gravel, shell and sand (none exceeding >70% surface cover)
5	Cobble—rocks < 256mm (10 ") but > 64mm (2.5") diameter
6	Boulder—rocks > 256mm
7	Shell hash[a]—complete or fragments of shell

(a) Used for substrate presence only

The third substrate category was defined as Artificial Substrate. This was generally reserved for man-made items either placed intentionally or unintentionally on the bottom. An item was included if it encompassed >10% of the bottom half of the viewable screen. Additional explanations about items were added as notes to the spreadsheet during post-processing.

Table 4. Artificial Substrate Classifications

Code	Description
c	Concrete blocks
t	Tires
b	Bulkheads
r	Riprap
l	Logs
pl	Pilings—concrete or wood
w	Woody debris
p	Pipe
j/o	Junk /other-- man made items and/or items identified as noteworthy of reporting such as crab pots

Macroalgae—There were four categories of macroalgae: Total Macroalgae (Table 5) and three species that were generally easily recognized and were of interest to King County: *Ulva*-like species (Table 6), *Nereocystis luetkeana* (Table 7) and *Sargassum muticum* (Table 8). Due to the nature and extent of coverage for *Ulva,* a density estimate similar to eelgrass was the most appropriate method for categorization. *N. luetkeana* and *S. muticum* were much less extensive and most easily represented as presence/absence. Total Macroalgae included all of the previously mentioned categories and was categorized as a density estimate.

Table 5. Total Macroalgae Cover Classifications

Code	Description
0	0 – <10%; none
1	10–30%; sparse coverage
2	30-70%; moderate coverage
3	70-100%; dense coverage

Table 6. *Ulva* and *Ulva*-like Classifications

Code	Description
0	0 – 10%; none to sparse coverage
1	10 – 50%; moderate coverage
2	>50%; dense coverage
3	Edge of dense bed

Table 7. Bull Kelp (*Nereocystis luetkeana)* Classification

Code	Description
0	*Nereocystis* absent
1	*Nereocystis* present

Table 8. *Sargassum muticum* Classification

Code	Description
0	*Sargassum* absent
1	*Sargassum* present

Fish— Fish were identified to the nearest species, genus or class possible. Because fish were assessed using a relatively non-invasive, *in-situ* technique (underwater video), they were easily grouped into two behavioral categories: schooling and non-schooling. Five categories, were associated with fish identification: Fish Presence (present = 1; absence = 0); Behavior Type (individual = 1; schooling = 2); Species Identification (22 codes); Fish Density (Code 1: <10 individuals; Code 2: 10-100 individuals; Code 3: >100); and Number of Fish. If a Fish Density code of 1 was recorded, the counted number of individuals was recorded under Number of Fish. If a Fish Density code was recorded as 2 or 3, then an estimate was provided of the number of individuals in Number of Fish. Almost without exception, the Behavior Type of Individual (Code 1) corresponded to a Fish Density code of 1 and the Behavior Type of Schooling (Code 2) corresponded to Fish Density code of 2 or 3. The fish species and classes identified in this study are shown in Table 9.

Macroinvertebrates—Macroinvertebrates were identified to the nearest species, genus or class possible from the video track lines parallel to shore only. The only exceptions were sea stars, which were enumerated, but not identified to genus and species. Six categories or spreadsheet columns were developed for macroinvertebrates: Macroinvertebrate Presence (present = 1; absence = 0); Species Identification (12 codes); Behavior Type (individual = 1; aggregate = 2); Invertebrate Density (Code 0 = 0

Table 9. Fish Species Identified in Study Area Using Underwater Video Camera

Schooling Fish

	Common Name	Scientific Name
Uid	Unidentified fish	
Emb	Surfperch	*Embiotocidae*
Pil	Pile Surfperch	*Damalichthys vacca*
Str	Striped Surfperch	*Embiotoca lateralis*
Shi	Shiner Surfperch	*Cymatogaster aggregata*
Uip	Striped or Pile Surfperch	*Embiotoca lateralis or Damalichthys vacca*
Tub	Tubesnout	*Aulorhynchus flavidus*
Uib	Herring or Sand lance	*Clupea harengus pallasi or Ammodytes hexapterus*

Non-schooling Fish

	Common Name	Scientific Name
Uif	Flatfish	*Bothidae or Pleuronectidae*
Cit	Sanddab	*Citharicthys spp.*
Ple	Right-eyed Flatfish	*Pleuronectidae*
Sta	Starry Flounder	*Platichthys stellatus*
Cot	Sculpin	*Cottidae*
Uis	Buffalo or Great Sculpin	*Enophrys bison or Myoxocephalus*
Gre	Greenling	*Hexagrammos spp.*
Cab	Cabezon	*Scorpaenichthys marmoratus*
Lin	Lingcod	*Ophiodon elongatus*
Loc	Lingcod or Cabezon	*Ophiodon elongatus or*
Seb	Rockfish	*Sebastes spp.*
Qui	Quillback Rockfish	*Sebastes maliger*
Rtf	Ratfish	*Hydrolagus colliei*
Raj	Skate	*Raja spp.*

individuals; Code 1 = 1 to 5 individuals; Code 2 = 5-10 individuals; Code 3 = >10 individuals); and Number of Macroinvertebrates. The exception to the Invertebrate Density code was *Metridium giganteum* where Code 2 = 5-15 and Code 3 = >15 were used. A separate column was used to assess sea pen density (*Ptilosarcus gurneyi*), which were extensive in some areas and too numerous to count as individuals. All macroinvertebrates were recorded from the bottom half of the video monitor with the exception of jellyfish, which were found suspended in the water column above the substratum, and therefore recorded if found in any part of the viewing area of the screen. A list of the quantified macroinvertebrates is found in Table 10.

Table 10. Macroinvertebrates Identified in Study Area Using the Underwater Video Camera

	Common Name	Scientific name
uis	Sea Star	**Class Asteroidea**
uiu	Anemone	*Urticina sp.*
uia	Anemone	**Class Anthozoa**
met	White-plumed Anemone	*Metridium gigantium*
osp	Orange Sea Pen	*Ptilosarcus gurneyi*
uic	Crab	**Class Crustacea**
can	Dungeness, Red Rock, or Slender Crab	*Cancer sp.*
cal	Sea Cucumber	*Parastichopus californicus*
uin	Nudibranch	**Class Gastropoda**
jel	Jellyfish	**Class Scyphozoa**
uib	Bivalve	**Class Bivalvia**

2.2.1.3 Video QA/QC

Several phases of QA checks were implemented to assess the video post-processing techniques and ensure the data recorded were as accurate as possible. Initial discussions were held to determine appropriate classifications of all categories and density coverages where relevant. Two individuals were trained to post-process the video data for substrate type, eelgrass, kelp, and macroalgae. Training sessions were conducted to ensure that both individuals were classifying habitat and substrate similarly and correctly. Frequent spot checks occurred to maintain consistency between observers. One individual analyzed all of the fish and macroinvertebrate data to maintain consistency and avoid bias.

After the data were post-processed, two other phases were implemented to assess and correct any identified errors. The first was a comparison of the video track line map overlays. By comparing the intersections of video data between parallel and perpendicular track lines that were post processed independently, any discontinuities were visually apparent, examined, and corrected. Substrate type, eelgrass, *Ulva spp.*, *N. luetkeana*, and *S. muticum* were examined in this manner. The primary discrepancy occurred with substrate type where gradations can occur between categories. These were corrected by discussion between the two observers until a consensus was reached.

A third phase involved an independent observation and spreadsheet recording of selected frames of the video data and comparison with the original video post-processing spreadsheet. Blank templates were created to sample the video data for a second independent observation at a frequency of one video frame for every 3 minutes of parallel track video data and one frame for every 1 minute of perpendicular video data. The original and second observations were compared between spreadsheets and an error type assessed:

Type 1 error: misidentification of substrate or habitat error (corrected)

Type 2 error: subjective call (identification changed)

Type 3 error: subjective call (no change necessary)

2.2.2 Side Scan Imagery and GIS Map Products

A mosaic of tiff images of each area with a UTM grid overlay and associated coordinates was imported into MapInfo Professional GIS software for geocoding. Tick marks of at least four known coordinates on the tiff image were used to georeference the image in MapInfo. Tick marks were checked to ensure that the control points were within a tolerance of 1 pixel before proceeding. Imagery was converted to Washington State Plane Coordinates Zone North in MapInfo.

The tiff images were also plotted on a large format printer at a pixel resolution of 0.50 m/pixel for delineation. A clear acetate overlay was placed over each survey area mosaic, and eelgrass, substrate, and kelp were delineated manually. Polygons were delineated manually using supporting video track line overlays plotted in MapInfo, field observations (particularly of kelp), and the acoustic signature, or targets of the side scan imagery.

Although a number of substrate types were observed in the video, only two major types were delineated for the final map products (sand and mixed coarse). Subtle substrate changes were difficult to detect in the sonar imagery, although definitive changes between sand and mixed coarse substrate (particularly close to shore) were easy to detect and delineate.

The acoustic signature of eelgrass was quite distinct, allowing easy detection and delineation of the edges of meadows as well as coverage estimates. Certain decision rules were employed to guide final polygon delineations. An eelgrass meadow (Code 3: dense cover) was considered a separate polygon if its dimensions on any one side were at least 30 m across. Dense meadows that did not meet this criterion were coded as 2, moderate or patchy. The delineation between sparse and moderate coverage was aided by video data. The polygon delineation classifications for eelgrass that were derived from video and side scan information, and used in the final map products are listed in Table 11.

Table 11. Eelgrass (*Zostera marina*) Polygon Coverages

Code	Description
0	0 – 10%: very sparse coverage
1	10 – 50%: sparse coverage
2	50 – 85%: moderate or patchy coverage
3	85 – 100%: dense coverage

Kelp was delineated primarily by visual surface observations, notes made in the field of surface foliage, and through underwater video observations. We intentionally avoided areas of dense kelp beds to avoid entanglement of gear with the kelp; however occasional acoustic kelp targets were observed on the sonar record and these were included in the final map products.

Delineated acetate overlays were reviewed and edited as necessary before digitization. Tick marks of at least four known coordinates on the UTM grid underlying the acetate were used to georeference the image in MapInfo. Tick marks were checked to ensure that the control points were within a tolerance of 0.01 inches. Polygons were then digitized on a digitizing table in point mode. Each type of polygon was placed in either a vegetation or substrate file for each area (24 files total), and each polygon represented a unique coverage that did not overlap any other coverage in that file.

By design, the collected side scan sonar and underwater video data overlapped between adjacent areas slightly, resulting in overlap of polygons. To merge coverage of all areas, close-ups of overlapping areas were compared with side scan mosaics and underwater video data to determine the best representation of the study area. The polygons were merged to create non-overlapping, continuous coverage polygons for substrate and vegetation. Statistics for basal area coverages, lengths of track lines, and number of observations were calculated using Seagate Crystal Reports software for MapInfo.

3.0 RESULTS

The results section includes an overview of the field data collected, GIS information and maps of the habitat coverages for each area, synthesis tables of macroalgae, fish and macroinvertebrate video data, and a discussion of the quality assurance data from the video and dive surveys. Detailed maps of the video observations for all types of data are included in Appendices C through M.

3.1 Overview of Collected Field Data

The underwater video and side scan sonar survey were conducted between October 6, 1999, and November 14, 1999. A total of 144 km of underwater video footage was collected and 1033 hectares of basal area coverage were mapped with side scan sonar. The areas mapped are defined in Table 12 and shown in Figure 2.

Table 12. Descriptions and Length of Mapped Shoreline Areas

Area	Description	Shoreline Length (km)
A	Picnic Point to Norma Beach	2.28
B	Norma Beach to Browns Bay	3.08
C	Browns Bay to north Edmonds	1.09
D	North Edmonds to Underwater Park	1.40
E	Edwards Point to Point Wells	2.07
F	Point Wells	1.19
G	Richmond Beach	2.19
H	Boeing Creek	2.18
I	Highlands	1.92
J	Carkeek Park	1.21
K	Blue Ridge to North Beach	2.68
L	Meadow Point	0.77

Specific information on the number and length of video track lines for each area and the basal area coverage of the side scan sonar is given in Table 13. The number of video tracks parallel to shore ranged from 3 (Area B) to 9 (Area E), depending on the distance between shore and a depth of -30 m depth (MLLW). Video transects perpendicular to shore ranged from 1 in Areas C and L to 22 in Area G, depending on the selected characteristics and priority given by King County. Transects were selected to represent the following attributes: high, low, or no bluff along shore, steep or shallow grade in the upper subtidal zone, stream outlets, developed and undeveloped shoreline, historical bluff slides, and CSO outfalls. Side scan sonar coverage ranged from 25 hectares in Area L to 149 hectares in Area K. Video data transect locations are shown in Figure 5 (Areas A - F) and 6 (Areas G - L).

Table 13. Length and Area Covered by Video and Side Scan Sonar for Each Area

Area	Length of shoreline (km)	# and length of parallel tracks (km)	# and length of perpend. tracks (km)	Total length of video tracks (km)	Side scan coverage (hectares)
A	2.276	5 / 8.87	6 / 1.87	10.74	69.37
B	3.075	3 / 8.85	3 / 1.36	10.21	94.63
C	1.094	4 / 6.56	1 / 0.47	7.03	70.41
D	1.404	7 / 10.38	3 / 1.94	12.32	98.65
E	2.071	9 / 16.81	15 / 10.05	26.86	150.15
F	1.193	5 / 5.10	3 / 1.25	6.35	55.75
G	2.196	4 / 12.29	22 / 10.62	22.91	146.34
H	2.184	6 / 10.53	9 / 3.42	13.95	112.66
I	1.922	4 / 6.77	2 / 0.93	7.7	88.94
J	1.205	5 / 5.67	2 / 0.30	5.97	64.64
K	2.676	6 / 15.85	3 / 1.38	17.23	149.17
L	0.767	4 / 2.48	1 / 0.52	3	25.29
Total	22.063	62 / 110.16	70 / 34.11	144.27	1126

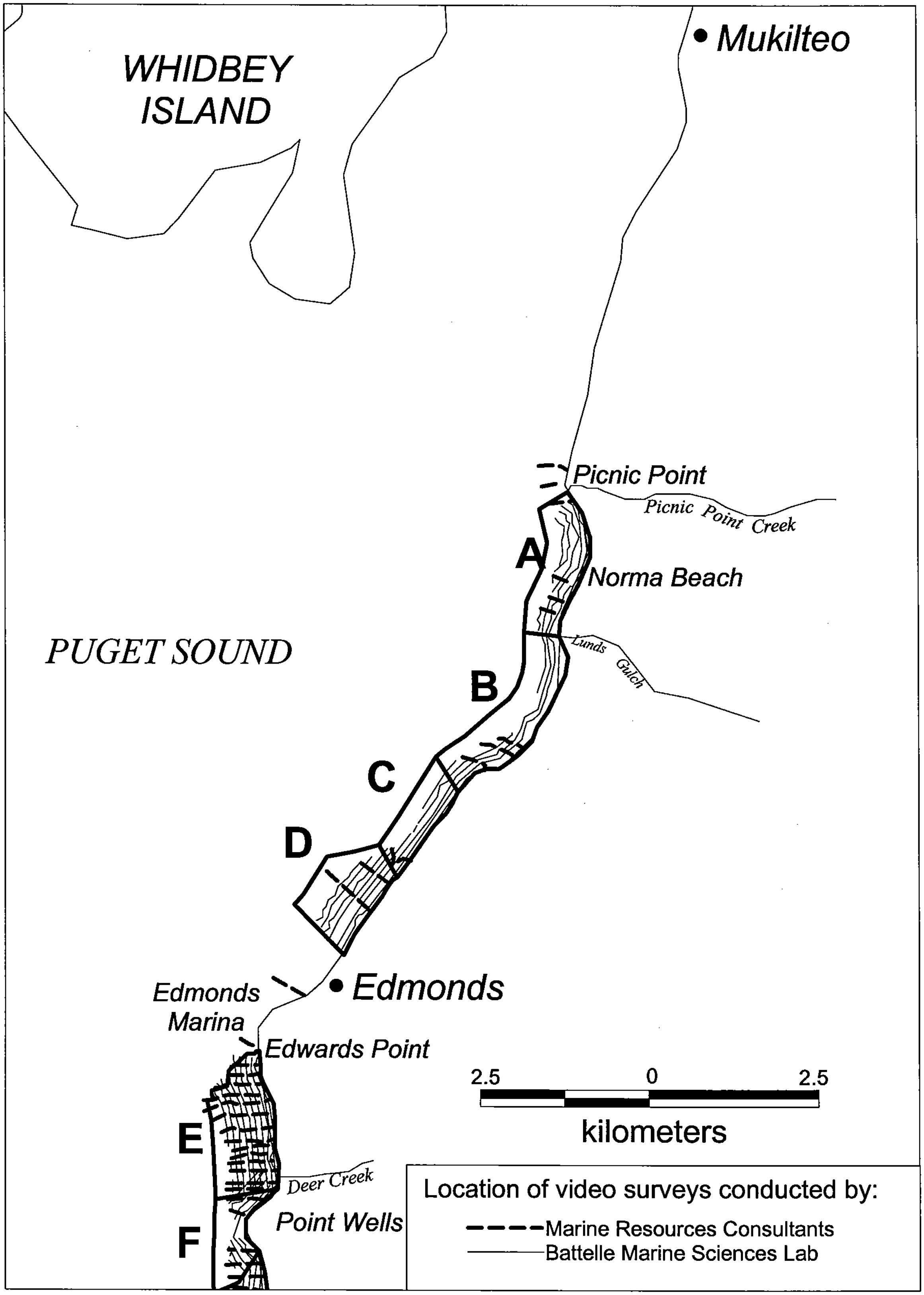

Figure 5. Location of video tracklines in Areas A-E.

