Conversion of Environmental Data to a Digital-Spatial Database, Puget Sound Area, Washington

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Abstract

Data and maps from the Puget Sound Environmental Atlas, compiled for the U.S. Environmental Protection Agency, the Puget Sound Water Quality Authority, and the U.S. Army Corps of Engineers, have been converted into a digital-spatial database using a geographic information system. Environmental data for the Puget Sound area, collected from sources other than the Puget Sound Environmental Atlas by different Federal, State, and local agencies, also have been converted into this digital-spatial database. Background on the geographic-information-system planning process, the design and implementation of the geographic information-system database, and the reasons for conversion to this digital-spatial database are included in this report.

The Puget Sound Environmental Atlas data layers include information about seabird nesting areas, eelgrass and kelp habitat, marine mammal and fish areas, and shellfish resources and bed certification. Data layers, from sources other than the Puget Sound Environmental Atlas, include the Puget Sound shoreline, the water-body system, shellfish growing areas, recreational shellfish beaches, sewage-treatment outfalls, upland hydrography, watershed and political boundaries, and geographic names. The sources of data, descriptions of the data layers, and the steps and errors of processing associated with conversion to a digital-spatial database used in development of the Puget Sound Geographic Information System also are included in this report. The appendixes contain data dictionaries for each of the resource layers and error values for the conversion of Puget Sound Environmental Atlas data.

INTRODUCTION

Background

The Puget Sound Environmental Atlas (PSEA), published by the U.S. Environmental Protection Agency, the Puget Sound Water Quality Authority, and the U.S. Army Corps of Engineers, provides a common source of collected maps and a cartographic base for natural and human-made features that define or affect available marine and nearshore aquatic and avian resources in the Puget Sound area, Washington (Evans-Hamilton, Inc., and D.R. Systems, Inc., 1987). The PSEA was prepared in digital format and compiled using CAD/CAM software. However, the graphic files produced are not directly usable with a geographic information system (GIS) because each file is independent of the other files and, therefore, cannot be combined for analyses or used in a relational database.

The Puget Sound is located in the northwestern United States, between latitudes 47°N and 49°N, and longitudes 124°W and 122°W. The PSEA divides the Puget Sound into 12 geographic regions, each displayed as a separate set of maps for the various resources. Four scales were used for these regional maps. Additionally, only the estuarine areas of the Puget Sound were covered by the PSEA. A generalized map of the project area, which includes the drainage boundary and hydrography of the Puget Sound area, is shown on figure 1.
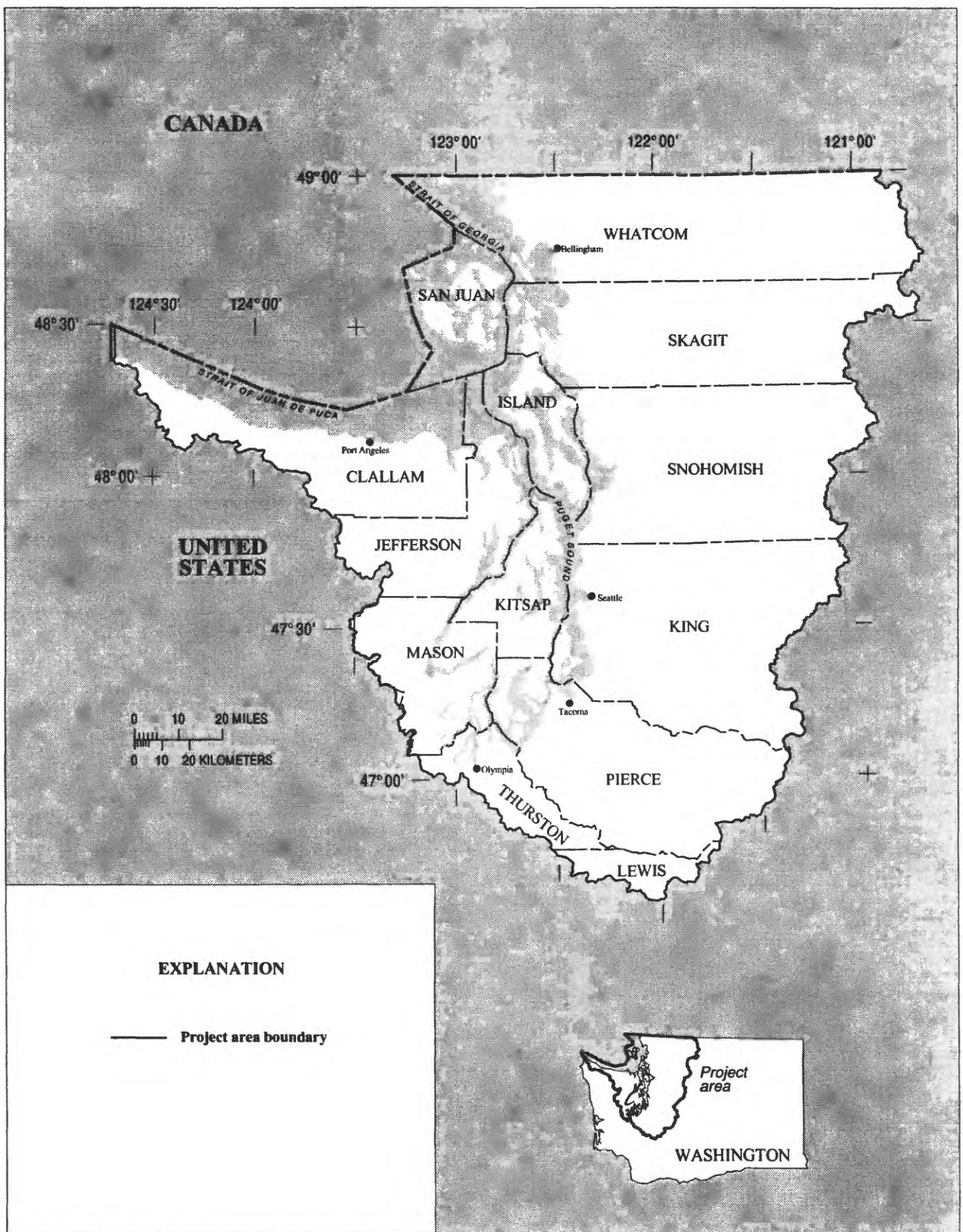
Figure 1. Location of the Puget Sound project area.

The Puget Sound Water Quality Authority adopted a recommendation (Puget Sound Water Quality Authority, 1990) to create a Puget Sound Geographic Information System (PSGIS). On the basis of that recommendation, a Puget Sound Water Quality Authority work group was formed to assess the user needs and potential applications of the available GIS data. To address the need for an integrated GIS, the U.S. Geological Survey, in cooperation with the Puget Sound Water Quality Authority, developed a digital-spatial database and converted appropriate PSEA data into a GIS-compatible format. Additional upland hydrography, basin and resource boundaries, and environmental data for the Puget Sound area from sources other than the PSEA were added to the PSGIS database. This expanded database provided those agencies responsible for managing the water resources of Puget Sound (Puget Sound Water Quality Authority, 1991) a versatile, digital-spatial database of common reference for analyzing geographic information. This report documents the methods used for developing the PSGIS digital-spatial database.

Purpose and Scope

This report documents the methods used to develop the PSGIS digital-spatial database. It describes the process of converting paper planimetric maps to a digital-spatial format. The method of converting PSEA data first to CAD/CAM files and then into GIS coverages is discussed. The procedure of digitizing or acquiring data from sources other than the PSEA and converting them directly to the PSGIS projection is also described. Database development, accomplished by linking the geographic data to attribute information, is documented for each data layer.

Although the PSEA covers the entire drainage of the Puget Sound area, this report principally concerns the marine-water part of the Puget Sound. The data layers created include all elements of a spatial database, such as lines, polygons and points, as well as the tabular information (attributes) associated with each resource. In this report, the digital conversion of Puget Sound environmental data is divided into two categories: data obtained from the PSEA, and environmental data for the Puget Sound area that were obtained from other sources (non-PSEA data). Included for each category of data is a description of each layer; an index of data sources; and a description of processing

and registration procedures and problems, as well as projection errors. Data-layer dictionaries and attribute definitions appear in Appendix A for non-PSEA data and in Appendix B for PSEA data.

Design of Puget Sound Geographic Information System Database

Representatives from Federal and State agencies, private firms, and Native American Indian Tribes in the area participated in the design of the PSGIS database. These representatives met several times during the pilot phase of the project to discuss priorities of data types, as well as issues of design and implementation. Initially, parts of the original CAD/CAM database were converted from Intergraph software format into ARC/INFO format—the software chosen for the PSGIS database. Data were edited to conform with the data requirements specified by the Puget Sound Water Quality Authority and the U.S. Geological Survey (Puget Sound Water Quality Authority, 1990).

The PSGIS database was designed to conform to a 1:100,000-scale resolution (100K) in a Universal Transverse Mercator (UTM) State Plane, Zone 10, coordinate system. Conversion limitations resulted from coordinate transfer and registration of data layers originally in Intergraph format to data layers in ARC/INFO format. Those conversion limitations have been documented in this report (see "Processing Procedures"). Transformation and conversion problems were insignificant and within National Mapping Accuracy Standards for other than PSEA data and were not addressed. The sources and dates of data are listed for both PSEA and non-PSEA categories.

Another aspect of the PSGIS design was to create a database in which data layers could be updated easily by the agency responsible for that information. For example, the Shellfish Inventory data layer is updated annually by the Washington Department of Health Shellfish Programs (Washington Department of Health, 1990). One method used to facilitate PSGIS database updates was the use of attribute names that correspond to each classification status within the Shellfish Inventory. By choosing that attribute name, each classification status layer easily could be selected and edited. Also, the Puget Sound Water Quality Authority requested additional attribute names that could be populated at a later date for resource-management options.

These additional attribute names, COMMERCIAL, RECREATIONAL, POTENTIAL_COM, NONE, and UNKNOWN, were added to the marine and shellfish data layers to facilitate future updates. Finally, all the PSGIS data layers were designed to match the topological representations in the PSEA.

The PSGIS project was developed in two phases. In the pilot phase, database organization and the conversion of data sources within Region 6 of the PSEA were tested. The pilot phase involved converting designated layers of PSEA data, editing map features and attributes, and creating a database using converted PSEA data and non-PSEA data.

The second phase was designed to evaluate the prototype database developed by the joint Puget Sound Water Quality Authority and GIS work group. The data layers for the remaining 11 PSEA regions were converted and additional non-PSEA data were incorporated to create the PSGIS.

DATA LAYERS FROM SOURCES OTHER THAN THE PUGET SOUND ENVIRONMENTAL ATLAS

The PSGIS database includes seven categories of data layers from non-PSEA sources. These seven categories constitute a diverse group of information,

which reflects the wide participation by Puget Sound area agencies and provides a complete background of all Puget Sound environmental resources. Fifteen digital coverages were created, 13 of which are described in this report. These 13 digitized layers include data for the Puget Sound shoreline, the Washington Department of Ecology embayments, the status and use of shellfish areas and recreational beaches, and data for sewage-treatment outfalls. The PSEA also includes layers of upland hydrography, watershed boundaries, political boundaries, and geographic names.

The final data-set products and attribute-field definitions were created with the DOCUMENT command, a user-contributed function to the ARC/INFO library (D.D. Nebert, U.S. Geological Survey, written commun., 1991). All documentation of sources used for the "Data-Layer Dictionary of Environmental Data for the Puget Sound Area from Sources Other Than the Puget Sound Environmental Atlas" is contained in Appendix A.

Data Sources

A wide variety of non-PSEA information sources also were used to establish the PSGIS database. Primary information sources, those individual agencies that originated and generated non-PSEA data, are listed in table 1. In some cases, non-PSEA data layers were

Table 1. Data sources other than the Puget Sound Environmental Atlas used for the Puget Sound Geographic Information System

Agency number	Agency label	Agency name	Data type
1	NOAA-data	National Oceanic and Atmospheric Administration	Bathymetric survey
2	NOAA-chart	National Oceanic and Atmospheric Administration	Nautical chart
3	USGS-NMD	U.S. Geological Survey, National Mapping Division	Digital line graphs
4	USGS-WRD	U.S. Geological Survey, Water Resources Division	River-reach digital data
5	WDNR	Washington Department of Natural Resources, Aquatic Resources	Water Resource Inventory Areas
6	WDOE	Washington Department of Ecology	Water body system
7	WDOH	Washington Department of Health	Shellfish inventory

obtained from a secondary source because that data layer information already was available in ARC/INFO format, as was the case with the Geographic Name Information System and the River Reach data.

The original 100K-scale topographic maps, from which the hydrography, boundary, and U.S. Public Land Survey System data were scanned or digitized to create the Digital Line Graph (DLG) files, are listed in table 2. A list of non-PSEA agencies, resources and respective data-layer names, and the dates or ranges of dates indicating the original period of information are shown in table 3.

Layer Descriptions

Shoreline

The Puget Sound shoreline data layer, an essential part of the PSGIS database, functions as a reference data layer and template for other data layers, such as embayments and usual and accustomed Tribal fisheries, and includes some data layers from the Washington Department of Health Shellfish Inventory.

The U.S. Geological Survey National Mapping Division 100K-scale hydrography in DLG format (U.S. Geological Survey, 1989a) was projected in UTM and used as the source for the shoreline. The shoreline data layer covers the Puget Sound and the Strait of Juan de Fuca coastline (fig. 2), but does not extend into Canada. The lines delineating the shoreline are a mean high-tide line from the 100K-scale topographic maps.

The shoreline data were extracted from the Pacific Northwest River Reach data set (Fisher, 1996). The U.S. Environmental Protection Agency River Reach Data (250K Trace Files) attributes were assigned to the 100K-scale DLG hydrography. The Pacific Northwest River Reach data were used because the DLG pieces were already paneled together. For more detailed information, refer to non-PSEA processing steps, Appendix A.

Water Body System

As part of the Clean Water Act (Section 305 [b]), the U.S. Environmental Protection Agency and the Washington Department of Ecology have delimited a set of water bodies in Washington State. This water body system in the Puget Sound, which includes 69 significant embayments and estuarine areas, was enclosed with artificial closure lines and digitized into a shoreline coverage of the Puget Sound. Each embayment was assigned a label, and the area of the embayment identified by that label was calculated in square miles. A plot of both the digital shoreline and embayments is shown in figure 2.

Table 2. List of Puget Sound Basin 1:100,000-scale U.S. Geological Survey topographic maps

[With GIS (geographic information system) abbreviation and date of last revision]

Map name	GIS name	Date	Map name	GIS name	Date
Bellingham	bell	1975	Robertson Mountain	robi	1979
Cape Flattery	flat	1981	Roche Harbor	roch	1981
Centralia	cent	1980	Sauk River	sauk	1978
Chehalis River	cheh	1979	Seattle	seat	1975
Mount Baker	mbak	1979	Shelton	shel	1979
Mount Olympus	moly	1979	Skykomish River	skyk	1975
Mount Rainier	rain	1978	Snoqualmie Pass	snoq	1978
Port Angeles	pang	1979	Tacoma	taco	1978
Port Townsend	ptow	1975	Twisp	twis	1978

Table 3. Resource name, source agency, and date of data that were collected for the Puget Sound Geographic Information System from sources other than the Puget Sound Environmental Atlas

[NOAA, National Oceanic and Atmospheric Administration; USGS, U.S. Geological Survey; NMD, National Mapping Division; USGS, U.S. Geological Survey; WRD, Water Resources Division of the USGS; WDNR, Washington Department of Natural Resources; WDOE, Washington Department of Ecology; WDOH, Washington Department of Health; WWRIA, Washington Water Resource Inventory Areas; DLGs, Digital Line Graphs]

Resource name	Data-layer name	1 NOAA data	2 NOAA chart	3 USGS NMD	4 USGS WRD	5 WDNR	6 WDOE	7 WDOH
Shoreline [1,2]	sound			1974–81	1990			
Water Body System [1]	embayments		1989–90				1990	
Hydrography general [1,2]	hy.'gis name'			1974–81	1990			
Hydrography network [1,2]	hydro'1-21'.utm			1974–81	1990			
Hydrologic Units	ps_huc			1984	1990			
Puget Sound Basin	ps_basin				1990			
WWRIA	ps_wria					1988		
Political Boundaries	bound			1974–81				
Public Land Survey	nd_'gis name'			1974–81				
Geographic Names	wagz_ps			1974–81				
Shellfish Inventory [1]	doh_shell;sew;rec		1987–88	1974–81				1990
Bathymetry data [3]	bathy	1935–87						
Grain Size data [3]	psamp	1935–87						

[1] Multiple sources are listed when the data layer was derived from a combination of sources. For example, the respective State agencies responsible for the embayment boundaries and the shellfish inventory data used NOAA nautical charts as base maps. Frequently, data were composited onto NMD DLG shoreline data.

[2] Individual 1:100,000 USGS Quadrangle DLGs used; dates are for NMD data (published topographic map).

3 Not described in this report.

Upland Hydrography

General Hydrography

The Pacific Northwest River Reach files for the general upland hydrography of Puget Sound were provided in two separate coverages. The first coverage contained centerlines, including the original single-stranded stream reaches, whose width was digitized as a single arc. Wider reaches, such as reservoirs and braided streams, were digitized as a single arc representing a hydrologic centerline connection through these features. The second coverage contained polygons representing lakes and double-banked streams. These two data layers were recombined and edited to produce the general hydrography data layer consisting of a 100K-scale quadrangle boundary tile structure having a total of 18 tiles that were stored in a UTM Zone 10 projection.

The marine shoreline and centerlines from the Pacific Northwest River Reach data layers were not included in the general hydrography data layer. The original U.S. Geological Survey 100K-scale DLGs were not used for two reasons: (1) the coverage lacked attributes such as stream name and U.S. Environmental Protection Agency-RF2 codes (Horn, 1986), and (2) edgematching the adjacent quadrangles and paneling the 64 pieces of 100K-scale DLGs had already been done for the Pacific Northwest River Reach project. The 100K-scale quadrangle maps were projected to UTM from an Albers Equal Area map projection. A plot of the general hydrography, including the shoreline, is shown in figure 3.

River Reach Network

In addition to the general hydrography layer, the PSGIS project also includes data transport layers called River Reach Networks for which GIS routing processes can be used and in which the double-banked streams and reservoirs have been centerlined. These layers were obtained from the Pacific Northwest River Reach study in April 1990 and were tiled by U.S. Geological Survey hydrologic unit code (HUC). The Puget Sound shoreline was deleted from each layer and the tile renamed to correspond to its respective HUC. The tile was projected to UTM from an Albers Equal Area map projection.

Project
area

WASHINGTON

CANADA

Bellingham

123°30'
49°00'

123°00'

122°30'

1

2

4

5

7

6

3

12

8

11

9

10

4

124°30'
48°30'

124°00'

13.1

3

16

24

22

23

25

14

13.0

15
Port Angeles

17

18

19

20

21

26

27

28

29

48°00'

33

31

32

0   10   20 MILES

0   10   20 KILOMETERS

30

UNITED
STATES

34

35

36

41
Seattle
68

38

39

44

43

EXPLANATION

47°30'   37

46

14   Puget Sound Environmental Atlas
      embayment number

45

47

48

42

55

53

49

50

54

52
51
Tacoma

58

56

57

59

67

60
61

66

63
65

62

64
Olympia

47°00'
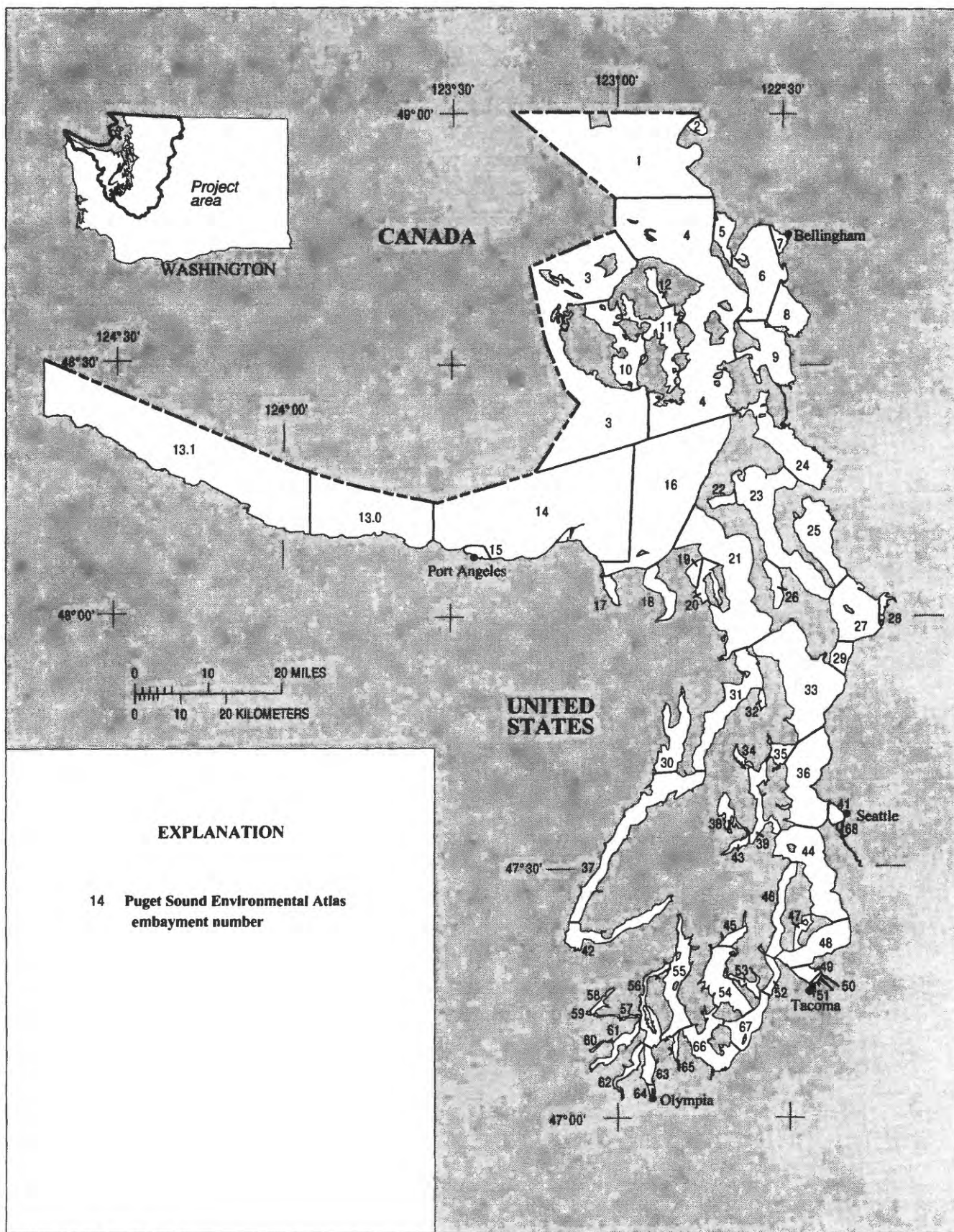
Figure 2. Puget Sound shoreline and embayments from digital data.

CANADA

123° 00'   122° 00'   121° 00'

49° 00'

124° 30'   124° 00'

48° 30'

48° 00'

UNITED
STATES

47° 30'

0   10   20 MILES

0   10   20 KILOMETERS

47° 00'

Seattle

Tacoma

Olympia

EXPLANATION

U.S. Geological Survey 1:100,000
hydrographic data layer

Project
area

WASHINGTON
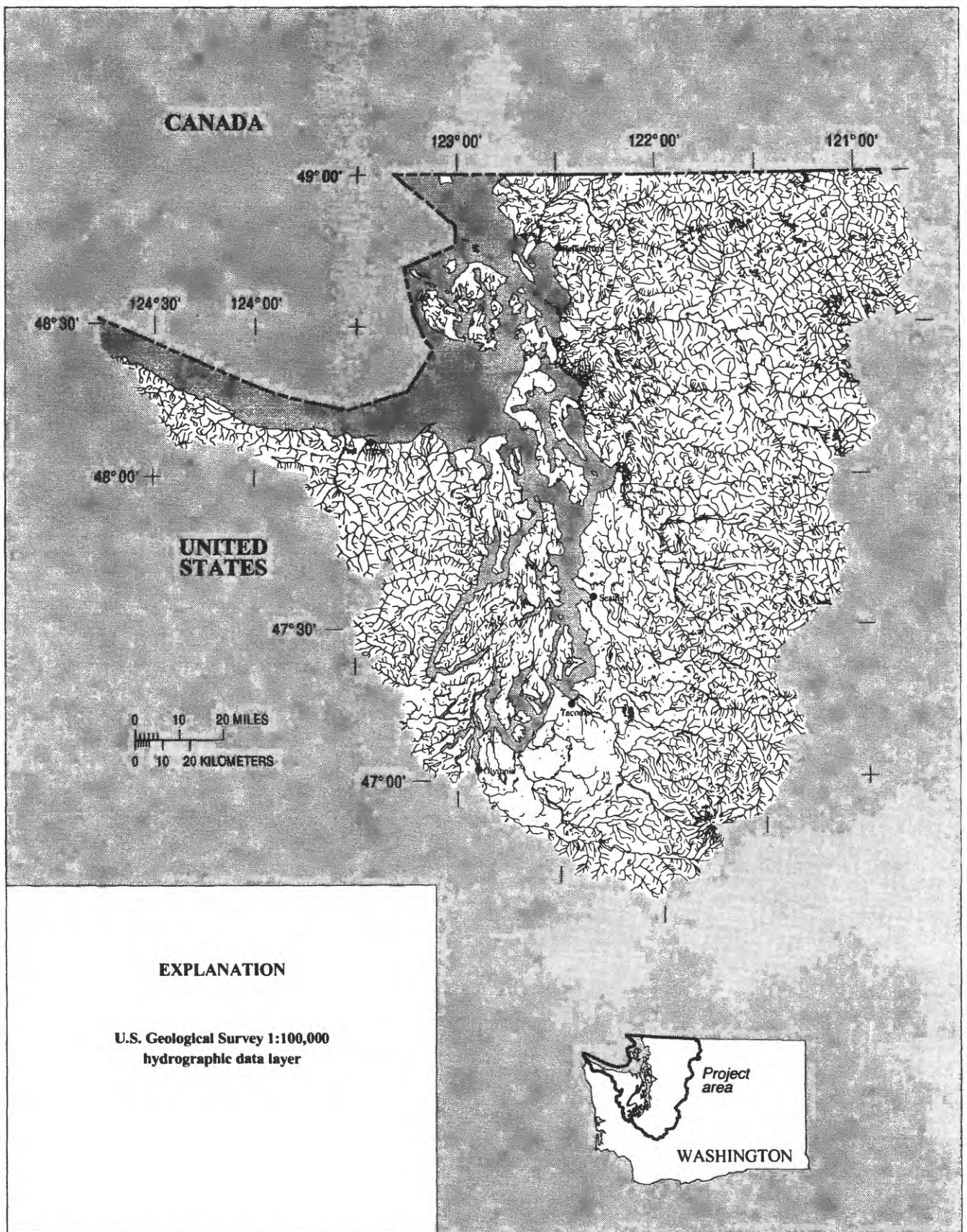
Base map from U.S. Geological Survey
1:100,000 Digital Line Graphs, 1989a.

Figure 3. General hydrography data layer with the Puget Sound shoreline.

Watershed Boundaries

Puget Sound Area

The PSGIS data layer of the Puget Sound area (HUC 17110000, which includes 21 subbasins—HUCs 17110001 through 17110021 [fig. 4]), was created as a reference layer for other data layers, such as the hydrography and Washington Water Resource Inventory Areas. The watershed boundary coverage for HUC 17110000 was obtained from the U.S. Geological Survey National Mapping Division as a generalized 1:2.5-million- scale coverage that was redelineated to capture headwater and lower reaches at 100K scale as part of the Pacific Northwest River Reach project. In order to create the Puget Sound Area data layer, all of the subbasin HUC boundaries under regional boundary 17 and subregional boundary 11 were eliminated. The resulting data layer consists of one outer boundary (HUC 17110000); the inner boundaries (accounting [00] and cataloging [01-21] units) have been removed.

Washington Water Resource Inventory Areas

The Washington Department of Ecology has delineated watershed areas, called Washington Water Resource Inventory Areas, that are similar to the U.S. Geological Survey HUCs (Washington Department of Ecology, 1986). The boundaries of the Washington Water Resource Inventory Areas differ from U.S. Geological Survey HUC boundaries by the additional subdivision of some subbasins, particularly subbasins at the Canadian border. In addition, only a few of the Washington Water Resource Inventory Areas follow the legal description of an area, which may not be entirely based on hydrology, as are the U.S. Geological Survey HUC boundaries. These Washington Water Resource Inventory Areas are the basis for the Washington Department of Ecology's water-management policies and are provided as an index and reference layer for the PSGIS. The digitized Washington Water Resource Inventory Areas were obtained from the Washington Department of Natural Resources, Division of Aquatic Resources, and the resulting data layer was projected from a Washington State Plane coordinate (south zone) to UTM Zone 10 projection. Washington Water Resource Inventory Areas that are not within the Puget Sound area (HUC 17110000) were removed from the original statewide data layer received from the Washington Department of Natural Resources. A map of the Puget Sound Washington Water Resource Inventory Areas is shown in figure 5.

