FINAL

GEOSPATIAL METHODOLOGY USED IN THE PSNERP COMPREHENSIVE CHANGE ANALYSIS OF PUGET SOUND

PUGET SOUND NEARSHORE ECOSYSTEM RESTORATION PROJECT

Prepared for

U.S. Army Corps of Engineers, Seattle District

and

Washington State Department of Fish and Wildlife

Prepared In Support of

PUGET SOUND
NEARSHORE
PARTNERSHIP

RESTORING OUR
ECOSYSTEM HEALTH

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Acronyms:

ART – Artificial
BA – Basin (one type of Delta Accounting Unit)
BAB – Barrier Beach
BE – Barrier Estuary
BL – Barrier Lagoon
BLB – Bluff-backed Beach
BTM – Baseline Thematic Mapping
CA – Change Analysis
CLM – Closed Lagoon or Marsh
CZ – Convergence Zone
D – Delta
DAU – Delta Accounting Unit
DEM – Digital Elevation Model
DES – Deschutes River
DLG – Digital Line Graph (*see also:* DRG)
DOS – Dosewallips River
DPU – Delta Process Unit
DRG – Digital Raster Graphic (*see also:* DLG)
DU – Drainage Unit
DUC – Duckabush River
DUN – Dungeness River
DUW – Duwamish River
DZ – Divergence Zone
EFG&S – Ecosystem Functions, Goods and Services
ELW – Elwha River
EM – Estuarine Mixing wetland class (one type of Delta Accounting Unit)
ESRI – Environmental Systems Research Institute
EU – Euryhaline Unvegetated wetland class (one type of Delta Accounting Unit)
FCSA – Feasibility Cost-Sharing Agreement
FGDC – Federal Geographic Data Committee
GDB – Geodatabase (*see also:* MDB)
GI – General Investigation
GIS – Geographic Information System
GLO – General Land Office
GSU – Geographic Scale Unit
H-sheet – U. S. Coast Survey (renamed U. S. Coast & Geodetic Survey in 1878) Hydrographic Sheet
HAM – Hamma Hamma River
HC – Hood Canal Sub-basin
JF – Strait of Juan de Fuca Sub-basin
LO – Local (one type of Delta Accounting Unit)
LULC – Land Use/Land Cover

LtoR – Left to Right
MDB – Geodatabase (*see also:* GDB)
MEA – Millennium Ecosystem Assessment
MRLC – Multi-Resolution Land Characteristics Consortium
NAD – No Appreciable Drift
NAD83 – North American Datum of 1983
NAIP – National Agriculture Imagery Program
NAS – National Academy of Sciences
NAVD88 – North American Vertical Datum of 1988
NC – North Central Puget Sound Sub-basin
NGVD29 – National Geodetic Vertical Datum of 1929 (or Sea Level Datum of 1929)
NKS – Nooksack River
NLCD – National Land Cover Database
NSQ – Nisqually River
NST – Nearshore Science Team
OCI – Open Coastal Inlet
OLE DB – Object Linking and Embedding Database
OT – Oligohaline Transition wetland class (one type of Delta Accounting Unit)
PB – Pocket Beach
PL – Plunging Rocky Shoreline
PSNERP – Puget Sound Nearshore Ecosystem Restoration Program
PU – Process Unit
PUY – Puyallup River
QA – Quality Assurance
QC – Quality Control
QUL – Quilcene Rivers
RDBMS – Relational Database Management System
RP – Rocky Ramp/Platform
RtoL – Right to Left
SAM – Samish River
SAU – Shoreline Accounting Unit
SC – South Central Puget Sound Sub-basin
SDE – Spatial Database Engine
SH – Shoreline
SJ – San Juan Islands and Georgia Strait Sub-basin
SKG – Skagit River
SKO – Skokomish River
SNAR – Strategic Needs Assessment Report
SNAT – Strategic Needs Assessment Team
SNH – Snohomish River
SP – South Puget Sound Sub-basin
SPU – Shoreline Process Unit
SSHIAP – Salmon and Steelhead Habitat Inventory and Assessment Program

STL – Stillaguamish River
SUBBASIN – Sub-basin
T-sheet – U. S. Coast Survey (renamed U. S. Coast & Geodetic Survey in 1878) Topographic Sheet
TF – Tidal Freshwater wetland class (one type of Delta Accounting Unit)
TNC – The Nature Conservancy
USACE – United States Army Corps of Engineers
USDA – United States Department of Agriculture
USGS – United States Geological Survey
UTM – Universal Transverse Mercator
WDFW – Washington Department of Fish and Wildlife
WDNR – Washington Department of Natural Resources
WDOE – Washington Department of Ecology
WH – Whidbey Sub-basin
WRI – World Resources Institute
WRIA – Washington Water Inventory Resource Area
ZU – Nearshore Zone Unit

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Preface by the Puget Sound Nearshore Ecosystem Restoration Project Nearshore Science Team

Introduction

The Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) was initiated in September 2001 by the Seattle District Army Corps of Engineers (Corps) as a General Investigation (GI) Study, based on a feasibility cost-sharing agreement (FCSA) between the Corps and the Washington Department of Fish and Wildlife (WDFW). The purpose of a GI Study is to establish a partnership between the federal government and the local sponsor to investigate water resources problems and opportunities; the product of this investigation is a Feasibility Study. The PSNERP GI is a large-scale, comprehensive initiative to protect and restore the natural processes and functions in the nearshore environments of Puget Sound. This preface provides the background to the following report, *Geospatial Methodology Used in the PSNERP Comprehensive Change Analysis of Puget Sound*, which describes an integrated geodatabase that comprehensively characterizes physical conditions affecting nearshore environments of Puget Sound. This report is expected to be included, as an appendix, in a scientific document written in the future by the PSNERP Nearshore Science Team (NST), which will provide a more complete explanation of the analytical framework and findings of the PSNERP Change Analysis. Because it is produced earlier than the encompassing future document, it will serve as an introduction to the PSNERP Change Analysis and to complement metadata associated with the geodatabase.

Goals and Purposes

PSNERP is guided by two overarching goals: protect and/or restore natural processes that create and maintain Puget Sound nearshore ecosystems; and, protect and/or restore ecosystem functions and structures that support valued ecosystem components. This focus yields results that pertain primarily to physical habitat conditions, and does not address factors such as environmental contaminant impacts on nearshore ecosystems. Although this focus is largely driven by the types of actions that can be implemented under authorities of the Corps, the PSNERP team acknowledges that there are a myriad of stressors on nearshore ecosystems and we are dedicated to planning restoration and protection in coordination with other actions that address those needs.

The purposes of the PSNERP Feasibility Study are to: evaluate significant degradation of nearshore ecosystems in the Puget Sound Basin; formulate, evaluate, and screen potential solutions to these problems; and, recommend a series of actions and projects that have a federal interest and are supported by a local entity willing to provide the necessary items of local cooperation.

Approach and Strategy

Under the guidance of the NST, PSNERP has focused the PSNERP GI goals to:

1. concentrate on shallow-water, nearshore (i.e., marine shoreline, estuarine) ecosystems;
2. emphasize the (dominantly physical) processes that create and sustain natural ecosystems; and
3. include both restoration and protection strategies.

The emphasis on the underlying processes that support nearshore ecosystems provides the essential scientific foundation for protecting and restoring sustainable ecosystems, rather than technological fixes or actions focused on nearshore habitats of specific species. The scientific and technical basis for this approach is documented in PSNERP guidance documents (e.g., Fresh et al. 2004; Goetz et al. 2004; Finlayson 2006; Simenstad et al. 2006); for all project documentation, see: http://www.pugetsoundnearshore.org/technical_reports.htm.

The NST emphasis on nearshore ecosystems processes diverges from other approaches that focus on ecosystem stressors or limited 'target' organisms or functions. The NST has adopted this approach for the preliminary "screening" analyses because:

1. the source of many stressors originates outside nearshore environments and thus cannot be directly addressed by nearshore restoration;
2. the distribution and concentration of many stressors, such as contaminants, are not known comprehensively around Puget Sound, which prevents a Sound-wide analysis;
3. many such stressors have been targeted by federal, state and local programs or have recently been the objective of new initiatives; and
4. an ecosystem-approach will widely address many "target" organisms or functions of concern because protection and restoration of nearshore ecosystem processes will benefit all associated ecosystem functions, goods and services.

As a result, PSNERP is generating synoptic, Sound-wide data on historic change and stressors on nearshore ecosystems that will inform more strategic, rather than opportunistic, restoration strategies.