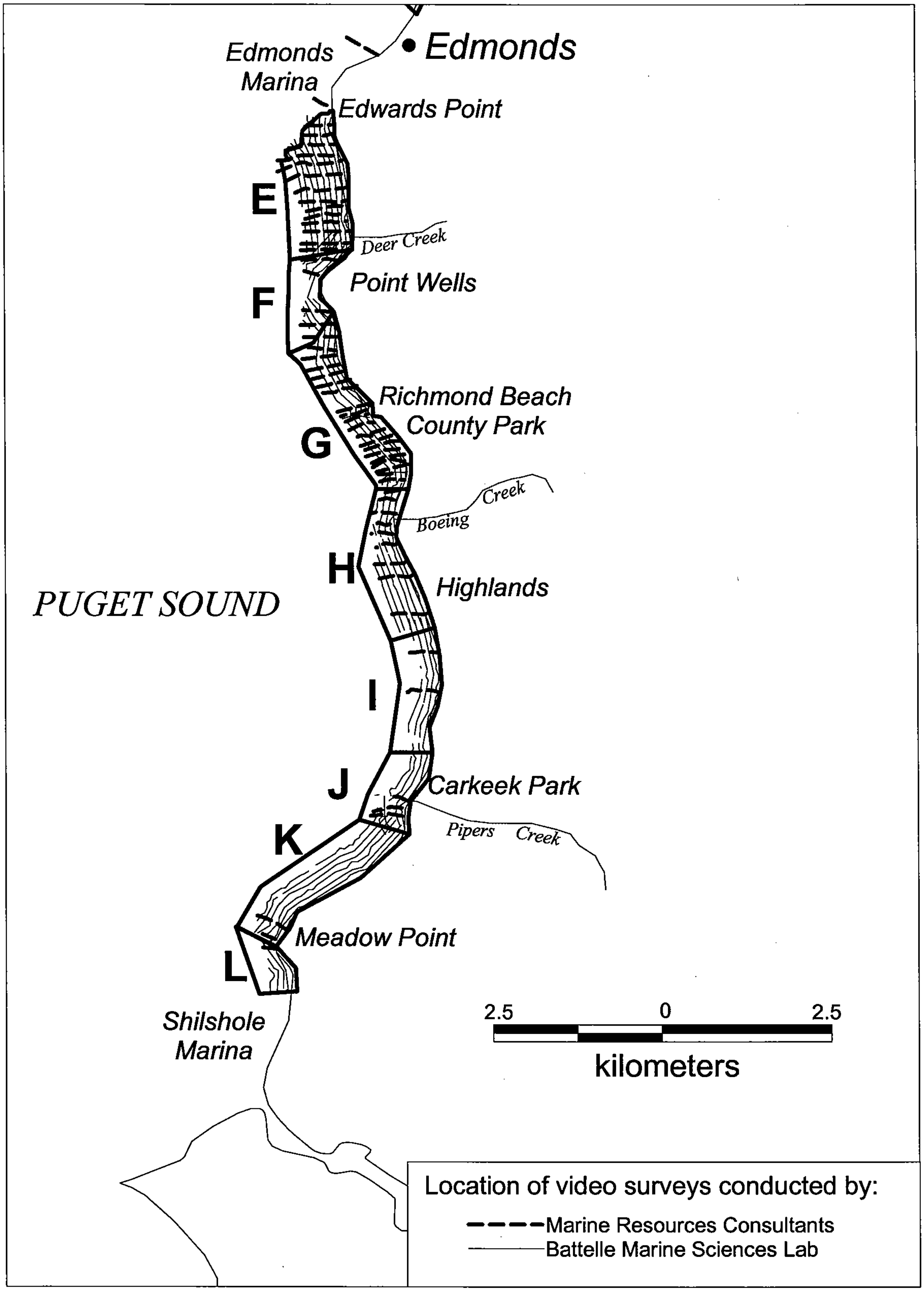

Figure 6. Location of video tracklines in Areas E-L.

3.2 Eelgrass, Substrate and Kelp Habitat Delineations

Habitat coverages were delineated using a combination of side scan sonar, underwater video and visual observations from the surface. The side scan sonar was extremely effective in delineating eelgrass habitat. This was supported by video as a means of 'ground-truthing', and was especially useful for interfaces between sparse, moderate, and dense coverages. Examples of various eelgrass coverages are shown in Figures 7 and 8 (dense coverage), Figures 9 and 10 (moderate coverage), and Figures 11 and 12 (sparse coverage).

The side scan data was supported to a greater extent by video observations for determination of substrate type. Definitive interfaces between substrate types were readily detectable in side scan data (Figure 13), however subtle changes between substrate type were more easily seen in the video. Features such as sand waves, approximately one to two meters in height, were also noted at the north end of Area E, just south of the pier using side scan sonar (Figure 14). Other targets, such as docks and piers (Figure 15 and 16), were identified readily with side scan sonar; wood debris (Figure 16) was also identified as a target and confirmed with underwater video.

3.2.1 Vegetation Coverages

Vegetation cover (eelgrass and kelp) for the entire study area is shown on Figure 17(a) and (b). The basemaps for all coverages are 1994 and 1996 USGS orthoquads. Eelgrass was found in all study areas and kelp beds found in all areas except G, J, K, and L. Polygons were delineated based on sparse, moderate, or dense coverage, and kelp (*N. luetkeana*) based on its presence or absence. In certain areas where kelp beds were extensive (e.g., Area D near the Edmonds Underwater Park), documentation of kelp

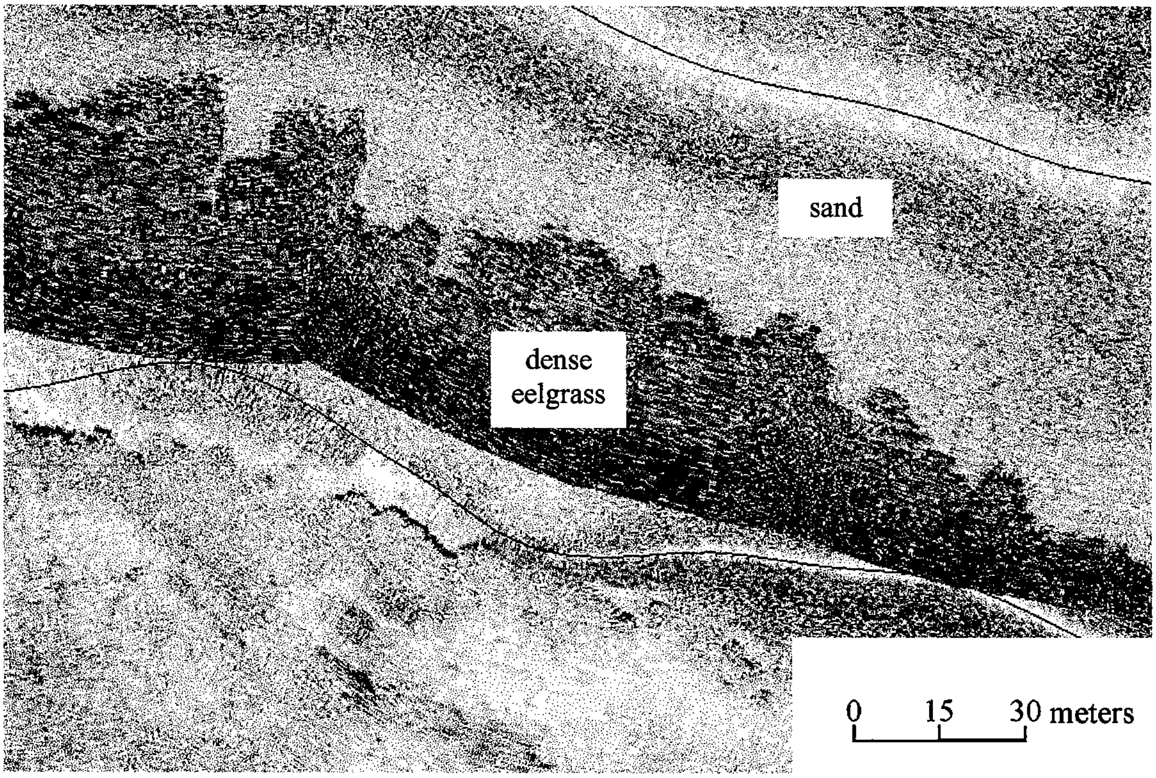

Figure 7. Example of dense eelgrass coverage in Area A.

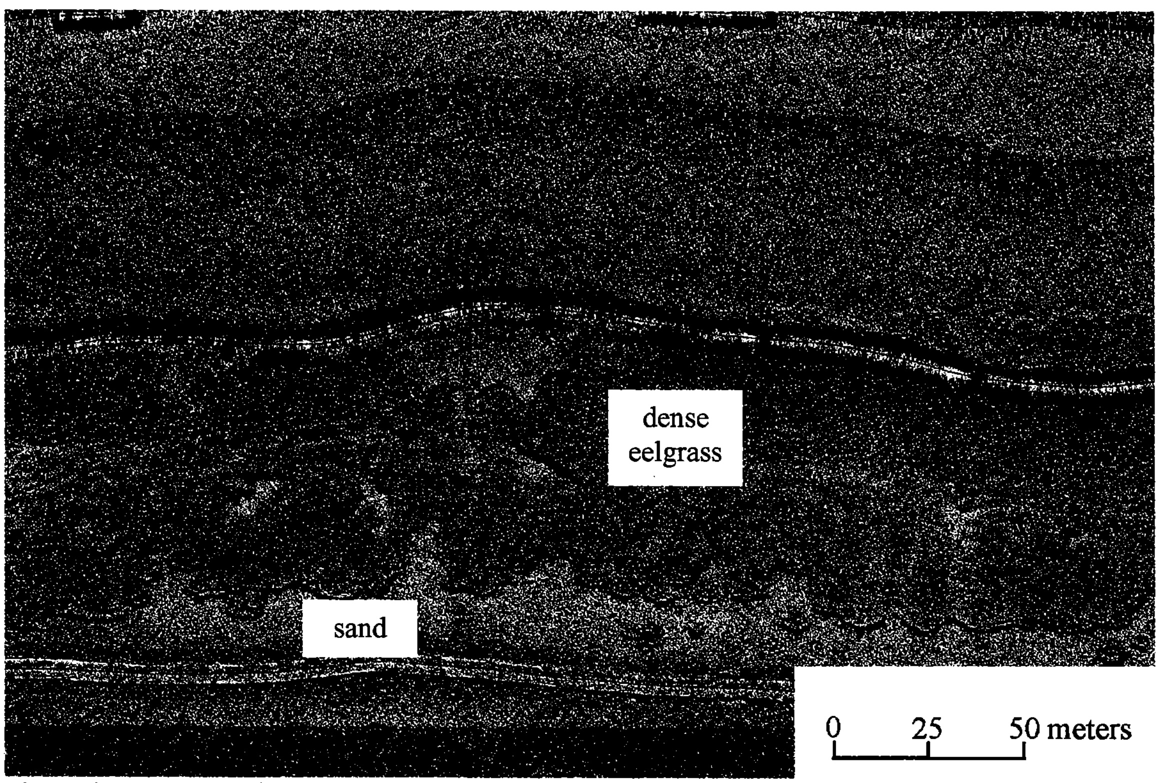

Figure 8. Example of dense eelgrass coverage in Area K.

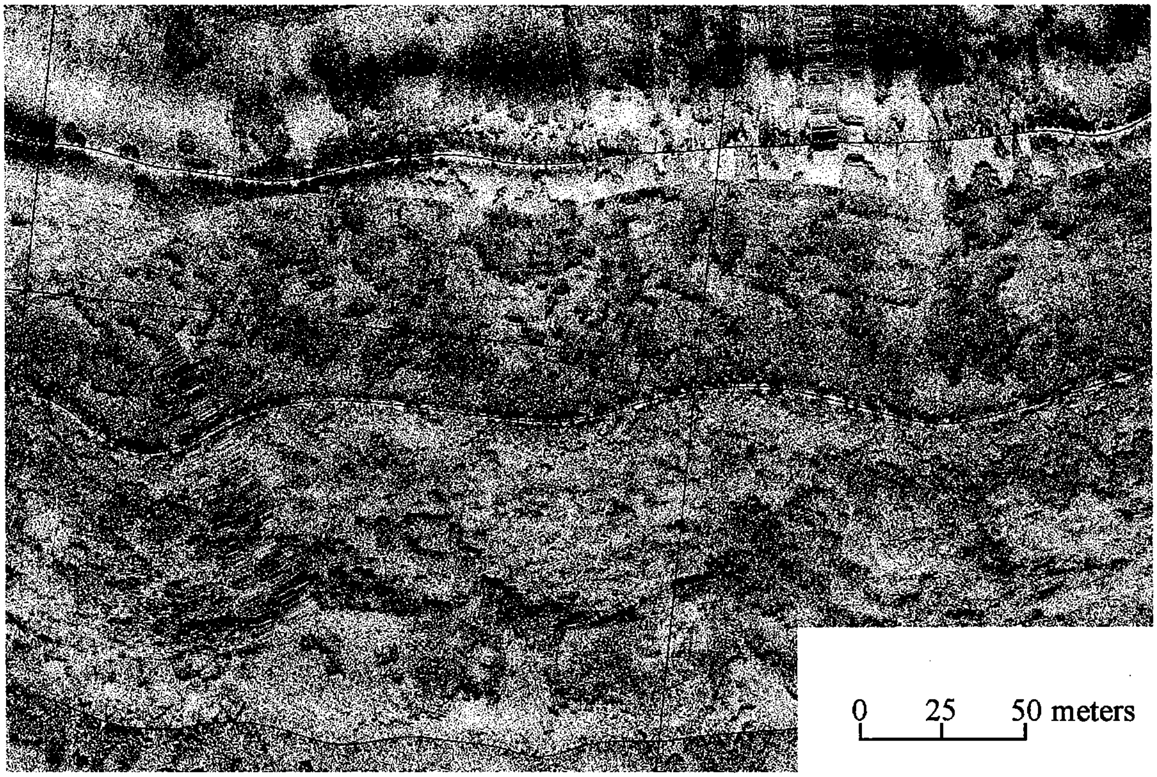

Figure 9. Example of moderate eelgrass coverage in Area E.

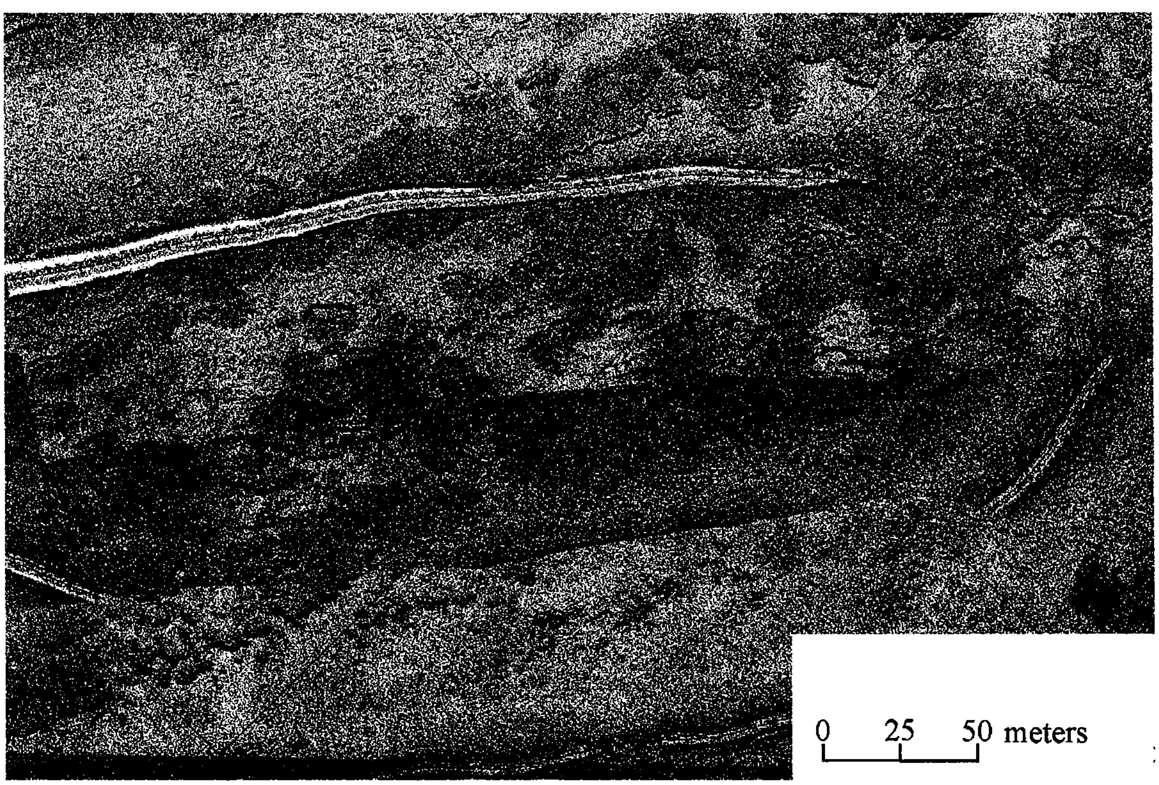

Figure 10. Example of moderate eelgrass coverage in Area K.