Political Boundaries and U.S. Public Land Survey System

The data layers containing political unit boundaries and U.S. Public Land Survey System features were obtained from the U.S. Geological Survey National Mapping Division 100K-scale DLGs. The boundary DLG data layer includes Federal and Tribal lands information and State and county Federal Information Processing Standard (FIPS) codes. The coverage of counties in the Puget Sound area was created by selecting the county FIPS code contained in the major and minor attributes and clipping with the Puget Sound boundary (U.S. Geological Survey, 1989a). DLGs of the U.S. Public Land Survey System contain township and range section lines, benchmark monument locations, surveyed section corners, and other surveyed data (refer to Appendix A for additional processing steps).

Geographic Names

The Geographic Names data layer, obtained from the Washington State Department of Fish and Wildlife, is a point data layer developed from the U.S. Geological Survey, National Mapping Division, Geographic Names Information System file for the State of Washington. The data layer was converted from the Washington State Plane coordinate system (south zone) to UTM Zone 10 projection. The point data layer was clipped to match the extent of the Puget Sound area and includes 7,941 point locations for cities, towns, landmarks, and geographic and hydrologic features.

Shellfish Inventory

Shellfish Growing Areas

The location of commercial growing areas, obtained from the 1990 Shellfish Inventory produced by the Washington Department of Health Shellfish Programs (Washington Department of Health, 1990), was digitized. The official classification status for harvesting and growing of commercial shellfish in the area of the Puget Sound is identified in the 1990 Shellfish Inventory. Each polygon or growing area was assigned an attribute for classification status. This classification status is divided into five categories: Commercial Area, Approved, Conditionally Approved, Restricted, and Prohibited. Several status areas overlapped and were assigned an attribute with a combined double name, such as Commercialprohibited. A map of the digitized 1990 Shellfish Inventory is shown in figure 6. Further processing procedures are detailed in Appendix A.

CANADA

123°00'   122°00'   121°00'

49°00'   17110001

17110002

17110001

17110004

Bellingham

17110005

17110003

124°30'   124°00'

48°30'   17110007

17110021

17110008   17110006

Port Angeles   17110011

48°00'   17110020

17110009

UNITED
STATES

17110018

47°30'   17110012   Seattle

17110017   17110010

17110019

0   10   20 MILES

0   10   20 KILOMETERS   17110013

Tacoma

47°00'   Olympia   17110014

17110016   17110015

EXPLANATION

17110017   U.S. Geological Survey hydrologic
unit code

Project
area
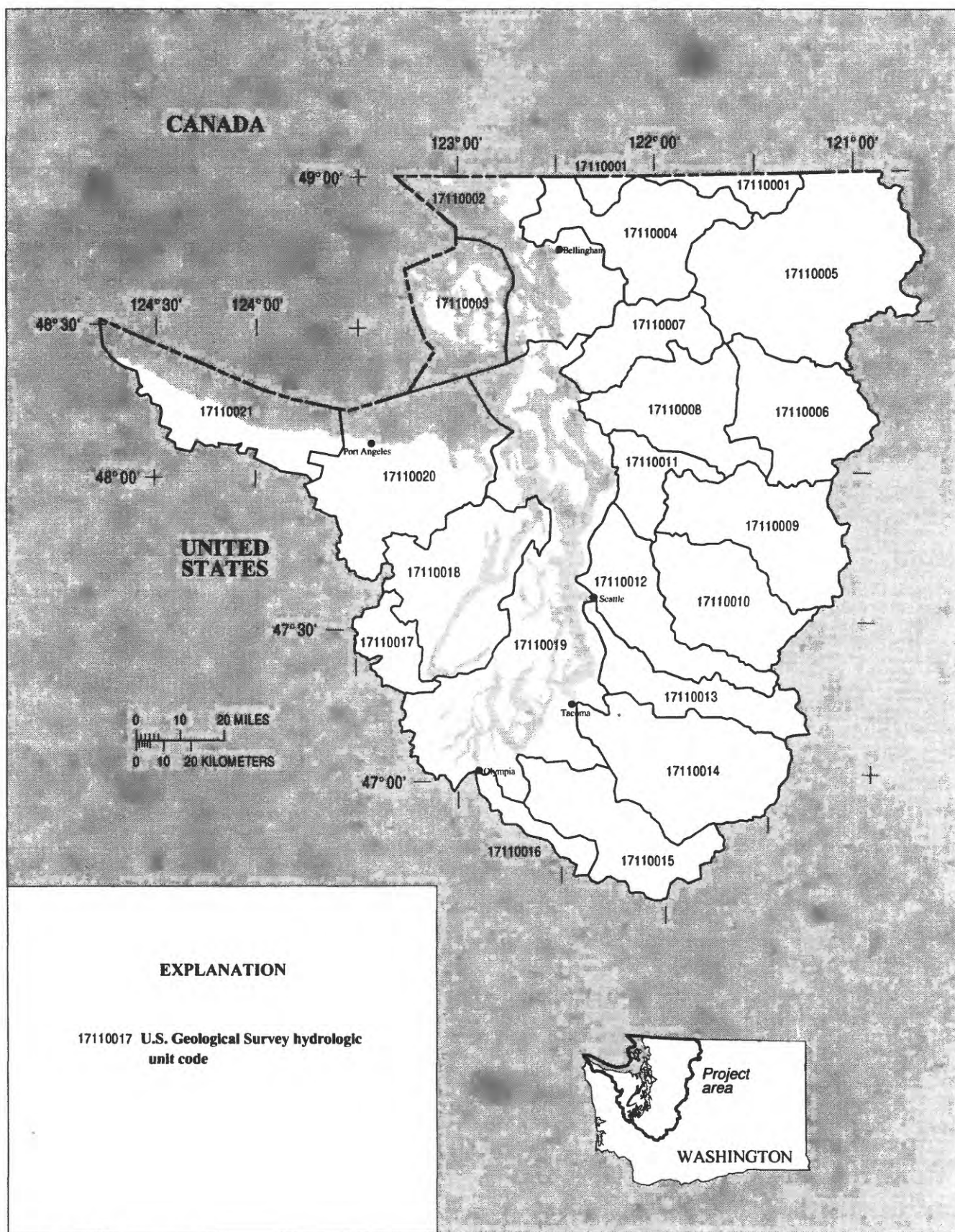
WASHINGTON

**Figure 4.** U.S. Geological Survey hydrologic unit boundaries for the Puget Sound area.

10
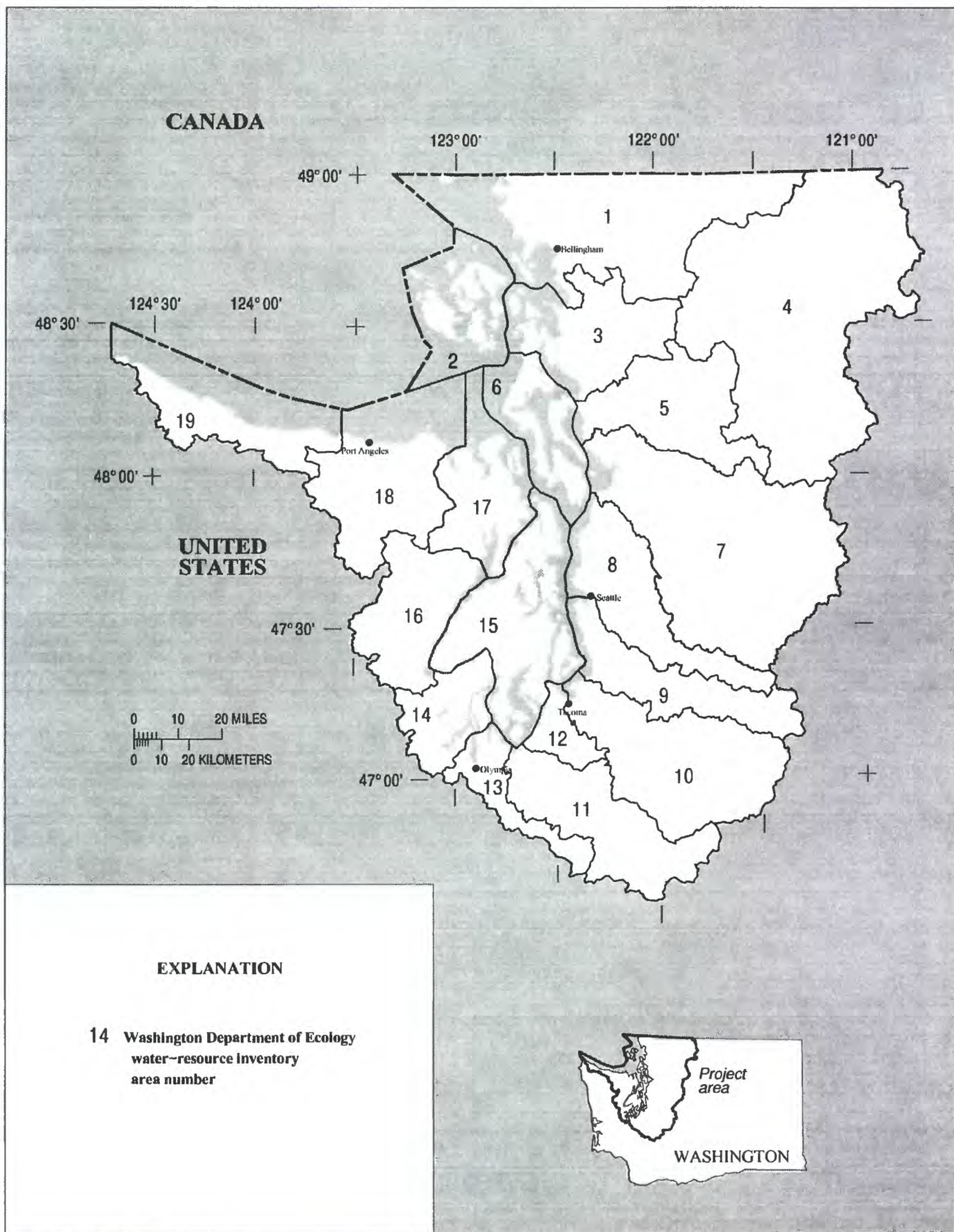
Figure 5. Washington Department of Ecology water-resource inventory areas for the Puget Sound Basin.

EXPLANATION

14   **Washington Department of Ecology water-resource inventory area number**
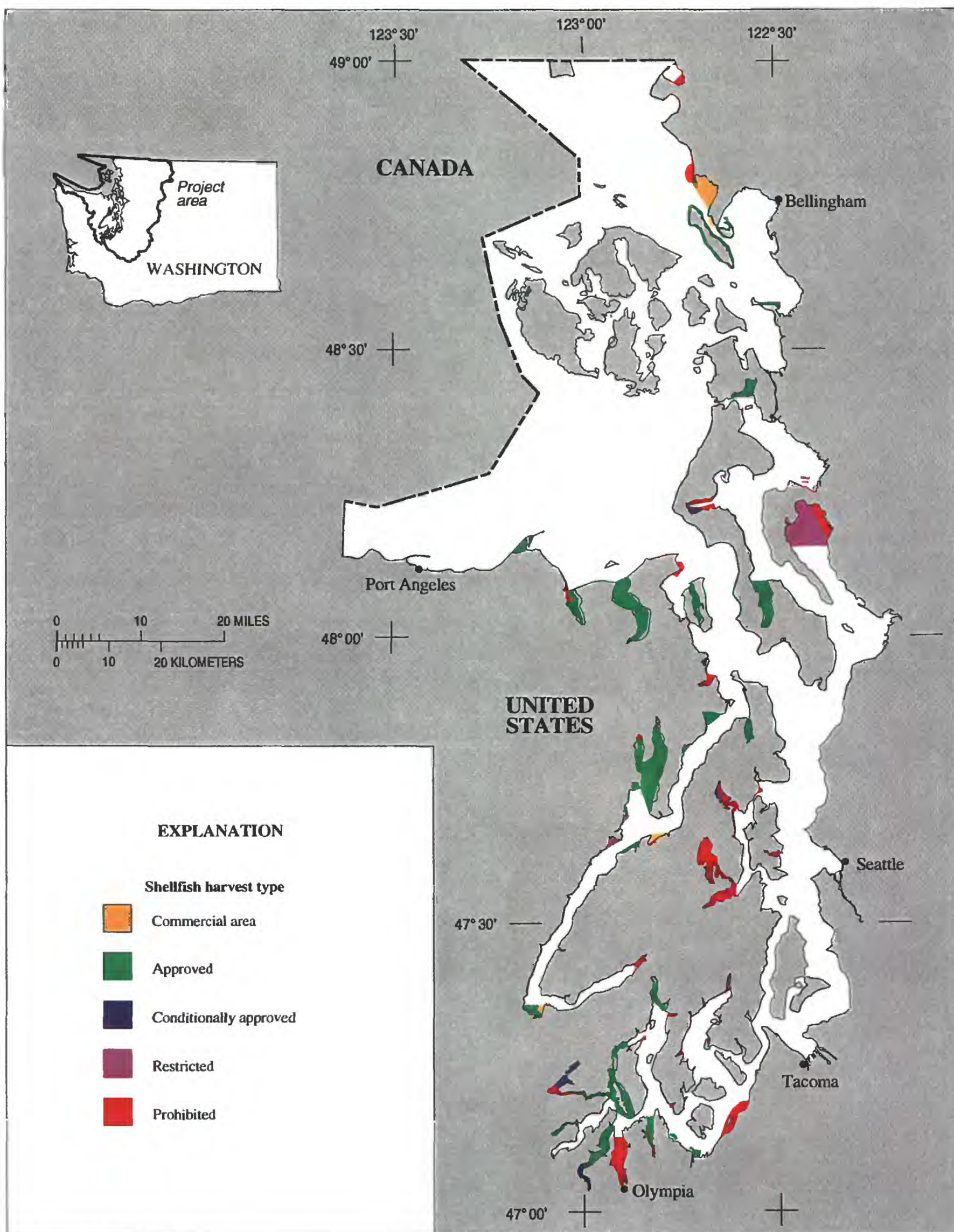
Figure 6. Shellfish growing areas from the Washington Department of Health 1990 Shellfish Inventory.

Recreational Shellfish Beaches

The location of recreational shellfish beaches, shown in the 1990 Shellfish Inventory (Washington Department of Health, 1990), was digitized as a point coverage. The 1990 Shellfish Inventory depicts recreational shellfish beaches in State, Washington Department of Natural Resources, and county parks. Symbols and numbers denote the agency responsible for maintaining the beach or park and the beach or park name. Attributes were included to indicate this information (see Appendix A for more information).

Sewage-Treatment Outfalls

The location of municipal sewage-treatment outfalls, shown in the 1990 Shellfish Inventory (Washington Department of Health, 1990), also was digitized as a point coverage. Municipal sewage-treatment outfall locations are represented by a triangular symbol. A point coverage was created by digitizing the approximate center point of the triangle. Because the 1990 Shellfish Inventory maps did not have precise coordinates for the outfalls, the triangles and their centers should be considered as cartographic representations of real-world data; exact latitude/longitude coordinates for the points digitized were not known and were approximated. An attribute for the name of the sewage-treatment outfall was included. The recreational shellfish beaches and sewage-treatment outfalls are shown in figure 7.

Processing Procedures

Processing procedures for non-PSEA data varied widely. An effort was made during the pilot phase to identify existing sources of digital data, such as DLG files. Whenever possible, the data were acquired from an agency that already had the information in ARC/INFO format. When existing digital data were not available, the resource-layer maps were digitized.

Quality assurance for resolution and registration errors was performed after processing the data. National Map Accuracy Standards (U.S. Geological Survey, 1989b), were used in the quality assurance process. As an example, for 100K-scale data layers, the map precision in ground units is 50.9 meters. This quality inspection varied for different data themes and sources.

For instance, because the 1990 Shellfish Inventory areas were transferred manually to a base of higher precision and then digitized, the shape, location, and attributes of the data were rigorously checked. However, in the case of the U.S. Public Land Survey System data, in which DLGs from the National Mapping Division of the U.S. Geological Survey were imported to ARC/INFO format, only the edgematching of adjacent panels underwent quality checks (Nebert, 1989).

Digital Line Graph Files

DLGs from the National Mapping Division of the U.S. Geological Survey, the initial source for the shoreline and upland hydrography data layers, also were converted to ARC/INFO format for the Puget Sound boundary and the U.S. Public Land Survey System data layers. The 100K-scale DLG data are ordered by quadrangle sheet (30 × 60-minute series) and divided into from 4 to 32 sections, depending on the data type, for each east and west half of the quadrangle sheet. The DLGs were processed using the ARC/INFO command: DLGARC[1]. All of the data (line, area, label, node) contained in the DLGs were imported into ARC/INFO. For the U.S. Public Land Survey System data, this meant that some quadrangle sheets had two final data layers. One data layer contained line, polygon, and label data; a second data layer contained point data, such as benchmarks and surveyed monuments.

Existing Digital-Spatial Data

Processing required for data layers formatted in ARC/INFO ranged from basic projection of a data layer into the PSGIS-UTM-coordinate system to extensive manual editing and manipulation of a data layer to achieve the desired resolution and naming convention. The hydrography, including the shoreline, existed in ARC/INFO format as Pacific Northwest River Reach data sets. The Pacific Northwest River Reach product consists of a topologically linked, network data layer with centerlines replacing double-banked streams and water bodies, and a polygon, banks data layer of these double-banked streams and water bodies. From these two products, the PSGIS derived three data sets: a Puget Sound shoreline, a cartographic-general hydrography, and a linked-network hydrography.

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[1] All ARC/INFO commands in this report are capitalized and use software version 5.0.1; refer to Environmental Systems Research Institute, Inc., 1989, for a complete explanation.
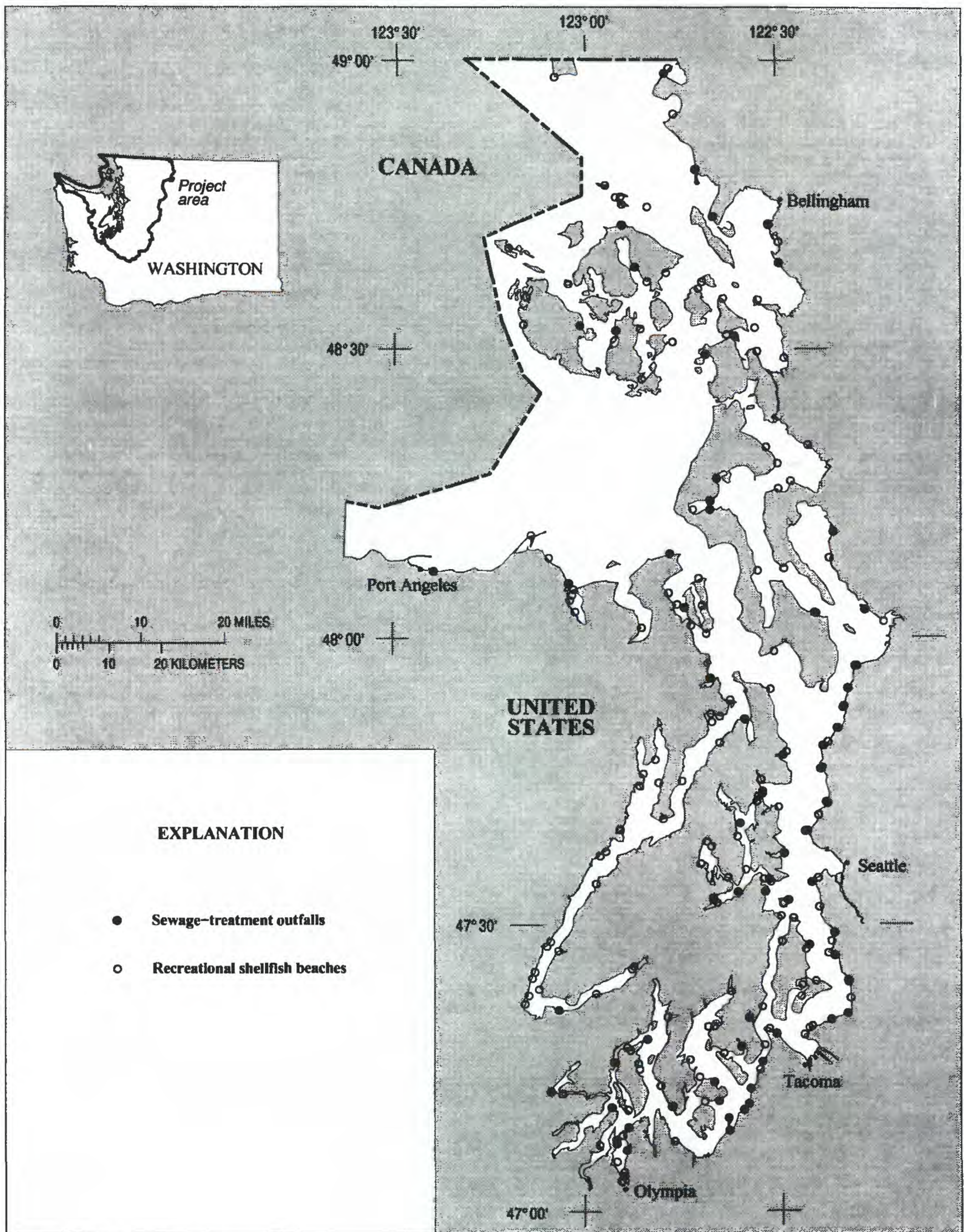
Figure 7. Sewage-treatment outfalls and recreational shellfish beaches from the Washington Department of Health 1990 Shellfish Inventory.

Shoreline Data Layer

To create the Puget Sound shoreline data layer, arcs were extracted from the banks data layer. For Puget Sound shoreline pieces missing from the banks data layer coverage, the network data layers of each subbasin (HUCs 17110001 through 17110021) in the Puget Sound area were used. Where double-banked streams entered the Puget Sound, an arc was added to close off the mouth of the stream. These arcs were given a COVER-ID equal to 9999 as a flag for later reference. The closures were added to create a topologically correct coverage where the water body of Puget Sound is contained in a single polygon. These closures were not field located at the beginning of an estuary or determined by head-of-tide zones but were hand digitized by visual alignment with the existing shoreline. These closures may require modification for certain applications. A section of the San Juan Island data set, which was missing from the Pacific Northwest River Reach data set, also was digitized.

Upland Hydrography Data Layer

The general upland hydrography cartographic data layer was created by merging the network and banks data layers together and eliminating the center-lines. This process is detailed in Appendix A. The Puget Sound subbasins (HUCs 17110001 through 17110021) were merged at the boundaries of the 100K-scale quadrangles. The hydrography was clipped into the tiles chosen by the multi-agency PSGIS design work group.

Network Data Layer

The linked-network hydrography is a final product of the Pacific Northwest River Reach project. This coverage is a topological network with an extended database; routing up or down from a given reach is possible either with the spatial network or within the tabular database. There are items within this extended database to relate the topological network to the 250K-scale U.S. Environmental Protection Agency River Reach files (Horn, 1986), the U.S. Environmental Protection Agency STORET Data Base, and the Northwest Environmental Data Base (Bonneville Power Administration, 1990). A provisional network data layer was acquired for the PSGIS in March of 1990. Since that time, the final product has been modified to remove the pseudo nodes that broke the stream network at 100K-scale quadrangle, 24K-scale quadrangle, and county boundary lines. However, because the Puget

Sound Water Quality Authority wanted to retain these pseudo-node features, the earlier version of the PSGIS network data layer was used instead of the modified version (Fisher, 1996).

Data Digitized for the Puget Sound Geographic Information System

Data that were digitized included the Washington Department of Ecology Water Body System delineation and the Washington Department of Health 1990 Shellfish Inventory.

Water Body System

The embayment delineation and numbering system was depicted on six National Oceanic and Atmospheric Administration nautical chart base maps. Five of these base maps were in unique Mercator projections at a scale of 1:80,000 and one was in a Polyconic projection at 1:40,000. The Puget Sound shoreline data layer was used as a template and was transformed into the same projection as each nautical chart base map. The shoreline template was overlaid on the shoreline of each nautical chart base map, and the delimiting embayment boundaries were digitized and joined to a copy of the shoreline data layer. Attributes were added to indicate the Washington Department of Ecology embayment number and area in square miles.

Shellfish Inventory

The 1990 Shellfish Inventory maps from the Washington Department of Health were created by delineating the status areas on four National Oceanic and Atmospheric Administration nautical chart base maps in Mercator or Polyconic projection, which were later reproduced by commercial photocopy. This photocopy process produced maps of poor quality that could not be registered within accepted tolerances (root-mean-square [RMS] errors must be less than 0.003) and, therefore, the photocopied maps could not be used as a source for digitizing. In addition, information necessary to the accurate replication of data, such as scale, projection, and date of the base map, were blanked out from the National Oceanic and Atmospheric Administration nautical chart base map by the 1990 Shellfish Inventory map legend and by other text.

The photographic negatives used to create the photocopies were acquired. Although the photographic negatives are a stable base, the 1990 Shellfish Inventory status areas had been identified using zip-a-tone on mylar. Because the patterns were difficult to

distinguish and there were 16 separates, the photographic negatives were not digitized. Instead, the four maps were hand traced onto a plot of the shoreline data layer projected to Mercator or Polyconic. Using this plot of the shoreline data layer as a template, the hand-traced status areas were digitized by overlaying the 1990 Shellfish Inventory shoreline onto the shoreline data layer. The final product joined a copy of the shoreline data layer with the hand-traced status areas and was projected back to UTM. With this method, no additional resolution, registration, or projection errors would be introduced because all layers would contain identical shorelines.

The 1990 Shellfish Inventory contains additional information about recreational shellfish beaches and sewage-treatment outfalls. This information also was digitized and placed into separate ARC/INFO data layers. Refer to information about DOHREC and DOHSEWAGE attributes in Appendix A.

PUGET SOUND ENVIRONMENTAL ATLAS DATA LAYERS

Data Sources

The PSEA was originally compiled by Evans-Hamilton, Inc., for the Puget Sound Water Quality Authority. Digital cartographic files were created by D.R. Systems of Vancouver, British Columbia, Canada (Evans-Hamilton, Inc., and D.R. Systems, Inc., 1987). These digital files were archived by the U.S. Army Corps of Engineers in Seattle, Washington. The archived files are Intergraph design files in VAX backup format and were written to magnetic tape as "Base" and "Extra" file data. Base and Extra are project-specific nomenclature for the design files. Base refers to the first items included on the base map and Extra to items added onto the base (Environmental Systems Research Institute, Inc., 1988). The Bonneville Power Administration, which has both Intergraph and ARC/INFO capability, converted the design file format to AutoCAD Drawing Interchange Format (DXF). The AutoCAD DXF could then be imported to ARC/INFO. The conversion to AutoCAD was completed by Bonneville Power Administration for all 12 regions of the PSEA. Two DXF files were created from 2 Intergraph files for each of the 12 PSEA regions: a DXF Base file contained 90 percent of the desired PSGIS data; a DXF Extra file contained the kelp and eelgrass data, as well as other information.

Layer Descriptions

Data topics from the PSEA were composited in logical groups to form PSGIS data layers that included seabirds, habitat type, marine mammals and fish, as well as shellfish resources and bed type. Because location of many of the resources are coincident (clams and oysters can occupy the same beds), many of the data fields created in the PSGIS are simple presence/absence flags, in which the particular resource attribute is given a value equal to 1 if present and 0 if not present. The simplicity of this data structure allows the coincident location of resources to be described in a single, composited data layer. In addition, the original, uncomposited species and resources data in each of the data layers are provided as separate coverages. The individual coverages that constitute the composited data layer are listed in table 4. The final data-set products and attribute-field definitions are documented in Appendix B.

Seabird Nesting Areas

The PSEA contains information on the location of seabird nesting sites in the Puget Sound area. Seabird species represented in this data set include glaucous-winged gull, double-crested cormorant, pelagic cormorant, pigeon guillemot, tufted puffin, rhinoceros auklet, black oystercatcher, and arctic tern. The seabird data layer in the PSGIS is a reproduction, presented in digital form, of PSEA information and associated database files. The digitized locations of many of the seabird nesting areas, by species, are shown in figure 8.

Nearshore Habitat

Habitat data compiled in the PSEA includes an "Eelgrass, Kelp beds" map sheet for each of the 12 PSEA regions. The PSEA also contains information on Habitat Management Areas, National Estuarine Sanctuaries, Nature Preserves, and National Wildlife Refuges. Only the eelgrass and kelp bed data were converted and composited into the nearshore-habitat data layer. The polygon label points of the digitized kelp and eelgrass beds throughout the Puget Sound area are shown in figure 9. Because of their small size and similarity to the shoreline data layer, polygons of the eelgrass and kelp bed areas were not plotted. Instead, to increase the visibility of the kelp and eelgrass bed areas, symbols were used for the label points.