Scope and Definitions

The PSNERP GI study area includes the entire portion of Puget Sound, and the Strait of Juan de Fuca and southern Strait of Georgia that occur within the borders of the United States; data is also acquired for watershed drainage areas of Puget Sound rivers that extend into Canada (Figure Pref-1). The PSNERP GI Study Area was divided into 7 sub-basins for analysis and reporting.

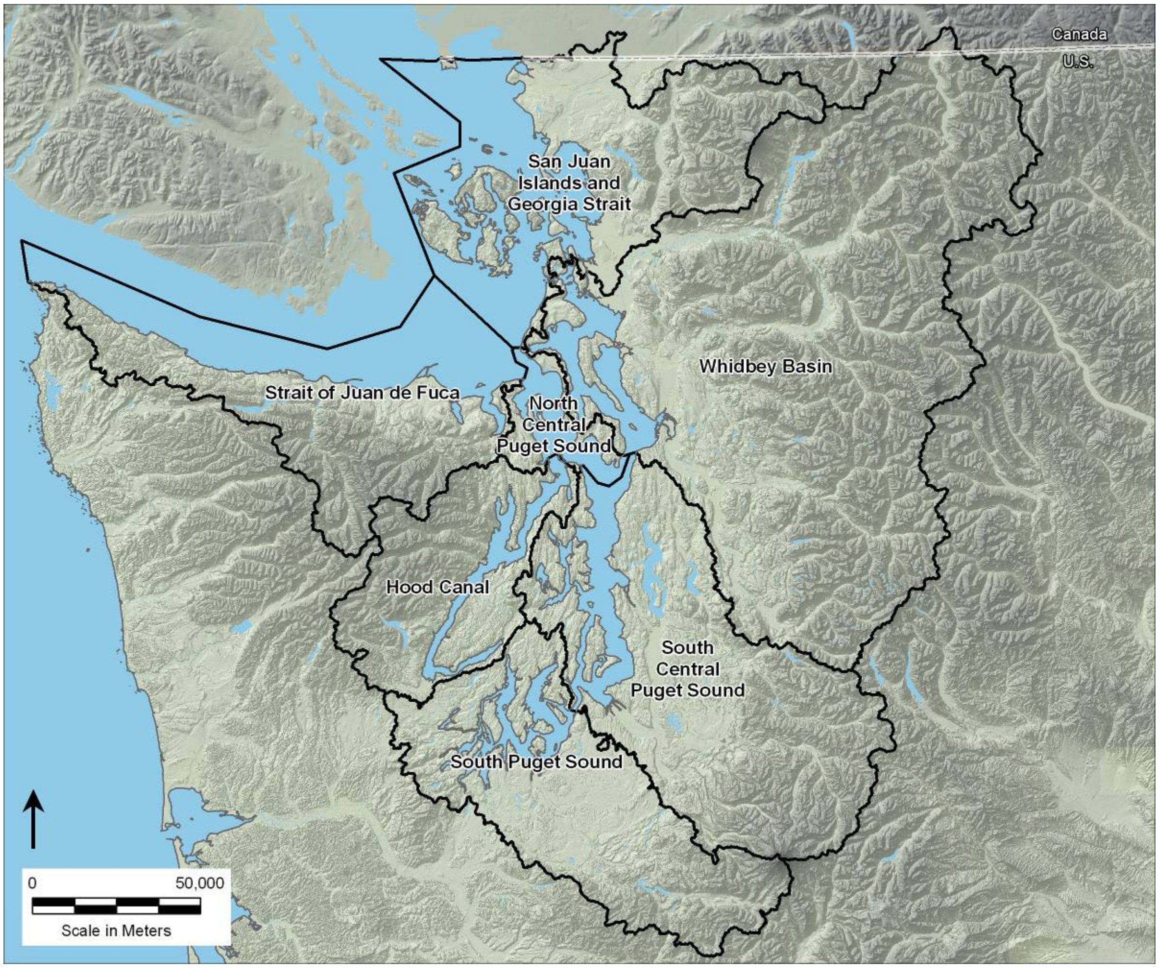


Figure Pref-1
PSNERP GI Study Area with Delineated Sub-Basins

Nearshore Ecosystems and Processes

Within the prescribed region, PSNERP confined its focus of restoration and preservation to nearshore ecosystems, defined to occur within *estuarine delta/ marine shoreline, beaches and areas of shallow water from the top of the coastal bank or bluffs, and tidal waters from the head of tide to depth of ~10 meters (m) relative to Mean Lower Low Water (MLLW)* (Figure Pref-2). By definition, this includes the entire shoreline within the study area as a contiguous band of diverse ecosystems shaped by coastal geomorphology and local environmental conditions, such as wave energy and salinity. The framework for PSNERP's analysis of restoration and preservation needs rests on linking changes in nearshore ecosystem processes to physical (structure) changes of the shore and the resulting impairment of ecosystem functions, goods and services that natural ecosystems provide. Ecosystem processes are *interactions* among physical, chemical and/or biological attributes of an ecosystem that lead to an outcome of change in character of the ecosystem and its components, i.e., changes in ecosystem *state*.

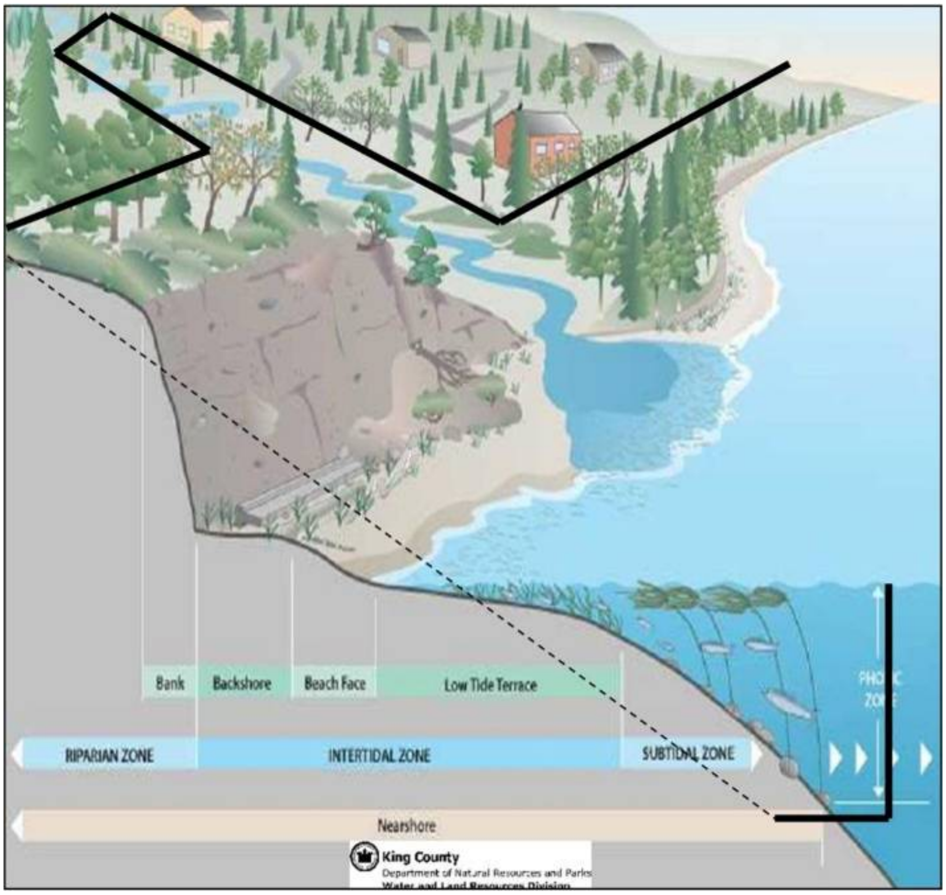


Figure Pref-2
Boundaries of Nearshore Ecosystems between Riparian and Subtidal Zones (PSNERP; after Gelfenbaum et al. 2006)

Ecosystem processes that influence the beaches, estuaries and deltas of Puget Sound occur and vary over diverse spatial and temporal scales, from the large-scale, long-term factors (*regional influences*) that form the backdrop for broad physiographic processes within which occur even more local, fine-scale geochemical and ecological processes. *Regional influences* include factors such as climate, wave exposure, geology, inherited physiography, sea level history, and tidal regime. The *broad physiographic processes* are those we consider landscape-forming processes, which are embedded within regional influences but vary considerably on scales of kilometers or fractions thereof. Examples of this scale of nearshore ecosystem processes include: sediment supply to and transport along beaches; freshwater input; tidal hydrology; distributary and tidal channel formation and migration; and the energy associated with localized wind and waves. Because they are responsible for creation and maintenance of the different complexes of shoreforms and energy regimes that characterize Puget Sound's shorelines, these *broad physiographic processes* tend to be the focus of the PSNERP assessment of nearshore ecosystem impairment, restoration and preservation needs and the strategies for addressing those needs. Accordingly, *local geochemical and ecological processes* that occur within a given landscape structure and vary within the local structure of nearshore ecosystems are shaped by the combined effect of the *regional influences* and *broad physiographic processes*. They vary on the order of meters, *within* the local structure of nearshore ecosystems, and thus are spatially and temporally complex. Examples of *local geochemical and ecological processes* include: geochemical reactions that lead to nutrient cycling; primary production of plants; decomposition of organic detritus; food web interactions; organism behavior and physiology; and diverse ecological interactions among animals in their ecosystems. Local processes result in many of the desirable functions that we attribute to natural nearshore ecosystems in Puget Sound.