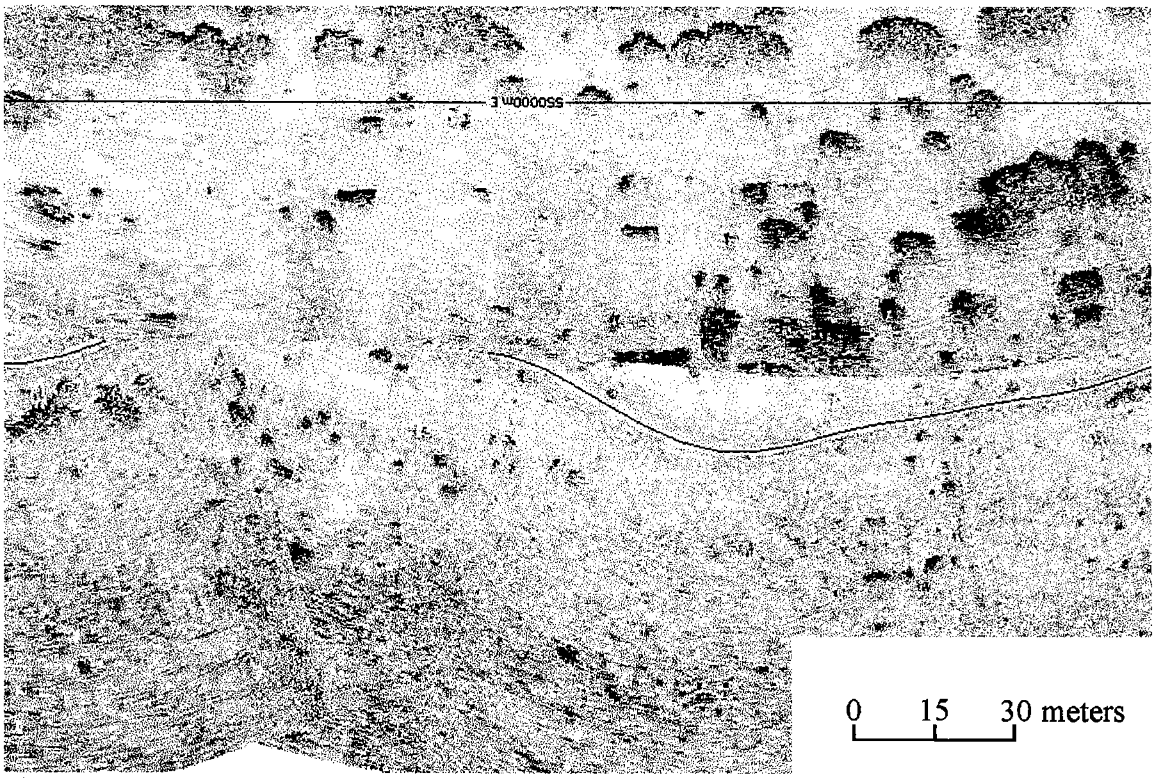

Figure 11. Example of sparse eelgrass coverage in Area A.

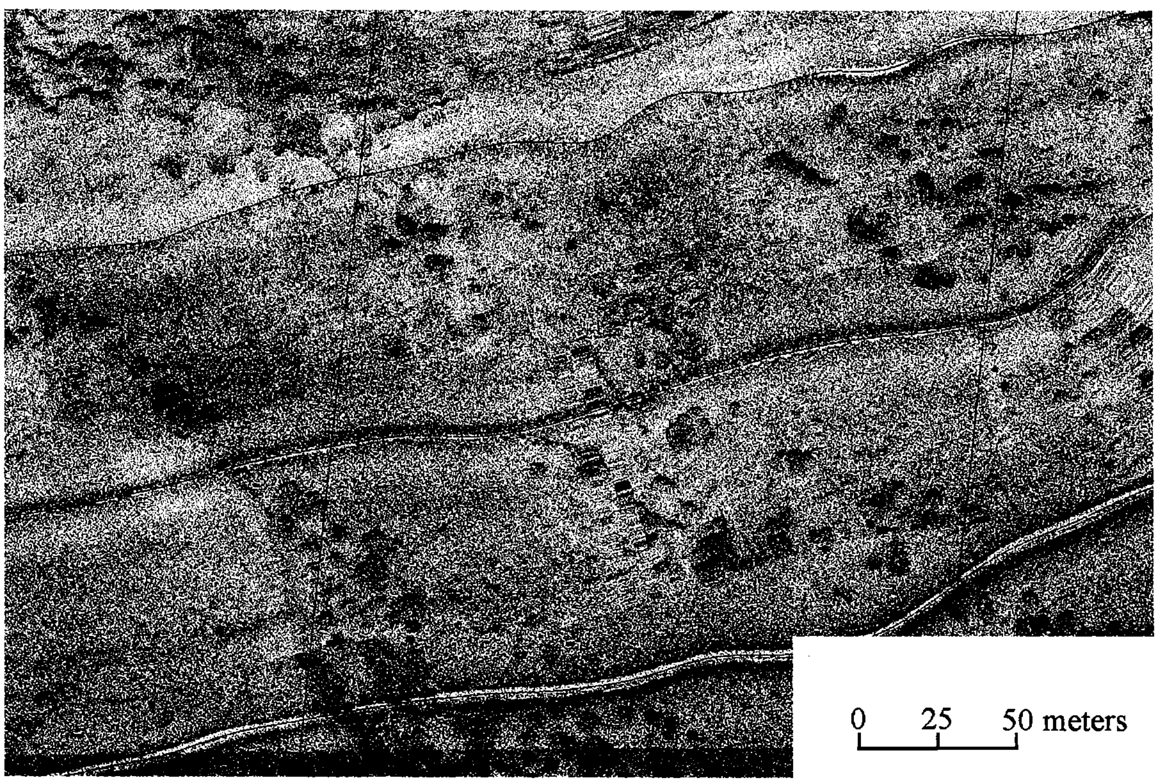

Figure 12. Example of sparse eelgrass coverage in Area E.

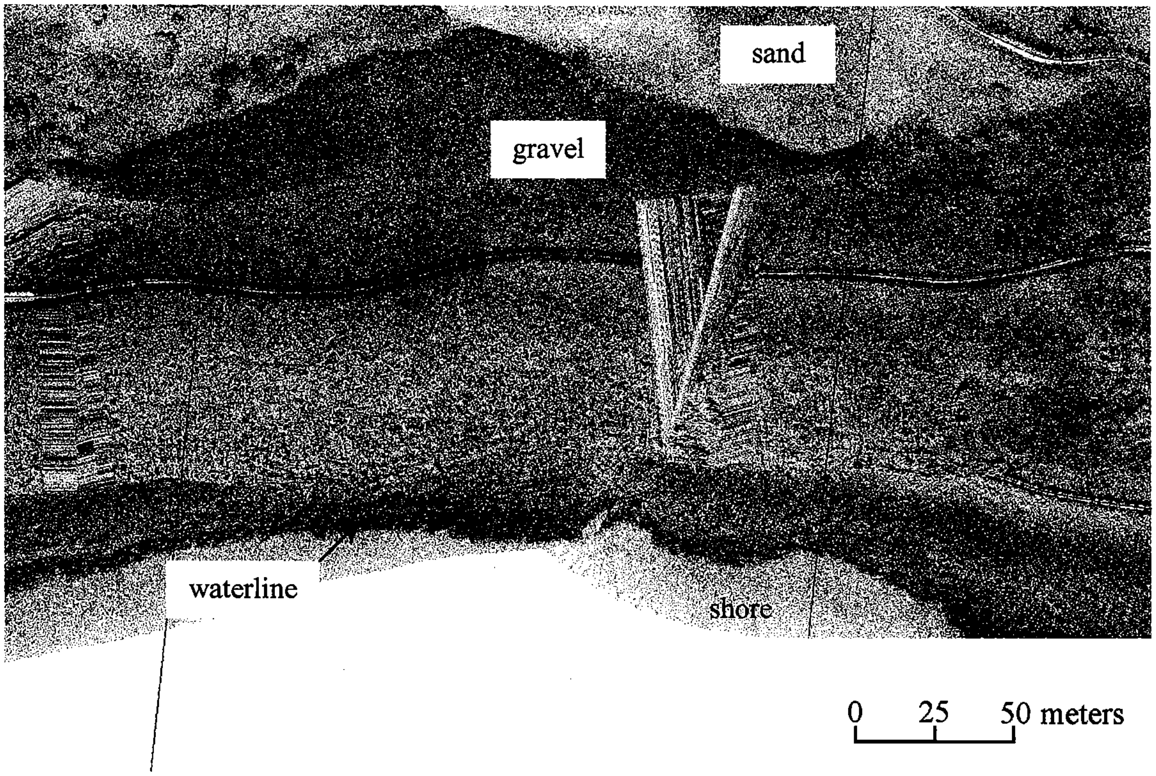

Figure 13. Example of the interface between sand and gravel, and the shoreline.

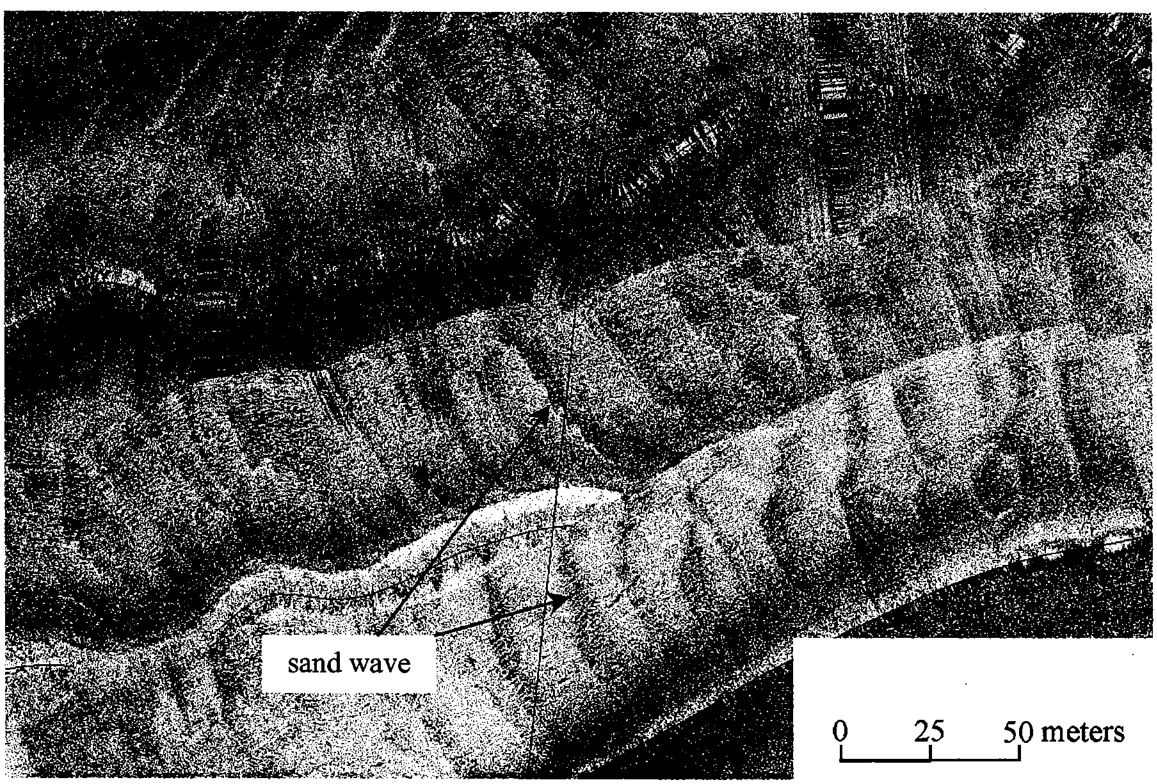

Figure 14. Example of sand waves near pier at north end of Area E.

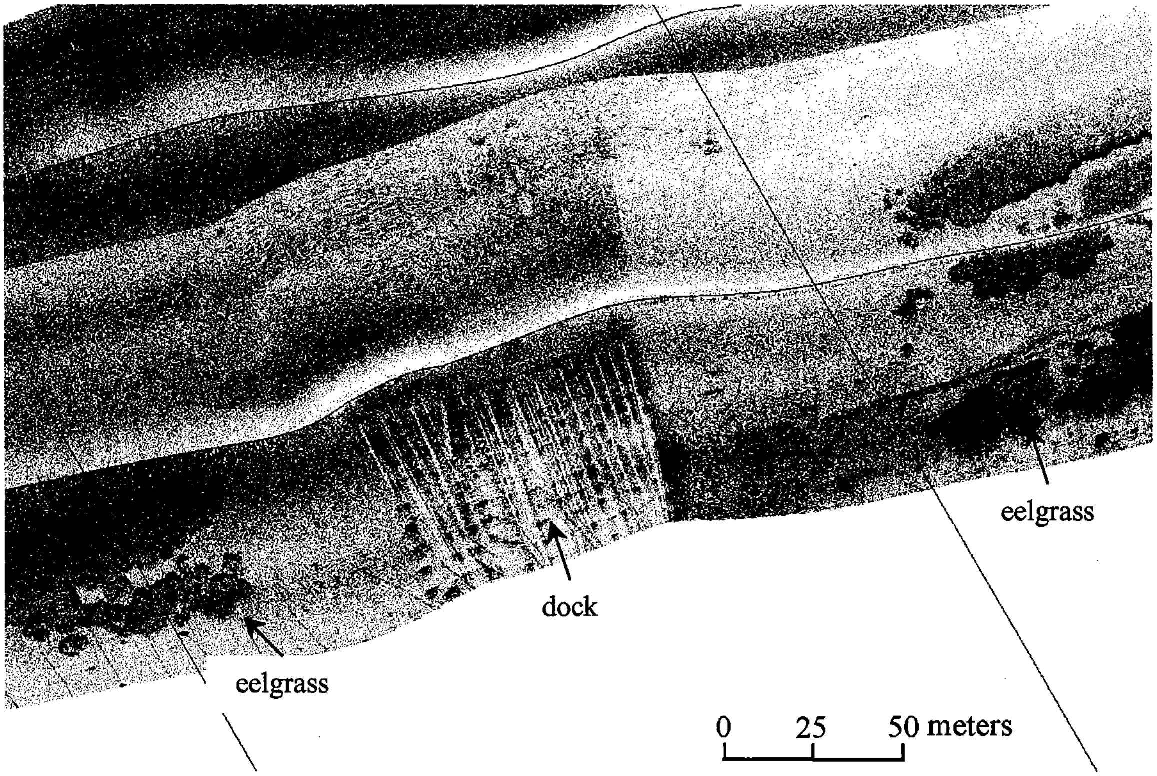

Figure 15. Example of dock and eelgrass meadows at Meadowdale (Area B).

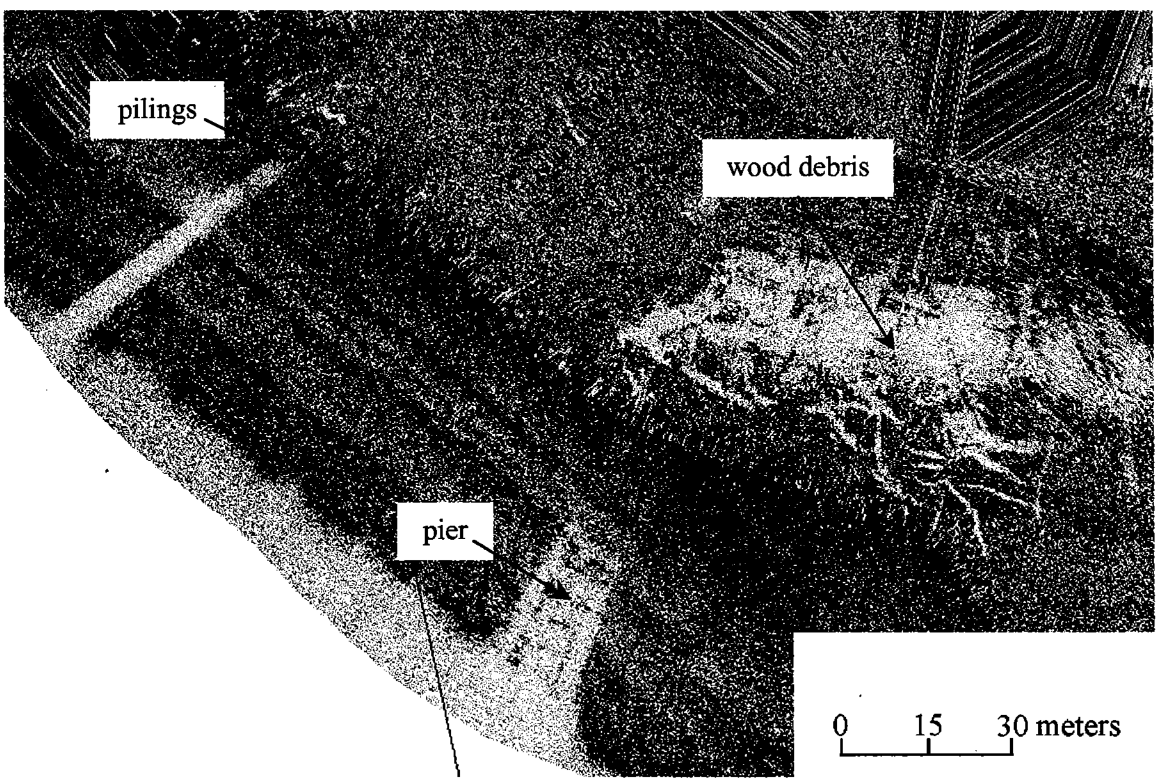

Figure 16. Example of pier, pilings, and wood debris (confirmed with underwater video) at Point Wells (Area F).

coverage was based on surface visual observation only (see Section 2.2.2). Detailed vegetation coverages for individual areas are shown in Figures 18 through 23. The maps of video track line coverage of eelgrass for each area are provided in Appendix C. Basal area estimates for density coverages of eelgrass and kelp are shown in Table 14.

3.2.2 Substrate Coverages

Substrate coverages include the Dominant Substrate type, docks, and smaller artificial structures. Substrate and habitat cover for the entire study area are shown in Figure 24 (a - b). Sand and mixed coarse substrate with eelgrass and kelp coverage are identified separately. Large structures (docks) are also delineated. Detailed coverages for individual areas are shown in Figures 25-30. Corresponding video track line data for Dominant Substrate is provided in Appendix D. Sand was the predominant substrate in all areas; some mixed coarse substrate was found in each area, generally close to the shoreline. Basal area estimates for substrate type and artificial structures are shown in Table 15. A Waterline category is given in Table 15 which refers to areas recorded in the side scan sonar record that were above the waterline, or water's edge at the time the record was collected. Under certain conditions, sonar can detect where the water surface and the bottom topography meet. This was included in the record primarily as a geographic reference point. Other artificial structures that were observed and recorded from the video data (e.g., logs, other wood debris, crab pots) are documented in Appendix E. Basal area estimates of habitat types (e.g. sand with eelgrass, sand with kelp) are provided in Table 16.