Table 4. Data layers, resource layers, and definitions of the Puget Sound Environmental Atlas

[ID#, data-layer identification number; GIS, geographic information system]

Data-layer name (uncomposited)	ID# [2]	Resource layer[1] (composited)	Definition
AUKLET	1	Bird	Rhinoceros auklet
D_CORM	2	Bird	Double-crested cormorant
GUILLEMOT	3	Bird	Pigeon guillemot
GULL	4	Bird	Glaucous-winged gull
OYSTERCAT	5	Bird	Black oystercatcher
PUFFIN	6	Bird	Tufted puffin
P_CORM	7	Bird	Pelagic cormorant
TERN	8	Bird	Arctic tern
EELGRASS	9	Habitat	Eelgrass
HMA	10	Habitat	Habitat Management Area
KELP	11	Habitat	Kelp
NES	12	Habitat	National Estuarine Sanctuary
NP	13	Habitat	Nature Preserve
NWR	14	Habitat	National Wildlife Refuge
C_SEALION	15	Mammal	California sea lion
DALL_PORP	16	Mammal	Dall's porpoise
HARB_PORP	17	Mammal	Harbor porpoise
HARB_SEAL	18	Mammal	Harbor seal
MINKE	19	Mammal	Minke whale
N_SEALION	20	Mammal	Northern sea lion
OTTER	21	Mammal	River otter habitat
EX-PEN_CULT	22	Marine	Existing pen culture
FISH_COM	23	Marine	Salmon resources - commercial fishing areas
FISH_SPORT	24	Marine	Salmon resources - sport fishing areas
GROUNDFISH	25	Marine	Groundfish resources and fishing areas
HERR_HOLD	26	Marine	Pacific herring holding area
HERR_SPAWN	27	Marine	Pacific herring spawning area
SMELT	28	Marine	Surf smelt spawning beach
B_CULT	29	Shellfish	Bottom culture
CLAM_MAJ	30	Shellfish	Subtidal clams - major
CLAM_OY	31	Shellfish	Clams and oysters - commercial
CRAB	32	Shellfish	Dungeness crab
GEO_COM	33	Shellfish	Geoducks - commercial
GEO_MAJ	34	Shellfish	Geoducks - major
OYSTERS	35	Shellfish	Oysters - commercial
SHRIMP	36	Shellfish	Shrimp
SUSP_CULT	37	Shellfish	Suspended culture
TRIBES	38	Tribes	Tribal usual and accustomed fishing places
PRO_PEN	39	Marine	Proposed pen culture

[1] These resource layer names are the digital-data names used in the GIS processing and correspond to the following composite of data-layers in text.

Digital name	Heading in text
Bird	Seabird nesting areas
Habitat	Nearshore habitat
Mammal	Marine mammal
Marine	Marine fish
Shellfish	Shellfish
Tribes	Tribal areas

[2] The ID#'s are the coverage-ID's in the INFO database assigned to each data layer in the Puget Sound Geographic Information System. Cover-ID's are the integer numbers in the feature attribute table that are used to identify arcs, polygons, points, and nodes.
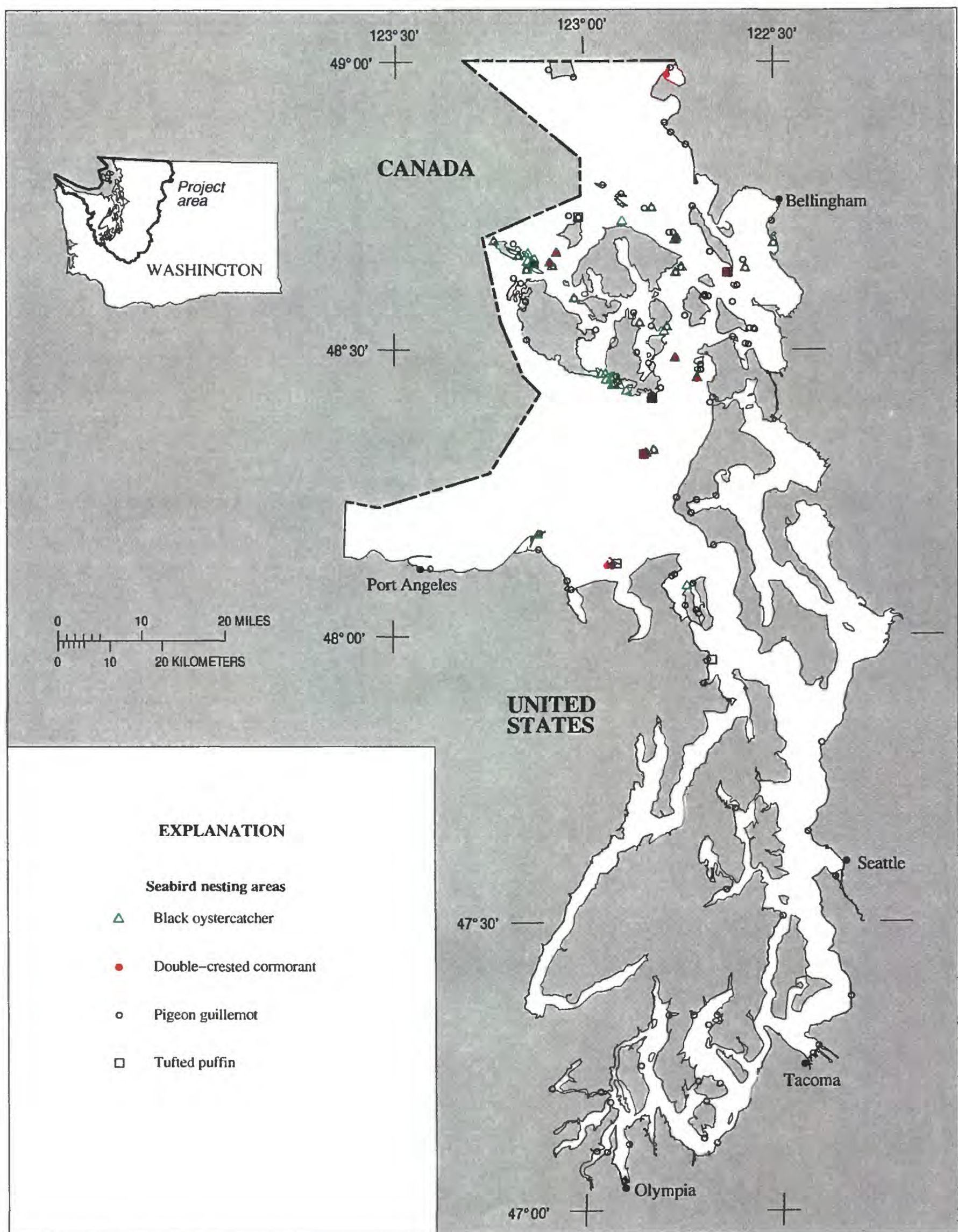
Figure 8. Digitized locations of seabird nesting areas for selected species.

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Base map from U.S. Geological Survey
1:100,000 Digital Line Graphs, 1989a.
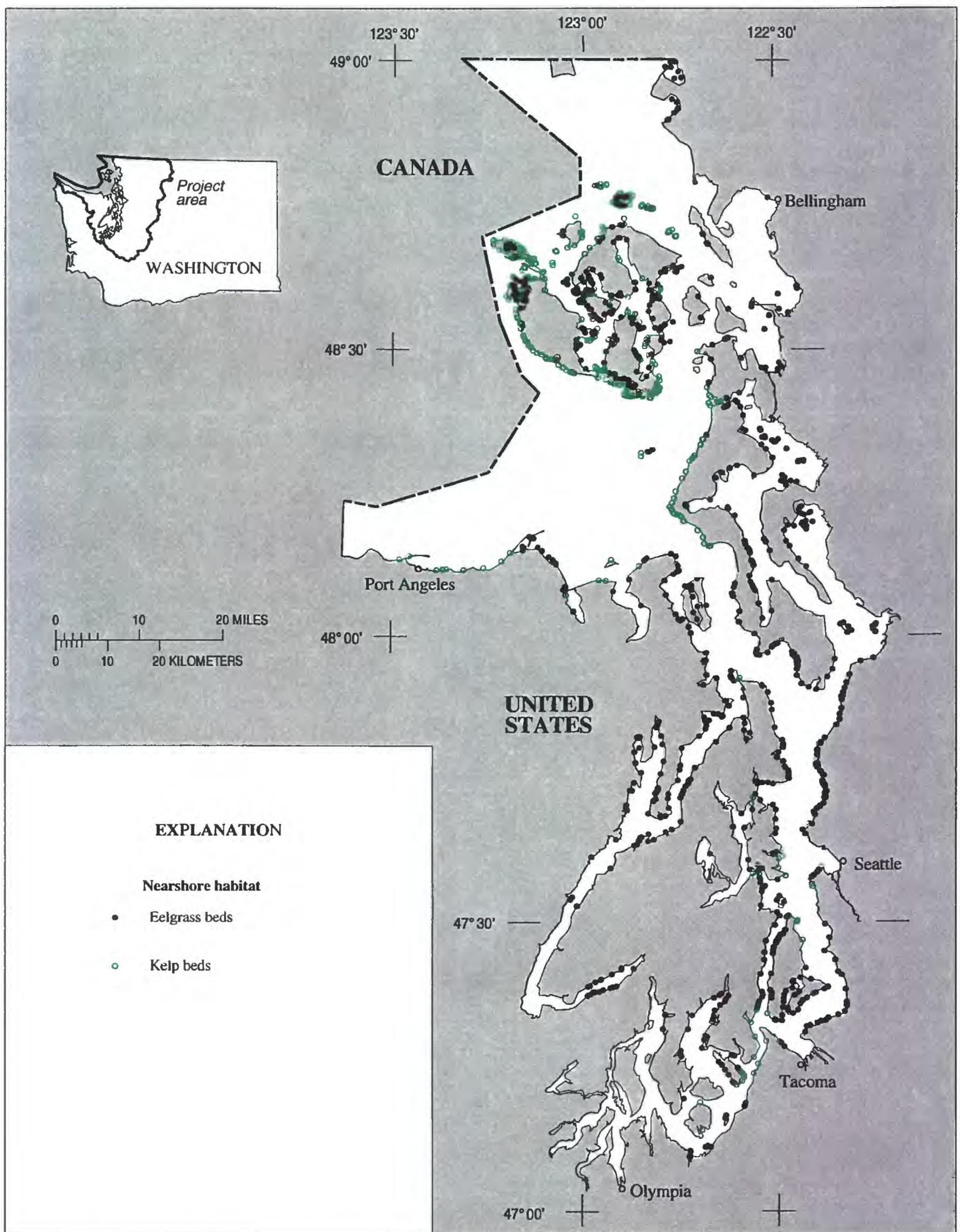
Figure 9. Digitized locations of kelp and eelgrass beds larger than one acre.

Marine Mammal

Data on marine mammals, compiled in the PSEA and converted to PSGIS, consists of haul-out locations and confirmed sightings. Species at haul-out sites include harbor seal, northern sea lion, and California sea lion. Species sighted included Dall's porpoise, harbor porpoise, and minke whales. Habitat also was delineated for the river otter. Some of the data portrayed in the PSEA for Regions 4, 5, and 6 were not available in the digital data files and some were digitized from original PSEA mylars. A plot of the digitized locations for selected marine mammals, except for minke whales, is illustrated in figure 10.

Marine Fish

The marine fish data layer in PSGIS consists of information from PSEA map sheets on Aquaculture, Salmon Resources, and Marine Fish Resources. Species and location information in the marine fish data layer includes existing and proposed pen aquacultures; salmon resources—commercial and sport fishing areas; marine fish resources—groundfish resource and fishing areas, Pacific herring holding and spawning areas, and surf smelt spawning beaches. The digitized salmon and groundfish resources are shown in figure 11 and the Pacific herring areas in figure 12.

Tribal Areas

Separate information from the PSEA map sheets was compiled for Tribal names and areas. Information on Tribal areas was contained on the same map sheet as the Salmon Resources and was listed as Usual and Accustomed Fishing Places; the specific Tribal designation also was included. Like the water body data layer, the lines delimiting Tribal areas were digitized and added to a copy of the shoreline data layer. Attributes for a Tribal name were assigned to respective Tribal areas, and a data layer for named Tribes was created.

Shellfish

The shellfish layer consists of data from PSEA map sheets of Shellfish Resources and Aquaculture/Shellfish Bed Certification Status. Attribute items included the species present (clams, oysters, shrimp, Dungeness crab, and geoducks) and area-use type, such as commercial or potential commercial. Aquaculture information includes data on suspended and bottom cultures.

Because of the many species in the Shellfish Resources maps, there are overlaps between data layers. For instance, the crab data layer contains numerous combinations of the other data layers at certain locations. When each species layer is plotted, a mottled pattern of overlapping results making it difficult to discern the actual area in which a species may be present. For this reason, crab and shrimp areas were depicted separately (figure 13). The bottom-dwelling species—clams, geoducks, and oysters—were grouped with bottom and suspended cultures.

Processing Procedures

The processing of the PSEA data layers consisted of three steps. First, the Intergraph files were converted to ARC/INFO format. Second, the data layers were correctly registered to a world-coordinate system with a low RMS error. Third, each resource type was extracted as a unique data layer.

Drawing Interchange Format File Conversion

The DXF file is in a compatible exchange format between Intergraph and ARC/INFO software. The Intergraph design files contain 35 separate levels of graphic data which directly correspond to AutoCAD DXF layers. The DXF format is an ASCII file and contains information about line types, annotation, color, as well as the coordinate values for the line data. The DXF files are large. As an example, the primary file (BASE6.EHI) for PSEA Region 6 was 6.8 megabytes. Shorelines were digitized in stream mode, which increased the number of vertices per arc (line) and added to the size of the DXF file. These unneeded vertices were deleted after the DXF file was converted to an ARC/INFO data layer.

Each DXF file was converted to a composite ARC/INFO data layer with the ARC command DXFARC ($REST ALL options). It was determined during the pilot phase of the project that it was easier to transform all of the data at a single time to a world-coordinate system during the registration process rather than to transform each layer separately. Topology was then constructed using the BUILD command with the LINE option. When the layers were converted, the attributes from DXFARC were contained in an INFO ".ACODE" file (Environmental Systems Research Institute, Inc., 1989). The ACODE file was merged with the coverage Arc Attribute Table (.AAT) to associate the attributes to their corresponding arcs.
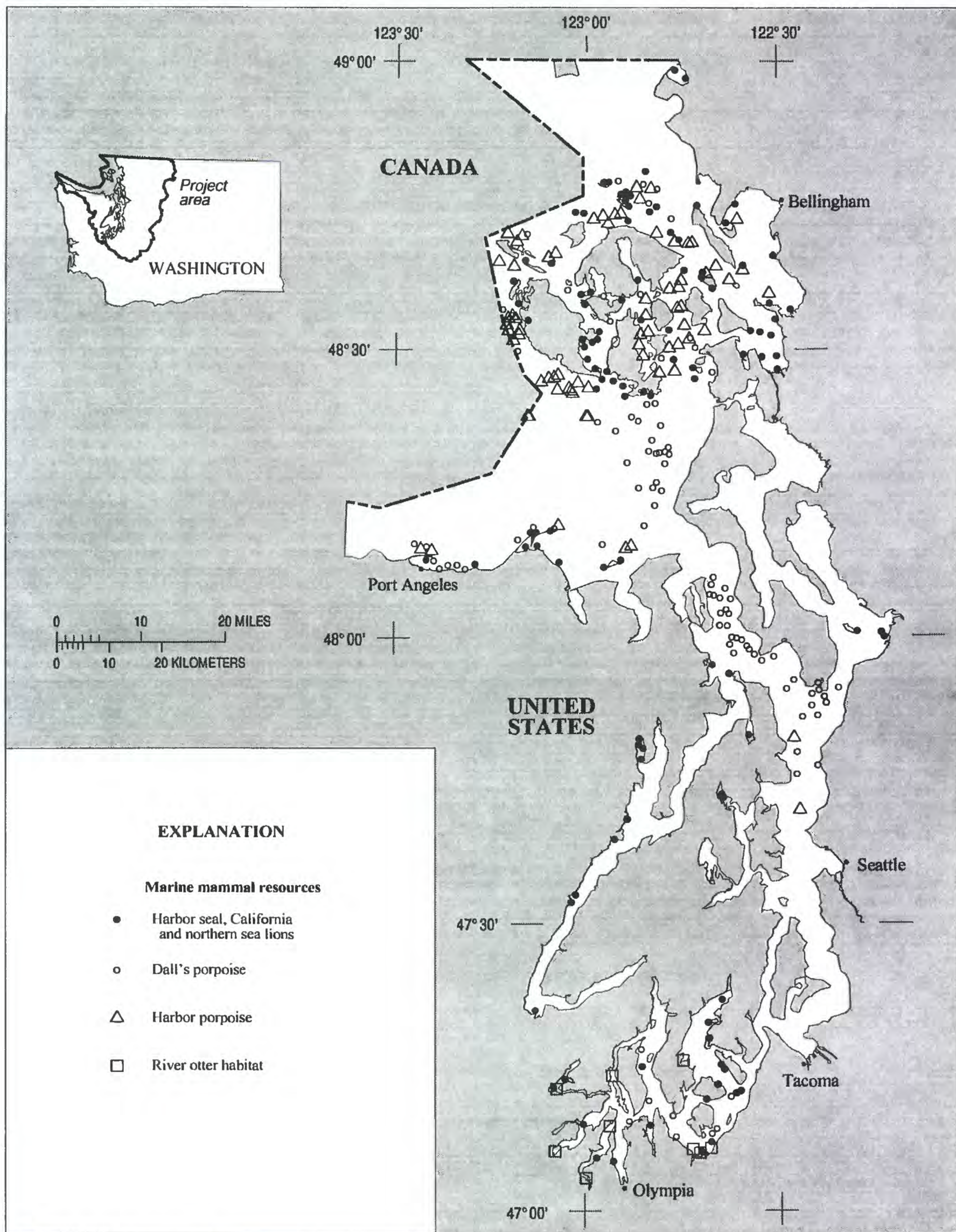
Figure 10. Marine mammal digital points for selected species.

EXPLANATION

Marine mammal resources

- ● Harbor seal, California and northern sea lions

- ○ Dall's porpoise

- △ Harbor porpoise

- □ River otter habitat
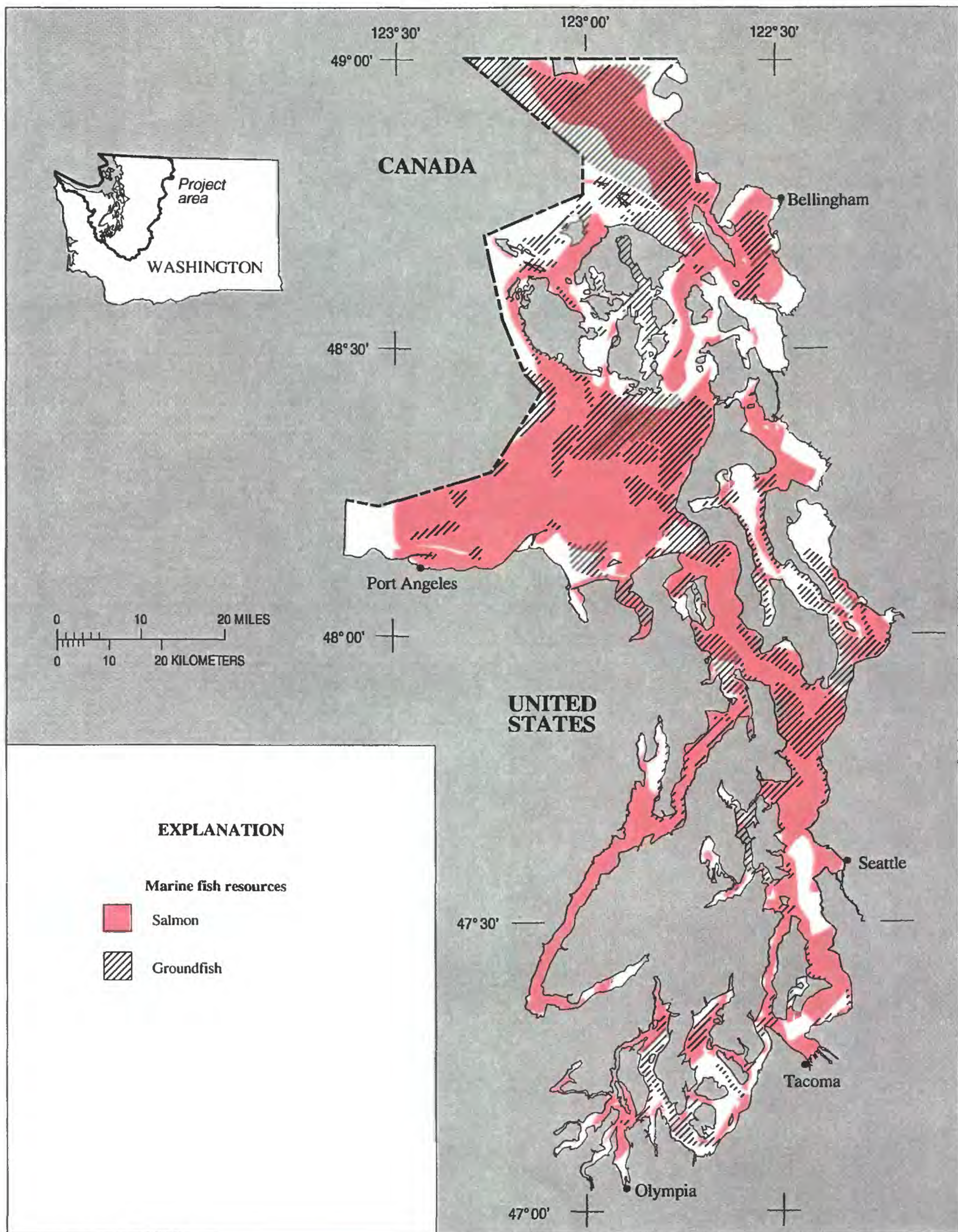
Figure 11. Salmon and groundfish resources.

CANADA

• Bellingham

UNITED
STATES

Port Angeles

• Seattle

• Tacoma

Olympia

WASHINGTON

Project area

EXPLANATION

Marine fish resources

Salmon

Groundfish

CANADA

• Bellingham

Port Angeles

UNITED
STATES

Seattle

Tacoma

Olympia

EXPLANATION

Herring marine resources

Pacific herring spawning areas

Pacific herring holding areas
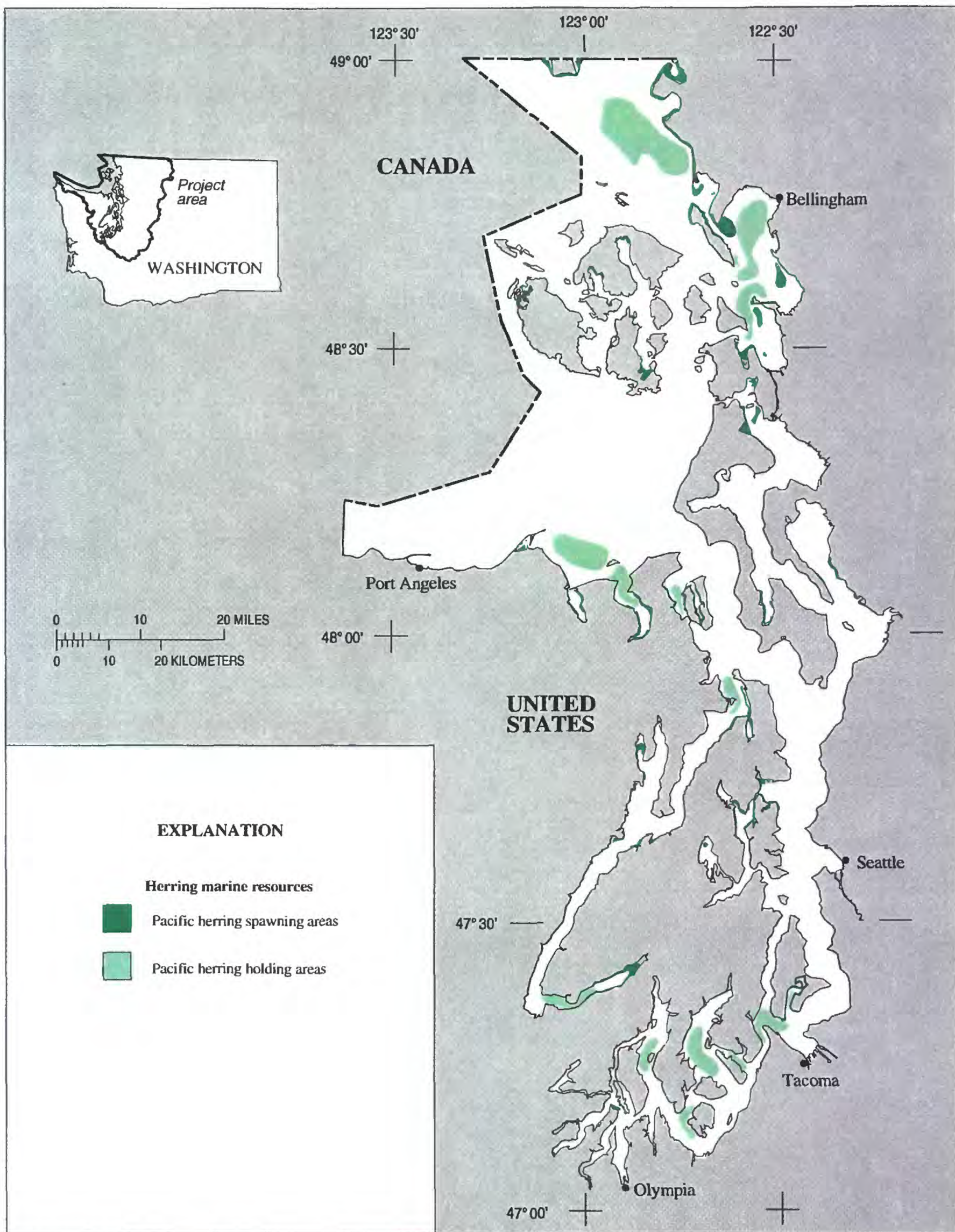
Figure 12. Pacific herring resources.

CANADA

Bellingham

Project
area

WASHINGTON

48° 30'

Port Angeles

0   10   20 MILES

0   10   20 KILOMETERS

48° 00'

UNITED
STATES

Seattle

EXPLANATION

Selected shellfish resources

Crab only

Shrimp only

47° 30'

Clams, geoducks, oysters,
bottom and suspended
cultures only

Tacoma

Olympia

47° 00'
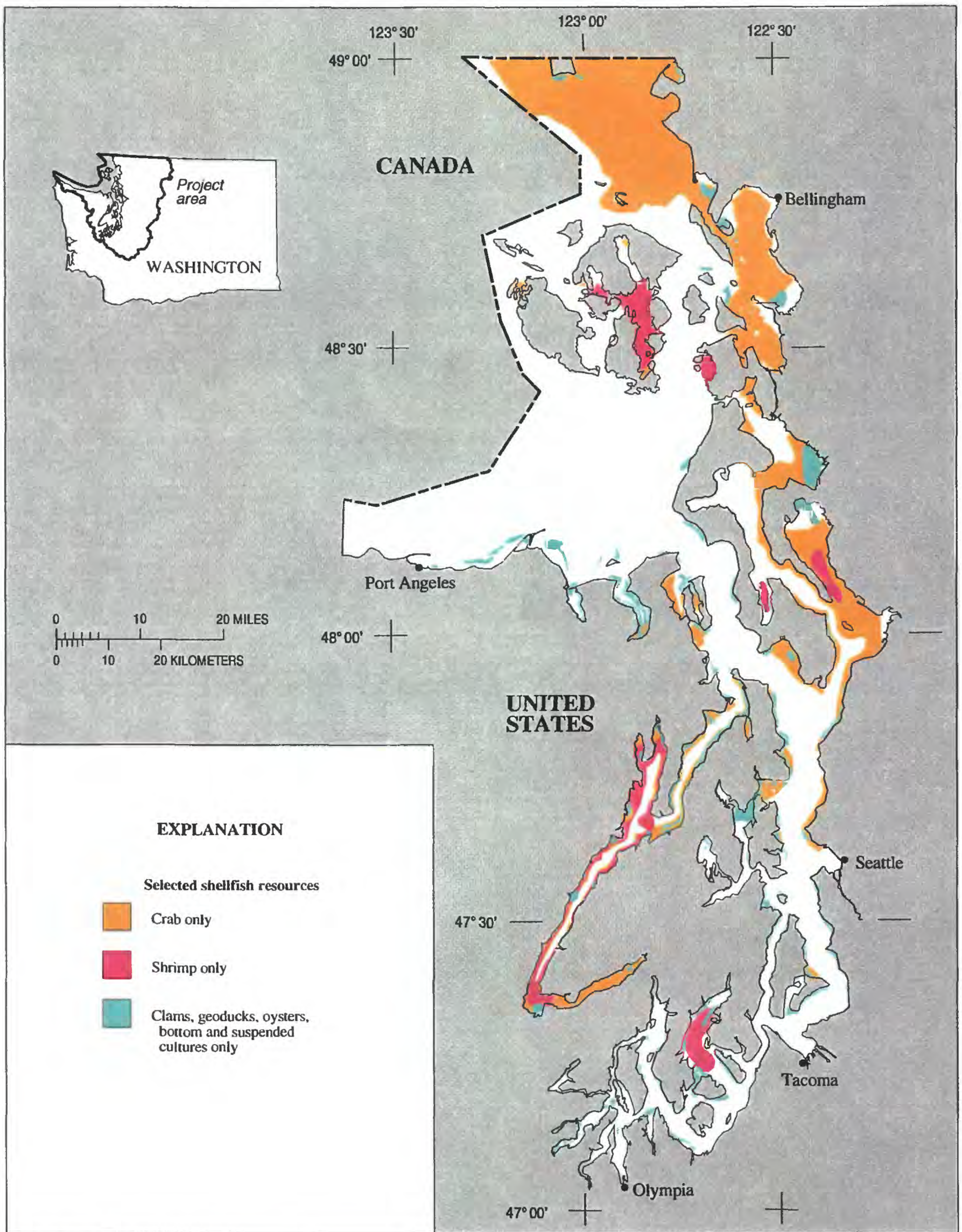
Figure 13. Selected shellfish resources.

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The JOINITEM command was used to merge data fields. The data layers were now ready to be extracted into separate resource data layers using the ARC RESELECT command.

Registration of Data Layers

The Intergraph design files and subsequent DXF files were not in a known, world-coordinate system. The native coordinate system for the Intergraph design files should use millimeter coordinates in a Polyconic projection. Thus, if the data were plotted at a 24K scale, they would overlay a U.S. Geological Survey 24K-scale quadrangle sheet. The DXF Base and DXF Extra files received by the U.S. Geological Survey used at least three different origin locations and were not always in millimeter coordinates. Because the coordinates were not always the same, the DXF Base and DXF Extra files for each PSEA region did not always precisely overlay each other.