By focusing on these hierarchical scales of nearshore ecosystem processes, PSNERP will be most likely to incorporate factors into its restoration/preservation planning that promote ecosystem connectivity, biocomplexity, sustainability and resilience.

Change Analysis

As an essential step in PSNERP's restoration and preservation planning for Puget Sound's nearshore ecosystems, the Change Analysis is a comprehensive, spatially-explicit assessment of the extent of change over Puget Sound's shorelines, estuaries and deltas. The PSNERP NST designed an analytical approach to systematically quantify historic change over the last approximately 125 years, between the earliest land surveys of the General Land Office and U.S. Coast and Geodetic Survey in the 1850s through 1890s and present conditions (2000-2006). This change is documented in a geospatial template that places structural change and the occurrence and amount of stressors on nearshore ecosystems in the context of dominant ecosystem processes. Furthermore, this template provides the mechanism to qualitatively interpret the spatially-explicit significance of these various changes and stressors in terms of the current impairment of ecosystem functions, goods and services (EFG&S) that natural nearshore ecosystems could provide.

Concept Development and Data Acquisition

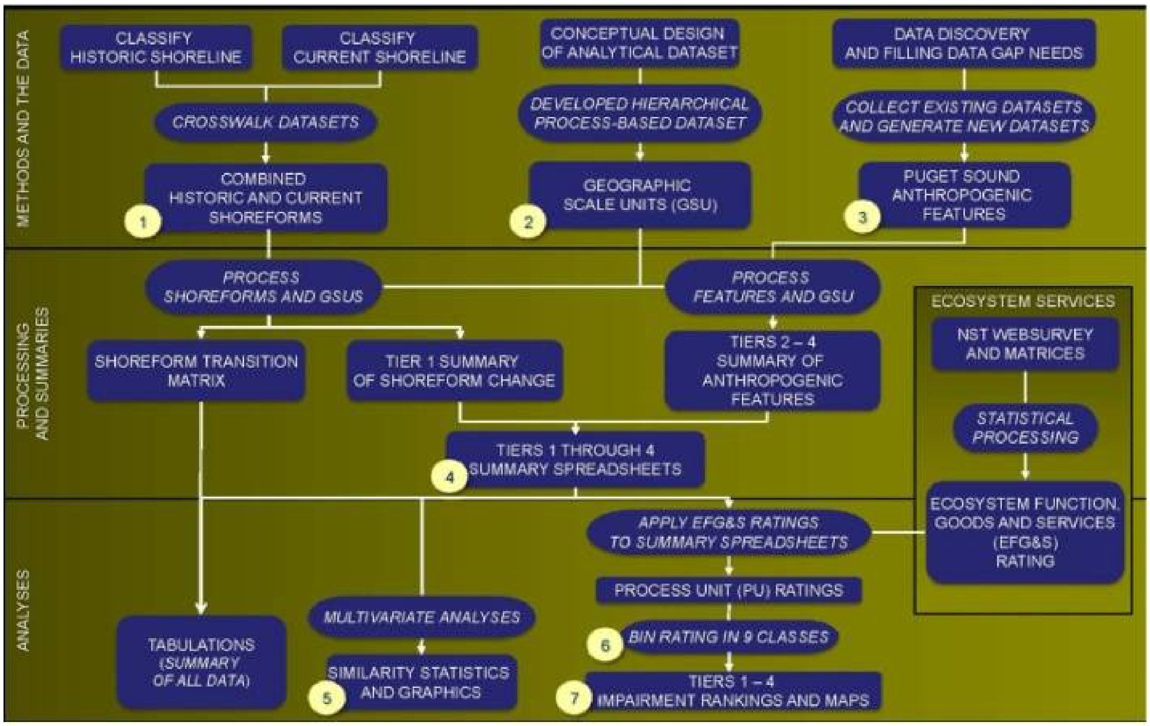


Figure Pref-3
Flowchart of the Analytical Process for PSNERP Change Analysis (numbers refer to specific text references)

The PSNERP conceptual and analytical approach (Figure Pref-3) to Change Analysis was developed by a NST working group that, in addition to NST members, was expertly facilitated by Chris Davis and Jessemine Fung of CommEn Space and benefited as well with advice from Phil Bloch (formerly Washington Department of Natural Resources, now Washington State Department of Transportation), Steve Todd (Point-No-Point Treaty Council), and Aundrea McBride (Skagit River System Cooperative). Initial data development was conducted by the

Puget Sound River History Project at the University of Washington (Collins and Sheikh 2005). Employing these initial data, a pilot project based on initial data for Washington Water Inventory Resource Area (WRIA) 9 was conducted by Fung and Davis (2005). Subsequent support of the Change Analysis has been provided by the Anchor QEA Consultant Team, including the expert assistance of Paul Schlenger (Anchor QEA), Erin Iverson (Anchor QEA), Allison Bailey (Sound GIS), Charles Kiblinger (Anchor QEA), Peggy Myre (Exa Data & Mapping) and Wendy Gerstel (Qwg Applied Geology), who are the sources of this "Methods Report."

PSNERP expended substantial effort to locate data on historic change that met the requisite criteria of being: (1) related directly (documented change) to direct or indirect (stressors) changes in nearshore ecosystem processes; (2) spatially explicit; (3) comprehensive, complete and of uniform resolution and quality Sound-wide; (4) well documented; and, (5) in, or rapidly convertible, to geographic information systems (GIS) format.

Documented change was based on the comparison of shoreform classification and estuarine wetland delineations between the historic T-sheet and H-sheet surveys (1850-1870's) and contemporary (circa 2000-2006) maps (Figure Pref-3 No. 2) and geospatial delineation of anthropomorphic features that are presently in place along Puget Sound's shoreline (Figure Pref-3 No. 3). Extensive data discovery was required on the part of the NST Change Analysis Working Group and support contractors (Anchor Environmental Consultant Team 2008a). Although many datasets that were considered desirable for inclusion in Change Analysis were evaluated, many (e.g., nearshore dredging) had to be rejected because they did not meet the evaluation criteria. In cases where datasets were almost spatially complete and otherwise met the criteria, PSNERP partners (e.g., Salmon and Steelhead Habitat Inventory and Assessment Program [SSHIAP]) or contractors (i.e., Anchor QEA) acquired the necessary data and integrated it into the existing data.

Data Architecture

The NST's analytical template underlying the Change Analysis is based on the spatial arrangement of the dominant ecosystem processes along Puget Sound's beaches, estuaries, and river deltas. In order to meet this need for a spatially-explicit accounting of changes nearshore ecosystem processes Sound-wide, we delineated the Puget Sound shoreline into geomorphic segments (*shoreforms*) based on the PSNERP (Shipman 2008) Geomorphic Classification (Classification; Table Pref-1). The Classification provided us with the basis for independently classifying both historic and current shoreforms (Figure Pref-3 No. 1) that reflect varying sedimentation processes (beaches) and freshwater inflow and tidal mixing (estuaries/deltas) as the dominant controlling factors.