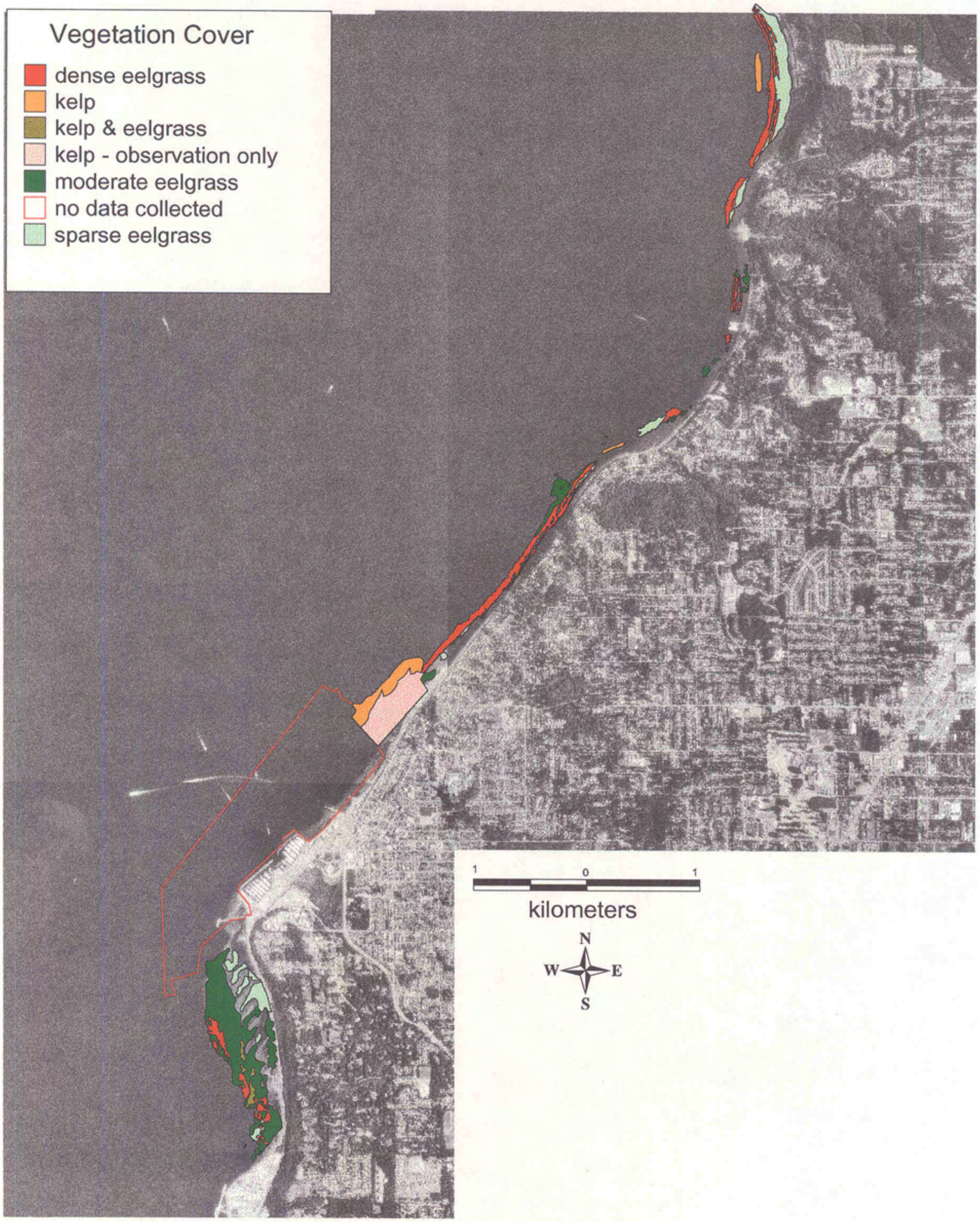

Figure 17a. Vegetation cover from Picnic Point to Point Wells (Areas A-E).

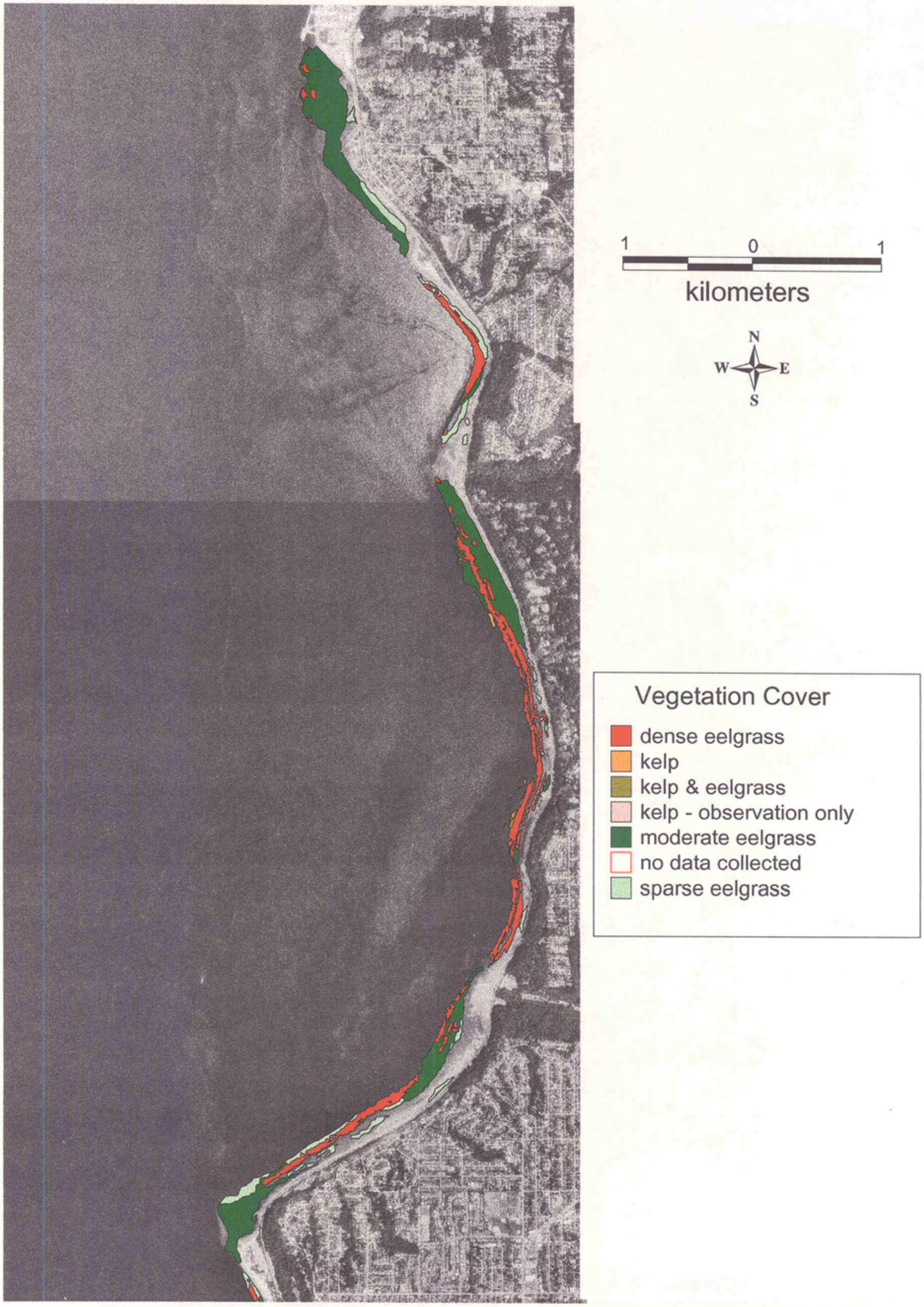

Figure 17b. Vegetation cover from Point Wells to Shilshole Marina (Areas F-L).

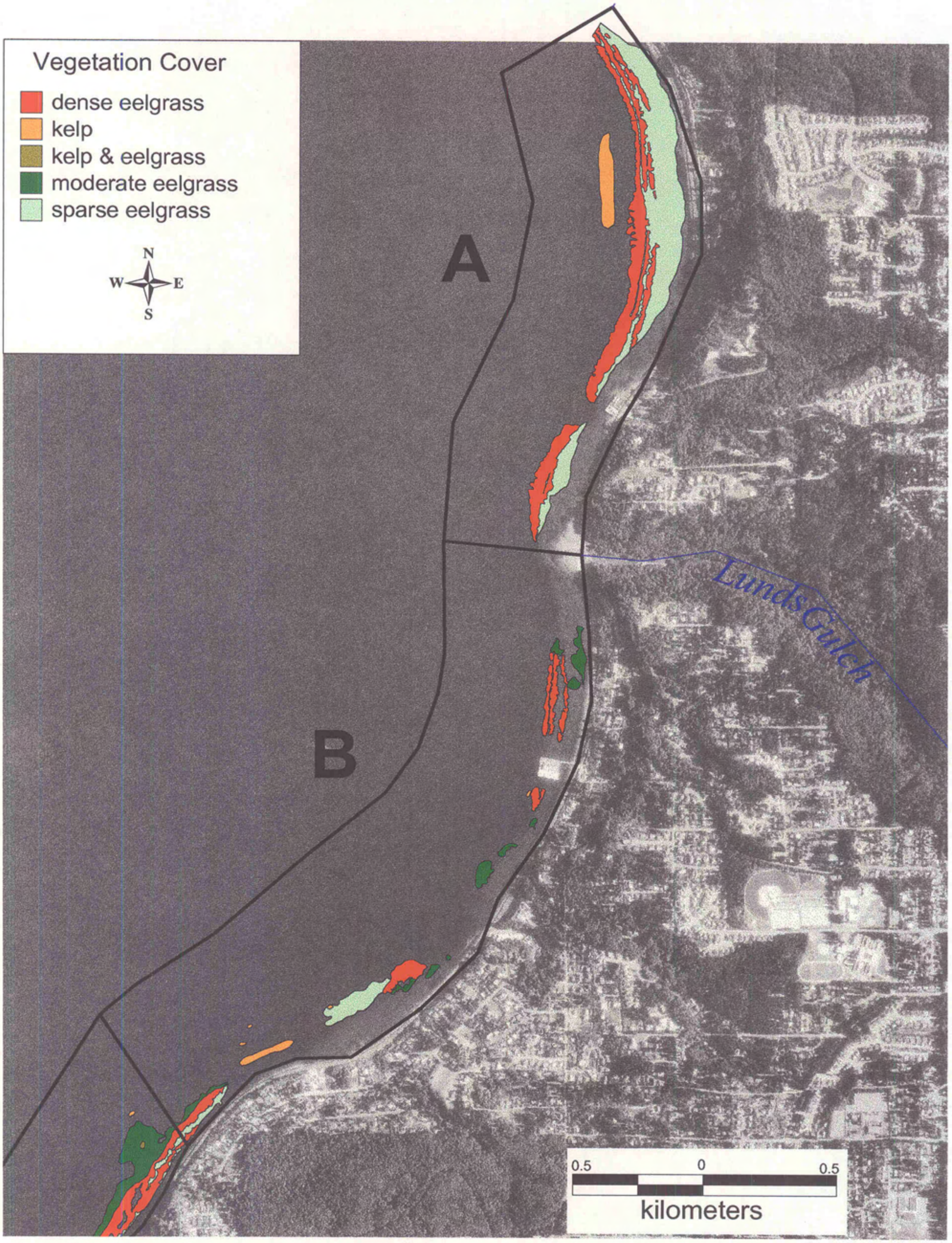

Figure 18. Vegetation cover at Areas A and B.

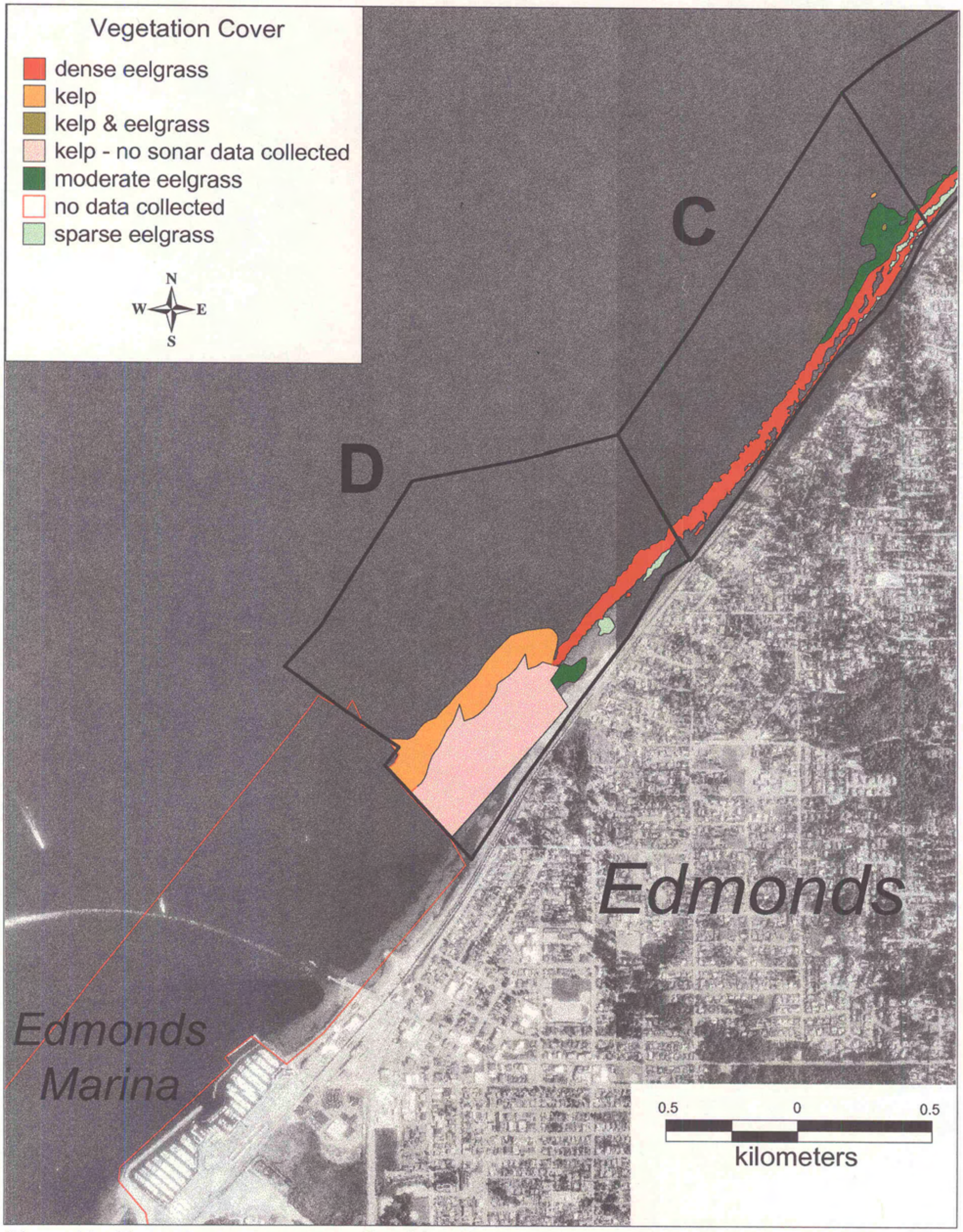

Figure 19. Vegetation cover at Areas C and D.

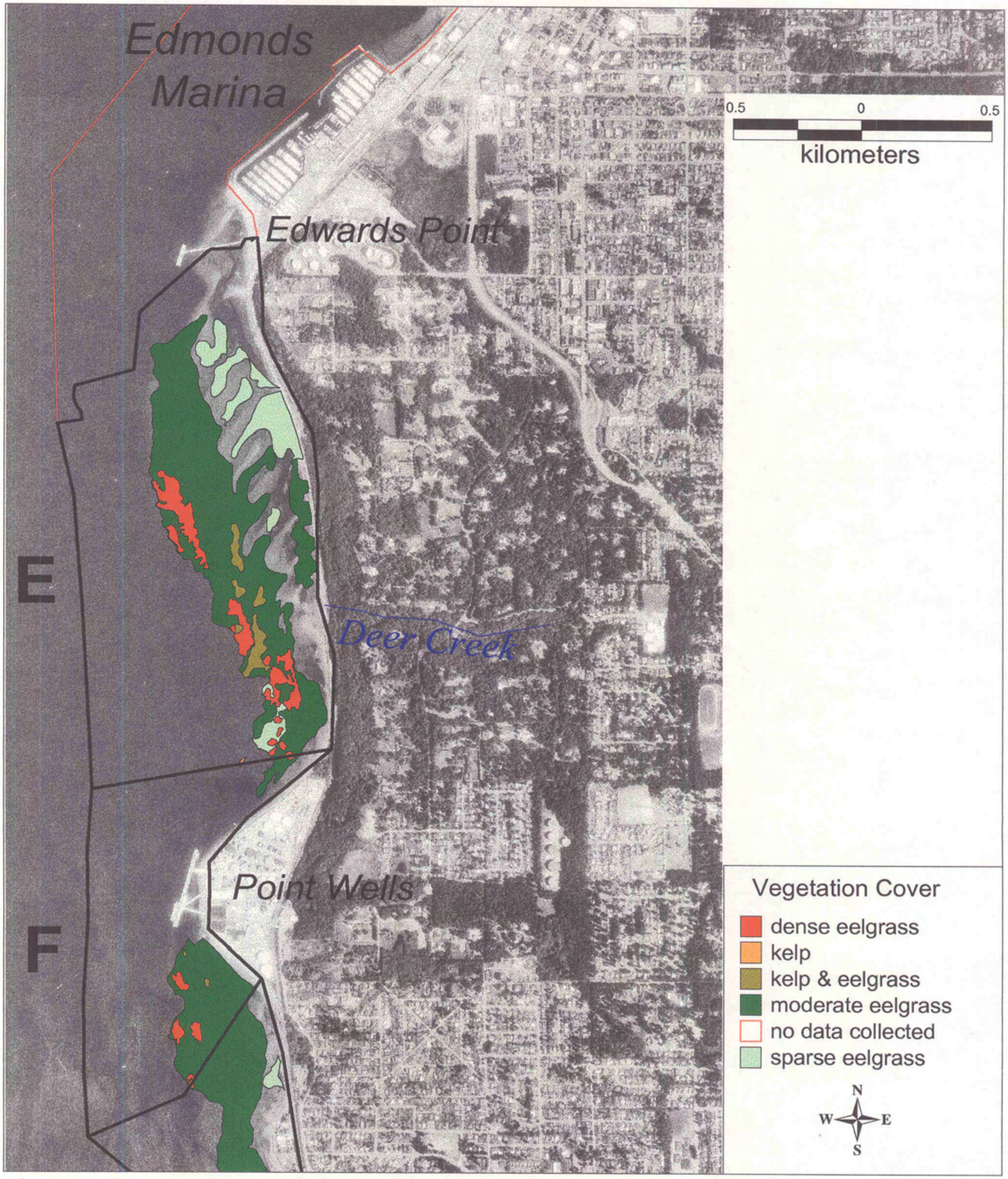

Figure 20. Vegetation cover at Areas E and F.