Registration Coordinates

A set of latitude/longitude grid tics were contained in layer 58 of the DXF Base files. These grid tics were used as geographic controls in the transformation process to register the DXF Base and DXF Extra files. This DXF layer was extracted from the composite ARC/INFO data layer using the ARC RESELECT command. The layer consisted of short lines around the edges of a PSEA region that indicated latitude/longitude line locations. Tics were created at the intersection of these lines but were not attributed. Lines were added to connect these tics and to create a latitude/longitude grid in the native-coordinate system. The intersections of the latitude/longitude grid became the control points for the transformation into a world-coordinate system.

The latitude/longitude grid was extracted to create a separate data layer, and the ARC NODEPOINT command was used to create points at the latitude/longitude intersections. The transformation process requires that each geographic control point be uniquely identified. The INFO internal ID values were used as unique identifiers, instead of renumbering manually. Each PSEA region had from 21 to 55 control points, depending on the size of the region. The ID values for the point data layers were modified to uniquely identify each point in a region and each point in all the combined regions.

The formula used in the calculation was (in INFO syntax using PSEA Region 12 as an example):

CALC B12_DXFTIC-ID = 1200 + B12_DXFTIC-ID

This method was used to create a uniquely numbered set of points for the extent of the PSEA area. The points were converted to ARC/INFO tics with the POINT-TIC.AML (S.W. McKillop, U.S. Geological Survey, written commun., 1990). The four arbitrary tics created with the ARC command DXFARC were deleted with the ARC DELETETIC command and the new latitude/longitude tics were substituted into each data layer.

Control Coordinates

The next step was the creation of a matching geographic-control data layer, in a world-coordinate system. To create this data set, the latitude/longitude for each of the PSEA tic-intersection points was entered into a file as units of degrees, minutes, and seconds. The file coordinates were converted to decimal-degree coordinates with the ARC/INFO PROJECT command. ID numbers matching the corresponding coordinates in the DXF data layers were given to the new data set and a point data layer was created with the ARC/INFO GENERATE command. ARC/INFO tics were created from the points in each PSEA region with the POINTTIC.AML. All of the tics were then appended into one data layer covering the entire area into a tic coverage called RALL_TIC. These tic IDs and the latitude/longitude coordinates in degrees, minutes, and seconds are listed in Appendix C.

The DXF files are not in a known projection system but when plotted will overlay the U.S. Geological Survey 7-1/2- minute (24K-scale) quadrangle sheets (Environmental Systems Research Institute, Inc., 1988). A Lambert Conformal Conic or Polyconic projection is used for the 24K-scale quadrangles in the study area, yet each has its own unique projection parameters. A Lambert Conformal Conic projection that covers the same area as the PSEA regions would not have exactly the same parameters as each 24K-scale quadrangle sheet, but the differences should be small (Snyder, 1987). The State Plane coordinate system also can be in Lambert Conformal Conic. For States such as Washington that have a predominant east-west expanse, Lambert Conformal Conic has the advantage of using only one set of projection parameters; such was the case for the entire Puget Sound area of Washington (Snyder, 1987).

Ideally, an accurate transformation to a world-coordinate system would be made with the same projection as the original base map from PSEA. In this case, the DXF coverages were transformed into either a Lambert Conformal Conic or Polyconic projection. Paper copies of these world coordinate, control data layers were generated in Lambert Conformal Conic, State Plane Zone 5626, and UTM and were named RALL_TIC.LAM, RALL_TIC.SP, and RALL_TIC .UTM, respectively. The three projections were used in the early transformation stages to determine the most accurate and the easiest method of registering the DXF coverages.

Root-Mean-Square Error

There exists inherent error in all transformations of digital data. RMS values are used to quantify this error by performing a mathematical operation on the original and the transformed data. Regions 5 and 6 of the PSEA were used to test the transformation process. The desired end projection was UTM, the projection for the PSGIS and DLG data. The DXF coverages were converted to UTM coordinates by three methods: transformation to Lambert Conformal Conic coordinates and projection to UTM coordinates, transformation to State Plane coordinates and projection to UTM coordinates, and transformation directly into UTM. The RMS error was compared for all three methods. The mathematical formula used to compute the RMS errors and the values calculated are shown in table 5.

That two-step process of conversion first to Lambert Conic Conformal or State Plane before conversion to UTM did not significantly improve the RMS error when compared with direct transformation to UTM (table 5), although the RMS error remained high despite the direct conversion to UTM. As a result, a shift occurred between the converted DXF and PSGIS shoreline data layers. This shift was visible as two distinct data layers, when both shoreline data layers were viewed on a CRT display at full zoom. The resulting error was not anticipated, because the original data were created in a highly accurate CAD/CAM system.

Different transformation processes of the DXF files to world coordinates were used to decrease this registration error. Early transformation of the PSEA data used only four control points per PSEA region. The final PSGIS tic-data set totaled 312 control points and produced an RMS error greater than 60 meters.

A second iteration transformed each DXF file into a tic set that approximately matched 1 of the 12 corresponding PSEA regional tic sets. That is, instead of using a combined tic set for all 12 PSEA regions, the DXF files for each region were transformed one at a time using their own unique tic set and then combined into one data set. This stepwise transformation of each DXF region into the combined data set also reduced, but did not eliminate, the visible shift and resulting RMS error. As a final test, original Puget Sound Water Quality Authority mylar base maps were acquired and

Table 5. Root-mean-square error, in meters, for data transformation to three projection systems in the Puget Sound Environmental Atlas, Regions 5 and 6

[DXF, Drawing Interchange Format; UTM, Universal Transverse Mercator; measurements given are in meters; RMSE[1], root-mean-square error]

Region	DXF coverage name	Lambert	State plane	UTM
5	(B5ALL)	53.267	175.050	53.224
6	(B6ALL)	43.076	(2)	43.030

[1] Root-mean-square error is a statistical method to determine correlation between two sets of data. The equation for root-mean-square error is:

$$RMSE = \sqrt{\Sigma \frac{(x-y)^2}{n}}$$

where
x = DXF value
y = new projection value
n = total number of values

[2] State Plane coordinate system was not used due to the high root-mean-square error for Region 5 of the Puget Sound Environmental Atlas.

digitized for DXF files lacking data, which included the marine bird and mammal files. When the mylars were registered on the digitizer to the latitude/longitude intersection tics, RMS error values identical to direct transformation to UTM coordinates resulted. Therefore, it was assumed the cause of the shift was incorrect location of the latitude/longitude tics on the published and the digitized PSEA maps. A list of the PSEA regions and the corresponding RMS errors are in table 6.

Individual tic-coordinate error, in both the x and y directions, is displayed with the ARC TRANSFORM command. The coordinate error records for this transformation are in Appendix D. The range and distribution of individual errors are summarized in figure 14 for both the x and y directions.

Extra File Conversion and Registration

The Extra DXF files for each region contain the kelp and eelgrass information for the habitat data layer of the PSGIS. Although the DXF Extra and DXF Base file conversion process to composite data layers is identical, there are differences in the registration process.

The latitude/longitude grid tics (layer 58) present in the Base DXF data layers were missing from the Extra DXF data layers, resulting in a northward offset for specific Extra data layers when overlaid onto Base data layers.

In addition, three Extra data layers had coordinates that were different from those in the Base data layers. For those three Extra data layers, layer 62 was used for registration because layer 58 was missing. Layer 62 contained cross-hair tics in the upper-left and lower-right corners that were used to create grid-tic lines for correct registration of the Extra data layers to the Base data layers. Once registered, the control tics from the Base data layers were substituted for the tics in the Extra data layer and the transformation process continued in the same manner as for the Base composite data layer.

Data layers for PSEA Regions 2, 3, and 4 did not have plotting grid tics and virtually no geographic controls to register to the Base data layers or to transform to UTM coordinates. Those data layers were transformed to UTM coordinates by substituting the Base data layer control tics without matching the Extra data layer to the Base data layer. Once in UTM, the desired data layers for kelp and eelgrass were manually fitted by visually placing the beds on the corresponding UTM Base data layer. Although there is no method to measure the accuracy of this placement, it was the only alternative for PSEA Regions 2, 3, and 4 of the Extra files.

Data-Layer Extraction

The registered PSEA data layers, now in ARC/INFO format with UTM coordinates, contained cartographic representations of the Puget Sound area resources.

Table 6. Root-mean-square error, in meters, for latitude/longitude tics on Puget Sound Environmental Atlas regional maps

[RMSE [1], root-mean-square error]

Region	RMSE	Region	RMSE	Region	RMSE
1	27.073	5	53.224	9	13.448
2	36.650	6	43.030	10	12.324
3	30.897	7	13.647	11	61.771
4	12.174	8	11.846	12	12.295

[1] Root-mean-square error is a statistical method to determine the correlation between two sets of data. The equation for root-mean-square error is:

$$RMSE = \sqrt{\Sigma \frac{(x-y)^2}{n}}$$

where x = Drawing Interchange Format (DXF) value
       y = new projection value
       n = total number of values
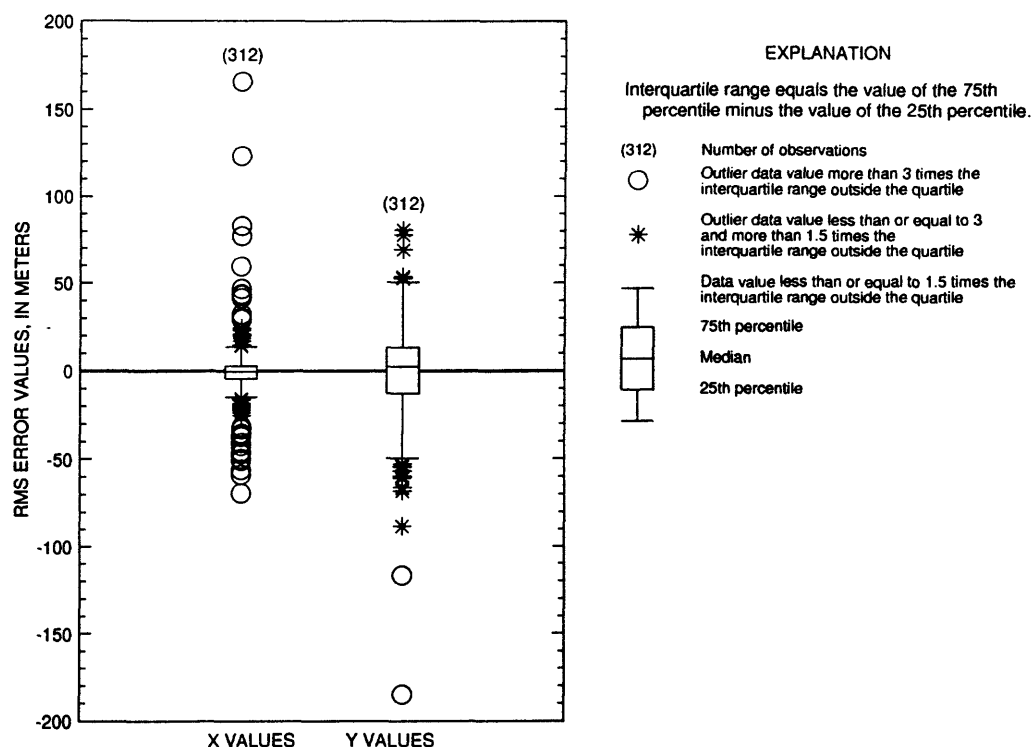
Figure 14. Root-mean-square error for Base and Extra DXF (Drawing Interchange Format file transformation).

The digital data were a representation of a published PSEA map sheet. For example, an area depicting the location of Dungeness crab resources was filled with angled hachure lines. In a vector GIS environment, this area is represented by a polygon. Once the polygon has been created and topology constructed (gaps are closed, sliver polygons and dangling arcs eliminated), attributes can be assigned for that particular area. The creation of the PSGIS data layers from the PSEA required taking the cartographic representations of areas—such as lines (unbroken and dashed), hachured areas, and symbols—and creating topologically correct, polygon data layers for the desired resources.

PSEA resources were extracted from the composite DXF data layer using the DXF-LAYER INFO item and the ARC RESELECT command to create single, resource data layers. For example, the features with a DXF-LAYER value of 46 contained the cartographic representations of clam, oyster, and geoduck resource areas. Each resource was then extracted into its own data layer for further editing and attribution. There were four possible types of areas that could be extracted from each DXF layer. The following is a description of those areas and the methods used for extraction.

Line-Delimited Areas

The areas of the PSEA Shellfish Resources maps showing geoduck resources are examples of line-delimited areas. Areas made up of unbroken lines in the PSEA files were easy to select manually (using a CRT display in ARCEDIT) and place into new coverages with the PUT command. Other areas—represented with broken or dashed lines—required manual connection before polygon topology could be created. Usually, the dashed lines were selected and put into a new coverage before final editing.

Shoreline Areas

Beaches where surf smelt spawning occurs are examples of shoreline areas that are indicated by a thick line along the shore with short perpendicular branches pointing landward to distinguish the area from the regular shoreline. To assure feature coincidence with the 100K shoreline DLG, a segment of the PSGIS shoreline data layer that matched the geographic extent of the PSEA surf smelt spawning beach was used. These lines were placed into a separate data layer and buffered by 20 meters to create polygons.

The 20-meter radius was chosen because a smaller radius tended to collapse into lines during later processing. This data layer, now in a GIS with calculated areas, was added to the final Marine resource layer of the PSGIS.

Hachured Areas

Hachured areas (relief features indicated on a map by short, parallel lines) were the most complex representations in the PSEA data sets. Often, as in layer 46, multiple PSEA resources were represented by hachures of varying angles and separation distances to distinguish resources from one another. Hachure lines indicating the extent of polygons in the data layer can be manipulated by setting up geographic-coordinate relations that give the hachures unique association to resources. Hachure lines for a given resource all run in the same direction. The ARC TURNTABLE command will create a .TRN file in INFO for all of the nodes in the data layer. One of the attributes in the .TRN file is the azimuth of the arcs. This attribute can be used to associate each hachure with a resource. In ARCEDIT, a RELATE was established between the .AAT file and the .TRN file to determine the azimuth of all the arcs of a particular set of hachure lines; that is, all of the arcs for a resource were represented by those hachures. A detailed explanation of that process, in ARC and INFO commands from DXF layer 41 (Dungeness crab areas), is given in Appendix E.

Once individual resource hachures are selected out and placed into their own data layers, a bounding polygon is placed around the area indicated by each set of hachures. An AML (LINEPOLY.AML) procedure was developed to automate this task. LINEPOLY .AML buffered the hachure lines with a buffer distance slightly greater than half the distance between hachures, and then snapped the resulting delimiting polygon back to the nodes at the end points of the hachures. This automatically created a polygon that corresponded to the area represented by the hachures.

Symbol Areas

Seabird nesting areas, and marine mammal haul-out sites and sightings are represented in the PSEA as circles with a number in the center that identifies a particular species in the legend. When converted into real-world coordinates, the circles symbolizing nesting areas become large areas. Because the original information, including the precise coordinates on nesting

sites was unavailable, the data were digitized directly from the PSEA. Points were digitized at the center of the circle to represent the nesting site. Additional sites in the PSEA were identified with a pointer line from the circle to a point on the shore. In these cases, a point was created at the end of the pointer line to represent the site. Individual species data layers were created for each PSEA region, and each species was given unique identifiers to facilitate creation and attribution of the final composite.

Because the PSEA resource layers were primarily polygonal features, it was determined that the seabird and marine mammal resources would better match the rest of the PSEA data if polygons were created to represent the information. The points identifying nesting or haul-out sites were buffered with a radius of 20 meters. A label point was maintained in the center of each polygon.

In some instances, the PSEA information represented a length of shoreline, usually indicating a colony—such as pigeon guillemot or harbor seal. The specified shoreline segment was extracted from the 100K-scale Puget Sound Area data layer. This line feature was buffered with a 20-meter radius to create a polygon feature. Attributes were then assigned to the polygons. The separate bird or mammal data layers were composited together with the ARC UNION command to form the seabird and mammal resource data layer.

Compilation of Puget Sound Environmental Atlas Data

Individual resource data layers were created and managed in a directory structure organized by PSEA region. Resource data layers within each of the 12 regional directories were assigned the same name. This type of organization facilitates automation of as much of the final editing and attributing as possible. The final coverage ID in the .PAT and .AAT files was attributed with a unique code indicating the resource and the PSEA region. Refer to table 4 for the unique resource ID numbers and data-layer names and definitions.

Unique ID values were calculated by multiplying the region number by 100, and adding the resource ID number to the product. For example, the following formula would be used to attribute the shrimp data layer in the PSEA region 12 directory:

CALC SHRIMP-ID = (12 * 100) + 36 = 1236

After the data layers in the PSEA regional directories were completed and checked, the data layers were copied to a resource directory, such as shellfish, and composited into Puget Sound area-wide resource data layers with the UNION command. The UNION command paneled the adjacent PSEA regions together. The ARC DISSOLVE command was applied to the unioned data layer to eliminate the borders of polygons that were located in more than one PSEA region. The dissolved data layers were then composited, again with the UNION command, to produce the final PSGIS resource layer from PSEA data. Based on the unique IDs, attribute fields were added to the composite and then populated. When attribution was complete, unneeded data fields were dropped from the .PAT files. The final products do not have line topology, but if built with the LINE option, the IDs would reflect the origin resource of each line.

The separate uncomposited data layers, used to construct these final composited resource layers, also are provided. Attributes for these individual data layers are the standard Arc Attribute Tables (.AAT) and/or the Polygon Attribute Tables (.PAT), and include a unique item-name matching that of the data layer. For example, the groundfish data layer, as part of the marine fish composited resource layer, has an item in the .PAT called GROUNDFISH which is equal to 25, the unique ID number from table 4.

SUMMARY

Data from the Puget Sound Environmental Atlas have been converted to the Puget Sound Geographic Information System using the ARC/INFO software. Each data layer is available as a graphic coverage (ARC) with associated tabular data (INFO database), as an individual data layer, and as a composited resource layer composed of these corresponding data layers. Additional environmental data layers, not contained in the Puget Sound Environmental Atlas, also are included in the Puget Sound Geographic Information System. The processing methods used to convert the data layers to a geographic information system are discussed. Sources of error, inherent with any conversion of cartographic data to a geographic information system, also are addressed. The Appendixes contain data dictionaries for data from the Puget Sound Environmental Atlas and other sources, root-mean-square error values for atlas data, tic-coordinate error values, and a detailed list of commands used to manipulate the hachure atlas data. Data can be retrieved by contacting the State of Washington Department of Natural Resources (Division of Aquatic Resources) or the U.S. Geological Survey.

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—PAGE 33 FOLLOWS—

GLOSSARY

Albers Equal Area. A conical map projection system with two standard parallels (lines of latitude) along which there is no distortion. The first parallel is at the top of map and the second parallel on the bottom. A central meridian (a true vertical line of longitude usually in the middle of a map) also is used. Areas with predominant east-west expanse are best portrayed.

AML. ARC Macro Language that is modeled after the PRIME[2] Computer's Command Procedure Language. The AML provides fourth generational programming capabilities and tools using an independent processor. These capabilities include a set of directives and inline functions used interactively or in programs, logical branching and loops, macro- and menu-building tools, and mathematical operations.

Arc. A string of x,y coordinate pairs called vertices that begin at one location and end at a different location. Connecting the vertices creates a line. An arc may represent a linear feature or polygon boundary. A single line feature may contain many arcs.

Arc Attribute Table (.AAT). An INFO (a relational database manager) data file containing the feature attributes for lines (arcs) in a digital map (coverage). These data files also may hold all thematic data for the arc features of a coverage.

ARCEDIT. The graphics (locational) and database (descriptive) editor for the ARC/(INFO) environment. ARCEDIT provides map-digitizing capabilities using computer-aided design functions; allows for editing of features, attributes, and map annotation; and includes commands for rubber sheeting and map-sheet edge-matching.

ARC/INFO. A geographic information system and registered trademark of the Environmental Systems Research Institute of Redlands, California. ARC/INFO provides automation, manipulation, analysis and display of geographic data in digital form. The main programming environment (ARC) provides the graphic functions, file management, error check, and verification commands. ARC is combined with INFO—the database manager of the tabular data associated with the geographic information.

ASCII. American Standard Code for Information Interchange. Individual alphanumeric codes represent each of a specific set of 128 numerals, letters, and control characters. Text files created with a text editor of a computer system commonly are referred to as ASCII files.

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[2] For a more detailed description of terms, see Environmental Systems Research Institute, Inc., 1992.

attribute. A descriptive characteristic of a geographical feature, usually stored in a tabular format and linked to that feature by a relational database. The attribute can be numeric, text, or image.

AutoCAD. A computer-aided design program developed by Autodesk, Inc., of Sausalito, California, that is used for automated computer-aided design and drafting functions. The resulting Drawing Interchange Format files are, in turn, used to store and convert vector data to ASCII or binary files.

base map. A map having essential outlines and features of the project area. Additional geographical or topographical data may be overlaid for comparison or correlation.

benchmark. Used in land surveying as a surface point inscribed on a permanent monument to provide a fixed reference control of elevation above a specified datum plane, such as mean sea level.

binary file. A file containing data or program instructions in a computer-readable format. Only the digits 0 and 1 are used.

buffer. Automated procedure to artificially expand a line or point coverage a specified distance in order to create a polygon coverage.

CAD/CAM. Computer-Aided Drafting/Computer-Aided Manufacturing. Several CAD/CAM systems include major features for a geographic information system and automated design, drafting, mapping, and display of graphically oriented information.

cartographic base. Term for planimetric base maps that show the correct horizontal position of natural resource features.

centerlines. A feature or process (centerlining) used for routing purposes in which cartographic features, such as the banks of a lake or large stream are replaced by a single line. The procedure can be automated with a resulting line at the calculated center of the lake or stream or hand-edited to approximate the center route position of the feature.

clip. An ARC/INFO process used to extract spatial features from one coverage that reside within the boundary of another coverage known as the clip cover. Clipping works much like a a cookie cutter.

coincident. Lines or arcs that occur as cartographic duplicates of each other. Usually, one set of arcs is deleted.

coordinate. A pair of measurements, used from a planimetric system denoting horizontal (x) and vertical (y) locations, usually defined by a particular map projection, datum, central meridian, or standard parallel.

coverage. A digital version of a map forming the basic unit of vector-data storage in ARC/INFO.

COVER-ID. A user-assigned INFO integer item, found in feature attribute tables such as .AAT or .PAT files, that identifies arc or polygon features in the coverage.

CRT display. The screen of a cathode-ray tube in a computer monitor that is used to view alphanumeric and graphic output.

dangling arcs. An arc with the identical polygon on its left and right side and with at least one node not connected to another arc. Usually the arc is short in length and results from overshoots during digitizing.

design file. Interactive graphics design software file that contains information about CAD processing parameters such as level, color, element type, and line style and weight.

digitize. To encode map features as x,y coordinates in a digital form by using an electron-digitizing tablet. Features are encoded using a digitizing cursor that registers spatial position, thereby defining the shape or location of a feature.

double-banked. Describes larger streams in the Pacific Northwest River Reach data layer that digitally occur as two separate sides or lines. Although dependent on resolution of data, smaller streams generally occur as single lines or arcs. Lakes, when digitally connected to larger streams, also are considered double-banked.

DXF. Drawing Interchange Format. A format for storing vector data in ASCII or binary files that is used by AutoCAD and may be converted to ARC/INFO coverages.

edgematching. A procedure to digitally link adjacent quadrangle maps by adjusting selected features along a common map edge. Usually executed before map sheets are joined in order to create a smooth and continuous final product.

export. An ARC command that converts an ARC/INFO coverage or file to an interchange file for transfer to another platform running ARC/INFO.

FIPS codes. Federal Information Processing Standard integer codes for identifying a State or county.

grid tic lines. A coverage generated using longitude and latitude values to identify intersections and connecting lines.

hachures. A series of several, short parallel representing a resource feature.

hydrologic unit code (HUC). A coding system, developed by the U.S. Geological Survey, that uses an 8-digit integer comprised of regional, subregional, accounting, and cataloging unit numbers to identify drainage basins.

import. An ARC command that converts an ARC/INFO interchange file (usually an exported coverage) into an ARC/INFO coverage and associated INFO data files.

Intergraph. Is a geographic information system AutoCAD software program and a registered trademark of Intergraph Corporation of Huntsville, Alabama.

label point. An ARC/INFO feature used to represent either a point feature or to identify a polygon. The point is stored as a single x,y location with assigned identification numbers and other attributes. When identifying polygons, the point can occur anywhere within the polygon.

Lambert Conformal Conic. A conical map projection in which parallels are unequally spaced and meridians equally spaced. Distances are true only along standard parallels. Lambert Conformal Conic is widely used for many U.S. Geological Survey topographic maps and is used best for areas with a predominant east-west expanse. Distortion of shapes and areas is minimal.

map projection. A mathematical model that transforms locations from the surface of the Earth, a three-dimensional spheroid, to locations on a planar two-dimensional surface. The three basic types of map projection are cylindrical, azimuthal, and conic.

megabytes. A byte is a group of binary digits, usually eight, stored as memory and data units which measure file size. A megabyte is 1 million bytes and contains values of 0 to 255.

Mercator. A cylindrical map projection with true distances only along the Equator with distortion increasing substantially toward the poles. Because of the distance from the equator, areas and shapes of large regions are distorted. Used in equatorial navigation maps with rhumb lines (lines of constant direction) for direction.

networks. A linear data layer of interconnected arcs, representing possible paths or routes for the movement of resources from one location to another.

node. The digital start or end of an arc. A node is the point where three or more arcs connect, is topologically linked to all arcs that meet at the same point, and is the point at which lines connect in a polygon network or a triangular irregular network.

paneling. A geographic information system process that appends contiguous digital map files into a single map coverage. The 100K Digital Line Graphs from National Mapping Division are distributed as a series of 32 contiguous map files. A macro program called DLGPANEL processes these map files into a single coverage by using the ARC DLGARC, APPEND, and MATCHNODE commands. Paneling is a colloquial term used to describe this process.

planimetric map. A map indicating only the horizontal positions of features without regard to elevation, in contrast with a topographic map that indicates both horizontal and vertical positions.

Polyconic. A conical map projection, used for large-scale maps of the United States until the 1950's, with distances true only along each parallel and the central meridian. Because direction is true only at the central meridian, the best application of polyconic map projection is in areas with a north-south expanse.

polygon. A multisided, closed figure that represents an area on a map. An areal feature defined by the arcs that make up the polygon boundary. Every polygon contains one label point inside its boundary.

pseudo nodes. An ARC/INFO term that describes the location where only two lines or arcs intersect, or where a single arc connects with itself.

registration. An ARC/INFO process where a coverage is either created or edited using a digitizer. Tic-identification numbers and locations (at least 4) must first be entered at the digitizer and a root-mean-square error calculated. If the root-mean-square error is within acceptable tolerances, features can then be added or edited.

relational database. A collection of information that is structured as tables that can logically interrelate to other tables by shared attributes. If the name of the table, the attribute name, and the value of the related item are known, any data element can be found in a relational database.

RMS error. Root-Mean-Square (RMS) error is used primarily in the ARC/INFO geographic information system for tic registration and represents the amount of error between the original and new coordinate locations. The general rule is to keep the RMS error below 0.004 when digitizing.

routing. A process whereby ordered collections of arcs or parts of arcs are used to represent linear features. A single line coverage can contain many route systems,

such as a river or highway network. For example, stream or road quality features or events can be positioned along routes and later located by attributes such as distance measurements.

shellfish. An aquatic animal, such as mollusks (clams and geoducks) or crustacean (crabs and shrimp) that possesses a shell or shell-like exoskeleton.

sliver polygons. A small areal feature frequently occurring along polygon boundaries when two or more coverages are overlain. The boundaries may not match exactly because of resolution or registration differences occurring during coverage generation.

snapping. An ARC/INFO process of moving a feature—such as a node or arc—to coincide exactly with coordinates of another feature, thereby connecting the two features. A connecting distance is usually specified. Snapping can occur on any of the features—arc, node, label, tic, and annotation.

State Plane coordinate system. A defined set of coordinate systems that vary from State to State. They are not themselves map projections, and are normally used only in conjunction with certain types of map projections. Each State is divided into zones and each zone has different sets of parameters, such as the central meridian and origin of coordinates. States with an east-west expanse use Lambert Conformal Conic projection. States with a north-south orientation use Universal Transverse Mercator projection.

STORET. A STOrage and RETrieval database for water-quality information established and maintained by the U.S. Environmental Protection Agency.

stream mode. A technique used with some digitizing hardware that allows continuous input of data points by constant depression of the cursor button instead of manually entering each point (intermittent-mode). The rate (in points per second) at which data points are entered usually can be selected.

tics. A geographic control point used in ARC/INFO coverages that represents known locations on the surface of the Earth. Map sheets are registered to tics and then firmly affixed to a digitizing table. The digitizer units are transformed to coverage units, usually the projection units, thereby providing a common reference system for all coverage features.

tile. A spatial unit by which geographic data is stored and organized. The structure can be regular, as with the 100K-scale quadrangle Digital Line Graphs or irregular, as with the U.S. Geological Survey hydrologic unit codes.

topological method. The method in which geographic features, such as arcs, nodes, polygons, and points, are linked together to define the spatial relation between connecting and adjacent features. This method includes the from- and to-nodes, and the left and right polygons of an arc. Redundant coordinates, such as an arc coordinate used as both a linear and a polygon feature, are deleted when topology is developed. These spatial relations are often complex and are defined mathematically as area, connectivity, and contiguity.

transformation. A process by which the coordinates of a single data layer are converted from one system to another. Transformation is commonly used to convert a coverage in digitizer units (usually inches) to a map projection system, such as Universal Transverse

Mercator meters. The ARC/INFO TRANSFORM method uses scaling; rotation; x,y shifts; polynomials for warping images; and root-mean-square errors to calculate and convert to a new coordinate system.