Table Pref-1
Systems, Characteristics and Components of Nearshore Shoreforms in Puget Sound (Shipman 2008)

Systems	Shoreforms	Components
Beaches -- Shorelines consisting of loose sediment and under the influence of wave action	***Bluffs*** -- Formed by landward retreat of the shoreline	Bluff face Backshore Beach face Low tide terrace
	Barriers -- Formed where sediment accumulates seaward of earlier shoreline	Backshore Beach face Low tide terrace
Rocky Coast -- Resistant bedrock with limited upland erosion	**Plunging** -- Rocky shores with no erosion/deposition and no erosional bench or platform	Cliff/slope
	Platform -- Wave-eroded platform/ramp, but no beach	Cliff Ramp/platform
	Pocket Beaches -- Isolated beaches contained by rocky headlands	Cliff Backshore Beachface Low tide terrace
Embayments -- Protected from wave action by small size and sheltered configuration	***Open Coastal Inlets*** -- Small inlets protected from wave action by their small size or shape, but not significantly enclosed by a barrier beach	Stream delta Tide flats Salt marsh Channels
	Barrier estuaries -- Tidal inlet largely isolated by a barrier beach and with a significant input of freshwater from a stream or upland drainage	Stream delta Tide flats Salt marsh Channels Tidal delta
	Barrier lagoons -- Tidal inlet largely isolated by a barrier beach and with no significant input of freshwater	Tide flats Salt marsh Channels Tidal delta
	Closed lagoons and marshes -- Back-barrier wetlands with no surface connection to the Sound	Salt marsh Pond or lake
River Deltas -- Long-term deposition of fluvial sediment at river mouths	***River-dominated deltas*** ***Wave-dominated deltas*** ***Tide-dominated deltas*** ***Fan deltas***	Alluvial floodplain Tidal floodplain Salt marsh Tide flats Subtidal flats Distributary channels Tidal channels

The Puget Sound geomorphic shoreforms became one of the primary units in a geospatial hierarchy of data organized in four geographic scale units (GSUs; Figure Pref-3 No. 2):

1. shoreforms;
2. shoreline drainage units;
3. process units (drift cell or delta hydrogeomorphic components); and
4. various larger ("user defined") scales of shoreline-delta organization, such as large embayments or sub-basins of Puget Sound.

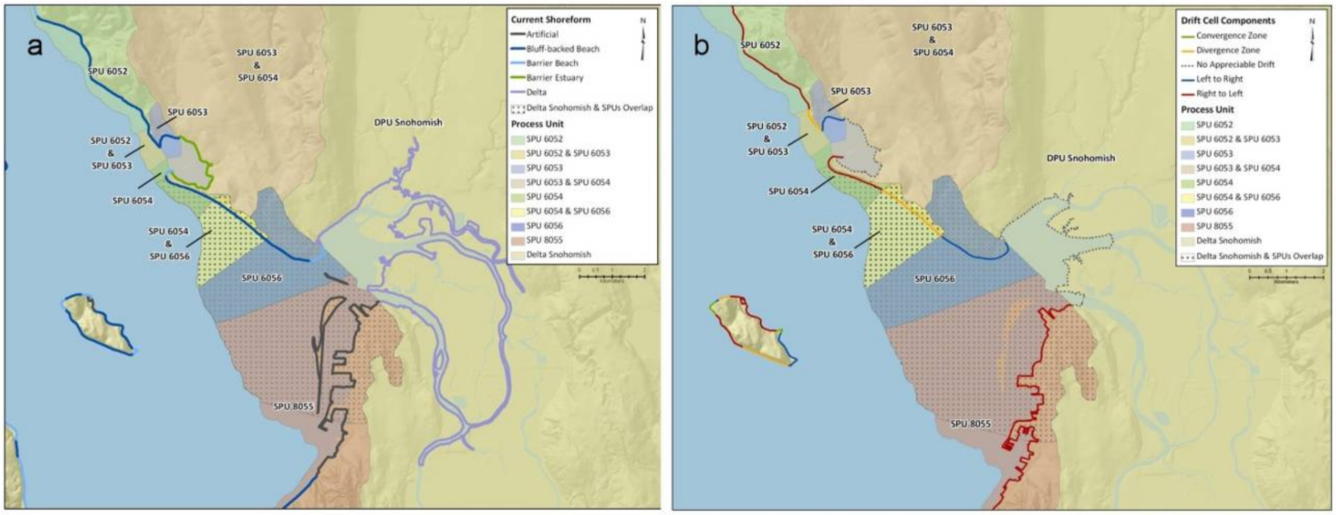


Figure Pref-4
Examples of Hierarchical Organization of PSNERP Geospatial (GSU) Units for Geomorphic Shoreforma (a) and Littoral Drift Cell Components (b) Mapped on Shoreline Process Units (SPUs) and Delta Process Units (DPUs)

Because of the PSNERP emphasis on addressing change in nearshore ecosystem processes, GSUs were organized around the spatial limits of two dominant nearshore ecosystem "process units" (PUs; Figure Pref-4): (1) shoreline process units (SPUs) for beaches associated with littoral drift cells (primary ecosystem process is sediment delivery and transport along the beach); and (2) delta process units (DPUs) in large river deltas and drainages organized by different seawater-freshwater mixing zones (primary ecosystem process is flooding duration and frequency by different salinity ranges). Commensurate with our intent to capture the full spatial and temporal scale of nearshore processes, we specifically decided to incorporate into the geospatial data structure the natural overlap in these process units; where SPUs typically overlap with each other at divergence or convergence zones (see multiple SPU, Figure Pref-4) and SPUs and DPUs often overlap at the outer (Sound-ward) margins of deltas. Although this might result in some confusion where process units and their associated attributes were assumed to be additive Sound-wide, the NST sought to capture the hydrological, physical and ecological process interactions among these physiographic units of the Sound's shoreline.

The boundary of a PU outlines the upland drainage (catchment) area and extends from shore to the 10-m depth contour, and individual shoreform segments are constrained within the process units (Figure Pref-4a). DPUs and SPUs may overlap where nearshore sediment drift is active (speckled area, Figure Pref-4). In general, a PU comprises one or more shoreform types and drainage units that are associated with a single drift cell unit. The drift cell unit is composed of a sediment transport zone and adjacent divergence and convergence zones, or areas of no appreciable drift (Figure Pref-4b). Thus, data on nearshore ecosystem changes could be assessed at various geospatial scales of tabulation and mapping ("units"), but the primary process units that we used for this basic screening effort were the drift cell or delta hydrogeomorphic components of this hierarchy. And, while the geodatabase data can be aggregated at any scale, the NST chose to compile and compare the Change Analysis data by seven sub-basins that somewhat reflect distinct physiographic and oceanographic settings in Puget Sound (see Figure Pref-1).

Describing Change

Historic change is analyzed for each PU in Puget Sound, as well as at the PSNERP sub-basin scale, in four categories, also referred to as "tiers" in the accompanying report (Figure Pref-5):

1. Shoreform Transition: changes in shoreform composition;
2. Shoreline Alterations: changes in historic attributes, such as wetlands, or anthropogenic modifications (considered stressors) along the shoreline;
3. Adjacent Upland Change: anthropogenic changes within 200-m of the adjoining uplands; and
4. Watershed Area Change: anthropogenic changes in the drainage area.

The NST determined that at this stage of the Change Analysis PSNERP should not weight any of these categories of changes or tiers to be more or less important than any other.
Historic change is being tabulated and illustrated in a variety of analytical outputs at the individual PU level and summarized within Puget Sound sub-basins, among sub-basins, and

Sound-wide (Figure Pref-3 No. 4 and No. 5). Categories of change (e.g., groups PUs having similar types and magnitudes of change) are classified using multivariate analyses.