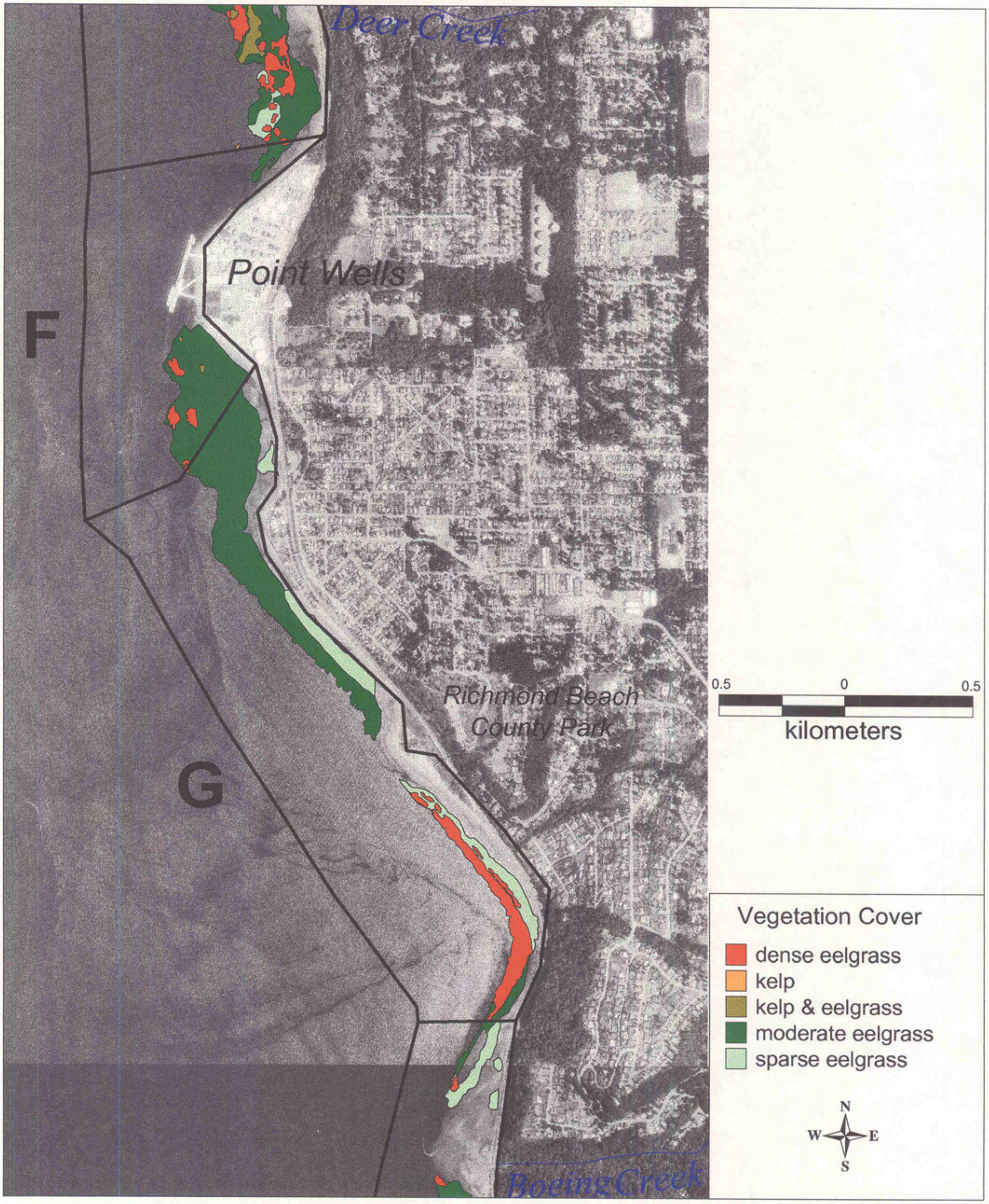

Figure 21. Vegetation cover at Areas F and G.

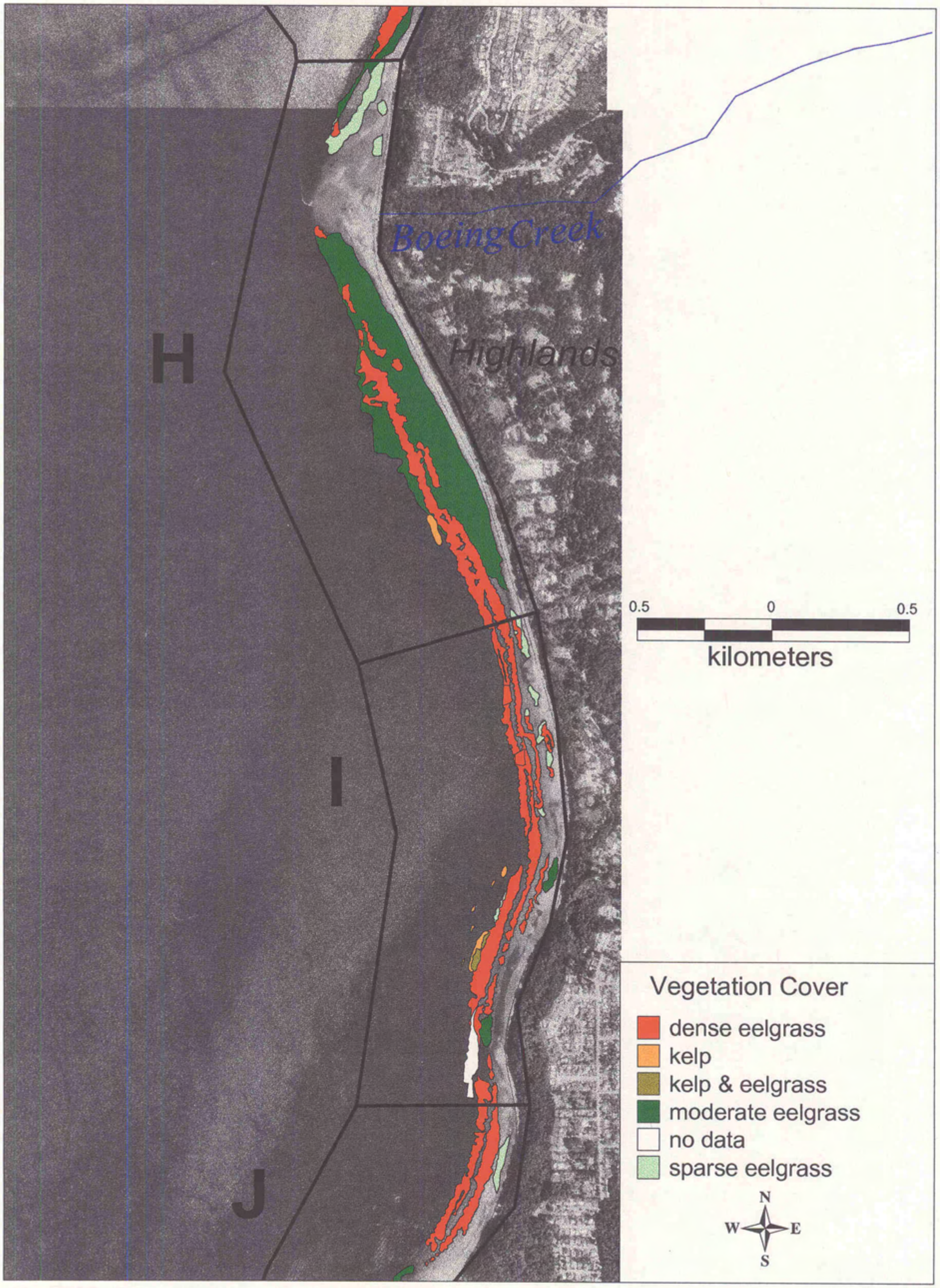

Figure 22. Vegetation cover at Areas H and I.

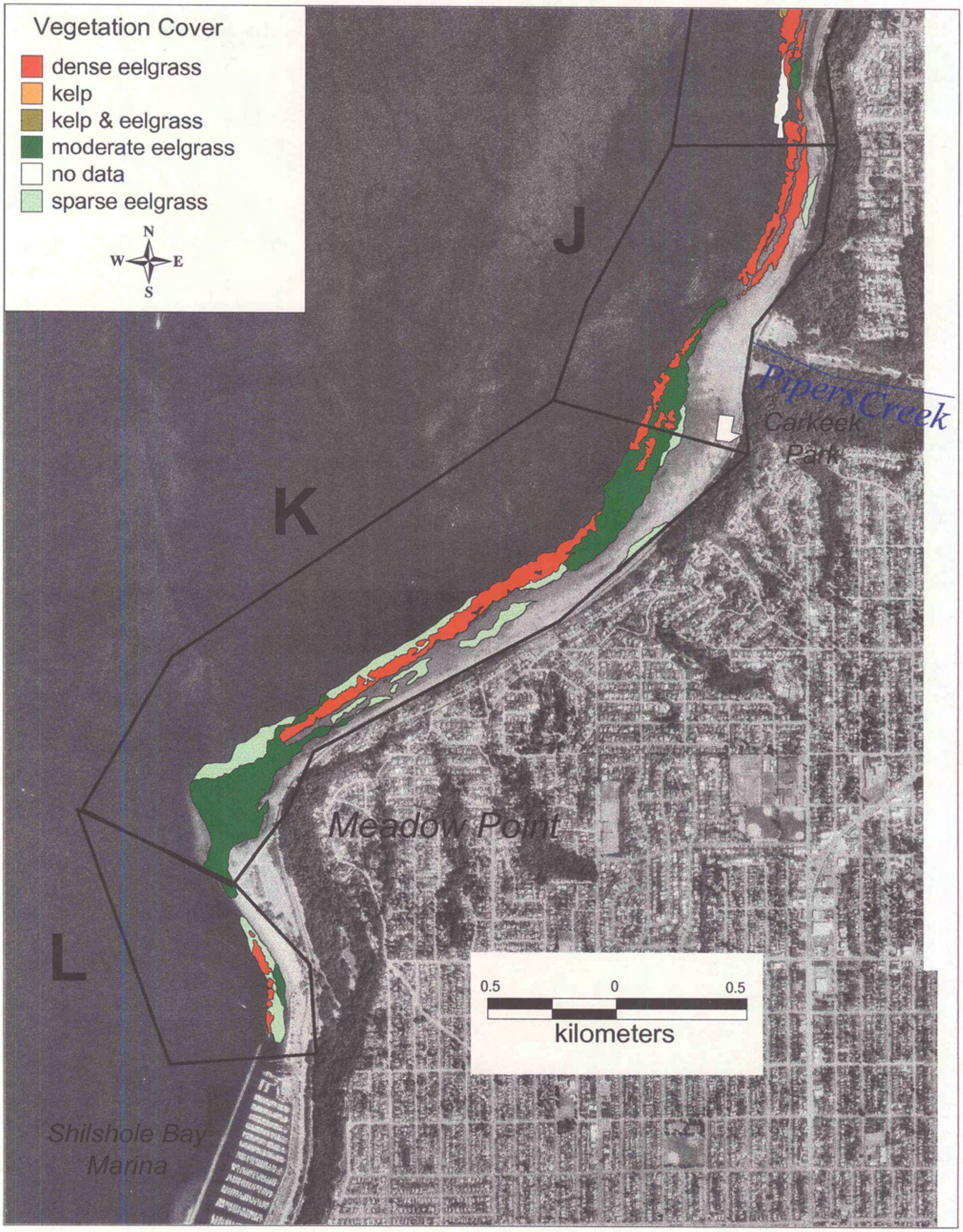

Figure 23. Vegetation cover at Areas J, K, and L.

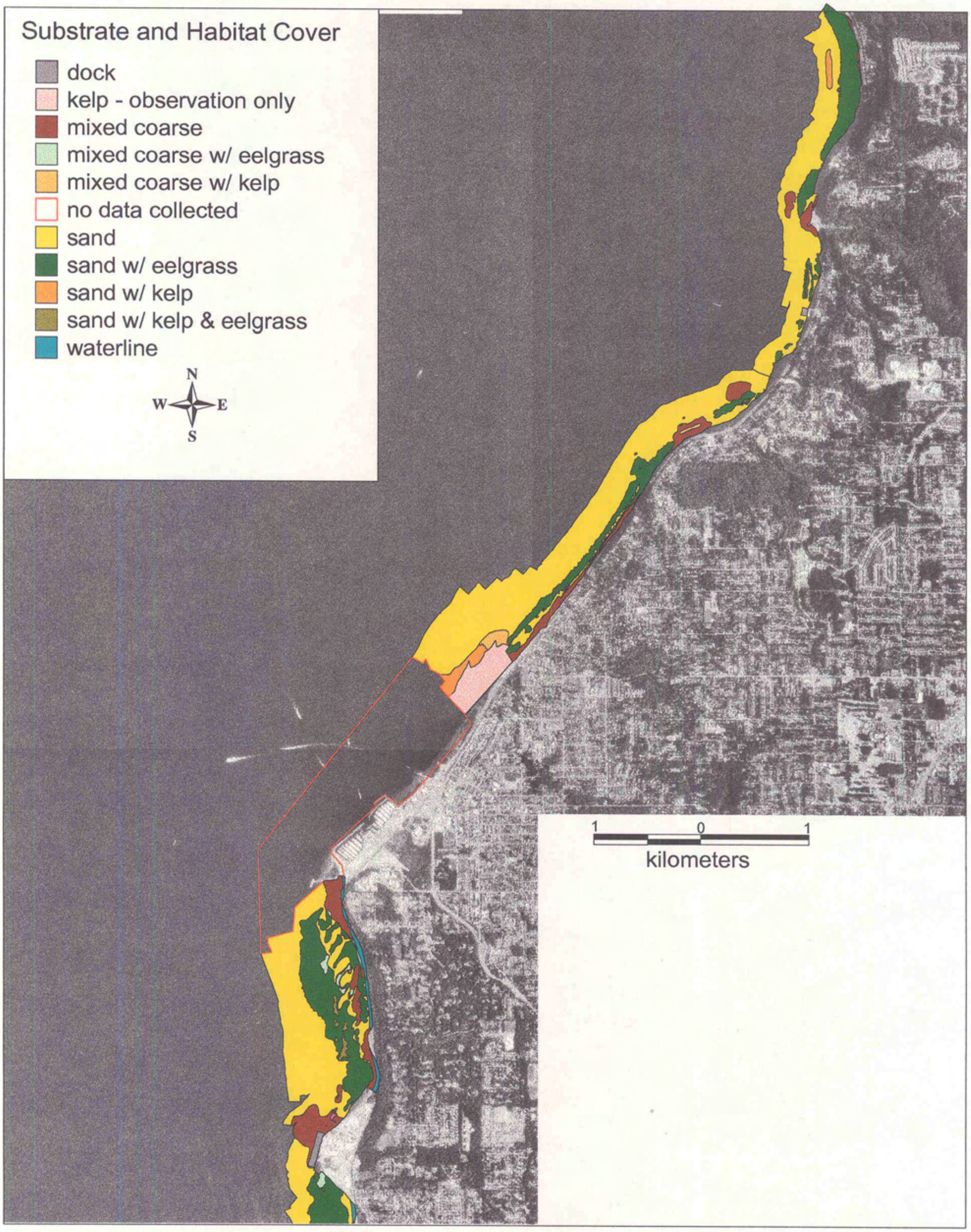

Figure 24a. Substrate and habitat cover from Picnic Point to Point Wells (Areas A-E).

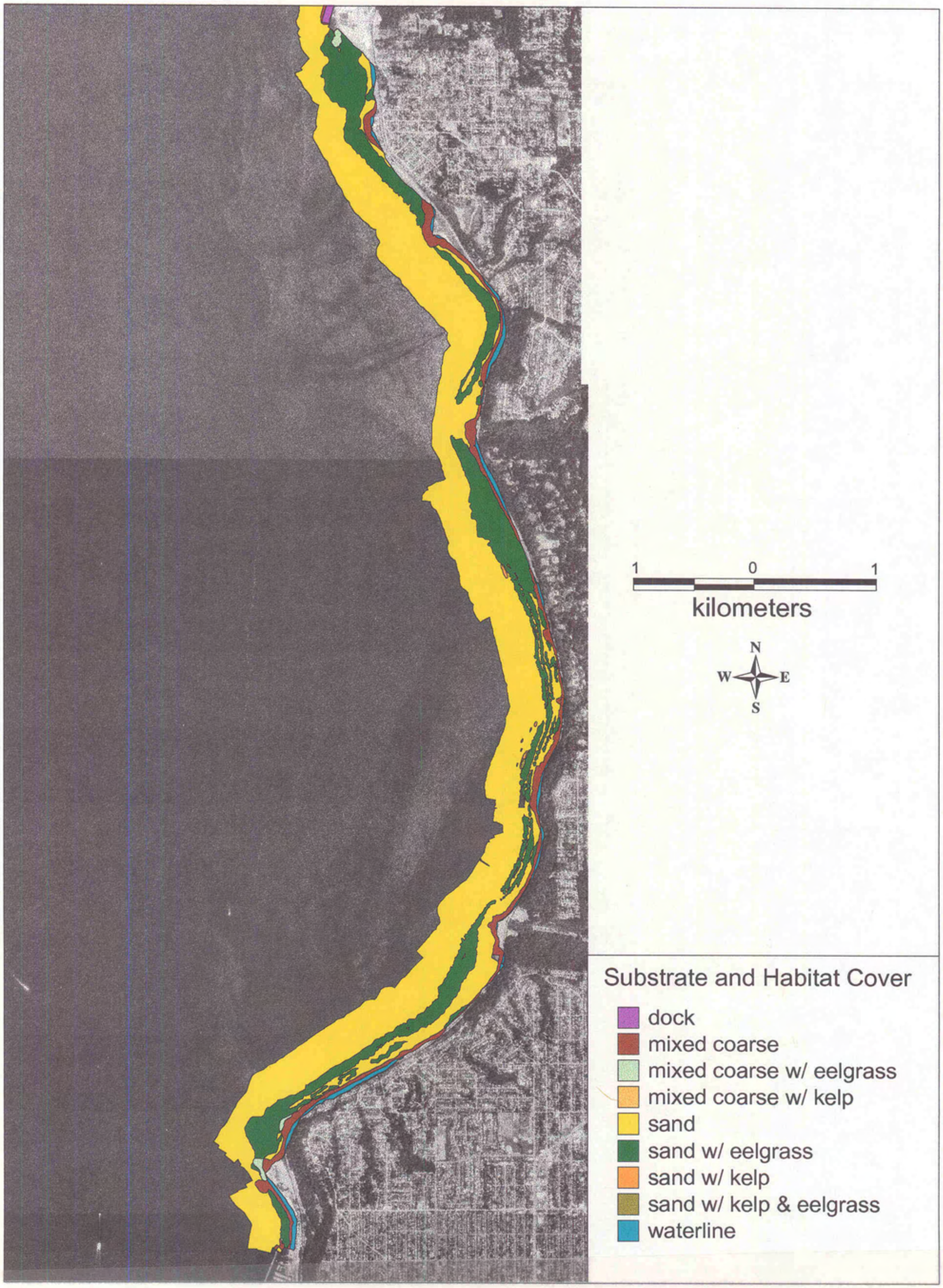

Figure 24b. Substrate and habitat cover from Point Wells to Shilshole Marina (Areas F-L).