Universal Transverse Mercator (UTM). A coordinate system defined by the Transverse Mercator projection (cylindrical type) and a set of zones and offsets.

Distortion of the coordinate system increases away from the central meridian. This system is used in USGS 250K-scale quadrangle maps; UTM is not used for large areas. Puget Sound is within Zone 10. Zone 10 ranges in longitude from 126°W to 120°W; the central meridian is 123°W.

VAX. Geographic information system work station from the Digital Equipment Corporation.

vector. A data structure represented by linear map features ordered by a set of x,y coordinates. Another data structure, called raster, is cell-based. A vector-coordinate system assigns attributes to features, whereas a raster-coordinate system assigns grid cells to the attributes.

weeded. An ARC/INFO processing term that eliminate vertices along an arc within a specified distance.

zone. The relation of a section or region of the Earth, the United States, or a State of the United States to a particular map projection. Universal Transverse Mercator map projections divide the entire world into 60 zones; State Plane zones are assigned to each state, and larger states are divided into more than one zone. For example, Washington has two State Plane Zones (north-5601 and south-5626).

APPENDIXES

APPENDIXES

The appendixes are generated by the DOCUMENT command, a user contributed ARC library function (D.D.Nebert, U.S. Geological Survey, written commun., 1991). These appendixes provide additional information about individual data layers and are specific in content. Such information may include a detailed list of processing steps used in generating a data layer, attribute item names used, persons and telephone numbers to contact for additional information, map projection, and scale and resolution used. In some cases, portions of the appendixes acquired from the document.aml may be edited or deleted if information is duplicated from the main body of the report. For example, processing steps that are previously covered in the main text may either be reclarified or eliminated from the appendixes.

Much of what follows is output from the INFO data base, the header information is normally abbreviated and is explained below. This header listing is identical for all INFO files used in this report:

COLUMN: The column in which data-field begins.

ITEM NAME: The name given to the attribute, can be user or INFO
               derived.

WIDTH: Number of spaces or columns for storing item values.

OUTPUT
WIDTH: Number of spaces or columns to display item values.

TYPE: The item types used in this report are:
               F = internal floating point, B = binary, I = integer,
               N = real number, C = character

NUMBER OF
DECIMALS: The number of decimal spaces for numeric items.

DEFINITION: This category added to clarify items, not INFO derived.

The standard INFO files for Arc Attribute Tables (.AAT) and the
Polygon/Point Attribute Tables (.PAT) are identical for many of the
data layers in this report. In order to save text space, these
standard INFO .AAT or .PAT files are not listed. The banner
"STANDARD .AAT or .PAT FILE" appears in its place. The standard
INFO .AAT and .PAT files are listed below. The name COVERAGE is
used in place of the actual coverage or data layer name. If items
in addition to the standard items are present they will occur after
the banner.

STANDARD .AAT FILE

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
1	FNODE#	4	5	B	-	Internal number of from-node
5	TNODE#	4	5	B	-	Internal number of to-node
9	LPOLY#	4	5	B	-	Internal number of polygon to left of arc
13	RPOLY#	4	5	B	-	Internal number of polygon to right of arc
17	LENGTH	4	12	F	3	Length of arc in meters
21	COVERAGE#	4	5	B	-	Internal feature number
25	COVERAGE-ID	4	5	B	-	User-assigned feature number

STANDARD .PAT FILE
(Polygon/Point)

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
1	AREA	4	12	F	3	Area of polygon in square meters
5	PERIMETER	4	12	F	3	Perimeter of polygon in meters
9	COVERAGE#	4	5	B	-	Internal feature number
13	COVERAGE-ID	4	5	B	-	User-assigned feature number

9   (Area and Perimeter for point coverages equal zero)

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APPENDIX A

Data-Layer Dictionary of Environmental Data
for the Puget Sound Area from Sources Other Than the
Puget Sound Environmental Atlas

Shoreline

```
DOCUMENTATION FOR DATA LAYER: Shoreline, coverage name; SOUND
SOURCE REFERENCE: U.S. Geological Survey-National Mapping Division
                  (USGS-NMD) 1:100,000-scale Digital Line Graphs
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Shoreline
DESCRIPTION: The Puget Sound Shoreline was extracted from the
             Pacific Northwest (PNW) River Reach data set.
CONTACT PERSON/S: Mark Uhrich
CONTACT INSTRUCTIONS: Uhrich 503-251-3292
ORGANIZATION: U.S. Geological Survey (USGS)
LOCATION DESCRIPTION:  Northwest Washington, Puget Sound shoreline
                  Longitude:125°-122°,Latitude:47°-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS: Puget Sound Water Quality Authority (PSWQA);
                   Washington Department of Natural Resources
                   (DNR), Division of Aquatic Resources
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```
INFO ITEM DEFINITIONS FOR SOUND.PAT FILE:


COL  ITEM NAME     WDTHOPUT TYP N.DEC DEFINITION

                   STANDARD .PAT FILE (Polygon)
 17 SOUND            1   1    I    -   Polygons with SOUND = 1 are
                                      embayment water bodies;
                                      (69 polygons),
                                      polygons with SOUND = 0 are
                                      land; (271 polygons)


INFO ITEM DEFINITIONS FOR SOUND.AAT FILE:


                   STANDARD .AAT FILE
```

COVERAGE NARRATIVE:

Abstract - The Puget Sound Shoreline was extracted from the
1:100,000-scale (100K) DLG's to provide the Puget Sound Geographic
Information System (PSGIS) with a uniform shoreline data set. The
Sound coverage was used as a template in a number of coverages,
including embayments, tribes, and the shellfish inventory. In some
Puget Sound Environmental Atlas (PSEA) data layers it was used as
an erase coverage.

Processing steps- The Puget Sound shoreline layer was constructed
from each of the PNW River Reach Hydrologic Unit Code (HUC)
coverages (17110001- 17110021). HUC coverages were created from
USGS-NMD 100K Hydrology DLG's. River Reach attributes were not
needed in this layer and were deleted. A flag item denoting water
or land (SOUND) was added. Most all of the shoreline was acquired
from the River Reach project network coverages, but some segments
were missing and were found in the "banks" coverages. To ensure the
entire Puget Sound was topologically one polygon required
considerable editing of the shoreline arcs. The ARC log files that
accompany this coverage also contain details on the ARC commands
used along with additional notes entered at the time of processing.

Reference:

U.S. Geological Survey, 1989, Digital line graphs from
1:100,000-scale maps—Data users guide 2: Reston, Virginia, 88 p.

Water-Body System

```
DOCUMENTATION FOR DATA LAYER: Embayments
SOURCE REFERENCE:USGS-NMD, 1:100,000-Scale Digital Line Graphs
MAP PROJECTION: UTM, Zone 10
PRECISION:  Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Embayments
DESCRIPTION: The Puget Sound was divided by the Washington
             Department of Ecology (DOE) into significant water
             bodies by adding artificial boundaries to shorelines
             on National Oceanic and Atmospheric Administration
             (NOAA) navigational maps. A series of NOAA maps were
             used as base maps that include the entire Puget Sound.
             The NOAA Map Series number is provided in the
             "Additional notes" section. Embayments areas uniquely
             define significant water-body systems and estuarine
             areas.
CONTACT PERSON/S: Mark Uhrich(1), or Tom Gries(2)
CONTACT INSTRUCTIONS:1. Uhrich 503-251-3292
                     2. Gries 360-407-7536
ORGANIZATION: 1.USGS 2. Washington DOE, Sediment Management Unit
LOCATION DESCRIPTION: Puget Sound shoreline
                     Longitude:122°-125°, Latitude:47°-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS:PSWQA;Washington DNR,
                  Division of Aquatic Resources
```

```
INFO ITEM DEFINITIONS FOR EMBAYMENTS.PAT FILE:
 COL ITEM NAME      WDTH OPUT TYP N.DEC DEFINITION


                STANDARD .PAT FILE (Polygon)


  17 SQ_MILES        8   16   F   2   Area of embayment polygon in
                                      square miles
  25 EMBAYMENT#      4    4   N   1   U.S. Environmental Protection
                                      Agency (USEPA)/Washington DOE
                                      number for each Embayment
                                      polygon
  29 SOUND           1    1   I   -   Polygons with SOUND = 1 are
                                      embayment water bodies
                                      (69 polygons),
                                      polygons with SOUND = 0 are
                                      land (271 polygons)
 INFO ITEM DEFINITIONS FOR EMBAYMENTS.AAT FILE:
                STANDARD .AAT FILE
```

COVERAGE NARRATIVE:

Abstract - The USEPA and Washington DOE delimited a water-body
system for the entire Puget Sound. The system includes 69
significant embayments and estuarine areas constructed by
enclosing the water bodies with artificial closure lines. These
closure lines were digitized into the SOUND shoreline coverage of
the Puget Sound. Labels were added to each of the embayment areas
and an area value in square miles was calculated.

Processing steps- The Puget Sound shoreline layer was constructed
from each of the PNW River Reach HUC coverages (17110001-
17110021). HUC coverages were created from USGS-NMD 100K Hydrology
DLG's. River Reach attributes were not needed in this layer and
were dropped. Items for embayment area in square miles, embayment
number and a flag for water or land (SOUND) were added. Most of the
shoreline was acquired from the PNW River Reach network coverages,
missing segments were added from the "banks" coverages. To create
a single, topologically correct polygon for the entire Puget Sound
required considerable editing of the shoreline arcs. The ARC log
files that accompany this coverage contain more details on the ARC
processing used. The artificial embayment lines were digitized from
lines drawn by the Washington DOE on six NOAA nautical maps of
varying map projections and scales (see "Additional notes").
Embayment lines were given -ID code = 9999 and artificial lines
drawn to close river mouths had -ID codes = 9998. A small piece of
San Juan Island (northeast corner of Port Angeles), missing from
the DLG data was digitized from the 100K quad sheet (-ID = 9999).
The NOAA nautical maps were digitized in their respective
projections, then projected into UTM before registering with the
embayment shoreline coverage.

Reference:

U.S. Geological Survey, 1989, Digital line graphs from
1:100,000-scale maps—Data users guide 2: Reston, Virginia, 88 p.

Additional notes:

Name	Projection	Scale
NOAA CHART 18421	Mercator	1:80000
NOAA CHART 18424	Polyconic	1:40000
NOAA CHART 18427	Mercator	1:80000
NOAA CHART 18441	Mercator	1:80000
NOAA CHART 18448	Mercator	1:80000
NOAA CHART 18465	Mercator	1:80000

Shellfish Inventory

Shellfish Growing Areas

```
DOCUMENTATION FOR DATA LAYER: DOH_Shell
SOURCE REFERENCE: Washington Department of Health (DOH),
                    Shellfish Inventory.
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Shellfish Inventory and Status
DESCRIPTION: This data layer includes status definitions for
            shellfish resources and aquaculture harvest areas.
            The four classification types as defined by the
            Washington DOH, Office of Shellfish Programs are:
            Approved, Conditionally Approved, Restricted, and
            Prohibited.
CONTACT PERSON/S: Mark Uhrich(1) or
                Don Lennartson(2)
CONTACT INSTRUCTIONS: 1. Uhrich 503-251-3292
                    2. Lennartson 360-586-8127
ORGANIZATION: 1. U.S. Geological Survey-Water Resources Division
                (USGS-WRD)
            2.Washington DOH
LOCATION DESCRIPTION: Puget Sound Basin
                Longitude: 125°-120°, Latitude: 46°30″-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS: PSWQA; Washington DNR,
                Division of Aquatic Resources
```

INFO ITEM DEFINITIONS FOR DOH_SHELL.PAT FILE:

COL   ITEM NAME   WDTH OPUT TYP N.DEC DEFINITION

```
                    STANDARD .PAT FILE (Polygon)
 17   AREA_STAT       24  24   C   -   Area status (e.g., commercial,
                                        approved, restricted,
                                        conditionally approved,
                                        prohibited)
```

INFO NAME DEFINITIONS FOR DOH_SHELL.AAT FILE:

STANDARD .AAT FILE

COVERAGE NARRATIVE:

Abstract - The Washington DOH, Shellfish Programs, 1990 Shellfish Inventory was digitized. The Inventory identifies the use areas and status for commercial and recreational shellfish beds.

Processing steps - The 1990 Shellfish Inventory Maps were created by mapping the status areas on four NOAA base maps in Mercator or Polyconic projection and later reproduced on large-format, commercial photocopies. The ARCPLOT command: MAPPROJECTION was used to convert the UTM "clipped" portions of the SOUND coverage to match the four NOAA maps. These paper maps were used as templates from which to digitize the shellfish resources. Overlapping did occur with the commercial classification layer and other classification layers. These classifications were listed under the INFO item AREA_STAT as Commercialprohibited, Commercialconditional and Commercialrestricted. See non-PSEA processing procedures in the main text.

Reference:

Washington Department of Health, 1990, Third annual inventory of commercial and recreational shellfish areas in the Puget Sound: Olympia, Washington, Environmental Health Program, Office of Shellfish Programs, 10 p., 4 maps.

DOCUMENTATION FOR DATA LAYER: DOH_REC
SOURCE REFERENCE: Washington DOH, 1990 Shellfish Inventory
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Recreational Shellfish Beaches.
DESCRIPTION: This data layer includes Recreational Shellfish
            Beaches from Washington DOH, 1990 Shellfish
            Inventory. State Park beaches, Washington DNR
            beaches, and County beaches are included.
CONTACT PERSON/S: Mark Uhrich   (1) or
                  Don Lennartson(2)
CONTACT INSTRUCTIONS: 1.Uhrich 503-251-3292
                     2.Lennartson 360-586-8127
ORGANIZATION: 1. USGS-WRD, 2. Washington DOH
LOCATION DESCRIPTION: Puget Sound Basin
                     Longitude: 125°-120°, Latitude: 46°30″-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS: PSWQA; Washington DNR,
                  Division of Aquatic Resources

INFO ITEM DEFINITIONS FOR DOH_REC.PAT FILE:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
			STANDARD	.PAT	FILE	(Point)
17	BEACH#	4	4	C	-	Washington DOH Shellfish Inventory Beach number
21	STATEPARK	1	1	I	-	Indicator flag: 1 = State park, 0 = Washington DNR or County park
22	DNRPARK	1	1	I	-	Indicator flag: 1 = Washington DNR park, 0 = State or County park
23	COUNTYPARK	1	1	I	-	Indicator flag: 1 = County park, 0 = State or Washington DNR park
24	NAME	30	30	C	-	Recreational beach or park name.

INFO NAME DEFINITIONS FOR DOH_REC.AAT FILE:

STANDARD .AAT FILE

COVERAGE NARRATIVE:

Abstract - The Washington DOH, Shellfish Programs, 1990 Shellfish
Inventory was digitized. The Inventory depicts recreational
shellfish beaches, along with the use areas and status for
commercial and recreational shellfish beds.

Processing steps - Attributes were added to the beach location
points to indicate the Shellfish Inventory beach number (BEACH#),
Agency responsible for the park or beach (STATEPARK, DNRPARK,
COUNTYPARK, as well as the name of the park or beach (NAME).

Reference:

Washington Department of Health, 1990, Third annual inventory of
commercial and recreational shellfish areas in the Puget Sound:
Olympia, Washington, Environmental Health Program, Office of
Shellfish Programs, 10 p., 4 maps.

Sewage Treatment Outfalls

DOCUMENTATION FOR DATA LAYER: DOH_SEWAGE
SOURCE REFERENCE: Washington DOH, 1990 Shellfish Inventory
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Shellfish Inventory and Status
DESCRIPTION: This data layer identifies the 1990 Washington DOH
            Shellfish Inventory sewage treatment plant outfall
            locations.
CONTACT PERSON/S: Mark Uhrich(1) or
                Don Lennartson(2)
CONTACT INSTRUCTIONS: 1. Uhrich 503-251-3292
                    2. Lennartson 360-586-8127
ORGANIZATION: 1. USGS-WRD, 2. Washington DOH
LOCATION DESCRIPTION: Puget Sound Basin
                    Longitude: 125°-120°, Latitude: 46°30″-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS: PSWQA; Washington DNR,
                    Division of Aquatic Resources

```
INFO ITEM DEFINITIONS FOR DOH_SEWAGE.PAT FILE:

COL  ITEM NAME     WDTH OPUT TYP N.DEC DEFINITION

                    STANDARD .PAT FILE (Point)
  17 PLANT#         2    2    C   -   Municipal sewage treatment
                                      plant number
  19 NAME           30   30   C   -   Municipal sewage treatment
        .                             plant name

INFO NAME DEFINITIONS FOR DOH_SEWAGE.AAT FILE:

                    STANDARD .AAT FILE
```

COVERAGE NARRATIVE:

Abstract - The Washington DOH, Shellfish Programs, 1990
Shellfish Inventory was digitized. The Inventory identifies the
outfalls for sewage treatment plants, along with use areas
and status for commercial and recreational shellfish beds.

Processing steps - Attributes were added to denote the Municipal
sewage treatment plant number assigned by Washington DOH (PLANT#)
and name (NAME). Sewage outfalls were mapped using a triangular
symbol. Outfall positions were digitized as points at the
approximate center of each symbol.

Reference:

Washington Department of Health, 1990, Third annual inventory of
commercial and recreational shellfish areas in the Puget Sound:
Olympia, Washington, Environmental Health Program, Office of
Shellfish Programs, 10 p., 4 maps.

General Hydrography

DOCUMENTATION FOR DATA LAYER: HY."ABBREVIATED QUADRANGLE NAME"
                    (See Additional Notes for Quadname abbreviations)
SOURCE REFERENCE: USGS-NMD 1:100,000-scale Digital Line Graphs
MAP PROJECTION: UTM
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Hydrography
DESCRIPTION: Digital Hydrography for the Puget Sound Basin,
             1:100,000 scale quadrangles (18 quads)
CONTACT PERSON/S:Mark Uhrich or Bruce Fisher
CONTACT INSTRUCTIONS: Uhrich   503-251-3292
                      Fisher   503-251-3228
ORGANIZATION: USGS-WRD
LOCATION DESCRIPTION: 18 100K quadrangles covering
                    Longitude: 125°-120°, Latitude: 46°30"-49°
                    USGS Hydrologic Units 171100(01-21)
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS: PSWQA; USGS-WRD; USEPA, Seattle

INFO ITEM DEFINITIONS FOR HY."QUADNAME".PAT FILE:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
		STANDARD	.PAT FILE (Polygon)			
17	MAJOR1	6	6	I	-	NMD feature classifier. Major1 = 50 is combined hydrography category, Major1 = 170 is transportation
23	MINOR1	6	6	I	-	NMD feature classifier. Minor1 = 412 is stream, Minor1 = 999 is artificial reach
29	MINOR2	6	6	I	-	NMD feature classifier. Minor2 = 610 is ephemeral, Minor2 = 9999 is river mouth closure
35	MINOR3	6	6	I	-	NMD feature classifier. Used as a placer for some processing steps
41	HUC	8	8	I	-	USGS Hydrologic Unit Code. Puget Sound codes = 17110001-17110021
49	STR-NAME	30	30	C	-	Stream name from NMD 100K Digital Line Graphs or USEPA 250K Trace files

INFO NAME DEFINITIONS FOR HY."QUADNAME".AAT FILE:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
			STANDARD	.AAT FILE		
29	MAJOR1	6	6	I	-	NMD feature classifier. Major1 = 50 is combined hydrography category, Major1 = 170 is transportation
35	MINOR1	6	6	I	-	NMD feature classifier. Minor1 = 412 is stream, Minor1 = 999 is artificial reach
41	MINOR2	6	6	I	-	NMD feature classifier. Minor2 = 610 is ephemeral, Minor2 = 9999 is river mouth closure
47	MINOR3	6	6	I	-	NMD feature classifier. Used as a placer for some processing steps
53	HUC	8	8	I	-	USGS Hydrologic Unit Code. Puget Sound codes = 17110001-17110021
61	SEG	4	4	I	-	USEPA segment number. HUC + SEG = unique reach id
65	RMI	5	5	N	2	River mile index calculated for same numbered SEG reaches. Base reach numbers begin with 0.0
70	LEVEL	2	2	I	-	USEPA assigned stream level. Tributary is one level higher than mainstream. Uses reverse Strahler order
72	SEQNUM	11	11	C	-	USEPA hydrologic sequence number. Most upstream reaches have lowest numbers
83	FLAGS	5	5	C	-	USEPA item used for routing. EX: Transport reaches = 1, shoreline = 0
88	STR-NAME	30	30	C	-	Stream name from NMD 100K Digital Line Graphs or USEPA 250K Trace files
118	STATE	4	4	C	-	State reach falls within
122	COUNTY	15	15	C	-	County reach falls within
137	QUAD100	26	26	C	-	USGS 100K quad reach falls within
163	QUAD75	25	25	C	-	USGS 7.5 min quad reach falls within
188	RRN	17	17	C	-	HUC + SEG + RMI

COVERAGE NARRATIVE:

Abstract- The hydrography data layer provides the river, stream and channel lines (arcs) with lake and waterway boundaries(polygons) in a 100K tile structure projected in UTM for Zone 10. Along with other Geographic Information System (GIS) data layers, the hydrography data layer will be used to assess the resources, demographics and environmental conditions of the Puget Sound Basin.

Processing steps- The original NMD 100K Digital Line Graphs were not used for the Puget Sound general hydrography layer for two reasons: (1) the lack of attributes, such as stream-name and USEPA codes, and (2) edgematching and paneling the DLG hydrography had already been done for the River Reach project. The PNW River Reach study supplied data for the Puget Sound general hydrography by combining two separate coverages: centerlines (network) and polygons (lakes and double-banked streams). The following is a list of the processing steps used to rejoin these coverages to create the general hydrography. The ARC commands used are capitalized and referenced in Environmental Systems Research Institute, Inc., 1989; the AMLS are available upon request from the USGS, Portland, Oregon:

a. Added a blank .PAT file to the network HUC coverages.
   (patlinks.aml)
b. Added a blank .AAT file to the bank HUC coverages.(aatbanks.aml)
c. Executed PULLITEMs on .AAT file for necessary Puget Sound items.
d. Executed IDENTIFY with banks coverages to acquire county and
   quad names.
e. Both network and banks coverages were projected back to UTM
   (Zone 10) from Albers (albtoutm.aml).
f. The network and bank coverages were APPENDed once items were
   identical in each.
g. The coverages were tiled to 100K quads by first creating 18
   separate clipcovers for the Puget Sound Basin (makeindex.aml).
   Next, MAPJOIN was used to piece together the necessary HUC
   coverages for each of the quads, using the clipcovers as a quad
   boundary cookie cutter. (hydrojoin.aml, hydroquad.aml)
h. Once the quads were reconstructed the centerlines were put into
   separate coverages (quad.999) and then deleted.
i. Slight differences in map projections and index coverages from
   the PNW River Reach to Puget Sound Geographic Information System
   (PSGIS) projects meant additional editing was needed to ensure
   segments were in their correct quad.
j. Strname was added to the banks.aat file by hand editing and by
   nametrans.aml.
k. A frequency AML was used as a error check on items such as
   STRNAME, QUAD100, QUAD75 and COUNTY. (freq.aml)
l. As an additional check, the quads were plotted and compared to
   the NMD 100K quad map sheets. (quadplot.aml)

References:

Environmental Systems Research Institute, Inc., 1989, ARC/INFO command references: Redlands, California, Volume 2, Version 5.0.1, Appendix D.

Horn, C. R., 1986, River-reach file manual (Draft): U.S. Environmental Protection Agency, Washington, D.C., 50 p. [Available from U.S. Environmental Protection Agency, 401 M St. SW, Washington, D.C. 20460]

U.S. Geological Survey, 1989, Digital line graphs from 1:100,000-scale maps—Data users guide 2: Reston, Virginia, 88 p.

Additional notes:

Quadname abbreviations:

Quadrangle name	Coverage name
Cape Flattery	hy.flat
Port Angeles	hy.pang
Roche Harbor	hy.roch
Bellingham	hy.bell
Port Townsend	hy.ptow
Seattle	hy.seat
Tacoma	hy.taco
Mount Baker	hy.mbak
Sauk River	hy.sauk
Skykomish River	hy.skyk
Snoqualmie Pass	hy.snoq
Mount Rainier	hy.rain
Robinson Mtn.	hy.robi
Twisp	hy.twis

River Reach Network

DOCUMENTATION FOR DATA LAYERS: HYDRO"1-21".UTM, BANKS"1-21".ID)
Numbers 1-21 are the PSGIS HUC's
SOURCE REFERENCE: USGS-NMD 1:100,000-scale Digital Line Graphs
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Hydrography (centerlines)
DESCRIPTION: Topological network coverages of hydrography, with centerlined double-banked streams, reservoirs and some lakes, tiled at USGS Hydrologic Units (17110001-17110021) for the Puget Sound Basin. Does not include Puget Sound shoreline.

CONTACT PERSON/S: Mark Uhrich or Bruce Fisher
CONTACT INSTRUCTIONS: Uhrich   503-251-3292
                      Fisher   503-251-3228
ORGANIZATION: USGS-WRD
LOCATION DESCRIPTION: Puget Sound Basin covering
                     Longitude: 125°-120°, Latitude: 46°30″-49°
                     18 NMD 100K quads
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS: PSWQA; USGS-WRD; USEPA, Seattle

INFO ITEM DEFINITIONS FOR HYDRO″1-21″.UTM.PAT or
                       BANKS″1-21″.ID.PAT FILES:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
		STANDARD	.PAT	FILE	(Polygon)	
17	MAJOR1	6	6	I	-	NMD feature classifier. Major1 = 50 is combined hydrography category, Major1 = 170 is transportation
23	MINOR1	6	6	I	-	NMD feature classifier. Minor1 = 412 is stream, Minor1 = 999 is artificial reach
29	MINOR2	6	6	I	-	NMD feature classifier. Minor2 = 610 is ephemeral, Minor2 = 9999 is river mouth closure
35	MINOR3	6	6	I	-	NMD feature classifier. Used as a placer for some processing steps
41	HUC	8	8	I	-	USGS Hydrologic Unit Code. Puget Sound codes = 17110001-17110021

INFO NAME DEFINITIONS FOR HYDRO″1-21″.UTM.AAT or
                       BANKS″1-21″.ID.AAT FILES:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
		STANDARD	.AAT	FILE		
29	MAJOR1	6	6	I	-	NMD feature classifier. Major1 = 50 is combined hydrography category, Major1 = 170 is transportation

35	MINOR1	6	6	I	-	NMD feature classifier. Minor1 = 412 is stream, Minor1 = 999 is artificial reach
41	MINOR2	6	6	I	-	NMD feature classifier. Minor2 = 610 is ephemeral, Minor2 = 9999 is river mouth closure
47	MINOR3	6	6	I	-	NMD feature classifier. Used as a placer for some processing steps
53	HUC	8	8	I	-	USGS Hydrologic Unit Code. Puget Sound codes = 17110001-17110021
61	SEG	4	4	I	-	USEPA segment number. HUC + SEG = unique reach id
65	RMI	5	5	N	2	River mile index calculated for same numbered SEG reaches. Base reach numbers begin with 0.0
70	LEVEL	2	2	I	-	USEPA assigned stream level. Tributary is one level higher than mainstream. Uses reverse Strahler order
72	SEQNUM	11	11	C	-	USEPA hydrologic sequence number. Most upstream reaches have lowest numbers
83	FLAGS	5	5	C	-	USEPA item used for routing. EX: Transport reaches = 1, shoreline = 0
88	STR-NAME	30	30	C	-	Stream name from NMD 100K Digital Line Graphs or USEPA 250K Trace files
118	STATE	4	4	C	-	State reach falls within
122	COUNTY	15	15	C	-	County reach falls within
137	QUAD100	26	26	C	-	USGS 100K quad reach falls within
163	QUAD75	25	25	C	-	USGS 7.5 min quad reach falls within
188	RRN	17	17	C	-	HUC + SEG + RMI

COVERAGE NARRATIVE:

Abstract-In addition to the 100K quad general hydrography layer, the Puget Sound GIS project also includes PNW River Reach data layers, in which the double-banked streams and reservoirs have been centerlined for routing purposes. These data layers, also referred to as network coverages, have had additional editing performed to meet the criteria of the PSWQA. The ARC log files of each coverage list specific ARC commands used and additional notes.

Processing steps- The double-banked streams, reservoirs, and most lakes are put into separate "banks" coverages by the PNW River Reach project. The double-banked coverages were rejoined with the centerlined coverages for the general PSGIS hydrography layer. The coverages, acquired in April, 1990 from the PNW River Reach study were not their final product. A later revision of the River Reach Files removed the nodes created at political boundaries and added to every reach the second most predominant STATE, COUNTY, QUAD100 and QUAD75 name. These items are not included. The ARC command: PULLITEMS was used on each coverage to attain the desired PSGIS attributes.