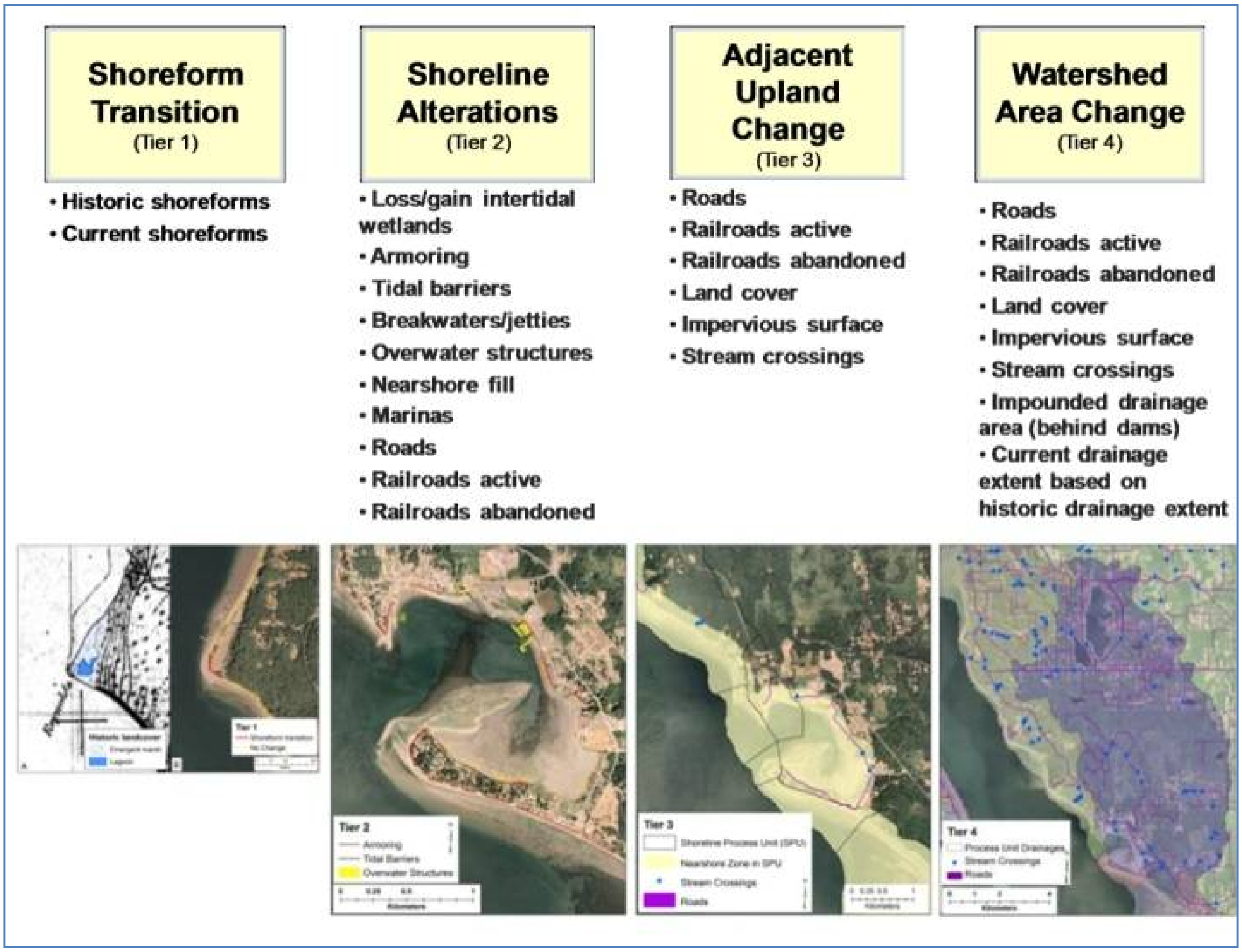


Figure Pref-5
Four Categories (Tiers) and Associated Metrics Used to Describe Nearshore Ecosystem Change by PSNERP

Interpreting Change Scaled over Puget Sound and Sub-Basins

The Change Analysis provides the basis for assessing the effect of altered ecosystem processes on nearshore structure, both as a response and as causal factor. In order to translate structural change to actual changes in nearshore ecosystem processes, the NST used the Conceptual Model (Simenstad et al. 2006) understanding and expert opinion to attribute and rank the relationships of biotic and abiotic nearshore ecosystem processes to shoreforms, attributes (e.g., wetlands associated with shoreforms), and anthropogenic modifications. To further associate changes in nearshore ecosystem structure and process to ecological, social and cultural importance, we generated an NST-based assessment of EFG&S that would be associated with all possible changes at all tier levels (Figure Pref-3 No. 7).

Based on recent applications for restoration and conservation planning (Leslie and McLeod 2007; NAS 2007; Halpern et al. 2008), the NST adopted the Millennium Ecosystem Assessment's EFG&S (MEA 2005; WRI 2005) and other variations (e.g., de Groot et al. 2002) as a template for ranking the level of cumulative impairment of nearshore ecosystem processes among the SPUs and DPUs. Using a Delphi process, the NST ranked EFG&S by changes at each category (tier) of change and generated aggregate maps scaled for each Puget Sound sub-basin (Figure Pref-6) as well as Sound-wide.

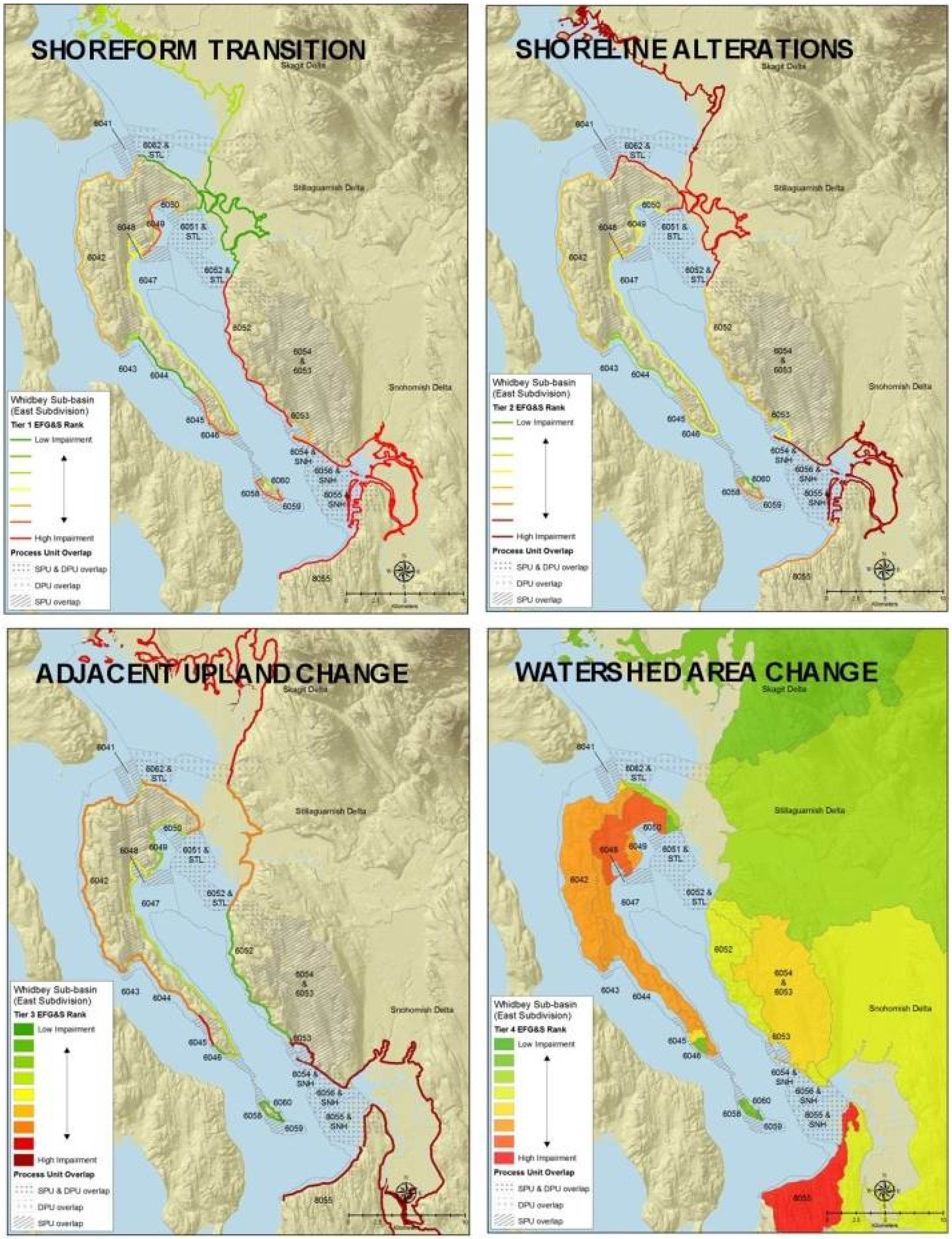


Figure Pref-6
Example of PSNERP Scaling of Four Categories of Nearshore Ecosystem Impairment in Puget Sound

Roles and Responsibility in Execution of PSNERP Workplan

The Change Analysis approach and framework was developed by PSNERP restoration practitioners and scientists. The Anchor QEA Consultant Team accomplished tasks and products as directed by the Puget Sound Nearshore Partnership NST, Change Analysis Working Group and the Corps in consultation with the PSNERP project management team. This direction was facilitated by having a GIS Technical Manager from the NST serve as the primary point of contact for the consultant team on technical issues.