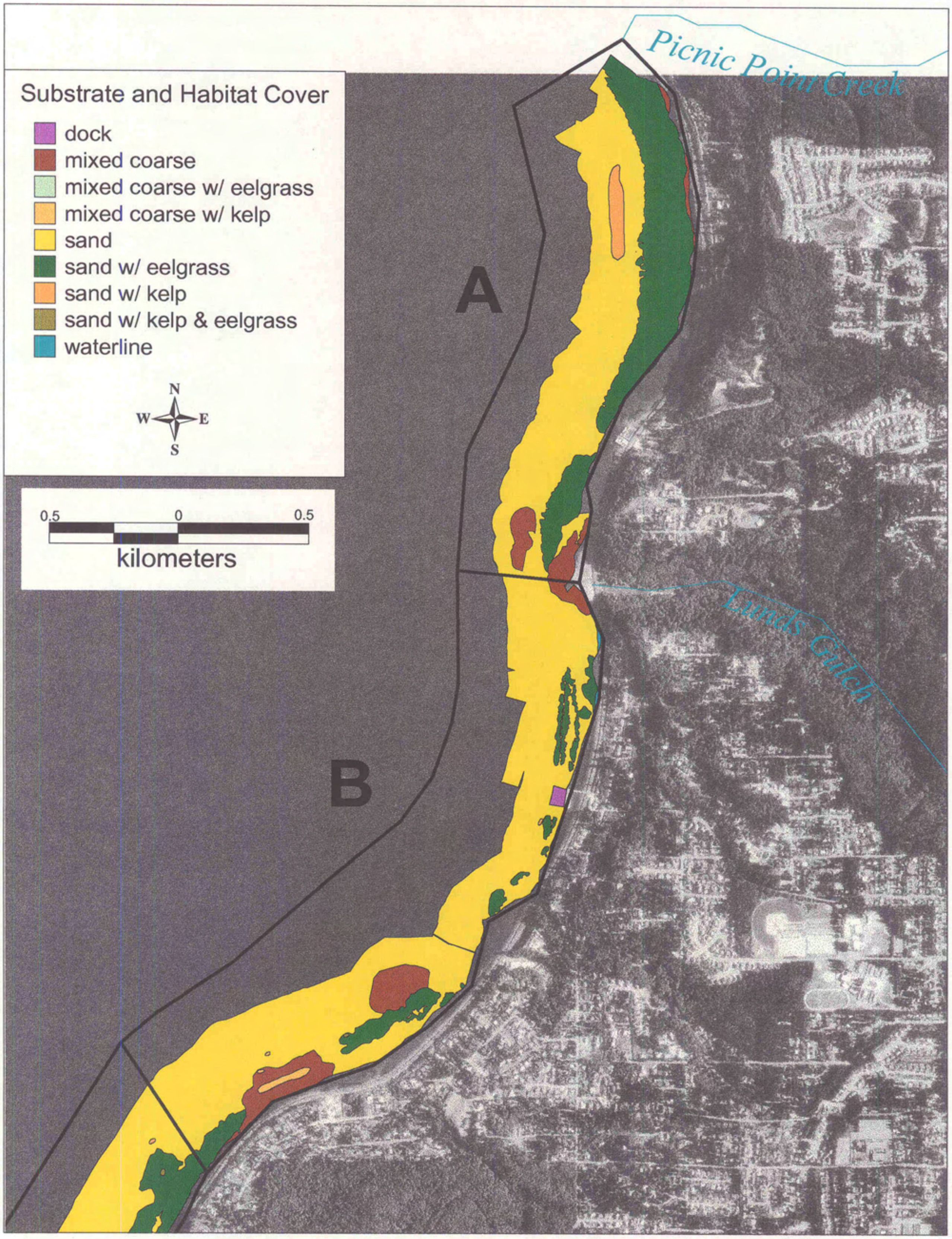

Figure 25. Substrate cover at Areas A and B.

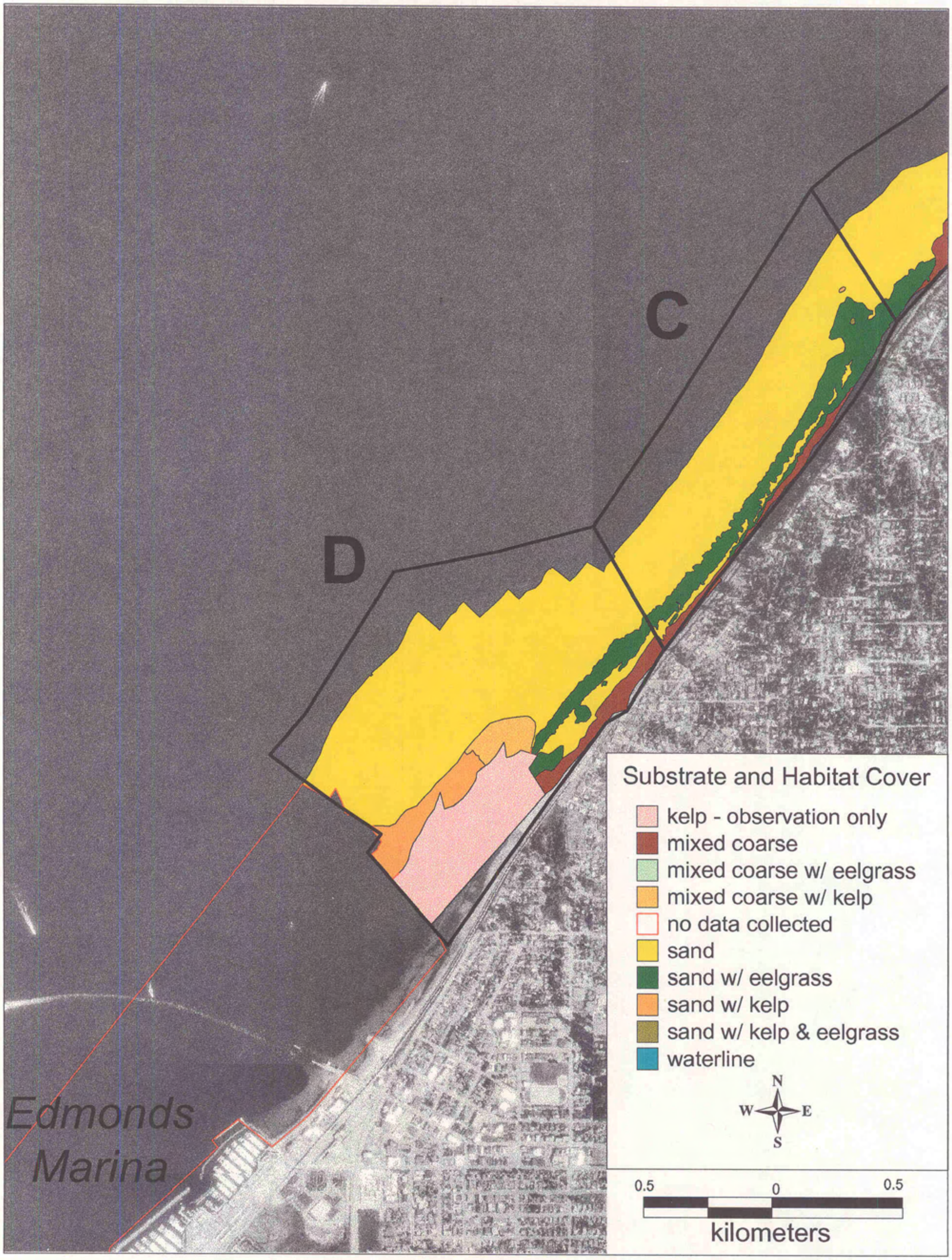

Figure 26. Substrate cover at Areas C and D.

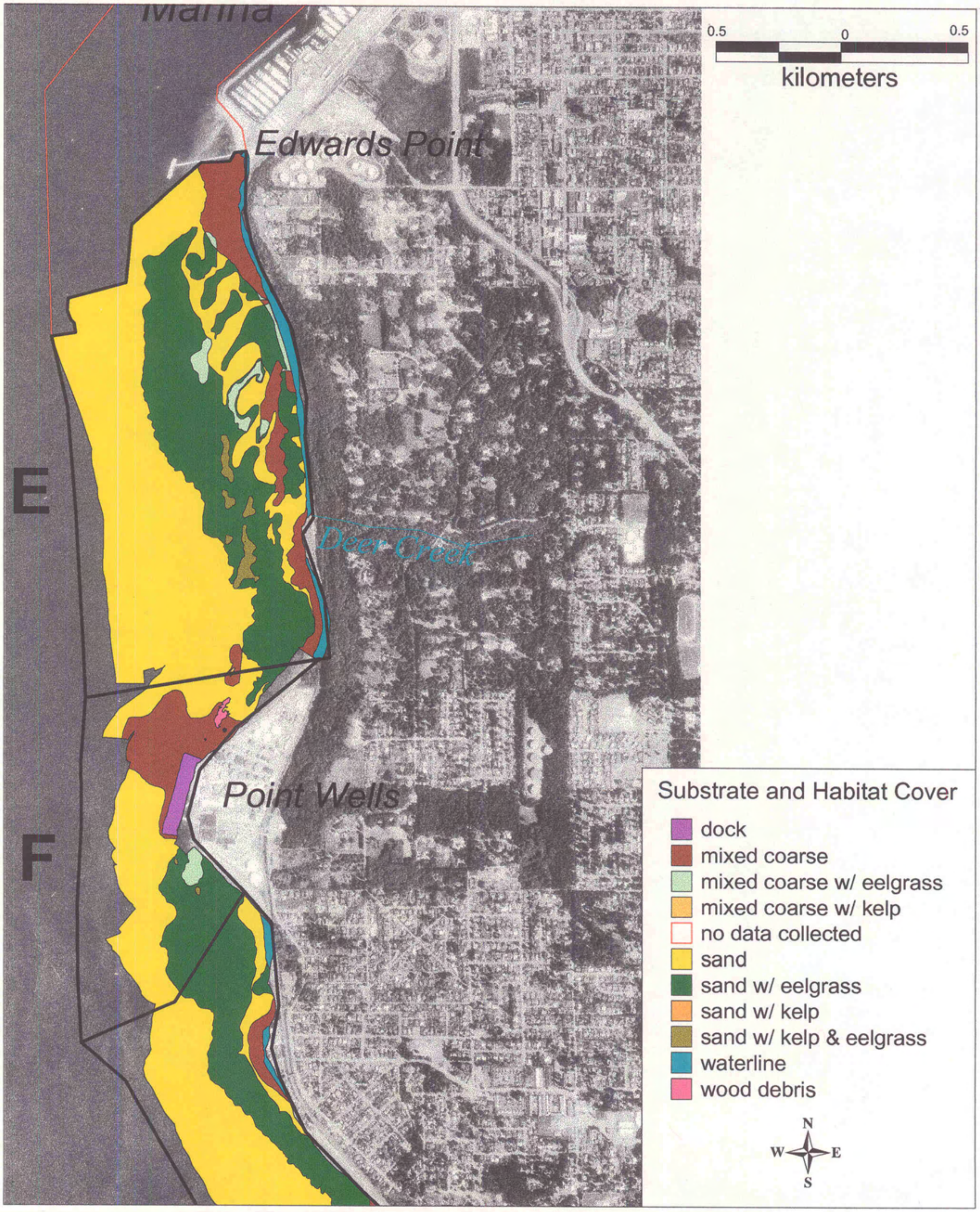

Figure 27. Substrate cover at Areas E and F.

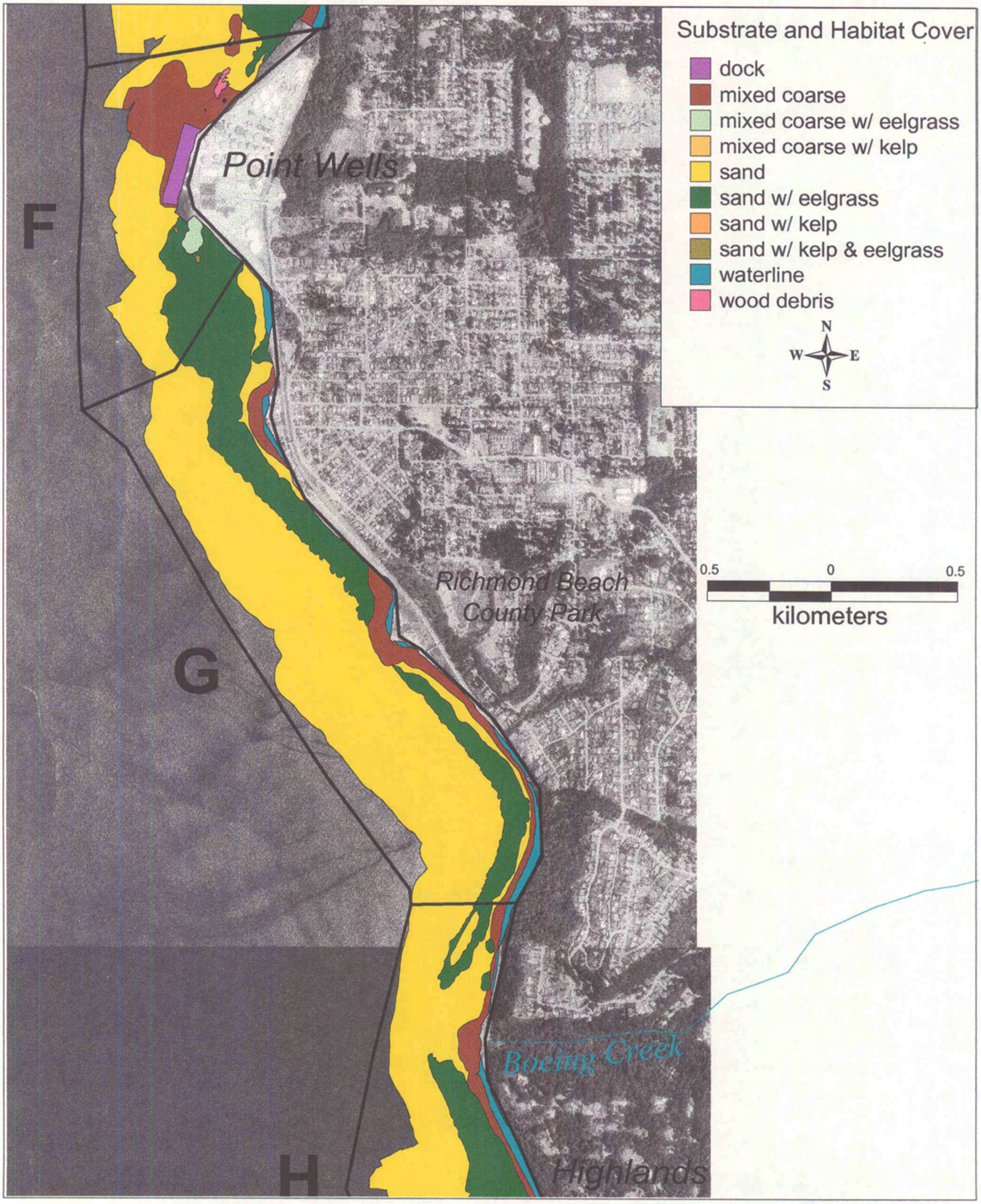

Figure 28. Substrate cover at Areas F and G.