The editing performed on the network coverages involved correcting USGS-NMD minor code attributes such as minor1 = 103 for glaciers. Differences in minor1 codes for shoreline existed in each of the coverages. Some lakes were given a code of 200, others 421. Many of the minor1 codes of 421 were recalculated to 200 to standardize the attributes. Other discrepancies were found with the River Reach data. For instance, some inland lakes were put into the banks coverages and deleted, some were put into the banks and not deleted from the network coverage. Some lakes were kept in the network coverage and not put into the banks, and still others were deleted entirely and not put into the banks. Some network coverages routed up the side of an inland lake, others used a centerline. Of the network coverages routing up inland lake shorelines, some were given minor1 codes = 999, which should only have been given to artificial centerlines. Most of these problems were corrected. Check the coverage ARC log files for detailed information. The Puget Sound shoreline was put into the Sound and Embayment PSGIS data layers and deleted from the centerlined coverages. No figure of the network data was included since at a scale of 1:2,000,000 the plot was not significantly different than the general hydrography plot.

References:

Horn, C. R., 1986, River-reach file manual (Draft): U.S. Environmental Protection Agency, Washington, D.C., 50 p. [Available from U.S. Environmental Protection Agency, 401 M St. SW, Washington, D.C. 20460].

U.S. Geological Survey, 1989, Digital line graphs from 1:100,000-scale maps—Data users guide 2: Reston, Virginia, 88 p.

Watershed Boundaries

U.S. Geological Survey Hydrologic Unit Codes

```
DOCUMENTATION FOR DATA LAYER: PS_HUC
SOURCE REFERENCE: USGS-NMD 1:100,000-scale Digital Line Graphs
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Hydrography, Basin Boundary
DESCRIPTION: Basin Boundary for the Puget Sound watershed
CONTACT PERSON/S: Mark Uhrich or Bruce Fisher
CONTACT INSTRUCTIONS: Uhrich  503-251-3292
                     Fisher  503-251-3228
ORGANIZATION: USGS-WRD
LOCATION DESCRIPTION: Puget Sound Basin
                     Longitude: 125°-120°, Latitude: 46°30"-49°
                     USGS Hydrologic Unit 171100
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS: PSWQA; Washington DNR,
                   Division of Aquatic Resources


ITEM DEFINITIONS FOR PS_HUC.PAT FILE:


COL  ITEM NAME      WDTH OPUT TYP N.DEC DEFINITION


           STANDARD .PAT FILE (Polygon)
 17 HUC         8   8    I    0   USGS-WRD Hydrologic Unit Code
                                  number


INFO NAME DEFINITIONS FOR PS_HUC.AAT FILE:


               STANDARD .AAT FILE
```

COVERAGE NARRATIVE:

Abstract - The Puget Sound Basin HUC coverage was used to reference
other layers to it, such as the hydrography and Water Resource
Inventory Areas (WRIA). It consists of the Regional/Subregional
USGS Hydrologic Unit Code 1711 and 21 cataloging units.

Processing steps - The 100K HUC watershed boundary data
layer was obtained from the PNW River Reach project
(B.J. Fisher, U.S. Geological Survey, oral commun., 1992).
The HUC coverage was projected from Albers Equal Area to UTM.

All of the subbasins that existed within the Puget Sound HUC (1711)
were selected and a subset coverage was created (ps_huc).

References:

U.S. Geological Survey, 1989, Digital line graphs from
1:100,000-scale maps—Data users guide 2: Reston, Virginia, 88 p.

Horn, C. R., 1986, River-reach file manual (Draft): U.S.
Environmental Protection Agency, Washington, D.C., 50 p.
[Available from U.S. Environmental Protection Agency, 401 M St. SW,
Washington, D.C. 20460].

Puget Sound Basin

DOCUMENTATION FOR DATA LAYER: PS_BASIN
SOURCE REFERENCE: USGS-NMD 1:100,000-scale Digital Line Graphs
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Hydrography, Basin Boundary
DESCRIPTION: Basin Boundary for the Puget Sound watershed
CONTACT PERSON/S: Mark Uhrich or Bruce Fisher
CONTACT INSTRUCTIONS: Uhrich 503-251-3292
                     Fisher 503-251-3228
ORGANIZATION: USGS-WRD
LOCATION DESCRIPTION: Puget Sound Basin
                    Longitude: 125°-120°, Latitude: 46°30″-49°
                    USGS Hydrologic Unit 171100
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS: PSWQA; Washington DNR,
                   Division of Aquatic Resources

INFO ITEM DEFINITIONS FOR PS_BASIN.PAT FILE:

STANDARD .PAT FILE (Polygon)

INFO NAME DEFINITIONS FOR PS_BASIN.AAT FILE:

STANDARD .AAT FILE

COVERAGE NARRATIVE:

Abstract - The Puget Sound Basin coverage was created as a
reference layer and clip coverage. It consists of basins with the
Hydrologic Unit Code 1711, (Region=17,Subregion=11).

Processing steps - The 100K HUC watershed boundary data layer was obtained from the PNW River Reach project. The HUC coverage was projected from Albers Equal Area to UTM. All of the subbasins that were within the Puget Sound HUC (1711) were selected and a subset coverage was created (PS_HUC). To create the Basin Boundary coverage, all of the HUC boundaries were eliminated below the 1711 identifier. Twenty-one subbasins make up the 1711 Puget Sound Basin (17110001-17110021). These were aggregated using the ARC command DISSOLVE on the value 1711 for the item HUC of the ps_huc data layer.

References:

Horn, C. R., 1986, River-reach file manual (Draft): U.S. Environmental Protection Agency, Washington, D.C., 50 p. [Available from U.S. Environmental Protection Agency, 401 M St. SW, Washington, D.C. 20460].

U.S. Geological Survey, 1989, Digital line graphs from 1:100,000-scale maps—Data users guide 2: Reston, Virginia, 88 p.

Water Resource Inventory Areas

DOCUMENTATION FOR DATA LAYER: PS_WRIA
SOURCE REFERENCE: Washington DNR, Division of Aquatic Resources
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound, WRIA
DESCRIPTION: The Washington DNR has delimited watershed areas
            for administrative and management purposes. This
            theme is provided as an index and reference
            layer for the PSGIS.
CONTACT PERSON/S: Elizabeth Lanzer(1), or
            Elizabeth Thompson (2)
CONTACT INSTRUCTIONS: (1) Lanzer 360-902-1074
            (2) Thompson 360-902-1224
ORGANIZATION: (1) Washington DNR, Division of Aquatic Resources
            (2) Washington DNR, Division of Forest Practices
LOCATION DESCRIPTION: Puget Sound Basin
            Longitude: 125°-120°, Latitude: 46°30"-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS: PSWQA; Washington DNR,
            Division of Aquatic Resources

```
INFO ITEM DEFINITIONS FOR PS_WRIA.PAT FILE:

COL       ITEM NAME WDTH OPUT TYP N.DEC DEFINITION

                  STANDARD .PAT FILE (Polygon)
   17 WRIA         4    5    B   -  WRIA identifier.

INFO NAME DEFINITIONS FOR PS_WRIA.AAT FILE:

                  STANDARD .AAT FILE
```

COVERAGE NARRATIVE:

Abstract - The Washington DNR has delimited watershed boundaries
for management purposes throughout the state. These WRIA's were
obtained from Washington DNR, Division of Aquatic Resources.

Processing steps - An ARC/INFO format coverage for the WRIA's was
obtained from the Washington DNR, Aquatic Resources. The coverage
was projected from State Plane south zone (5626) to UTM, Zone 10.
The WRIA coverage was reduced from a statewide coverage to one
within the extent of the Puget Sound Basin.

References:

Washington Department of Ecology, 1986, Water-resources inventory
areas subbasins, Washington Administrative Code, Title 173-500-
990: Olympia, Washington, p. 490-492.

Political Boundaries and Public Land Survey System (PLSS)

Boundary Data Layer

DOCUMENTATION FOR DATA LAYER: Name given as 100K "Quadname", data-
                                   layers in the BOUND directory, See
                                   Table 2 for quadname abbreviations
SOURCE REFERENCE: USGS-NMD 1:100,000-scale Digital Line Graphs
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Political Boundaries
DESCRIPTION: Standard USGS-NMD Boundary DLG data which includes
            data for Federal and Tribal lands, State and
            County FIPS codes.
CONTACT PERSON/S: Mark Uhrich
CONTACT INSTRUCTIONS: Uhrich 503-251-3292
ORGANIZATION: USGS-WRD
LOCATION DESCRIPTION: Puget Sound Basin
                         Longitude: 125°-120°, Latitude: 46°30"-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATION: PSWQA

INFO ITEM DEFINITIONS FOR BOUND/"QUADNAME".PAT FILE:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
		STANDARD	.PAT	FILE	(Polygon)	
17	MAJOR1	6	6	I	-	NMD feature classifier.
23	MINOR1	6	6	I	-	NMD feature classifier.
29	MAJOR2	6	6	I	-	NMD feature classifier.
35	MINOR2	6	6	I	-	NMD feature classifier.
41	MAJOR3	6	6	I	-	NMD feature classifier.
47	MINOR3	6	6	I	-	NMD feature classifier.
53	MAJOR4	6	6	I	-	NMD feature classifier.
59	MINOR4	6	6	I	-	NMD feature classifier.

```
INFO NAME DEFINITIONS FOR BOUND/"QUADNAME".AAT FILE:

COL   ITEM NAME      WDTH OPUT TYP N.DEC DEFINITION

                        STANDARD .AAT FILE
   29 MAJOR1          6    6    I    -    NMD feature classifier.
   35 MINOR1          6    6    I    -    NMD feature classifier.
   41 MAJOR2          6    6    I    -    NMD feature classifier.
   47 MINOR2          6    6    I    -    NMD feature classifier.
   53 MAJOR3          6    6    I    -    NMD feature classifier.
   59 MINOR3          6    6    I    -    NMD feature classifier.
   65 MAJOR4          6    6    I    -    NMD feature classifier.
   71 MINOR4          6    6    I    -    NMD feature classifier.
```

COVERAGE NARRATIVE:

Abstract - The Boundaries data layer is from the USGS-NMD, 1:100,000 scale Digital Line Graphs. Information contained in boundary DLG's includes county, Federal, and Tribal boundaries and others.

Processing steps - The DLG's were converted to ARC/INFO format with the DLGARC command (Environmental Systems Research Institute, Inc., 1989). The DLGs come in four pieces for each half (east and west) of a 100K quadrangle sheet. The pieces were paneled together as were the east and west half of each coverage. Finally, all of the quadrangle sheet coverages were edgematched and appended into a composite, sound-wide boundary data layer. Using the county FIPS codes contained in the Major and Minor pairs, (USGS,1989), a Counties coverage was created using the DISSOLVE command on the FIPS code.

References:

Environmental Systems Research Institute, Inc., 1989, ARC/INFO command references: Redlands, California, Volume 2, Version 5.0.1, Appendix D.

U.S. Geological Survey, 1989, Digital line graphs from 1:100,000-scale maps—Data users guide 2: Reston, Virginia, 88 p.

DOCUMENTATION FOR DATA LAYER: Name given as 100K "Quadname", data-
                              layers in the PLSS directory, See
                              Table 2 for quadname abbreviations
SOURCE REFERENCE: USGS-NMD 1:100,000-scale Digital Line Graphs
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Public Land Survey
DESCRIPTION: Standard USGS-NMD PLSS DLG data which includes data
for Township, Range and Section, and surveyed benchmarks.
CONTACT PERSON/S: Mark Uhrich
CONTACT INSTRUCTIONS: Uhrich 503-251-3292
ORGANIZATION: USGS-WRD
LOCATION DESCRIPTION: Puget Sound Basin
                     Longitude: 125°-120°, Latitude: 46°30″-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATION: PSWQA

INFO ITEM DEFINITIONS FOR PLSS/"QUADNAME".PAT FILE:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
		STANDARD	.PAT	FILE	(Polygon)	
17	MAJOR1	6	6	I	-	NMD feature classifier.
23	MINOR1	6	6	I	-	NMD feature classifier.
29	MAJOR2	6	6	I	-	NMD feature classifier.
35	MINOR2	6	6	I	-	NMD feature classifier.
41	MAJOR3	6	6	I	-	NMD feature classifier.
47	MINOR3	6	6	I	-	NMD feature classifier.
53	MAJOR4	6	6	I	-	NMD feature classifier.
59	MINOR4	6	6	I	-	NMD feature classifier.

INFO NAME DEFINITIONS FOR PLSS/"QUADNAME".AAT FILE:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
		STANDARD	.AAT	FILE		
29	MAJOR1	6	I	-	-	NMD feature classifier.
35	MINOR1	6	6	I	-	NMD feature classifier.
41	MAJOR2	6	6	I	-	NMD feature classifier.
47	MINOR2	6	6	I	-	NMD feature classifier.
53	MAJOR3	6	6	I	-	NMD feature classifier.
59	MINOR3	6	6	I	-	NMD feature classifier.
65	MAJOR4	6	6	I	-	NMD feature classifier.
71	MINOR4	6	6	I	-	NMD feature classifier.

COVERAGE NARRATIVE:

Abstract - The PLSS data layer was developed from the USGS-NMD, 1:100,000 scale Digital Line Graphs. Information contained in PLSS DLG's includes township and range section lines, benchmark monument locations, surveyed section corners, subdivision corners, ownership corners, etc.

Processing steps - The DLG's were converted to ARC/INFO format with the DLGARC command (ESRI, 1989). The DLG's come in four pieces for each half (east and west) of a 100K quad sheet. The pieces were paneled together as were the east and west half of each data layer. The PLSS data were edgematched, but were not paneled into a sound-wide data layer. There are two separate data layers for each 100K quad that contain line and point topology, respectively. The line data layer represents the section lines, the point data layer represents the different corners. No figure of this data was included in this report as the plotting scale of 1:2,000,000 used for the entire Puget Sound Basin would not provide sufficient resolution to determine the individual section lines.

References:

U.S. Geological Survey, 1989, Digital line graphs from 1:100,000-scale maps—Data users guide 2: Reston, Virginia, 88 p.

Environmental Systems Research Institute, Inc., 1989, ARC/INFO command references: Redlands, California, Volume 2, Version 5.0.1, Appendix D.

Geographic Names

DOCUMENTATION FOR DATA LAYER: WAGAZ_PS

SOURCE REFERENCE: USGS-NMD
                    Geographic Names Information System (GNIS)
        (acquired from Washington Department of Fish & Wildlife)
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Geographic Names
DESCRIPTION: The Puget Sound Geographic Names was extracted from
             the USGS-NMD Geographic Names Information System
CONTACT PERSON/S: 1. Mark Uhrich(1) or Shelly Snyder(2)
CONTACT INSTRUCTIONS: 1. Uhrich 503-251-3292
                       2. Snyder 360-902-2983
ORGANIZATION: 1. USGS   2.Washington Department of Fish & Wildlife
LOCATION DESCRIPTION: Puget Sound Geographic Names
                Longitude: 125°-122°, Latitude: 47°-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATIONS: PSWQA; Washington Department of Fish & Wildlife

INFO ITEM DEFINITIONS FOR WAGAZ_PS.PAT FILE:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
						STANDARD .PAT FILE (Point)
17	PTNAME	47	47	C	-	Place name (Upper Case)
64	PT.NAME	47	47	C	-	Place name (lower case)
111	FCLASS	10	10	C	-	Feature class (Upper Case)
121	F.CLASS	10	10	C	-	Feature class (lower case)
131	SCCODES	12	12	C	-	State and County FIPS codes
143	GCOORD	16	16	C	-	Geographic Coordinate in latitude/longitude with direction given, Ex:(473000N12230000W)
159	BGN	5	5	C	-	U.S. Board on Geographic Names decision date
164	ELEV	6	6	I	-	Elevation in feet if published on USGS topographic map
170	SCOORD	16	16	C	-	Source coordinate for linear feature, (stream, canyon), in same GCOORD format
186	GNISMC	20	20	C	-	GNIS Map Code, 4 digit number refers to 7.5' USGS map

206	QUADCODE$7	7	I	-	7 digit number identifies position of 7.5' USGS map.
213	QUADNAME	23	23	C	-	USGS 7.5' map name
236	Q100KCODE$	5	5	C	-	Washington DNR mapsheet 100k quad belongs
241	Q250KCODE$	5	5	C	-	Washington DNR mapsheet 250K quad belongs
246	DNRCODE$	4	4	I	-	Washington DNR naming convention to locate quads using row and columns
250	QUADCODE	4	7	B	-	Same as QUADCODE$, but binary
254	ITEM.NO	7	7	I	-	= WAGAZ_PS-ID, has comma's
261	X-COORD	4	12	F	3	X coordinate in UTM, Zone 10
265	Y-COORD	4	12	F	3	Y coordinate in UTM, Zone 10

REDEFINED ITEMS

64	PRINT.NAME	30	30	C	-	Same as PT.NAME with less character spaces
143	LAT	7	7	C	-	Separate latitude from GCOORD
150	LON	8	8	C	-	Separate longitude from GCOORD

COVERAGE NARRATIVE:

Abstract - The Geographic Names data layer was obtained from Washington Department of Fish & Wildlife. It is a point data layer developed from the USGS-NMD GNIS file for Washington. The point coverage was clipped to match the extent of the Puget Sound Basin.

Processing steps - The point data layer was projected from Washington state plane, south zone (5626), to UTM, Zone 10 coordinates. The original point coverage (WAGAZ) covered the entire state. The projected point data layer was clipped with the Puget Sound Basin outline to produce a GNIS coverage for the PSGIS (PS_WAGAZ). No attributes were altered from the data acquired from Washington Department of Fish & Wildlife.

APPENDIX B

Data-Layer Dictionary of the Puget Sound Environmental Atlas

The Puget Sound Environmental Atlas (PSEA) data existed in digital form as Intergraph design files archived with the Army Corps of Engineers in Seattle, Washington. The Intergraph files were obtained and converted to Drawing Interchange Format (DXF) files by the Bonneville Power Administration in Portland, Oregon. DXF files are an AutoCad file format that can be brought into ARC/INFO. See the Conversion and Registration sections of the PSEA Data-Layer Description for additional information. The Puget Sound Environmental Atlas DXF files contain up to 63 layers (or 63 Intergraph Design File levels) of data. The PSEA was divided into 12 regions with border overlap occurring between all regions (Evans-Hamilton, Inc., and D.R. Systems, Inc., 1987). Some of the DXF layers contain data from only one resource, others contain data from several composited resources. All of the DXF file layers were converted to ARC/INFO format in one composite coverage for each of the 12 regions and registered to real world coordinates.

The converted data accurately matched the cartographic representation in the PSEA. An item in the composite data layer called DXF-LAYER could be used to RESELECT a desired layer. Appendixes I-III in "An Analysis of The Puget Sound Environmental Atlas," (Environmental Systems Research Institute, Inc., 1988) contain information on which PSEA resources are within which Intergraph design file level. The design file level and DXF layer are the same in the converted data. A number of processing steps were needed to create a topologically correct and attributed data set.

Separate coverages were created for each individual species or resource, for each PSEA region. Final editing assured topologically correct data and each species/resource was attributed with a unique -ID number to assist in compositing and attributing the final species/resource data layer. Each of the PSEA regional species/ resource data layers were then paneled together with the UNION command and DISSOLVED on the unique -ID creating a sound-wide data layer for each species or resource. Appending each of the 12 regional species/resource data layers into a sound-wide species/ resource data layer was now possible and eliminated duplication of the overlap areas occurring along the 12 regional boundaries. Based on the unique -ID's of the unioned composite, the final attributes, such as the species presence/absence flags, were populated.

Reference:

Evans-Hamilton, Inc., and D.R. Systems, Inc., 1987, Puget Sound environmental atlas—Volumes I and II: Seattle, Washington, U.S. Environmental Protection Agency, Puget Sound Water Quality Authority, and U.S. Army Corps of Engineers.

Sea Bird Nesting Areas

DOCUMENTATION FOR DATA LAYER: BIRD
SOURCE REFERENCE: Puget Sound Environmental Atlas
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Sea Bird Nesting sites
DESCRIPTION: Sea bird nesting sites as small single polygons or
             linear polygonal features along a cliff or beach
             rookery. Attributed by species.
CONTACT PERSON/S: Mark Uhrich
CONTACT INSTRUCTIONS: Uhrich: 503-251-3292
ORGANIZATION: U.S. Geological Survey (USGS)-
              Water Resources Division(WRD)
LOCATION DESCRIPTION: Puget Sound Basin
                      Longitude: 125°-120°, Latitude: 46° 30-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATION: Puget Sound Water Quality Authority (PSWQA);
                  Washington Department of Natural Resources,
                  Division of Aquatic Resources

INFO ITEM DEFINITIONS FOR BIRD.PAT FILE:

COLITEM NAMEWDTH OPUT TYP N.DEC DEFINITION

STANDARD .PAT FILE (Polygon)

14	AUKLET	1	1	I	-	Rhinoceros auklet. Presence/Absence flag (0 = absent, 1 = present)
15	D_CORMORANT	1	1	I	-	Double-crested cormorant. Presence/Absence flag (0 = absent, 1 = present)
16	GUILLEMOT	1	1	I	-	Pigeon guillemot. Presence/Absence flag (0 = absent, 1 = present)
17	GULL	1	1	I	-	Glaucous-winged gull. Presence/Absence flag (0 = absent, 1 = present)
18	OYSTERCATCHER	1	1	I	-	Black oystercatcher. Presence/Absence flag (0 = absent, 1 = present)
19	PUFFIN	1	1	I	-	Tufted puffin. Presence/ Absence flag (0 = absent, 1 = present)
20	P_CORMORANT	1	1	I	-	Pelagic cormorant. Presence/Absence flag (0 = absent, 1 = present)
21	TERN	1	1	I	-	Arctic tern. Presence/Absence flag (0 = absent, 1 = present)

INFO ITEM DEFINITIONS FOR BIRD.AAT FILE:

STANDARD .AAT FILE

COVERAGE NARRATIVE:

Abstract - The PSEA contains compiled information on the location
of seabird nesting sites in the Puget Sound. The Seabird data layer
in the Puget Sound GIS (Geographic Information System) is a
reproduction of the information presented in the atlas in digital
form, with associated database files which store attribute
information.

Processing steps- The data layer extraction section in the main
text contains the information on processing the sea bird symbols.
Each species data layer from the 12 PSEA regions were composited
together with the UNION command. These separate sea bird data
layers were later composited, also using the UNION command, and
formed the Seabird data layer (BIRD). Each sea bird species was
given a unique identifier (the INFO COVERAGE-ID). These -ID numbers
are listed in the table below. The unioned species data layers were
given the naming convention; SPECIES_NAME.UN, e.g., AUKLET, (UN=
UNIONED).

PSEA Data Unique Feature Identification Numbers
(From INFO item SPECIES_NAME.UN-ID):

Species   ID# Definition

AUKLET   1   Rhinoceros auklet
D_CORM   2   Double-crested cormorant
GUILLEMOT 3   Pigeon guillemot
GULL   4   Glaucous-winged gull
OYSTERCAT 5   Black oystercatcher
PUFFIN   6   Tufted puffin
P_CORM   7   Pelagic cormorant
TERN   8   Arctic tern

A separate data layer was created for each species in the seabird
nesting area resource-layer (BIRD). An example INFO Polygon
Attribute Table (.PAT) for these unique data layers follows, the
term SPECIES would be replaced by the name of the specific sea bird,
e.g., P_CORM:

COLITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
1 AREA	4	12	F	3	Area of polygon in square meters
5 PERIMETER	4	12	F	3	Perimeter of polygon in meters
9 SPECIES#	4	5	B	-	Internal feature number
13 SPECIES-ID	4	5	B	-	User-assigned feature number
17 SPECIES.UN-ID	4	5	B	-	Unique species number

```
DOCUMENTATION FOR DATA LAYER: HABITAT
SOURCE REFERENCE: Puget Sound Environmental Atlas
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound kelp and eelgrass features
DESCRIPTION: The scope of this project allowed only the
             conversion of two of the Habitat features from
             the PSEA: Kelp and Eelgrass.
CONTACT PERSON/S: Mark Uhrich
CONTACT INSTRUCTIONS:  Uhrich: 503-251-3292
ORGANIZATION: USGS-WRD
LOCATION DESCRIPTION: Puget Sound Basin
                     Longitude: 125°-120°,Latitude: 46° 30-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATION: PSWQA; Washington DNR,
                  Division of Aquatic Resources
```

INFO ITEM DEFINITIONS FOR HABITAT.PAT FILE (Output = 18):

COLITEM NAMEWDTH OPUT TYP N.DEC DEFINITION

STANDARD .PAT FILE (Polygon)

		WDTH	OPUT	TYP	N.DEC	DEFINITION
14	KELP	1	1	I	-	Kelp. Presence/Absence flag (0 =absent, 1 = present)
15	EELGRASS	1	1	I	-	Eelgrass. Presence/Absence flag (0 = absent, 1 = present)

INFO ITEM DEFINITIONS FOR HABITAT.AAT FILE:

STANDARD .AAT FILE

COVERAGE NARRATIVE:

Abstract - The PSEA contains compiled information on the location
of habitat resources in the Puget Sound. The Habitat data layer in
the Puget Sound GIS is a reproduction of the information presented
in the atlas in digital form, with associated database files which
store attribute information.

Processing steps - The DXF files containing the data on kelp and
eelgrass were the Extra files. As explained in the DXF Conversion
and Registration sections of the main text, the Extra files were
often registered inaccurately and did not have any reference
feature to match the Base DXF file. In these cases the kelp and
eelgrass data were registered manually, by visually fitting the
reference features as close as possible.

Kelp and eelgrass were the only two data layers converted and were
represented in the PSEA and DXF files as polygons. The delimiting
polygon was selected in ARCEDIT and the PUT command was used to
place the feature into a eelgrass or kelp data layer for final
editing and attribution. Each eelgrass/kelp data layer from the 12
PSEA regions was composited together with the UNION command. These
separate eelgrass/kelp data layers were later composited, also
using the UNION command, and formed the Near-Shore Habitat data
layer (HABITAT). Each habitat species or resource was given a
unique identifier (the INFO COVERAGE-ID). These -ID numbers are
listed below. The unioned species data layers were given the naming
convention; SPECIES_NAME.UN, e.g., EELGRASS,(UN= UNIONED).

PSEA Data Unique Feature Identification Numbers
(From INFO item SPECIES_NAME.UN-ID):

Name	ID#	Definition
EELGRASS	9	Eelgrass
HMA	10	Habitat Management Area
KELP	11	Kelp
NES	12	National Estuarine Sanctuary
NP	13	Nature Preserve
NWR	14	National Wildlife Refuge

The INFO Polygon Attribute Table (.PAT) from the separate data
layers created for the two species in the HABITAT resource-layer
is given below. The term SPECIES is generic for either EELGRASS or
KELP:

COL	ITEM	NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
1	AREA		4	12	F	3	Area of polygon in square meters
9	PERIMETER		4	12	F	3	Perimeter of polygon in meters
17	SPECIES#		4	5	B	-	Internal feature number
21	SPECIES-ID		4	5	B	-	User-assigned feature number
25	SPECIES.UN-ID	4	5	B	-	Unique species number
29	SPECIES		1	1	I	-	Presence/Absence flag

DOCUMENTATION FOR DATA LAYER: MAMMAL
SOURCE REFERENCE: Puget Sound Environmental Atlas
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Marine Mammal Haulouts and sightings
DESCRIPTION: Marine Mammal haulout areas and frequent sighting
            locations
CONTACT PERSON/S: Mark Uhrich
CONTACT INSTRUCTIONS: Uhrich 503-251-3292
ORGANIZATION: USGS-WRD
LOCATION DESCRIPTION: Puget Sound Basin
                    Longitude: 125°-120°, Latitude: 46° 30-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATION: PSWQA; Washington DNR,
                Division of Aquatic Resources
INFO ITEM DEFINITIONS FOR MAMMAL.PAT FILE:

COLITEM NAMEWDTH OPUT TYP N.DEC DEFINITION

STANDARD .PAT FILE (Polygon)

14	C_SEALION	1	1	I	-	California sea lion. Presence/Absence flag (0 = absent, 1 = present)
15	DALL_PORP	1	1	I	-	Dall's porpoise. Presence/Absence flag (0 = absent, 1 = present)
16	HARB_PORP	1	1	I	-	Harbor porpoise. Presence/Absence flag (0 = absent, 1 = present)
17	HARB_SEAL	1	1	I	-	Harbor seal. Presence/Absence flag (0 = absent, 1 = present)
18	MINKE	1	1	I	-	Minke whale. Presence/Absence flag (0 = absent, 1 = present)
19	N_SEALION	1	1	I	-	Northern sea lion. Presence/Absence flag (0 = absent, 1 = present)
20	OTTER	1	1	I	-	River otter habitat. Presence/Absence flag (0 = absent, 1 = present)

INFO NAME DEFINITIONS FOR MAMMAL.AAT FILE:

STANDARD .AAT FILE

COVERAGE NARRATIVE:

Abstract - The PSEA contains compiled information on the location
of marine mammal sightings and haulout sites in the Puget Sound.
The marine mammal data layer in the Puget Sound GIS is a
reproduction of the information presented in the atlas in digital
form, with associated database files which store attribute
information.

Processing steps- The data layer extraction section in the main
text contains the information on processing the sea mammal symbols.
Each species data layer from the 12 PSEA regions was composited
together with the UNION command. These separate marine mammal data
layers were later composited together, also using the UNION
command, to form the MAMMAL data layer. Each species was given
unique identifiers (the INFO COVERAGE-ID) to aid in creation and
attribution of the final composite. These numbers are listed below
for the coverage SPECIES.UN-ID, where SPECIES is replaced by the
name of the specific mammal, e.g., C_SEALION, (UN= UNIONED).