The steps to assemble, create, and otherwise prepare geodatabases to support the PSNERP GI Study were conducted by the Anchor QEA Consultant Team with support and oversight by the GIS Technical Manager and other PSNERP experts. Numeric outputs from the geodatabases were used by PSNERP experts in multivariate analysis to inform the Change Analysis and Strategic Needs Assessment.

Data Availability

The Change Analysis geodatabase, and associated metadata and methodology (that described in the following document) will be available for public download in the near future. Questions about these data and their use should be directed to Mr. Scott Campbell at the U.S. Army Corps of Engineers, Seattle District (scott.w.campbell@usace.army.mil).

1 INTRODUCTION AND PROCESS OVERVIEW

To support the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) General Investigation (GI) Study described in the Preface, the Anchor QEA Consultant Team assembled a geographic information systems (GIS) spatial analysis database of available relevant datasets documenting the type and location of features and stressors in the PSNERP GI Study Area. This report and its appendices describe the datasets contained in the database, as well as the steps taken to create and assemble the database. This "Methods Report" aims to describe the contents and steps in sufficient detail to make the database preparation process coherent and repeatable. To this end, the text of the main report is geared toward restoration practitioners with some familiarity of the GIS capabilities and applications. Appendices are provided to describe additional background on the datasets as well as data preparations steps presented in more technical detail for GIS practitioners.

The activities conducted to create and assemble the database fall in four main steps as shown in Figure 1-1: Data Discovery, Database Structure Development, Data Development and Data Synthesis. In general, these steps were completed sequentially, although some overlap in timing and iterations through the steps occurred as the work progressed.

The four main steps also form the structure of the remainder of the report. Section 2 describes the Data Discovery activities. Section 3 presents the Database Structure Development. Section 4 describes the Data Development and Data Synthesis activities. Each step includes a more detailed flowchart of the activities conducted, as well as an accompanying description in the main text. Quality Assurance and Quality Control (QA/QC) was a fundamental part of each step and is described in Section 5.

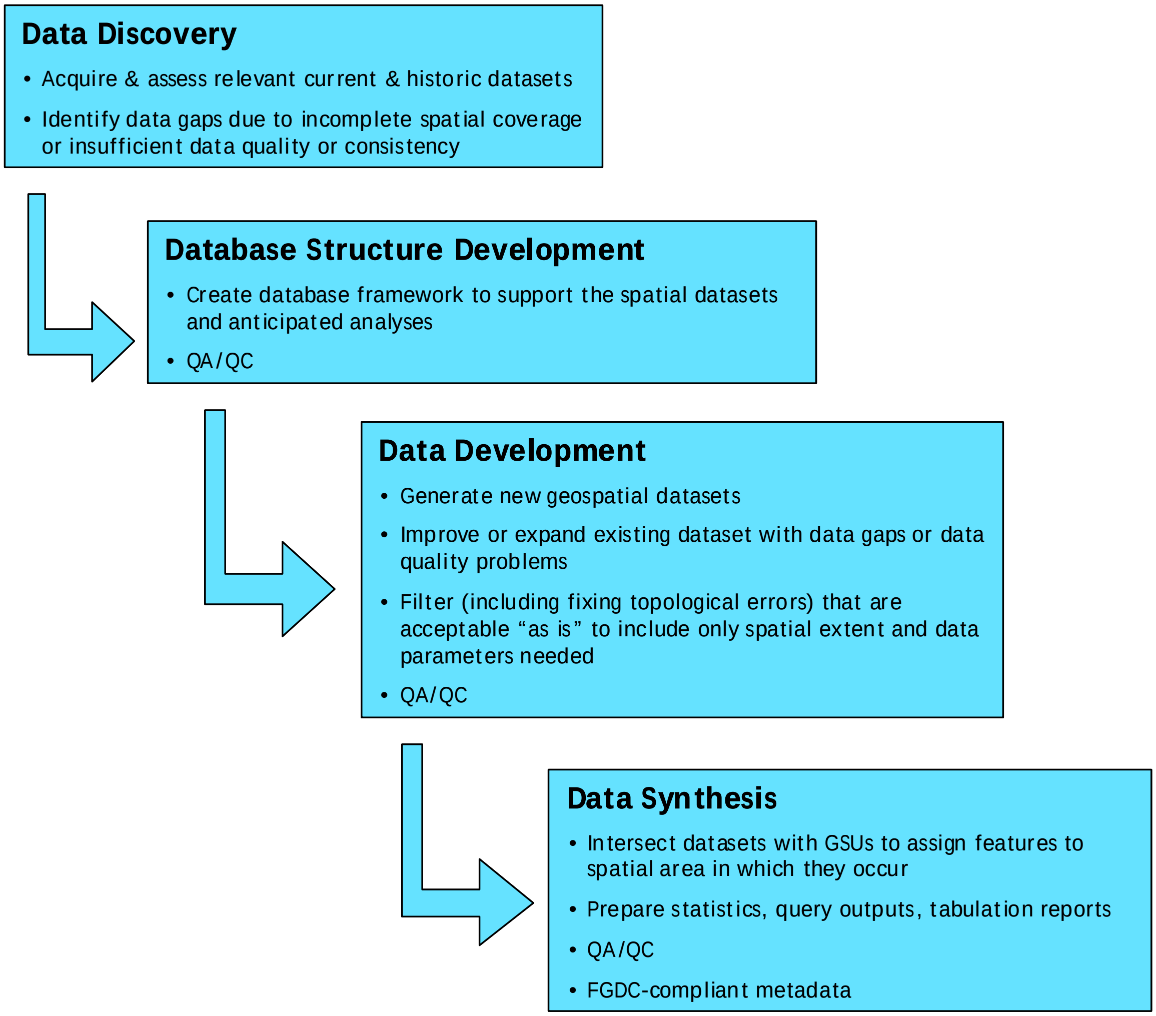


Figure 1-1
Overview of Steps to Prepare Geospatial Databases for Comprehensive Change Analysis of Puget Sound

2 DATA DISCOVERY

The first step in the development of the spatial database for the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) General Investigation (GI) Study was Data Discovery (see Figure 1-1). The Data Discovery step included identifying data sources, acquiring datasets, and assessing their suitability for the PSNERP GI Study (Figure 2-1).