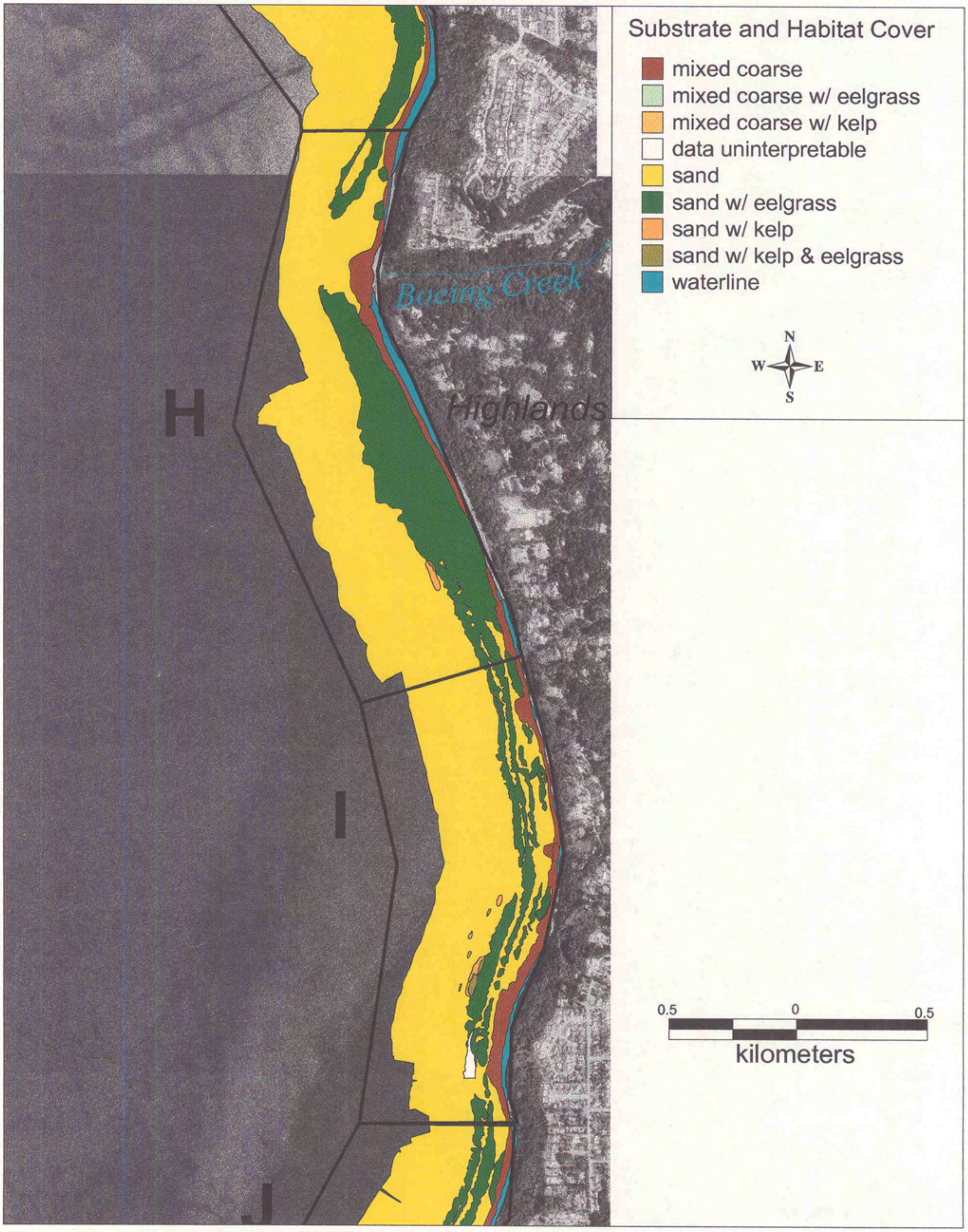

Figure 29. Substrate cover at Areas H and I.

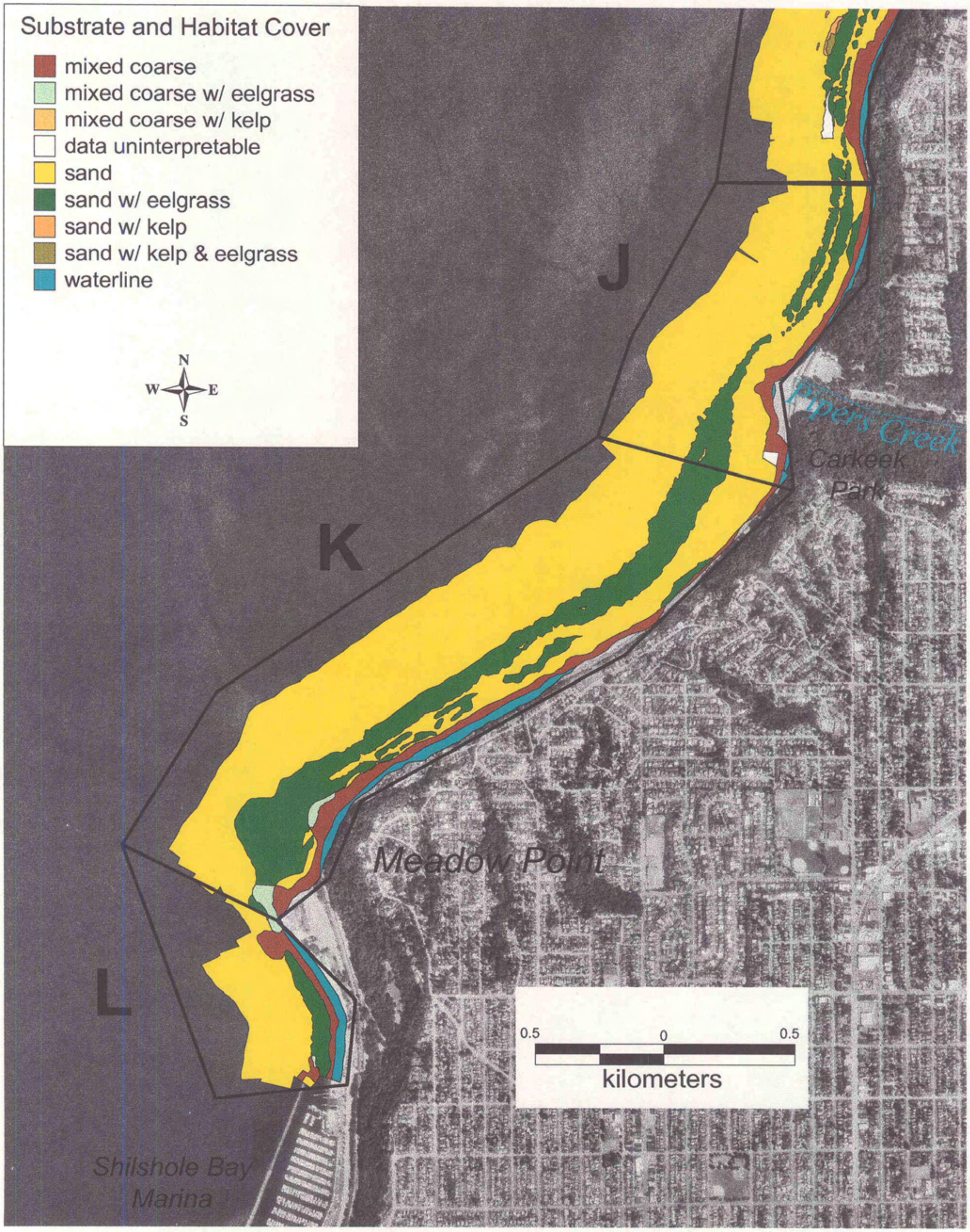

Figure 30. Substrate cover at Areas J, K and L.

Table 14. Basal Area Coverage of Eelgrass and Kelp (in Hectares)

Area	Eelgrass				Kelp and Eelgrass	Kelp	Kelp (no sonar data)	No Data
	Sparse	Moderate	Dense	Total				
A	15.24		10.71	25.95		1.77		
B	2.73	2.33	4.87	9.93		0.66		
C	1.21	4.13	9.23	14.57	0.04	0.03		
D	0.62	0.81	6.58	8.01		8.87	17.20	
E	8.26	36.46	5.46	50.18	2.19			
F	1.13	8.64	1.60	11.37	0.08	0.04		
G	6.22	28.41	5.83	40.46				
H	2.02	20.69	8.28	30.99		0.30		
I	0.99	1.12	11.41	13.52	0.26	0.38		1.00
J	0.98	4.04	6.75	11.77				0.67
K	8.60	18.56	8.78	35.94				
L	1.72	1.33	0.78	3.83				
Total	49.72	126.52	80.28	256.52	2.57	12.05	17.20	1.67

Table 15. Basal Area Estimates of Substrate and Artificial Structures (in Hectares)

Area	Sand	Mixed Coarse	Dock	Piling	Wood Debris	Outfall	Waterline	No Data	Total
A	66.53	2.84							69.37
B	82.78	11.19	0.39			0.05	0.22		94.63
C	66.47	3.94							70.41
D	90.67	7.98							98.65
E	130.01	15.39					4.75		150.15
F	42.21	11.19	2.00	0.03	0.32				55.75
G	133.85	9.03					3.46		146.34
H	103.40	6.12					3.14		112.66
I	79.73	6.71					1.50	1.00	88.94
J	58.49	4.26					1.22	0.67	64.64
K	136.74	8.88					3.55		149.17
L	19.74	3.43					2.12		25.29
Total	1010.62	90.96	2.39	0.03	0.32	0.05	19.96	1.67	1126.00

Table 16. Basal Area Estimates of Habitat Type (in Hectares)

Area	Sand Only	Sand w/Eelgrass	Sand w/Kelp	Sand w/Kelp and Eelgrass	Mixed Coarse Only	Mixed Coarse w/Eelgrass	Mixed Coarse w/Kelp	Kelp- no sonar data collected	Total
A	38.8	25.96	1.77		2.84				69.37
B	72.77	9.94	0.05	0.02	10.59		0.6		93.97
C	52.1	14.3	0.03	0.04	3.94				70.41
D	76.81	8.01	5.85		4.95		3.03	17.16	115.81
E	80.35	47.47		2.19	12.63	2.76			145.40
F	31.2	10.93		0.08	10.71	0.44	0.04		53.40
G	94.74	39.11			8.12	0.91			142.88
H	71.83	31.27	0.25	0.05	6.12				109.52
I	65.06	14.03	0.38	0.26	6.71				86.44
J	46.72	11.77			4.26				62.75
K	102.09	34.65			7.64	1.24			145.62
L	16.63	3.11			2.71	0.72			23.17
Total	749.1	250.55	8.33	2.64	81.22	6.07	3.67	17.16	1118.74

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3.3 Macroalgae Video Track Line Data

Macroalgae presence and density was estimated from the underwater video data. Total macroalgae was assessed for the parallel video track lines and included all species observed. Table 17 presents the total macroalgae data as a percentage by density category. A basal area coverage was not determined because of the variability of the area captured by the camera. The macroalgae track line data for each area is presented in Appendix F. The track lines are superimposed on side scan sonar imagery with individual observations represented as point data. *Ulva* and *Ulva*-like species (other green macroalgae) were assessed for both parallel and perpendicular track lines. Percentage of cover estimates are given in Table 18 with the corresponding track line data presented in Appendix G. *N. luetkeana* and *S. muticum* were also assessed for parallel and perpendicular track lines. These species occurred less frequently, and because they have individual rooted stalks, were assessed as individual observations (Table 19). The total number of video observations (referring to each 1 second of video imagery recorded with a unique time, date, and position stamp) is also provided in Table 19. The trackline observations for each area are presented in Appendix H.

3.4 Fish Video Track Line Data

Fish were grouped for analysis purposes based on their schooling or non-schooling behavior as viewed on the underwater video. Estimates are presented for numbers of individuals based on individual counts (primarily non-schooling species) and estimating numbers of individuals in schooling species. Consequently, the minimum and maximum estimates encompass a wide range for certain species, particularly perch and

Table 17. Percentage of Total Macroalgae Present Based on Video Track Line Length for Each Area

Area	Total Macroalgae by Video Track Line Length (%)				Length of Parallel Trackline (m)
	None-Sparse	Sparse	Moderate	Dense	
A	84%	9%	5%	2%	8,868
B	68%	21%	10%	1%	8,846
C	77%	19%	2%	2%	6,562
D	49%	33%	10%	8%	10,377
E	88%	10%	2%	0%	16,812
F	59%	23%	15%	3%	5,100
G	98%	2%	1%	0%	12,292
H	91%	6%	3%	0%	10,530
I	95%	5%	0%	0%	6,771
J	96%	4%	0%	0%	5,672
K	97%	2%	1%	0%	15,851
L	62%	23%	12%	3%	2,483
Total	83%	11%	4%	1%	110,162

Table 18. Percentage of *Ulva* and *Ulva*-like Species Present Based on Video Track Line Length for Each Area

Area	Total *Ulva* by Video Track Line Length (%)				Length of Parallel and Perpendicular Trackline (m)
	None-Sparse	Sparse	Moderate	Dense	
A	90%	5%	3%	1%	10,738
B	77%	19%	4%	0%	10,209
C	86%	14%	0%	0%	7,027
D	63%	28%	8%	0%	12,323
E	95%	3%	1%	0%	26,864
F	78%	17%	5%	0%	6,352
G	98%	1%	1%	0%	22,914
H	95%	5%	0%	0%	13,950
I	98%	2%	0%	0%	7,701
J	97%	3%	0%	0%	5,966
K	98%	2%	0%	0%	17,229
L	94%	5%	1%	0%	2,996
Total	90%	7%	2%	0%	144,268

Table 19. Number of Observations of *Nereocystis* and *Sargassum* in Each Area

Area	*Nereocystis*	*Sargassum*	Total # of Observations (all tracklines)
A	5	0	9,444
B	8	7	8,971
C	8	0	6,003
D	33	14	11,024
E	48	32	21,646
F	10	17	4,923
G	0	2	18,321
H	0	0	10,266
I	4	0	6,624
J	0	0	5,668
K	0	122	14,778
L	1	6	2,585
Total	127	200	120,253

tubesnout. The data are summarized for each area and species in Table 20. Data for each area are presented as a matrix by habitat type in Appendix I. The corresponding mapped video point data for fish observations are reported by density category: 1-9 individuals, 10-100 (estimated), and >100 (estimated) (Appendix J). A more detailed discussion of the fish observation data is found in Section 4.0.

3.5 Macroinvertebrate Video Track Line Data

Macroinvertebrates were assessed from parallel video track lines only. All macroinvertebrates were recorded; however, sea stars were not identified to species because of time limitations. Generally, individual organisms were counted with the following exceptions: anemones, commonly found in aggregates on hard structures (usually artificial substrate) were not easily counted as individuals and were therefore estimated; adult orange sea pens (*Ptilosarcus gurneyi)* were counted individually;

Table 20. Number of Fish Observed from Underwater Videography in Each Area

	A	B	C	D	E	F	G	H	I	J	K	L	All
Schooling Fish													
Surfperch	3	4	1	4	16-106	3	1	8	-	-	-	-	40-130
Pile Surfperch	-	26-206	1	-	>106	3	12-102	31-301	-	2	-	2	193->823
Striped Surfperch	-	8	-	-	-	-	-	10-100	-	-	-	-	18-108
Shiner Surfperch	220->400	1755->2205	511->601	750->1200	2572->3922	1353->1803	469->1009	544->904	-	-	-	665->1205	8839->13249
Striped or Pile Surfperch	-	4	-	-	85-715	21-111	3	10	1	-	>102	21-201	247->1147
Tubesnout	276->906	810->900	210->300	931->1111	963->1503	110->200	370->1000	770->1400	424->604	380->1100	410->500	120->200	5774->9824
Herring or Sand Lance	-	-	-	-	-	>410-500	-	-	-	-	-	-	410->500
Unidentified fish	22-202	18-108	2	35-215	37-217	2	9	8	20-200	1	>102	-	266->1166
Non-schooling Fish													
Sanddab	1	3	1	3	-	-	-	-	-	2	-	-	10
Flatfish	9	10	13	30	80	10	58	23	8	4	16	12	273
Right-eyed Flatfish	-	1	-	-	-	-	-	1	-	1	-	-	3
Starry Flounder	-	3	-	-	1	-	2	1	2	4	2	-	15
Sculpin	1	3	-	1	1	-	1	-	-	-	1	1	9
Buffalo or Great Sculpin	-	1	-	-	1	-	-	-	-	-	-	-	2
Greenling	-	-	-	1	-	5	-	-	-	-	-	-	6
Cabezon	2	-	-	1	2	2	-	-	-	-	1	1	9
Lingcod	-	-	-	-	-	3	-	-	-	-	1	-	4
Lingcod or Cabezon	-	-	-	-	1	1	2	1	-	-	-	-	5
Rockfish	-	2	-	-	-	-	-	1	-	-	-	2	5
Quillback Rockfish	-	-	-	3	-	-	-	6	-	-	-	-	9
Rat-fish	7	11	7	56	21	43	9	11	-	1	5	5	176
Skate	-	-	1	-	-	-	-	-	1	-	-	-	2

however juvenile *P. gurneyi* were so abundant in some areas that density estimates for juveniles were made separately. The estimated number of macroinvertebrates for each area is shown in Table 21. The corresponding matrix by habitat type is presented in Appendix K. The mapped video point data for macroinvertebrates are presented by density category for each species: 1-4 individuals, 5-10 (estimated), and >10 (estimated) (Appendix L). The mapped video data for juvenile *P. gurneyi* are presented in Appendix M. Data are presented as density estimates only: 5-10 individuals, 11-25, and >25 individuals.

3.6 Quality Assurance/Quality Control

Quality assurance/quality control analyses were performed by two methods: independent postprocessing of the video data and through diver surveys. Each is discussed below.