PSEA Data Unique Feature Identification Numbers:
(From the INFO item SPECIES.UN-ID)

Species   ID# Definition

C_SEALION 15 California sea lion
DALL_PORP 16 Dall's porpoise
HARB_PORP 17 Harbor porpoise
HARB_SEAL 18 Harbor seal
MINKE   19 Minke whale
N_SEALION 20 Northern sea lion
OTTER   21 River otter habitat

A separate data layer was created for each species in the MAMMAL
resource-layer. An example INFO Polygon Attribute Table (.PAT) for
these specific data layers follows, the item SPECIES is generic for
each mammal, e.g., HARB_SEAL:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
1	AREA	4	12	F	3	Area of polygon in square meters
5	PERIMETER	4	12	F	3	Perimeter of polygon in meters
9	SPECIES#	4	5	B	-	Internal feature number
13	SPECIES-ID	4	5	B	-	User-assigned feature number
17	SPECIES.UN-ID	4	5	B	-	Unique species number

Marine Fish

DOCUMENTATION FOR DATA LAYER: Marine Fish, coverage name; (MARINE)
SOURCE REFERENCE: Puget Sound Environmental Atlas
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Marine fish resources
DESCRIPTION: This data layer includes features for a variety of
            marine fish resources as well as attributes for
            use type and harvest areas.
CONTACT PERSON/S: Mark Uhrich
CONTACT INSTRUCTIONS: Uhrich 503-251-3292
ORGANIZATION: USGS-WRD
LOCATION DESCRIPTION: Puget Sound Basin
                     Longitude: 125°-120°, Latitude: 46° 30-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATION: PSWQA; Washington DNR,
            Division of Aquatic Resources

INFO ITEM DEFINITIONS FOR MARINE.PAT FILE:

COLITEM NAMEWDTH OPUT TYP N.DEC DEFINITION

STANDARD .PAT FILE (Polygon)

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
17	SALMON	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
18	GROUNDFISH	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
19	AREA#	3	3	I	-	Groundfish resource and fishing area number
22	HERRING_HOLD	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
23	HERRING_SPAWN	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
24	SMELT	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
25	COMMERCIAL	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
26	RECREATIONAL	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
27	POTENTIAL_COM	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
28	AQUACULTURE	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
29	PEN_CULTURE	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
30	NONE	1	1	I	-	Polygon has no fish resource, (1 = no resource)
31	UNKNOWN	1	1	I	-	Polygon fish resource unknown, (1 = resource unknown)

Listed below are items from the above .PAT file that are either renamed or added to the marine resource-layer.

COMMERCIAL- Renamed FISH_COM data layer from Salmon Resources.
RECREATIONAL- Renamed FISH_SPORT data layer from Salmon Resources.
POTENTIAL_COM- Potential Commercial item similar to item in ATLAS Shellfish Resources. Item not populated, added for future updates.
NONE-- Limited or no resource present, item not populated, added for future updates.
UNKNOWN-- Resource unknown, item not populated, added for future updates.

INFO NAME DEFINITIONS FOR MARINE.AAT FILE:

STANDARD .AAT FILE

COVERAGE NARRATIVE:

Abstract - The PSEA contains compiled information on the location of marine fish resources in the Puget Sound. The Marine fish data layer in the Puget Sound GIS is a reproduction of the information presented in the atlas in digital form, with associated database files which store attribute fields.

Processing steps - The Marine fish and Salmon resources are represented in the PSEA as hachure filled polygons or simply as a hachured areal distribution. Reselecting individual resources from the DXF composite coverage was a simple process when a single resource matched a DXF layer. However, when several resources were combined into the same layer the data needed to be separated, either manually or, if possible, automatically, before attribution and final editing.

Marine fish resources were represented cartographically in the PSEA and DXF files three basic ways: (1) Hachured areas with a bounding polygon, (2) Hachured areas without a bounding polygon, and (3) Areas delimited by a broken, or dashed, polygon. See Appendix E for hachure processing steps. The data layer extraction was also conducted using three procedures. The processing of features with a bounding polygon was relatively simple. The delimiting polygon was selected in ARCEDIT and the PUT command was used to place the feature into a new resource data layer for final editing and attribution. Areas represented by hachures without bounding polygons were placed into separate data layers by resource. An AML (linepoly.aml) was used to automatically generate a delimiting polygon in a new coverage. The new coverage was then attributed. Dashed-line polygons required manually connecting the separate line segments to create a closed polygon. In a limited number of polygons, various snapping procedures could be used to automate the connection.

Based on the unique -ID's of the unioned composite, the species/ resource presence/absence flags were populated as were the rest of the final attributes. Each fish species or resource was given a unique identifier (the INFO COVERAGE -ID). The -ID numbers are listed below and are for the coverage SPECIES.UN-ID, where SPECIES is replaced by the name of the specific marine fish or resource, e.g., GROUNDFISH, (UN = UNIONED).

PSEA Data Unique Feature Identification Numbers:
(From the INFO item SPECIES.UN-ID)

Name   ID# Definition

EX-PEN_CULT 22 Existing pen culture
FISH_COM   23 Salmon resources - Commercial fishing areas
FISH_SPORT   24 Salmon resources - Sport fishing areas
GROUNDFISH   25 Groundfish resource and fishing area
HERR_HOLD   26 Pacific herring holding area
HERR_SPAWN   27 Pacific herring spawning area
SMELT   28 Surf smelt spawning beach
PRO_PEN   39 Proposed pen culture

A separate data layer was created for each species or resource in
the MARINE resource-layer. An example INFO Polygon Attribute Table
(.PAT) for these specific data layers follows, the item SPECIES is
generic for a specific fish or resource, e.g., FISH_COM:

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
1	AREA	4	12	F	3	Area of polygon in square meters
5	PERIMETER	4	12	F	3	Perimeter of polygon in meters
9	SPECIES#	4	5	B	-	Internal feature number
13	SPECIES-ID	4	5	B	-	User-assigned feature number
17	SPECIES	2	2	I	-	Unique species number
19	AREA#	3	3	I	-	Area number for Groundfish data layer only

DOCUMENTATION FOR DATA LAYER: SHELLFISH
SOURCE REFERENCE: Puget Sound Environmental Atlas
MAP PROJECTION: UTM, Zone 10
PRECISION: Single
TOLERANCES: Fuzzy=.001 Dangle=1.0
THEME: Puget Sound Shellfish resources
DESCRIPTION: This data layer includes features for a variety of
             shellfish resources, as well as attributes for
             use type and aquaculture harvest areas.
CONTACT PERSON/S: Mark Uhrich
CONTACT INSTRUCTIONS: Uhrich 503-251-3292
ORGANIZATION: USGS-WRD
LOCATION DESCRIPTION: Puget Sound Basin
                     Longitude: 125°-120°, Latitude: 46° 30-49°
RESOLUTION: 167 ft (50.9 m)
SCALE: 1:100,000
ARCHIVE LOCATION: PSWQA; Washington DNR,
                  Division of Aquatic Resources

INFO ITEM DEFINITIONS FOR SHELLFISH.PAT FILE:

COLITEM NAMEWDTH OPUT TYP N.DEC DEFINITION

STANDARD .PAT FILE (Polygon)

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	DEFINITION
17	CLAMS	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
18	GEODUCKS	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
19	CRAB	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
20	SHRIMP	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
21	OYSTERS	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
22	MUSSELS	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
23	COMMERCIAL	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
24	RECREATIONAL	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
25	POTENTIAL_COM	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
26	AQUACULTURE	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
27	BOTTOM_CULT	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
28	SUSPENDED_CULT	1	1	I	-	Presence/Absence flag (1 = present, 0 = absent)
29	NONE	1	1	I	-	Polygon has no shellfish resource, (1 = no resource)
30	UNKNOWN	1	1	I	-	Polygon shellfish resource unknown, (1 = resource unknown)

Listed below are items from the above .PAT file that are either renamed or added to the shellfish resource-layer.

COMMERCIAL- Commercial clam, oyster and geoduck beds. Composite of CLAM_OY and GEO_COM.

RECREATIONAL- Item similar to Sport Fishing Areas from ATLAS Salmon Resources. Item not populated, added for future updates.

POTENTIAL_COM- Potential Commercial beds not currently utilized. Composite of CLAM_MAJ and GEO_MAJ.

NONE-- Limited or no shellfish resource present, item not populated, added for future updates.

UNKNOWN-- Shellfish resource unknown, item not populated, added for future updates.

INFO NAME DEFINITIONS FOR SHELLFISH.AAT FILE:

STANDARD .AAT FILE

COVERAGE NARRATIVE:

Abstract - The PSEA contains compiled information on the location of shellfish resources in the Puget Sound. The Shellfish data layer in the Puget Sound GIS is a reproduction of the information presented in the atlas in digital form, with associated database files which store attribute fields.

Processing steps - The Shellfish resources are represented in the PSEA as hachure filled polygons or simply a hachured areal distribution. Reselecting individual resources from the DXF composite coverage was a simple process when a single resource matched a DXF layer. However, when several resources were combined into the same layer the data needed to be separated, either manually or in some cases automatically, before attribution and final editing.

Shellfish resources were represented cartographically in the PSEA and DXF files as hachured areas, both bounded and unbounded polygons, and as dash-lined polygons without hachures. The processing methods were identical to the MARINE resource-layer. Each shellfish species or resource was given a unique identifier (the INFO COVERAGE-ID). The -ID numbers are listed below and are for the coverage SPECIES.UN-ID, where SPECIES is replaced by the name of the specific shellfish species or resource, for example, GEO_COM, (UN= UNIONED).

PSEA Data Unique Feature Identification Numbers:
(From the INFO item SPECIES.UN-ID)

Name   ID# Definition

B_CULT   29 Bottom culture
CLAM_MAJ   30 Subtidal clams- major, potential commercial beds
CLAM_OY   31 Clams and oysters- commercial
CRAB   . 32 Dungeness crab
GEO_COM   33 Geoducks commercial
GEO_MAJ   34 Geoducks- major, potential commercial beds
OYSTERS   35 Oysters commercial
SHRIMP   36 Shrimp
SUSP_CULT   37 Suspended culture

A separate data layer was created for each species or resource in
the SHELLFISH resource-layer. An example INFO Polygon Attribute
Table (.PAT) for these specific data layers follows, the term
SPECIES would be replaced by the specific shellfish or resource,
e.g., CRAB:

COLITEM NAMEWDTH OPUT TYP N.DEC DEFINITION

1	AREA	4	12	F	3	Area of polygon in square meters
5	PERIMETER	4	12	F	3	Perimeter of polygon in meters
9	SPECIES#	4	5	B	-	Internal feature number
13	SPECIES-ID	4	5	B	-	User-assigned feature number
17	SPECIES	2	2	I	-	Unique species number

APPENDIX C

Tic-Identification Numbers and Coordinates

(All tics are numbered starting from the upper right corner and moving to the left, except for Region 3, which starts from the upper left corner and moves to the right. Tic-ID, Tic-identificaton number)

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
		Region 1:	**Tics 1–24**		
101	-122°40'00"	48°55'00"	102	-122°45'00"	48°55'00"
103	-122°50'00"	48°55'00"	104	-122°55'00"	48°55'00"
105	-123°00'00"	48°55'00"	106	-123°05'00"	48°55'00"
107	-123°10'00"	48°55'00"	108	-123°15'00"	48°55'00"
109	-122°40'00"	48°50'00"	110	-122°45'00"	48°50'00"
111	-122°50'00"	48°50'00"	112	-122°55'00"	48°50'00"
113	-123°00'00"	48°50'00"	114	-123°05'00"	48°50'00"
115	-123°10'00"	48°50'00"	116	-123°15'00"	48°50'00"
117	-122°40'00"	48°45'00"	118	-122°45'00"	48°45'00"
119	-122°50'00"	48°45'00"	120	-122°55'00"	48°45'00"
121	-123°00'00"	48°45'00"	122	-123°05'00"	48°45'00"
123	-123°10'00"	48°45'00"	124	-123°15'00"	48°45'00"

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude

Region 2:   Tics 1–55

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
201	-122°25'00"	48°45'00"	202	-122°30'00"	48°45'00"
203	-122°35'00"	48°45'00"	204	-122°40'00"	48°45'00"
205	-122°45'00"	48°45'00"	206	-122°50'00"	48°45'00"
207	-122°55'00"	48°45'00"	208	-123°00'00"	48°45'00"
209	-123°05'00"	48°45'00"	210	-123°10'00"	48°45'00"
211	-123°15'00"	48°45'00"	212	-122°25'00"	48°40'00"
213	-122°30'00"	48°40'00"	214	-122°35'00"	48°40'00"
215	-122°40'00"	48°40'00"	216	-122°45'00"	48°40'00"
217	-122°50'00"	48°40'00"	218	-122°55'00"	48°40'00"
219	-123°00'00"	48°40'00"	220	-123°05'00"	48°40'00"
221	-123°10'00"	48°40'00"	222	-123°15'00"	48°40'00"
223	-122°25'00"	48°35'00"	224	-122°30'00"	48°35'00"
225	-122°35'00"	48°35'00"	226	-122°40'00"	48°35'00"
227	-122°45'00"	48°35'00"	228	-122°50'00"	48°35'00"
229	-122°55'00"	48°35'00"	230	-123°00'00"	48°35'00"
231	-123°05'00"	48°35'00"	232	-123°10'00"	48°35'00"
233	-123°15'00"	48°35'00"	234	-122°25'00"	48°30'00"
235	-122°30'00"	48°30'00"	236	-122°35'00"	48°30'00"
237	-122°40'00"	48°30'00"	238	-122°45'00"	48°30'00"
239	-122°50'00"	48°30'00"	240	-122°55'00"	48°30'00"
241	-123°00'00"	48°30'00"	242	-123°05'00"	48°30'00"
243	-123°10'00"	48°30'00"	244	-123°15'00"	48°30'00"
245	-122°25'00"	48°25'00"	246	-122°30'00"	48°25'00"
247	-122°35'00"	48°25'00"	248	-122°40'00"	48°25'00"
249	-122°45'00"	48°25'00"	250	-122°50'00"	48°25'00"
251	-122°55'00"	48°25'00"	252	-123°00'00"	48°25'00"
253	-123°05'00"	48°25'00"	254	-123°10'00"	48°25'00"
255	-123°15'00"	48°25'00"			

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude

Region 3: Tics 1–32

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
301	-123°27′30″	48°22′30″	302	-123°22′30″	48°22′30″
303	-123°17′30″	48°22′30″	304	-123°12′30″	48°22′30″
305	-123°07′30″	48°22′30″	306	-123°02′30″	48°22′30″
307	-122°57′30″	48°22′30″	308	-122°52′30″	48°22′30″
309	-123°27′30″	48°17′30″	310	-123°22′30″	48°17′30″
311	-123°17′30″	48°17′30″	312	-123°12′30″	48°17′30″
313	-123°07′30″	48°17′30″	314	-123°02′30″	48°17′30″
315	-122°57′30″	48°17′30″	316	-122°52′30″	48°17′30″
317	-123°27′30″	48°12′30″	318	-123°22′30″	48°12′30″
319	-123°17′30″	48°12′30″	320	-123°12′30″	48°12′30″
321	-123°07′30″	48°12′30″	322	-123°02′30″	48°12′30″
323	-122°57′30″	48°12′30″	324	-122°52′30″	48°12′30″
325	-123°27′30″	48°07′30″	326	-123°22′30″	48°07′30″
327	-123°17′30″	48°07′30″	328	-123°12′30″	48°07′30″
329	-123°07′30″	48°07′30″	330	-123°02′30″	48°07′30″
331	-122°57′30″	48°07′30″	332	-122°52′30″	48°07′30″

Region 4: Tics 1–21

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
401	-122°22′30″	48°22′30″	402	-122°27′30″	48°22′30″
403	-122°32′30″	48°22′30″	404	-122°37′30″	48°22′30″
405	-122°42′30″	48°22′30″	406	-122°47′30″	48°22′30″
407	-122°52′30″	48°22′30″	408	-122°22′30″	48°17′30″
409	-122°27′30″	48°17′30″	410	-122°32′30″	48°17′30″
411	-122°37′30″	48°17′30″	412	-122°42′30″	48°17′30″
413	-122°47′30″	48°17′30″	414	-122°52′30″	48°17′30″
415	-122°22′30″	48°12′30″	416	-122°27′30″	48°12′30″
417	-122°32′30″	48°12′30″	418	-122°37′30″	48°12′30″
419	-122°42′30″	48°12′30″	420	-122°47′30″	48°12′30″
421	-122°52′30″	48°12′30″			

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude

<div align="center">

Region 5:   Tics 1–21

</div>

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
501	-122°32′30″	48°10′00″	502	-122°37′30″	48°10′00″
503	-122°42′30″	48°10′00″	504	-122°47′30″	48°10′00″
505	-122°52′30″	48°10′00″	506	-122°57′30″	48°10′00″
507	-123°02′30″	48°10′00″	508	-122°32′30″	48°05′00″
509	-122°37′30″	48°05′00″	510	-122°42′30″	48°05′00″
511	-122°47′30″	48°05′00″	512	-122°52′30″	48°05′00″
513	-122°57′30″	48°05′00″	514	-123°02′30″	48°05′00″
515	-122°32′30″	48°00′00″	516	-122°37′30″	48°00′00″
517	-122°42′30″	48°00′00″	518	-122°47′30″	48°00′00″
519	-122°52′30″	48°00′00″	520	-122°57′30″	48°00′00″
521	-123°02′30″	48°00′00″			

<div align="center">

Region 6:   Tics 1–25

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Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
601	-122°10′00″	48°15′00″	602	-122°15′00″	48°15′00″
603	-122°20′00″	48°15′00″	604	-122°25′00″	48°15′00″
605	-122°30′00″	48°15′00″	606	-122°10′00″	48°10′00″
607	-122°15′00″	48°10′00″	608	-122°20′00″	48°10′00″
609	-122°25′00″	48°10′00″	610	-122°30′00″	48°10′00″
611	-122°10′00″	48°05′00″	612	-122°15′00″	48°05′00″
613	-122°20′00″	48°05′00″	614	-122°25′00″	48°05′00″
615	-122°30′00″	48°05′00″	616	-122°10′00″	48°00′00″
617	-122°15′00″	48°00′00″	618	-122°20′00″	48°00′00″
619	-122°25′00″	48°00′00″	620	-122°30′00″	48°00′00″
621	-122°10′00″	47°55′00″	622	-122°15′00″	47°55′00″
623	-122°20′00″	47°55′00″	624	-122°25′00″	47°55′00″
625	-122°30′00″	47°55′00″			

<div align="center">

Region 7:   Tics 1–25

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Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
701	-122°45′00″	47°52′30″	702	-122°50′00″	47°52′30″
703	-122°55′00″	47°52′30″	704	-122°60′00″	47°52′30″
705	-123°05′00″	47°52′30″	706	-122°45′00″	47°47′30″
707	-122°50′00″	47°47′30″	708	-122°55′00″	47°47′30″
709	-122°60′00″	47°47′30″	710	-123°05′00″	47°47′30″
711	-122°45′00″	47°42′30″	712	-122°50′00″	47°42′30″
713	-122°55′00″	47°42′30″	714	-122°60′00″	47°42′30″
715	-123°05′00″	47°42′30″	716	-122°45′00″	47°37′30″
717	-122°50′00″	47°37′30″	718	-122°55′00″	47°37′30″
719	-122°60′00″	47°37′30″	720	-123°05′00″	47°37′30″
721	-122°45′00″	47°32′30″	722	-122°50′00″	47°32′30″
723	-122°55′00″	47°32′30″	724	-122°60′00″	47°32′30″
725	-123°05′00″	47°32′30″			

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude

Region 8:   Tics 1–21

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
801	-122°12'30"	47°55'00"	802	-122°17'30"	47°55'00"
803	-122°22'30"	47°55'00"	804	-122°27'30"	47°55'00"
805	-122°32'30"	47°55'00"	806	-122°37'30"	47°55'00"
807	-122°42'30"	47°55'00"	808	-122°12'30"	47°50'00"
809	-122°17'30"	47°50'00"	810	-122°22'30"	47°50'00"
811	-122°27'30"	47°50'00"	812	-122°32'30"	47°50'00"
813	-122°37'30"	47°50'00"	814	-122°42'30"	47°50'00"
815	-122°12'30"	47°45'00"	816	-122°17'30"	47°45'00"
817	-122°22'30"	47°45'00"	818	-122°27'30"	47°45'00"
819	-122°32'30"	47°45'00"	820	-122°37'30"	47°45'00"
821	-122°42'30"	47°45'00"			

Region 9:   Tics 1–21

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
901	-122°15'00"	47°42'30"	902	-122°20'00"	47°42'30"
903	-122°25'00"	47°42'30"	904	-122°30'00"	47°42'30"
905	-122°35'00"	47°42'30"	906	-122°40'00"	47°42'30"
907	-122°45'00"	47°42'30"	908	-122°15'00"	47°37'30"
909	-122°20'00"	47°37'30"	910	-122°25'00"	47°37'30"
911	-122°30'00"	47°37'30"	912	-122°35'00"	47°37'30"
913	-122°40'00"	47°37'30"	914	-122°45'00"	47°37'30"
915	-122°15'00"	47°32'30"	916	-122°20'00"	47°32'30"
917	-122°25'00"	47°32'30"	918	-122°30'00"	47°32'30"
919	-122°35'00"	47°32'30"	920	-122°40'00"	47°32'30"
921	-122°45'00"	47°32'30"			

Region 10:   Tics 1–21

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
1001	-122°40'00"	47°27'30"	1002	-122°45'00"	47°27'30"
1003	-122°50'00"	47°27'30"	1004	-122°55'00"	47°27'30"
1005	-123°00'00"	47°27'30"	1006	-123°05'00"	47°27'30"
1007	-123°10'00"	47°27'30"	1008	-122°40'00"	47°22'30"
1009	-122°45'00"	47°22'30"	1010	-122°50'00"	47°22'30"
1011	-122°55'00"	47°22'30"	1012	-123°00'00"	47°22'30"
1013	-123°05'00"	47°22'30"	1014	-123°10'00"	47°22'30"
1015	-122°40'00"	47°17'30"	1016	-122°45'00"	47°17'30"
1017	-122°50'00"	47°17'30"	1018	-122°55'00"	47°17'30"
1019	-123°00'00"	47°17'30"	1020	-123°05'00"	47°17'30"
1021	-123°10'00"	47°17'30"'30"			

Tic-ID	Longitude	Latitude	Tic-ID	Longitude	Latitude
		Region 11: Tics 1–25			
1101	-122°20'00"	47°30'00"	1102	-122°25'00"	47°30'00"
1103	-122°30'00"	47°30'00"	1104	-122°35'00"	47°30'00"
1105	-122°40'00"	47°30'00"	1106	-122°20'00"	47°25'00"
1107	-122°25'00"	47°25'00"	1108	-122°30'00"	47°25'00"
1109	-122°35'00"	47°25'00"	1110	-122°40'00"	47°25'00"
1111	-122°20'00"	47°20'00"	1112	-122°25'00"	47°20'00"
1113	-122°30'00"	47°20'00"	1114	-122°35'00"	47°20'00"
1115	-122°40'00"	47°20'00"	1116	-122°20'00"	47°15'00"
1117	-122°25'00"	47°15'00"	1118	-122°30'00"	47°15'00"
1119	-122°35'00"	47°15'00"	1120	-122°40'00"	47°15'00"
1121	-122°20'00"	47°10'00"	1122	-122°25'00"	47°10'00"
1123	-122°30'00"	47°10'00"	1124	-122°35'00"	47°10'00"
1125	-122°40'00"	47°10'00"			
		Region 12: Tics 1–21			
1201	-122°40'00"	47°12'30"	1202	-122°45'00"	47°12'30"
1203	-122°50'00"	47°12'30"	1204	-122°55'00"	47°12'30"
1205	-123°00'00"	47°12'30"	1206	-123°05'00"	47°12'30"
1207	-123°10'00"	47°12'30"	1208	-122°40'00"	47°07'30"
1209	-122°45'00"	47°07'30"	1210	-122°50'00"	47°07'30"
1211	-122°55'00"	47°07'30"	1212	-123°00'00"	47°07'30"
1213	-123°05'00"	47°07'30"	1214	-123°10'00"	47°07'30"
1215	-122°40'00"	47°02'30"	1216	-122°45'00"	47°02'30"
1217	-122°50'00"	47°02'30"	1218	-122°55'00"	47°02'30"
1219	-123°00'00"	47°02'30"	1220	-123°05'00"	47°02'30"
1221	-123°10'00"	47°02'30"			

APPENDIX D

Root-Mean-Square Error
for Base and Extra Drawing Interchange Format File Conversion

[input units = millimeters; output units = meters]

Region 1

Scale (X,Y) = (1000.442, 1001.797) Translation = (506844.454, 5409831.637)
Rotation (degrees) = (0.009) RMS Error (input, output) = (0.027, 27.073)

Tic-ID	input x output y	input y output y	x error	y error
101	17.565	8.190		
	524419.625	5418030.000	-3.334	-9.172
102	11.479	8.179		
	518316.688	5418007.000	10.466	8.633
103	5.371	8.169		
	512213.812	5417990.000	2.938	20.420
104	-0.733	8.158		
	506103.000	5417980.000	7.272	25.211
105	-6.820	8.148		
	500000.000	5417977.000	19.834	23.015
106	-12.937	8.137		
	493897.000	5417980.000	3.746	14.794
107	-19.056	8.127		
	487786.312	5417990.000	-7.915	-0.429
108	-25.182	8.116		
	481683.312	5418007.000	-33.046	-22.657
109	17.583	-1.074		
	524460.312	5408760.000	-25.316	-19.898
110	11.509	-1.088		
	518347.188	5408736.000	11.072	-4.539
111	5.393	-1.102		
	512234.094	5408720.000	5.534	2.760
112	-0.722	-1.116		
	506113.094	5408710.000	9.704	4.062

Scale (X,Y) = (1000.442, 1001.797) Translation = (506844.454, 5409831.637)
Rotation (degrees) = (0.009) RMS Error (input, output) = (0.027, 27.073)

Tic-ID	input x output x	input y output y	x error	y error
113	-6.828 500000.000	-1.130 5408706.000	13.541	-0.625
114	-12.950 493886.906	-1.144 5408710.000	1.838	-13.335
115	-19.071 487765.906	-1.158 5408720.000	-0.513	-32.042
116	-25.197 481652.812	-1.172 5408736.000	-15.922	-56.757
117	17.600 524500.812	-10.339 5399500.000	-47.109	-41.236
118	11.538 518377.594	-10.340 5399476.000	11.720	-13.393
119	5.414 512254.312	-10.342 5399460.000	8.115	6.490
120	-0.711 506123.312	-10.343 5399450.000	11.948	20.373
121	-6.836 500000.000	-10.345 5399446.000	7.290	28.256
122	-12.964 493876.812	-10.346 5399450.000	0.032	28.141
123	-19.085 487745.688	-10.348 5399460.000	6.836	22.022
124	-25.211 481622.406	-10.349 5399476.000	1.269	9.906

Region 2

Scale (X,Y) = (1000.068, 999.768) Translation = (513833.598, 5379804.531)
Rotation (degrees) = (0.012) RMS Error (input, output) = (0.037, 36.650)

Tic-ID	input x output x	input y output y	x error	y error
201	29.045	19.755		
	542878.312	5399610.000	-2.238	-60.944
202	22.912	19.743		
	536755.125	5399567.000	-11.846	-28.677
203	16.790	19.731		
	530631.875	5399530.000	-10.863	-2.392
204	10.664	19.719		
	524500.812	5399500.000	-6.312	16.885
205	4.540	19.707		
	518377.594	5399476.000	-7.255	30.167
206	-1.583	19.695		
	512254.312	5399460.000	-8.039	35.448
207	-7.628	19.683		
	506123.312	5399450.000	77.296	34.867
208	-13.836	19.671		
	500000.000	5399446.000	-7.498	28.002
209	-19.962	19.659		
	493876.812	5399450.000	-10.242	13.281
210	-26.087	19.647		
	487745.688	5399460.000	-4.831	-7.441
211	-32.213	19.635		
	481622.406	5399476.000	-8.005	-34.163
212	29.116	10.495		
	542949.125	5390351.000	-0.166	-60.153
213	22.974	10.479		
	536815.812	5390307.000	-9.204	-30.177
214	16.840	10.464		
	530682.375	5390270.000	-9.277	-7.180
215	10.706	10.449		
	524541.312	5390240.000	-3.324	8.812

Region 2—Continued

Scale (X,Y) = (1000.068, 999.768) Translation = (513833.598, 5379804.531)
Rotation (degrees) = (0.012) RMS Error (input, output) = (0.037, 36.650)

Tic-ID	input x output x	input y output y	x error	y error
216	4.572	10.434		
	518407.906	5390217.000	-4.608	17.806
217	-1.563	10.418		
	512274.594	5390200.000	-6.711	20.798
218	-7.638	10.403		
	506133.312	5390190.000	59.400	16.927
219	-13.836	10.388		
	500000.000	5390187.000	-5.166	5.776
220	-19.972	10.373		
	493866.688	5390190.000	-8.359	-11.234
221	-26.108	10.357		
	487725.406	5390200.000	-3.897	-35.245
222	-32.246	10.342		
	481592.094	5390217.000	-8.647	-66.259
223	29.187	1.228		
	543019.875	5381081.000	2.016	-54.319
224	23.035	1.215		
	536876.500	5381037.000	-6.561	-21.962
225	16.891	1.203		
	530733.125	5381000.000	-7.971	3.409
226	10.747	1.190		
	524581.688	5380970.000	-0.263	21.782
227	4.603	1.177		
	518438.312	5380947.000	-2.113	33.152
228	-1.544	1.164		
	512294.812	5380930.000	-5.372	38.519
229	-7.648	1.151		
	506143.500	5380920.000	41.341	36.966
230	-13.835	1.138		
	500000.000	5380916.000	-2.843	29.256