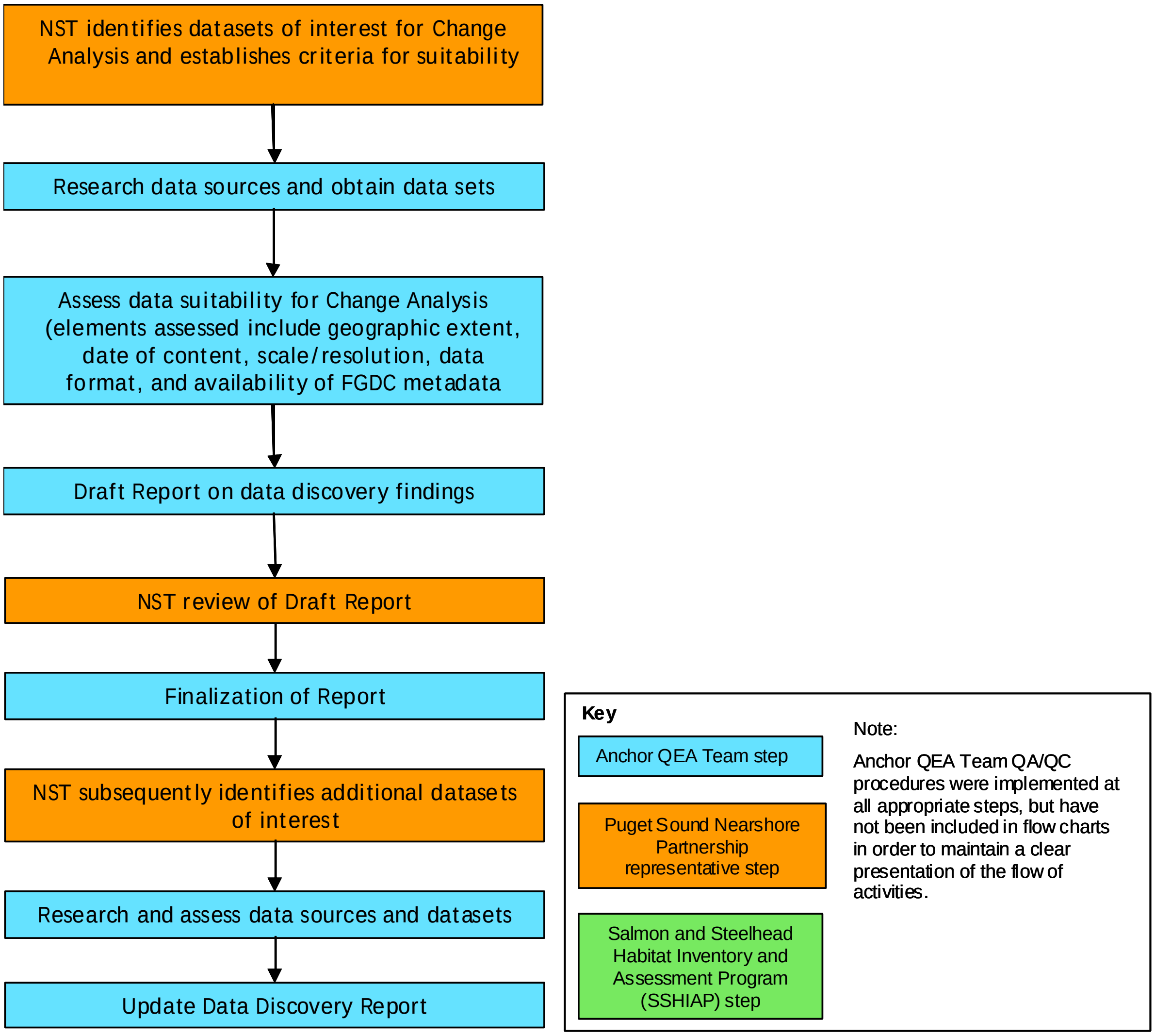


Figure 2-1
Data Discovery

The process of discovering and acquiring datasets for the database began with the identification of relevant datasets for characterizing nearshore features and stressors. This dataset identification step was completed by a subset of the PSNERP Nearshore Science Team (NST) and informed by the PSNERP GI Study goals (as described in the Preface) to concentrate on shallow-water nearshore ecosystems and emphasize the (dominantly physical) processes that create and sustain natural ecosystems. The 25 datasets identified for this data discovery effort included a combination of informative datasets for delineating current and historic shoreline features and stressors directly or indirectly related to changes in nearshore ecosystem processes. The datasets are listed below:

- Shoreline
- Bathymetry
- Digital Elevation Model (DEM)
- LiDAR (terrestrial)
- High resolution aerial imagery
- Oblique aerial imagery
- Hydrographic sheets (H-sheets)
- Puget Sound River History Project data
- Geology
- Slope stability
- Drift cells (net shore-drift)
- Streams
- Overwater structures
- Marinas
- Armoring
- Breakwaters/jetties
- Groins
- Levees/dikes
- Dams
- Nearshore fill
- Roads
- Railroads
- Impervious surfaces
- Land cover
- Parcels

Datasets were acquired by identifying and contacting one or more potential sources. Because the upper watersheds of two of the rivers flowing into Puget Sound extend into Canada, some Canadian datasets were also needed. Canadian datasets were obtained for relevant features in the upper watershed portions in Canada. If available, datasets from multiple sources were obtained to assess which ones best meet the PSNERP GI Study criteria. The criteria for identifying suitable datasets for the database were:

- Spatially explicit data
- Comprehensive, complete and of uniform resolution and quality Sound-wide
- Well documented with Federal Geographic Data Committee (FGDC) compliant metadata or other metadata documentation
- In, or rapidly convertible, to GIS format

The findings of this data compilation and evaluation were presented in a *2007 Data Discovery Summary Report* (Anchor Environmental Consultant Team 2007). This report documented dataset quality relative to the above criteria and provided a recommendation for which data source(s) to use for each dataset.

The *2007 Data Discovery Summary Report* also identified data gaps for several parameters that the NST wanted to include in the spatial analysis database. The datasets with incomplete data or otherwise not meeting NST criteria were drift cells (net shore-drift), armoring, marinas, breakwaters/jetties, levees/dikes, nearshore fill, and groins. For all of these datasets, except groins, activities were conducted to fill data gaps or otherwise correct data. The decision process for filling data gaps is described in the Data Development and Synthesis Section (Section 4).

The NST also requested additional research to identify the availability and quality of datasets for fish passage barriers, aquaculture, and protected lands. No dataset meeting the NST criteria was identified for aquaculture. Acceptable datasets were identified for fish passage barriers and protected lands. These two datasets were used in the Change Analysis.

The *Data Discovery Summary Report* was updated in 2008 to include information on datasets in which gaps were filled as well as the two datasets researched (Anchor Environmental Consultant Team 2008a; provided as Appendix A). Of the datasets investigated in the Data Discovery step, datasets meeting the NST criteria were obtained or developed (see Section 4) for 26 of the 28 datasets, with the exceptions being groins and aquaculture.

3 DATABASE STRUCTURE

The design of the database structure for the Change Analysis data was guided by the geospatial hierarchy, analysis scale(s), and metrics defined by the Nearshore Science Team (NST; as described in the Preface). The steps taken to develop the database structure are shown in Figure 3-1 and described below. The need for process-based analysis units that are not spatially discrete created some complexity in the database design, but this requirement was fundamental to the Change Analysis. The database architecture allows for analysis of datasets at multiple spatial scales within the Geographic Scale Unit (GSU) delineation framework developed by the NST and described in more detail below and in Section 4. This architecture is described in detail in the *Geodatabase Structure Report* (Exa Data & Mapping Services 2009; provided as Appendix B).

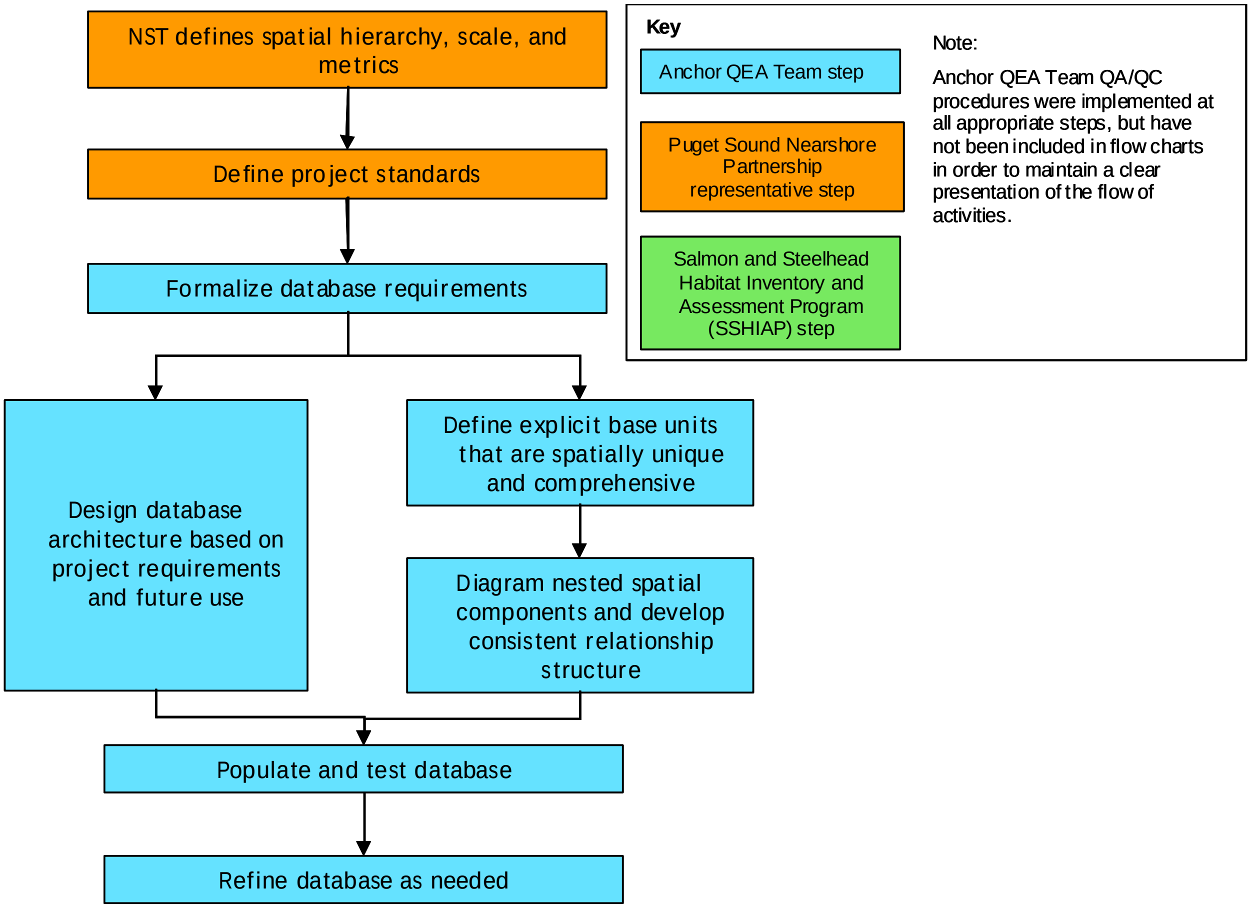


Figure 3-1
Database Structure

The following database requirements were developed in coordination with Puget Sound Nearshore Ecosystem Restoration Project (PSNERP):

- The database must support the goals of the PSNERP GI, and also support the larger user community.
- The database must be modular and expandable as spatial and measurement metrics are developed.
- Data will be summarized over the Process Unit scale of the GSU delineation structure, compatible with the goals of the Strategic Needs Assessment Report (SNAR).
- Queries used for data processing and summarizing must be documented and developed using consistent nomenclature.
- All data used for the analysis must be available and generally consistently applied across Puget Sound.
- Every database must have metadata.