3.6.1 Postprocessing of Video Data

Once video postprocessing was complete, independent observations were made of randomly selected video frames and compared with the original classification for substrate, vegetation and fish. A summary of errors recorded and the type of errors are shown in Table 22. For a Type-1 error, the misidentification error ranged from 0 to 1.05% for all classification categories. The greatest error (1.05%) occurred in the Substrate Presence category. The difficulty arose in estimating a grain size and hence assigning a classification of a substrate type under certain circumstances. Similarly, the greatest category of Type-2 error (subjective call; identification changed) was also Substrate Presence with an error rate of 3.6%. The subtle shifts from one substrate type to another sometimes presented a challenge in determining "when" to change the substrate classification. Type-3 errors (subjective call; identification not changed)

Table 21. Number of Macroinvertebrates Observed from Underwater Videography in Each Area

	A	B	C	D	E	F	G	H	I	J	K	L	All
Macroinvertebrate													
Sea Cucumber	1	10	7	4	1	18	5	4	2	1	4	3	60
Dungeness, Red Rock, or Slender Crab	15	23	8	3	5	2	3	1	1	3	8	-	72
Jellyfish	-	-	-	-	-	-	-	-	-		3	-	3
White-Plumed Anemone	69	249-329	48	64-74	323->463	671->1071	476-616	485->695	>39	24-34	591->851	337->557	3,337->4,846
Juvenile Sea Pen	0	2,510-5,350	26,676->45,585	405-810	37,600->59,945	8,845->11,990	1,912-3,890	19,107->33,015	25,861->51,170	7,019-15,580	16,348-36,710	12,479-28,330	158,762->292,375
Orange Sea Pen	-	7	2	1	1	8	1	23	5	2	42	4	96
Anemone	1	18	12	6	9	2	>25	11	-	-	4	1	>89
Bivalve	-	-	-	-	-	-	-	11	-	-	-	-	11
Crab	5	2	5	-	2	1	3	-	1	-	2	-	21
Nudibranch	-	1	-	1	-	-	-	-	-	-	-	-	2
Sea Star	81	68	55	113	90	>237	50	52	37	13	94	42	>932
Anemone (Urticina sp.)	84	6	-	11	14	31-36	12	10	-	-	5	-	173-178
Unidentified Invertebrate	-	1	-	-	-	-	-	-	30-60	-	30-60	-	61-121

Table 22. Percentage of Quality Control Errors by Error Type for Each Area

Percent of quality control errors by error type from parallel video footage

Error Type	eelgrass	dominant substrate	Substrate presence	artificial	kelp	sargassum	ulva	fish presence
Type 1	0.15%	0.15%	1.05%	0.15%	0.00%	0.00%	0.30%	0.00%
Type 2	0.75%	1.65%	3.60%	0.00%	0.00%	0.00%	1.35%	0.60%
Type 3	2.85%	5.70%	7.95%	0.15%	0.00%	0.00%	9.00%	1.35%

Percent of quality control errors by error type from perpendicular video footage

Error Type	eelgrass	dominant substrate	Substrate presence	artificial	kelp	sargassum	ulva	fish presence
Type 1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Type 2	0.22%	0.44%	0.44%	0.00%	0.00%	0.00%	0.44%	0.44%
Type 3	1.64%	5.02%	7.10%	0.33%	0.00%	0.22%	3.38%	1.20%

Error Type 1--misidentification of substrate or habitat error (corrected)

Error Type 2--subjective call (identification changed)

Error Type 3--subjective call (no change necessary)

ranged from 0 for *Sargassum* to 9% for *Ulva*. Often, Type-3 errors were the result of a timing issue in the QA process when comparing video frames with the original video data. For example, one observer would make a decision where to change a category call, and the QA observer might have changed the call a few seconds earlier or later. Generally, the largest occurrence of Type-3 errors occurred in classifications that represented a coverage designation such as substrate type or certain species (e.g., *Ulva spp.*) in which the observer was required to make a decision regarding a change of density, as opposed to individual count data such as kelp, *Sargassum*, *Nereocystis*, or fish. Details of the QA/QC data collected, including the number, types of errors, and video frames sampled are presented in Appendix M.

The overall assessment of error types indicates a majority of errors occurred in the Type-2 and Type-3 categories, subjective assessments in which two individuals might make different decisions on density categorizations. The Type-1 error (misidentification) occurred very rarely with a 0% error rate for all categories in the perpendicular video tapes and an average error rate of 0.22% for all categories combined in the parallel track video tapes. Based on this information, the training procedures and video post processing techniques used are considered to be extremely effective when combined with the side scan sonar data for nearshore subtidal habitat assessments.

3.6.2 Diver Assessment Survey

Divers were used to assess the positional accuracy of an eelgrass meadow that was delineated using side scan sonar. Estimated coordinates were determined from the side scan imagery followed by a dive survey to locate the meadow and mark four outer coordinates with anchors tethered to buoys. Positions of the buoys were then compared with the estimated coordinates from the side scan imagery. The four buoy locations are marked in Figure 4. The differences in buoy location and the edge of the meadow, which was approximately 30 m in diameter, were as follows: North buoy: 0 m; East buoy: 7.6 m; South buoy: 15 m; and the West buoy: 0.6 m. Although every attempt was made to place the buoys directly above the edge of the meadow, some positional error might have occurred with the placement due to the tether between the buoy and the anchor. Based on this information, we conservatively estimate our positional accuracy of this meadow to be ±15 m or better. The depth of the water column over the meadow was approximate 7 m, and at the deeper depths of our survey (30 m), our layback correction might not have been as accurate. Taking this into consideration and other possible sources of error (e.g., currents, wind), we conservatively estimate the positional accuracy of our survey to be ±25 m or better. In shallower areas where eelgrass occurred the positional accuracy is estimated to be within 10 m to 15 m, which is quite accurate for an assessment of this type.

Diver surveys were also conducted to verify the overall substrate and habitat types observed with the underwater video and side scan sonar. At 10-m intervals along two transects, divers recorded the type of substrate and eelgrass cover (continuous or patchy, sparse or dense) within their field of view. This was compared with the polygon delineation for the transect area based on side scan sonar and video information, which included all types of classification (none to sparse, sparse, moderate, and dense). Twenty-six of 32 observations matched the polygon delineation. Because the scales of observation and delineation were somewhat different, (3 m to 4 m for divers and 30 m for eelgrass polygon delineation), there were some diver observations (no eelgrass), which were delineated independently as moderate (patchy) from the side scan sonar data. Although we did not consider this a match based on our criteria, the definition of patchy includes areas of no eelgrass. Based on this diver assessment, we conservatively estimate our eelgrass coverage estimates to be 81% accurate for assessment of eelgrass classification types. If we allow for the moderate (patchy) categorization from the side scan data to include the "no eelgrass" category of the divers, the accuracy rate increases to 90%

4.0 DISCUSSION

The dataset collected during this study was extensive; however, it was beyond the scope of this work to fully analyze the data collected. Nonetheless, there are general observations that can be made regarding the habitats found in the study area and utilization of resources.

Eelgrass occurred to some extent in all areas, covering approximately 260 hectares, or 23% of the entire study site based on the area surveyed by side scan sonar. In most cases, eelgrass meadows were oriented parallel to shore because of the relatively steep nature of the subtidal slope, and were generally found to a depth of approximately 7 m (MLLW). Dense eelgrass coverage was usually associated with a steeper slope, and moderate/patchy density coverage was associated with a shallower slope. Sparse coverage was usually found on the inner (shallow bathymetry) or outer (deeper bathymetry) edges of moderate or dense coverages. This was most likely due to suboptimal conditions for growth and survival in these areas including reduced light availability along the outer edges of meadows and increased turbidity and wave exposure along the inner edges of meadows.

The predominant eelgrass density coverage was moderate/patchy (126 hectares), followed by 80 hectares of dense coverage and 50 hectares of sparse eelgrass coverage. Eelgrass generally occurred in sand substrate (254 hectares, 97% of the time) with the exception of about 6 hectares in Areas E, F, K and L, where it occurred in mixed coarse substrate.

Washington State Department of Fish and Wildlife (WDF&W) guidelines for eelgrass surveys recommend surveys be conducted between June 1 and October 1 for optimum density estimates, because the end of the growing season and storm events tend to remove or "thin" eelgrass meadows at later dates. Although this survey was conducted in October and the early part of November, maps were effectively and accurately developed to delineate eelgrass polygons and determine a density coverage type. The traditional WDF&W eelgrass surveys with divers use turion (shoot) counts to develop density estimates. Because eelgrass meadows are thinned somewhat during the off season, a traditional shoot count might not have been appropriate; however, the side scan sonar and underwater video provided density coverage and provided a more accurate delineation of the geographic locations and landscape architecture of the meadows.

A total of 29 hectares (2.6% of the study area) of kelp occurred in 7 of the 12 areas, and found in both sand and mixed coarse substrate. It was generally located on the outer fringes of eelgrass meadows, with the exception of an extensive bed in area D near the Edmonds Underwater Park, just north of the ferry terminal. Overall, kelp was found predominantly in mixed coarse substrate (20.8 hectares). The remaining 10.9 hectares of kelp were located in sand substrate, with 2.6 hectares of that associated with eelgrass.

The predominant substrate type was sand (1010 hectares) occurring in 90% of the study area. Mixed coarse substrate (91 hectares), which included gravel, shell hash, and cobble, generally occurred close to the shoreline, with several exceptions in areas A, B, and F where gravel beds were found in deeper water. There were occasional boulders found that were noted in the video and picked up as targets with side scan, however these areas were not large enough to be mapped as separate polygons. Extensive riprap existed along the shoreline but was outside our study area and not considered part of the mapping effort. Several large piers and docks were noted on the maps in Areas B and F, and occasional wood debris, crab pots and other unidentifiable artificial substrate were recorded on the video and noted during postprocessing. Crab pots and other debris often had extensive populations of anemones and other invertebrates associated with it. Mixed coarse substrate occurred close to shore around creek mouths (Lunds Gulch, Deer Creek, Boeing Creek, and Pipers Creek). Generally, very little eelgrass was found in these areas. The absence of eelgrass usually extended into the surrounding sand substrate as well. This was more pronounced to the south of Lunds Gulch, and around Boeing and Pipers Creek.

Total macroalgae and *Ulva* were present to some extent in all areas. Its presence occurred to a greater extent in areas A through F than in areas G through L, and was frequently found close to shore or in shallow areas. *Ulva* frequently occurred in close association with eelgrass and, for this reason, was sometimes difficult to assign a density classification. Video transects were conducted between Oct 15, 1999, and Nov. 14, 1999, beginning at the north end of the study site and finishing at the south end. Since this occurred over a 1-month period at the end of the growing season and there were several storm events during this time, the spatial distribution and occurrence of macroalgae and *Ulva* might have changed or been reduced relative to what might have been observed earlier in the season.

Fish were categorized based on their schooling or non-schooling behavior. The schooling species occurring most frequently were tubesnout and shiner surfperch (Table 23). These species were present in all areas except shiner surfperch, which did not occur in areas I, J, and K. Flatfish (unidentified to species) were the most common non-schooling species, followed by ratfish. Tables 23 and 24 rank the occurrence of fish

Table 23. Schooling Fish Rankings Based on Number of Observations of Fish Type in Major Habitat and Substrate Classifications[(a)]

	Common Name	Eelgrass	Sand	Gravel	Mixed Coarse	Cobble	Boulder
emb	Surfperch	2	1		3		4
Pil	Pile surfperch	3	1		2		
Str	Striped surfperch		1				
shi	Shiner surfperch	2	1	4	3		5
uip	Striped or Pile Surfperch	1	2		3		4
tub	Tubesnout	1	2	4	3		
uib	Herring or Sandlance	2	1	1			
uid	Unidentified fish	3	1	4	2		

(a) Rank of 1 equals greatest number of observations. Repetitive numbers equal the same number of observations

(schooling and non-schooling, respectively) based on the general habitat type, such as eelgrass, sand, or gravel. Based on this ranking, tubesnout occurred primarily in eelgrass habitat, whereas shiner surfperch were found primarily in sand. Other perch (striped, pile) were found predominantly in sand as well. Although a rather uncommon occurrence, it is possible that a small number of pipefish were present in our study area and misidentified as tubesnouts. However, based on the schooling behavior, horizontal orientation in the water column and frequent occurrence in eelgrass habitat, fish with these characteristics were considered to be tubesnouts and recorded as such. Flatfish and

Table 24. Non-Schooling Fish Rankings Based on Number of Observations of Fish Type in Major Habitat and Substrate Classifications[(a)]

	Common Name	Eelgrass	Sand	Gravel	Mixed Coarse	Cobble	Boulder
uif	Flatfish	3	1	4	2		
cit	Sanddab		1	2			
ple	Right-eyed flatfish		1				
sta	Starry flounder	2	1				
cot	Sculpin		1		2		
uis	Buffalo or Great Sculpin		1				
gre	Greenling		2		1		
cab	Cabezon	2	1	3			
lin	Lingcod	2			1		
loc	Lingcod or Cabezon	2	1		2		
seb	Rockfish		1				
qui	Quillback Rockfish		1				
rtf	Ratfish	4	1	3	2		4
raj	Skate		1				

(a) Rank of 1 equals greatest number of observations. Repetitive numbers for any species means the same number of observations.

ratfish were usually found in sand, as were almost all other non-schooling species. Very few rockfish or lingcod were noted, and those present were found on sand.

The underwater video method of observation allowed a greater understanding of the habitat utilization by fish. Comparison of parallel and perpendicular footage taken in the same locations on different days revealed similar patterns of occurrence. The drawbacks of this method are the higher frequency of unidentified species compared with more invasive techniques of collection and identification of organisms, and the possible underestimate of species and numbers recorded in eelgrass habitat which provides excellent refuge and cover for fish.

Macroinvertebrates were recorded and identified to specie where possible. The exceptions were sea stars, which were identified to class. White-plumed anemones and juvenile orange sea pens were the most abundant invertebrates recorded. Sea stars occurred frequently in all areas as well. All invertebrates were predominantly found on sand with the exception of jellyfish, which were found in the water column above eelgrass habitat (Table 25). Similar to fish, macroinvertebrates may have occurred more extensively in eelgrass habitat than were observed and recorded in the video because of the natural visual cover from predators.

Geoducks, *Panopea generosa,* were in all likelihood present in the study area based on the Geoduck Atlas (WDF&W, 1999) of known geoduck tracts in the state of Washington. However, our survey could not substantiate the presence of geoducks for several reasons. Numerous burrows were observed in the video footage at the depth range of commercially viable tracts (-6 m to -23 m MLLW). Unfortunately, these could not be confirmed as geoduck or some other bivalve burrows based on the size and shape of the burrow. Stock assessment regulations for geoducks require that geoduck surveys not be conducted between October 15th and February 28th due to the low "show factor" of geoducks during the winter months (Goodwin, 1973). This could explain our observations of no geoduck sitings in the study area. Additionally, regulation geoduck surveys are conducted by counting all "shows" diver transects, rather than through video.

Although our data does not indicate the presence of geoducks in the study area, it is quite probable that they exist and would be visible at other times of the year.

Table 25. Macroinvertebrate Rankings Based on Number of Observations of Macroinvertebrate Type in Major Habitat and Substrate Classifications[(a)]

	Common Name	Eelgrass	Sand	Gravel	Mixed Coarse	Cobble	Boulder
cal	Sea Cucumber		1		2		
can	Crab—Dungeness, Red Rock, or Slender Crab	2	1		2	3	
uic	Crab	2	1				
uib	Bivalve		1				
jel	Jellyfish	1	2				
met	White-Plumed Anemone		1	3	2		4
uiu	Anemone (Urticina Spp.)		1		2		
uia	Anemone		1		2		
osp	Orange Sea Pen	2	1				
uin	Nudibranch		1				
uis	Sea Star	3	1	5	2	4	
uid	Unidentified Invertebrate	2	1	3			

(a) Rank of 1 equals greatest number of observations. Repetitive numbers equal the same number of observations.

5.0 CONCLUSIONS

The primary emphasis of this report is the documentation of methods used to map the nearshore environment in northern King County and southern Snohomish County, as well as presentation of the data collected in the form of maps and summary tables of substrate, vegetation, fish, and macroinvertebrates. The data set collected was extensive, both in terms of spatial coverage and the breadth of resources documented. Analysis of the data for this report has been brief; however, it is anticipated that future studies related to the north treatment facility marine outfall siting study will be able to more fully utilize and analyze the data.

We found the combined tools of geo-referenced side scan sonar and underwater video to be a powerful technique for assessment and mapping of nearshore habitat in Puget Sound. Side scan sonar offers the ability to map eelgrass with high spatial accuracy and resolution, providing information on patch size, shape and coverage. It also provides information on substrate change and location of specific targets (e.g., piers, docks, pilings, large boulders, debris piles). The addition of underwater video is a complementary tool providing both ground-truthing for the sonar and additional information on macro fauna and flora. As a ground-truthing technique, the video was able to confirm differences between substrate types as well as detect subtle spatial changes in substrate. It also verified information related to eelgrass including classification of density and types of substrates. Video was also a powerful tool for mapping the location of macroalgae (including kelp and *Ulva*), fish, and macroinvertebrates. The ability to geo-locate these resources in their functional habitat provides an added layer of information and analytical potential.

Based on the experiences of the Fall 1999 mapping effort in Puget Sound, we offer the following refinements and recommendations for improving these techniques, both in terms of cost effectiveness and the quality of data acquisition:

- Establishing pre-survey track lines in a navigation software program is highly recommended to determine the amount of overall effort that will be required, and ensure complete coverage in the study area. Establishing track lines along the natural contour of the shoreline was effective for developing useable mosaic products of side scan imagery. The inshore track line should be run at high tide to ensure the maximum amount of nearshore habitat coverage. Side scan track lines conducted close to shore were able to delineate the shoreline edge.
- Conducting video track line surveys parallel to shore and slightly offset from side scan tracks. is highly effective for ground truthing and provides a reasonable "snapshot" of the aquatic species associated with the habitat. Additional track lines (such as perpendicular to shore) may not be necessary unless specific issues need to be addressed. Since post-processing of the video is expensive, careful initial planning of the track lines will provide the most cost-effective approach in the long run.
- Depending on the nature of the survey, reducing the side scan sonar survey depth to -15 m to -20 m MLLW, while extending thevideo to greater depths (-30 m MLLW) if necessary, could result in a cost savings. For this study, we conducted the survey to a depth of -30 m MLLW (i.e., beyond the photic zone), predominantly to assess resources such as geoduck and rockfish.

Because the side scan sonar data could not provide information regarding these resources, the cost-effectiveness of its use beyond -20 m MLLW is questionable. Although the video did not, in all likelihood assess geoduck resources adequately, it did provide information on other aquatic species of interest, including rockfish.

- Conducting these types of surveys between June 1 and October 1 could improve the overall quality of certain data collected and better meet agency guidelines regarding eelgrass and geoduck surveys. This timeframe should allow for a more comparable analysis of other data sets that are traditionally collected during the summer months.
- Developing methods to streamline the process required to delineate and digitize the substrate and vegetation cover is encouraged. Some relatively simple measures include the delineation of habitat polygons in a software program rather than by hand, thus eliminating the intermediate step of the digitizing table. In the longer term, methods that can automate the delineation process, such as automatic feature extraction algorithms or programs, should also be encouraged as a cost-saving measure.
- Although we cannot overemphasize the effectiveness of using the combined tools of side scan sonar and underwater video for mapping nearshore habitat resources in Puget Sound, these tools are most effective in terms of cost for large rather than small-scale projects. Combining several small projects would also increase cost effectiveness. As an additional cost saving measure, we would recommend conducting these types of surveys during the summer if at

all possible. The shorter daylight hours during the fall precluded video surveys later in the day. Although we were able to adequately conduct the survey during October and November, weather contributed to additional wear on the gear and slowed progress in general.

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