Region 2—Continued

Scale (X,Y) = (1000.068, 999.768) Translation = (513833.598, 5379804.531)
Rotation (degrees) = (0.012) RMS Error (input, output) = (0.037, 36.650)

Tic-ID	input x output x	input y output y	x error	y error
231	-19.982 493856.500	1.125 5380920.000	-6.379	13.623
232	-26.129 487705.188	1.112 5380930.000	-2.931	-8.012
233	-32.279 481561.812	1.100 5380947.000	-9.152	-36.650
234	29.257 543090.625	-8.017 5371821.000	4.028	-37.013
235	23.096 536937.125	-8.030 5371778.000	-3.981	-6.301
236	16.941 530783.500	-8.044 5371741.000	-6.376	18.422
237	10.789 524622.125	-8.057 5371710.000	2.678	37.153
238	4.633 518468.500	-8.071 5371687.000	0.567	47.876
239	-1.524 512315.000	-8.084 5371670.000	-4.016	52.595
240	-7.658 506153.594	-8.098 5371660.000	23.378	50.362
241	-13.835 500000.000	-8.111 5371657.000	-0.520	41.043
242	-19.992 493846.406	-8.125 5371660.000	-4.494	25.763
243	-26.150 487685.000	-8.138 5371670.000	-2.009	3.480
244	-32.311 481531.500	-8.152 5371687.000	-9.654	-25.807
245	29.328 543161.125	-17.280 5362562.000	6.438	-39.518

Scale (X,Y) = (1000.068, 999.768) Translation = (513833.598, 5379804.531)
Rotation (degrees) = (0.012) RMS Error (input, output) = (0.037, 36.650)

Tic-ID	input x output x	input y output y	x error	y error
246	23.158 536997.500	-17.300 5362518.000	-0.985	-13.813
247	16.991 530833.875	-17.319 5362481.000	-4.616	4.904
248	10.830 524662.375	-17.339 5362451.000	5.970	16.640
249	4.665 518498.812	-17.358 5362428.000	3.265	21.360
250	-1.504 512335.188	-17.378 5362411.000	-2.554	20.070
251	-7.668 506163.594	-17.397 5362401.000	5.466	11.798
252	-13.834 500000.000	-17.417 5362398.000	1.817	-3.485
253	-20.002 493836.406	-17.436 5362401.000	-2.758	-24.771
254	-26.172 487664.812	-17.456 5362411.000	-1.226	-53.063
255	-32.344 481501.188	-17.475 5362428.000	-10.398	-88.362

Region 3

Scale (X,Y) = (1000.356, 995.358) Translation = (486840.646, 5336832.782)
Rotation (degrees) = (0.034) RMS Error (input, output) = (0.031, 30.897)

Tic-ID	input x output x	input y output y	x error	y error
301	-20.780	21.146		
	466060.500	5357864.000	-20.013	-29.817
302	-14.608	21.116		
	472229.188	5357831.000	-14.008	-12.993
303	-8.409	21.086		
	478397.812	5357804.000	18.694	-2.238
304	-2.206	21.055		
	484574.406	5357784.000	46.771	1.507
305	3.892	21.026		
	490743.000	5357770.000	-20.889	-0.475
306	10.085	20.995		
	496911.688	5357763.000	4.797	-9.702
307	16.232	20.965		
	503088.312	5357763.000	-22.154	-25.812
308	22.427	20.935		
	509257.000	5357770.000	6.531	-49.048
309	-20.834	11.877		
	466005.188	5348605.000	-12.863	3.117
310	-14.653	11.847		
	472183.906	5348571.000	-8.786	20.998
311	-8.453	11.817		
	478362.594	5348545.000	14.745	30.828
312	-2.254	11.787		
	484549.312	5348524.000	30.040	35.659
313	3.882	11.757		
	490728.000	5348511.000	-10.780	32.656
314	10.069	11.727		
	496906.688	5348504.000	-0.638	23.522
315	16.233	11.696		
	503093.312	5348504.000	-20.319	7.444

Scale (X,Y) = (1000.356, 995.358) Translation = (486840.646, 5336832.782)
Rotation (degrees) = (0.034) RMS Error (input, output) = (0.031, 30.897)

Tic-ID	input x output x	input y output y	x error	y error
316	22.439 509272.000	11.666 5348511.000	9.076	-15.741
317	-20.888 465949.906	2.511 5339335.000	-6.250	-49.845
318	-14.699 472138.594	2.495 5339302.000	-3.891	-18.813
319	-8.498 478327.406	2.479 5339275.000	10.472	6.215
320	-2.301 484524.094	2.463 5339255.000	13.187	24.244
321	3.872 490712.906	2.447 5339241.000	-0.598	36.281
322	10.053 496901.688	2.431 5339235.000	-6.103	40.315
323	16.235 503098.312	2.415 5339235.000	-18.475	38.349
324	22.451 509287.094	2.399 5339241.000	11.524	30.372
325	-20.942 465894.688	-6.757 5330077.000	0.810	-17.025
326	-14.745 472093.500	-6.791 5330043.000	1.072	-2.550
327	-8.543 478292.312	-6.824 5330016.000	6.252	4.910
328	-2.349 484499.000	-6.858 5329996.000	-3.779	5.393
329	3.861 490697.812	-6.892 5329983.000	9.568	-1.173
330	10.037 496896.594	-6.925 5329976.000	-11.543	-13.630
331	16.236 503103.406	-6.959 5329976.000	-16.657	-33.163
332	22.464 509302.188	-6.993 5329983.000	14.208	-59.784

Region 4

Scale (X,Y) = (1.000, 1.000) Translation = (-308.519, 842.465)
Rotation (degrees) = (0.003) RMS Error (input, output) = (12.175, 12.174)

Tic-ID	Input x output x	Input y output y	x error	y error
401	546284.631	5357941.560		
	546284.688	5357951.000	1.170	-16.302
402	540111.132	5357912.996		
	540116.125	5357904.000	-3.680	0.849
403	533940.996	5357884.447		
	533939.500	5357864.000	2.895	11.017
404	527769.402	5357855.892		
	527770.875	5357831.000	0.011	14.178
405	521598.832	5357827.342		
	521602.188	5357804.000	-1.785	11.344
406	515426.812	5357798.785		
	515425.594	5357784.000	2.875	1.503
407	509253.751	5357770.743		
	509257.000	5357770.000	-1.507	-13.824
408	546360.945	5348677.052		
	546360.125	5348692.000	1.497	-20.128
409	540177.362	5348648.443		
	540181.375	5348645.000	-3.250	-3.024
410	533996.258	5348619.845		
	533994.812	5348605.000	2.294	7.093
411	527814.579	5348591.245	.	
	527816.125	5348571.000	-0.611	11.206
412	521634.800	5348562.653		
	521637.406	5348545.000	-1.586	7.329
413	515453.122	5348534.053		
	515450.812	5348524.000	3.416	-1.557
414	509269.089	5348505.442		
	509272.000	5348511.000	-1.718	-18.455
415	546437.264	5339412.063		
	546435.625	5339423.000	1.765	-14.436

Scale (X,Y) = (1.000, 1.000) Translation = (-308.519, 842.465)
Rotation (degrees) = (0.003) RMS Error (input, output) = (12.175, 12.174)

Tic-ID	input x output x	input y output y	x error	y error
416	540243.600	5339382.850		
	540246.812	5339376.000	-3.000	2.063
417	534051.529	5339353.645		
	534050.125	5339335.000	1.703	12.570
418	527859.767	5339324.441		
	527861.375	5339302.000	-1.223	15.078
419	521670.778	5339295.250		
	521672.594	5339275.000	-1.345	11.600
420	515479.440	5339266.049		
	515475.906	5339255.000	4.091	1.110
421	509284.439	5339233.013		
	509287.094	5339241.000	-2.012	-19.214

Region 5

Scale (X,Y) = (1002.545, 1001.556) Translation = (6386.976, -7976.827)
Rotation (degrees) = (0.083) RMS Error (input, output) = (0.053, 53.224)

Tic-ID	Input x output x	Input y output y	x error	y error
501	534.081	5334.714		
	534077.688	5334711.000	14.929	-8.104
502	527.883	5334.689		
	527883.875	5334678.000	-4.967	3.364
503	521.688	5334.663		
	521690.188	5334651.000	-21.999	8.843
504	515.490	5334.638		
	515488.406	5334631.000	-33.214	7.314
505	509.295	5334.613		
	509294.688	5334617.000	-50.862	-0.210
506	503.098	5334.587		
	503100.906	5334611.000	-69.443	-15.737
507	497.147	5334.563		
	496899.094	5334611.000	165.741	-36.412
508	534.136	5325.456		
	534132.875	5325442.000	28.987	-11.557
509	527.928	5325.437		
	527929.125	5325408.000	8.837	7.688
510	521.723	5325.419		
	521725.312	5325381.000	-8.245	19.941
511	515.516	5325.400		
	515513.500	5325361.000	-19.595	25.188
512	509.310	5325.382		
	509309.688	5325348.000	-37.296	23.439
513	503.103	5325.363		
	503105.906	5325341.000	-56.015	15.688
514	497.046	5325.345		
	496894.094	5325341.000	83.183	1.292
515	534.192	5316.193		
	534188.000	5316183.000	43.143	-29.860

Scale (X,Y) = (1002.545, 1001.556) Translation = (6386.976, -7976.827)
Rotation (degrees) = (0.083) RMS Error (input, output) = (0.053, 53.224)

Tic-ID	input x output x	input y output y	x error	y error
516	527.974	5316.175		
	527974.188	5316150.000	22.899	-11.189
517	521.758	5316.157		
	521760.312	5316123.000	5.726	1.489
518	515.541	5316.139		
	515538.594	5316103.000	-5.877	7.162
519	509.325	5316.120		
	509324.688	5316089.000	-23.637	6.838
520	503.108	5316.102		
	503110.906	5316082.000	-42.514	-0.487
521	496.945	5316.084		
	496889.094	5316082.000	0.219	-14.690

Region 6

Scale (X,Y) = (1003.621, 1000.530) Translation = (4007.221, -3149.250)
Rotation (degrees) = (0.065) RMS Error (input, output) = (0.043, 43.030)

Tic-ID	input x output x	input y output y	x error	y error
601	561.857 561861.125	5344.185 5344204.000	-1.699	3.051
602	555.681 555677.375	5344.135 5344140.000	-16.611	13.563
603	549.490 549493.688	5344.086 5344083.000	-45.960	16.950
604	543.308 543302.125	5344.036 5344033.000	-58.993	13.411
605	537.328 537118.312	5343.988 5343989.000	123.201	5.622
606	561.958 561961.375	5334.895 5334945.000	10.039	-33.095
607	555.770 555767.812	5334.852 5334882.000	-7.287	-17.139
608	549.570 549574.000	5334.808 5334825.000	-35.568	-7.268
609	543.376 543372.312	5334.765 5334774.000	-49.794	-3.350
610	537.337 537178.625	5334.723 5334731.000	83.075	-6.257
611	562.059 562061.875	5325.653 5325676.000	20.949	-11.303
612	555.858 555858.125	5325.603 5325612.000	1.787	-0.953
613	549.650 549654.312	5325.553 5325555.000	-25.390	2.327
614	543.445 543442.625	5325.503 5325505.000	-40.794	-1.359
615	537.347 537238.812	5325.454 5325461.000	43.082	-10.122
616	562.159 562162.000	5316.419 5316418.000	32.127	8.386
617	555.947 555948.312	5316.365 5316354.000	10.867	14.311
618	549.729 549734.375	5316.310 5316297.000	-15.090	13.190

Scale (X,Y) = (1003.621, 1000.530) Translation = (4007.221, -3149.250)
Rotation (degrees) = (0.065) RMS Error (input, output) = (0.043, 43.030)

Tic-ID	input x output x	input y output y	x error	y error
619	543.513	5316.256		
	543512.688	5316246.000	-31.677	6.084
620	537.357	5316.202		
	537298.875	5316203.000	3.176	-8.469
621	562.260	5307.157		
	562262.000	5307159.000	43.778	0.175
622	556.035	5307.104		
	556038.312	5307095.000	20.385	7.231
623	549.809	5307.050		
	549814.375	5307038.000	-4.555	7.270
624	543.582	5306.997		
	543582.688	5306988.000	-22.393	0.303
625	537.366	5306.944		
	537358.875	5306944.000	-36.653	-12.559

Region 7

Scale (X,Y) = (999.971, 1000.050) Translation = (512836.826, 5280839.638)
Rotation (degrees) = (0.000) RMS Error (input, output) = (0.014, 13.647)

Tic-ID	input x output x	input y output y	x error	y error
701	5.857	21.382		
	518694.500	5302219.000	-0.571	3.096
702	-0.373	21.372		
	512465.594	5302202.000	-2.042	10.582
703	-6.605	21.362		
	506228.812	5302192.000	3.138	11.066
704	-12.836	21.351		
	500000.000	5302189.000	0.897	4.552
705	-19.068	21.341		
	493771.188	5302192.000	-1.348	-7.963
706	5.887	12.119		
	518724.406	5292960.000	-0.435	-1.294
707	-0.353	12.102		
	512485.594	5292944.000	-2.021	-1.355
708	-6.595	12.086		
	506238.812	5292934.000	3.096	-7.420
709	-12.836	12.069		
	500000.000	5292930.000	0.817	-19.483
710	-19.078	12.052		
	493761.188	5292934.000	-1.480	-39.547
711	5.917	2.845		
	518754.312	5283692.000	-0.263	-7.652
712	-0.333	2.842		
	512505.594	5283675.000	-2.019	6.623
713	-6.585	2.838		
	506248.812	5283665.000	3.022	13.897
714	-12.836	2.835		
	500000.000	5283661.000	0.738	15.172
715	-19.088	2.832		
	493751.188	5283665.000	-1.537	8.446

Scale (X,Y) = (999.971, 1000.050) Translation = (512836.826, 5280839.638)
Rotation (degrees) = (0.000) RMS Error (input, output) = (0.014, 13.647)

Tic-ID	input x output x	input y output y	x error	y error
716	5.947	-6.403		
	518784.188	5274434.000	-0.144	1.573
717	-0.313	-6.410		
	512525.500	5274417.000	-1.942	12.452
718	-6.575	-6.417		
	506258.688	5274407.000	3.081	16.329
719	-12.836	-6.423		
	500000.000	5274403.000	0.659	14.206
720	-19.098	-6.430		
	493741.312	5274407.000	-1.765	4.084
721	5.978	-15.691		
	518814.000	5265176.000	0.168	-29.227
722	-0.293	-15.691		
	512545.406	5265159.000	-1.801	-11.550
723	-6.565	-15.691		
	506268.688	5265149.000	3.037	-0.873
724	-12.836	-15.691		
	500000.000	5265145.000	0.580	3.804
725	-19.108	-15.691		
	493731.312	5265149.000	-1.867	0.481

Region 8

Scale (X,Y) = (999.897, 999.510)D Translation = (535837.952, 5296823.247)
Rotation (degrees) = (0.006)D RMS Error (input, output) = (0.012, 11.846)

Tic-ID	input x output x	input y output y	x error	y error
801	23.316	10.284		
	559154.125	5307126.000	-1.816	-16.562
802	17.088	10.242		
	552922.375	5307066.000	2.437	-0.408
803	10.860	10.200		
	546698.625	5307012.000	-0.713	9.749
804	4.632	10.158		
	540474.812	5306965.000	-3.849	12.906
805	-1.591	10.116		
	534243.000	5306925.000	4.751	9.090
806	-7.821	10.074		
	528019.188	5306891.000	-0.241	-0.766
807	-14.045	10.032		
	521795.406	5306864.000	-0.428	-17.588
808	23.412	1.014		
	559249.125	5297857.000	-1.116	-12.894
809	17.173	0.971		
	553007.312	5297797.000	1.947	2.541
810	10.937	0.929		
	546773.625	5297743.000	0.056	11.998
811	4.699	0.886		
	540539.812	5297696.000	-3.628	14.442
812	-1.536	0.844		
	534298.000	5297656.000	3.760	9.908
813	-7.776	0.801		
	528064.188	5297622.000	-1.060	-0.657
814	-14.009	0.758		
	521830.406	5297595.000	-0.242	-18.181
815	23.509	-8.256		
	559343.875	5288599.000	-0.168	-20.110

Scale (X,Y) = (999.897, 999.510)D Translation = (535837.952, 5296823.247)
Rotation (degrees) = (0.006)D RMS Error (input, output) = (0.012, 11.846)

Tic-ID	input x output x	input y output y	x error	y error
816	17.258	-8.296		
	553092.125	5288539.000	1.557	-2.788
817	11.013	-8.337		
	546848.375	5288485.000	1.032	8.574
818	4.765	-8.378		
	540604.625	5288438.000	-3.275	12.911
819	-1.482	-8.419		
	534352.812	5288398.000	2.895	10.264
820	-7.731	-8.459		
	528109.125	5288364.000	-1.878	1.597
821	-13.973	-8.500		
	521865.312	5288337.000	-0.022	-14.025

Region 9

Scale (X,Y) = (1000.012, 999.041) Translation = (535837.543, 5274828.555)
Rotation (degrees) = (0.007) RMS Error (input, output) = (0.013, 13.448)

Tic-ID	input x output x	input y output y	x error	y error
901	20.423	9.102		
	556262.875	5283934.000	-0.464	-8.228
902	14.176	9.059		
	550014.125	5283877.000	0.645	4.966
903	7.921	9.017		
	543757.375	5283826.000	2.657	12.110
904	1.668	8.974		
	537508.625	5283782.000	-2.073	12.262
905	-4.582	8.931		
	531259.875	5283746.000	-3.176	4.440
906	-10.834	8.889		
	525003.125	5283715.000	1.257	-8.400
907	-17.083	8.846		
	518754.312	5283692.000	1.376	-29.214
908	20.515	-0.170		
	556352.500	5274676.000	-0.046	-13.260
909	14.257	-0.210		
	550093.812	5274619.000	0.376	3.277
910	7.991	-0.249		
	543827.125	5274568.000	1.252	13.765
911	1.730	-0.288		
	537568.375	5274524.000	-1.326	17.283
912	-4.531	-0.327		
	531309.688	5274487.000	-3.323	13.805
913	-10.792	-0.366		
	525042.875	5274457.000	2.182	3.322
914	-17.053	-0.405		
	518784.188	5274434.000	0.440	-14.154
915	20.606	-9.453		
	556441.875	5265418.000	0.728	-29.166

Scale (X,Y) = (1000.012, 999.041) Translation = (535837.543, 5274828.555)
Rotation (degrees) = (0.007) RMS Error (input, output) = (0.013, 13.448)

Tic-ID	input x output x	input y output y	x error	y error
916	14.337 550173.312	-9.489 5265361.000	0.384	-8.951
917	8.060 543896.688	-9.524 5265310.000	0.110	5.217
918	1.791 537628.000	-9.560 5265267.000	-0.389	11.430
919	-4.480 531359.375	-9.595 5265230.000	-3.294	11.629
920	-10.750 525082.688	-9.631 5265199.000	3.086	5.835
921	-17.023 518814.000	-9.666 5265176.000	-0.405	-7.969

Region 10

Scale (X,Y) = (999.923, 999.280) Translation = (504836.908, 5243828.240)
Rotation (degrees) = (0.001) RMS Error (input, output) = (0.012, 12.324)

Tic-ID	input x output x	input y output y	x error	y error
1001	20.289	12.095		
	525122.375	5255931.000	1.879	-18.168
1002	14.005	12.088		
	518843.812	5255907.000	-3.579	-0.387
1003	7.727	12.081		
	512565.312	5255891.000	-2.476	9.400
1004	1.444	12.075		
	506278.594	5255880.000	2.157	14.183
1005	-4.836	12.068		
	500000.000	5255877.000	1.339	10.968
1006	-11.119	12.061		
	493721.406	5255880.000	-3.108	1.750
1007	-17.399	12.055		
	487434.812	5255891.000	3.839	-15.465
1008	20.329	2.837		
	525162.125	5246673.000	2.437	-11.597
1009	14.035	2.828		
	518873.594	5246650.000	-2.883	2.809
1010	7.747	2.819		
	512585.094	5246633.000	-2.064	11.223
1011	1.454	2.810		
	506288.500	5246623.000	2.717	12.632
1012	-4.836	2.800		
	500000.000	5246619.000	1.399	8.043
1013	-11.130	2.791		
	493711.500	5246623.000	-3.556	-4.550
1014	-17.421	2.782		
	487414.906	5246633.000	1.850	-23.141
1015	20.370	-6.436		
	525201.688	5237416.000	3.247	-20.874

Scale (X,Y) = (999.923, 999.280) Translation = (504836.908, 5243828.240)
Rotation (degrees) = (0.001) RMS Error (input, output) = (0.012, 12.324)

Tic-ID	input x output x	input y output y	x error	y error
1016	14.065	-6.442		
	518903.312	5237392.000	-2.093	-2.284
1017	7.767	-6.448		
	512604.906	5237375.000	-1.675	9.310
1018	1.465	-6.454		
	506298.406	5237365.000	3.275	13.901
1019	-4.836	-6.460		
	500000.000	5237362.000	1.473	11.493
1020	-11.140	-6.466		
	493701.594	5237365.000	-3.988	3.082
1021	-17.443	-6.472		
	487395.094	5237375.000	-0.190	-12.328

Region 11

Scale (X,Y) = (1000.320, 996.613) Translation = (540837.890, 5241875.240)
Rotation (degrees) = (0.029) RMS Error (input, output) = (0.062, 61.771)

Tic-ID	input x output x	input y output y	x error	y error
1101	9.326 550213.125	18.892 5260727.000	-37.059	-2.922
1102	3.100 543931.375	18.849 5260676.000	17.052	-8.376
1103	-3.179 537657.875	18.806 5260632.000	9.383	-21.315
1104	-9.453 531384.312	18.763 5260595.000	6.884	-41.207
1105	-15.734 525102.625	18.720 5260565.000	5.288	-68.166
1106	9.424 550292.500	9.626 5251469.000	-22.558	20.963
1107	3.170 544000.875	9.583 5251418.000	12.971	15.249
1108	-3.119 537717.375	9.540 5251375.000	5.231	1.216
1109	-9.403 531433.812	9.497 5251338.000	2.632	-18.770
1110	-15.694 525142.312	9.454 5251307.000	1.734	-44.813
1111	9.523 550371.812	0.359 5242201.000	-7.976	52.933
1112	3.240 544070.312	0.319 5242150.000	8.945	49.948
1113	-3.059 537776.875	0.278 5242107.000	1.055	38.818
1114	-9.353 531483.375	0.238 5242070.000	-1.717	21.732
1115	-15.653 525181.875	0.198 5242039.000	-1.735	-1.399

Scale (X,Y) = (1000.320, 996.613) Translation = (540837.890, 5241875.240)
Rotation (degrees) = (0.029) RMS Error (input, output) = (0.062, 61.771)

Tic-ID	input x output x	input y output y	x error	y error
1116	9.621 550451.000	-8.903 5232943.000	6.672	80.699
1117	3.310 544139.625	-8.942 5232893.000	5.014	78.003
1118	-2.999 537836.312	-8.981 5232849.000	-3.076	69.321
1119	-9.303 531532.875	-9.019 5232812.000	-6.010	53.681
1120	-15.612 525221.500	-9.058 5232782.000	-5.267	31.005
1121	9.723 550530.125	-18.459 5223686.000	24.356	-184.990
1122	3.382 544208.812	-18.426 5223636.000	2.786	-116.816
1123	-2.938 537895.625	-18.394 5223592.000	-6.162	-54.701
1124	-9.253 531582.312	-18.361 5223555.000	-9.828	0.399
1125	-15.571 525261.000	-18.329 5223524.000	-8.615	49.507

Region 12

Scale (X,Y) = (1000.100, 999.424) Translation = (506836.474,5220821.830)
Rotation (degrees) = (0.007) RMS Error (input, output) = (0.012, 12.295)

Tic-ID	input x output x	input y output y	x error	y error
1201	18.403	7.323		
	525241.312	5228148.000	1.247	-17.005
1202	12.097	7.313		
	518933.000	5228124.000	2.802	0.255
1203	5.783	7.303		
	512624.688	5228107.000	-3.317	10.506
1204	-0.527	7.293		
	506308.312	5228097.000	1.793	13.760
1205	-6.838	7.283		
	500000.000	5228094.000	-1.859	10.014
1206	-13.148	7.273		
	493691.688	5228097.000	-3.552	0.270
1207	-19.458	7.263		
	487375.312	5228107.000	2.495	-16.474
1208	18.444	-1.941		
	525280.812	5218891.000	1.652	-18.132
1209	12.126	-1.950		
	518962.594	5218867.000	0.988	-0.689
1210	5.804	-1.960		
	512644.406	5218850.000	-3.197	9.751
1211	-0.517	-1.970		
	506318.188	5218840.000	1.305	13.191
1212	-6.838	-1.980		
	500000.000	5218837.000	-2.918	9.631
1213	-13.157	-1.990		
	493681.812	5218840.000	-4.354	0.073
1214	-19.471	-1.999		
	487355.594	5218850.000	7.305	-16.479
1215	18.485	-11.201		
	525320.188	5209634.000	2.169	-16.076

Scale (X,Y) = (1000.100, 999.424) Translation = (506836.474,5220821.830)
Rotation (degrees) = (0.007) RMS Error (input, output) = (0.012, 12.295)

Tic-ID	input x output x	input y output y	x error	y error
1216	12.155	-11.211		
	518992.188	5209610.000	-0.833	0.869
1217	5.828	-11.221		
	512664.188	5209593.000	-0.704	10.818
1218	-0.505	-11.232		
	506328.000	5209583.000	2.405	13.761
1219	-6.838	-11.242		
	500000.000	5209580.000	-3.979	9.703
1220	-13.169	-11.252		
	493672.000	5209583.000	-7.426	-0.353
1221	-19.489	-11.263		
	487335.812	5209593.000	7.978	-17.396

APPENDIX E

ARC/INFO Hachure Processing Commands

[ARC/INFO commands are capitalized; system
prompts in standard text; user input italicized]

1. Execute RENODE on the data layer. This assigns each node a
    unique identification number.

2. Execute TURNTABLE on the DXF data layer to create a .TRN file
    (like the .AAT). One of the attributes in .TRN file is the
    azimuth of the arcs, which will be used later in selecting
    arcs with specific azimuth directions. In this example the L41
    data layer (Dungeness crab) is used. TURNTABLE is a command
    in the optional NETWORK module of ARC.

3. To be able to relate to the .TRN file call INFO and redefine
    the NODE# item to FNODE# (from node) and TNODE# (to node); so
    that the FNODE# and TNODE# items in the .AAT will match. The
    commands are as follows:

```
ARC:              info
ENTER USER NAME>          arc

ENTER COMMAND>           SEL L41.TRN

ENTER COMMAND>           REDEFINE

ENTER DATAFILE           DEFINITION

ITEM   STARTING          COLUMN> 1

ITEM   NAME>             FNODE#

ITEM   WIDTH>            4

ITEM   OUTPUT WIDTH>     5

ITEM   TYPE>             B


ENTER STARTING COLUMN>   1

ITEM   NAME>             TNODE#

ITEM   WIDTH>            4

ITEM   OUTPUT WIDTH>     5

ITEM   TYPE>             B

ENTER STARTING COLUMN>   <hit return>

ENTER COMMAND>           Q STOP
```

4. Start the ARCEDIT module and set up an environment that uniquely displays the 'from' and 'to' nodes on the arcs. This is accomplished by using the arrows option for the DRAWENVIRONMENT, which will allow you to distinguish the 'from' and 'to' nodes on the display screen. The RELATE command in ARCEDIT is also used to associate the editcoverage to the .TRN file. An example of these ARCEDIT start-up and relate sessions is as follows:

```
ARC:        arcedit
Arcedit:    display 4207 or 9999
Arcedit:    editcoverage L41
Arcedit:    editfeature arc
Arcedit:    drawenvironment arc arrows
Arcedit:    relate add
```

What follows is the ARCEDIT: RELATE environment dialogue:

```
Relation name:      turn
Table Identifier:   L41.TRN
Database:           info
INFO Item:          fnode#
Relate Column:      fnode#
Relate Type:        linear
```

5. Use the "turn" relation just established to select all of the arcs for a given set of hachures. This is accomplished by determining the azimuth of a representative set of hachure arcs and then selecting all arcs with that azimuth value. The commands are:

```
Arcedit:    select many
```

Select with the cursor the desired set of similar hachure arcs.

```
Arcedit:    list turn//azimuth
Record      TURN//AZIMUTH
            224.233
```

In this example all arcs selected have the azimuth: 224.233

6. Select all the arcs with that azimuth. Since azimuth is specified to three decimal places, it is best to select within a range of values. The command is:

   Arcedit: *select turn//azimuth < 225 and turn//azimuth > 224*

7. To view what has been selected use the ARCEDIT command:

   Arcedit: *setdraw 2* (establishes a color, 2 = red)
   Arcedit: *drawselect*

8. In some cases, the direction of the arcs are reversed. Add to this selected set all azimuths in the reverse direction so a complete set of resource hachures can be obtained. In this example, the reverse of 224.233 is 44.233 (224.233 - 180 = 44.233). Therefore, execute the following command:

   Arcedit: *aselect turn//azimuth > 43 and turn//azimuth < 46*

9. Put the selected features into a new data layer, such as "CRAB".

   The command is:

   Arcedit: *put crab*

10. Delete the hachures out of the original data-layer and repeat the procedure for the next resource.