The following technical standards were specified by the U.S. Army Corps of Engineers (Corps) and PSNERP:

- The projection will be Universal Transverse Mercator (UTM) North American Datum of 1983 (NAD83), Zone 10, meter mapping units.
- The vertical datum standard will be National Geodetic Vertical Datum of 1988 (NGVD88).
- Metadata will be compliant with the Federal Geographic Data Committee (FGDC 1998) standard.
- Units of measure will include linear (meters [m]), areal (square meters [m^2]), percent, and count.
- Geographic information systems (GIS) software for spatial analyses will be ESRI™ (Environmental Systems Research Institute, Inc.) ArcGIS 9.x integrated with a personal geodatabase (Microsoft™ Access), both of which are commercial-off-the-shelf software programs.

3.1 Spatial Hierarchy, Scale, and Metrics

As described in the Preface, PSNERP defined four tiers of change to analyze:

- Tier 1: Shoreform transition – changes in shoreform composition

- Tier 2: Shoreline Alterations – changes in historic attributes, such as wetlands, or anthropogenic modifications (considered stressors) along the shoreline
- Tier 3: Adjacent Upland Change – anthropogenic changes within 200 m of the adjoining uplands
- Tier 4: Watershed Area Change – anthropogenic changes in the drainage area

Queries were developed to generate summary metrics to quantify modifications within each of the four tiers at multiple scales. At the smallest spatial scale, these metrics were summarized by Process Unit for both the shoreline and delta environments. Change Analysis metrics were also calculated for each of the seven sub-basins, and for Puget Sound as a whole.

Data for each of the seven sub-basins is stored a separate geodatabase (Figure 3-2). Sound-wide metrics are calculated using a single geodatabase compiled from the seven sub-basins. This single database has a slightly modified structure that allows sound-wide data to fit within the file size limits of personal geodatabases. Below the level of sub-basin, the database supports summarization of data over the explicitly-defined nested GSUs, as well as over user-defined spatial units (e.g., bays, islands, etc.) that are not yet defined.

For Tier 1, the primary output is the shoreform transition matrix which quantifies the number shoreline segments that have changed from historic to current times. For Tier 2, the calculated metrics are primarily lengths of the stressor (e.g., roads, armoring) normalized by the length of the current shoreline. Some of the Tier 2 metrics are areas of the stressor (e.g., overwater structures) normalized by the aquatic area. Tier 3 metrics are primarily areas of the stressor (e.g., impervious surface, road polygons) within and normalized by the upland areas adjacent to the shoreline. Tier 4 metrics are similar to Tier 3 metrics, but are looking at impacts in the entire upland watershed, and therefore calculate areas of the stressor within the entire upland drainage basin and normalize with the upland area of the Process Unit.

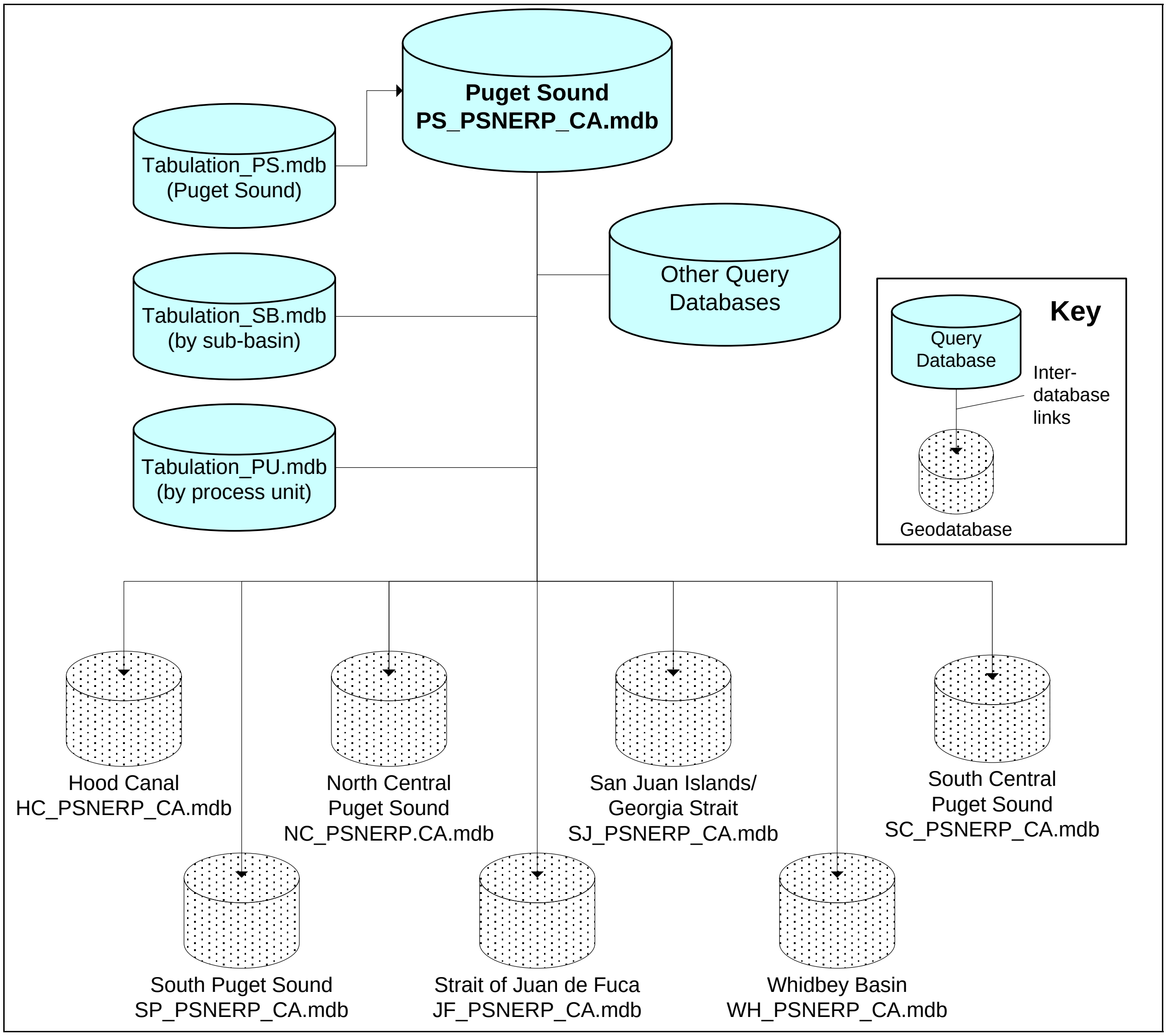


Figure 3-2
PSNERP GI Study Framework for Sub-basin Geodatabases and Related Query Databases

3.2 Nested Spatial Components (Geographic Scale Units [GSUs])

The nested spatial summary units developed for the Change Analysis are called Geographic Scale Units (GSUs). The spatial hierarchy and relationships (one-to-one or one-to-many) of the GSUs are shown in Figure 3-3. Below the sub-basin scale, due to the differences in geomorphic processes, the GSUs are divided into shoreline and delta types. Figure 3-3 shows the how the spatial units nest according to size. With the exception of specific overlapping unit types, the largest GSUs are at the top and the smallest GSUs are at the bottom of the figure.

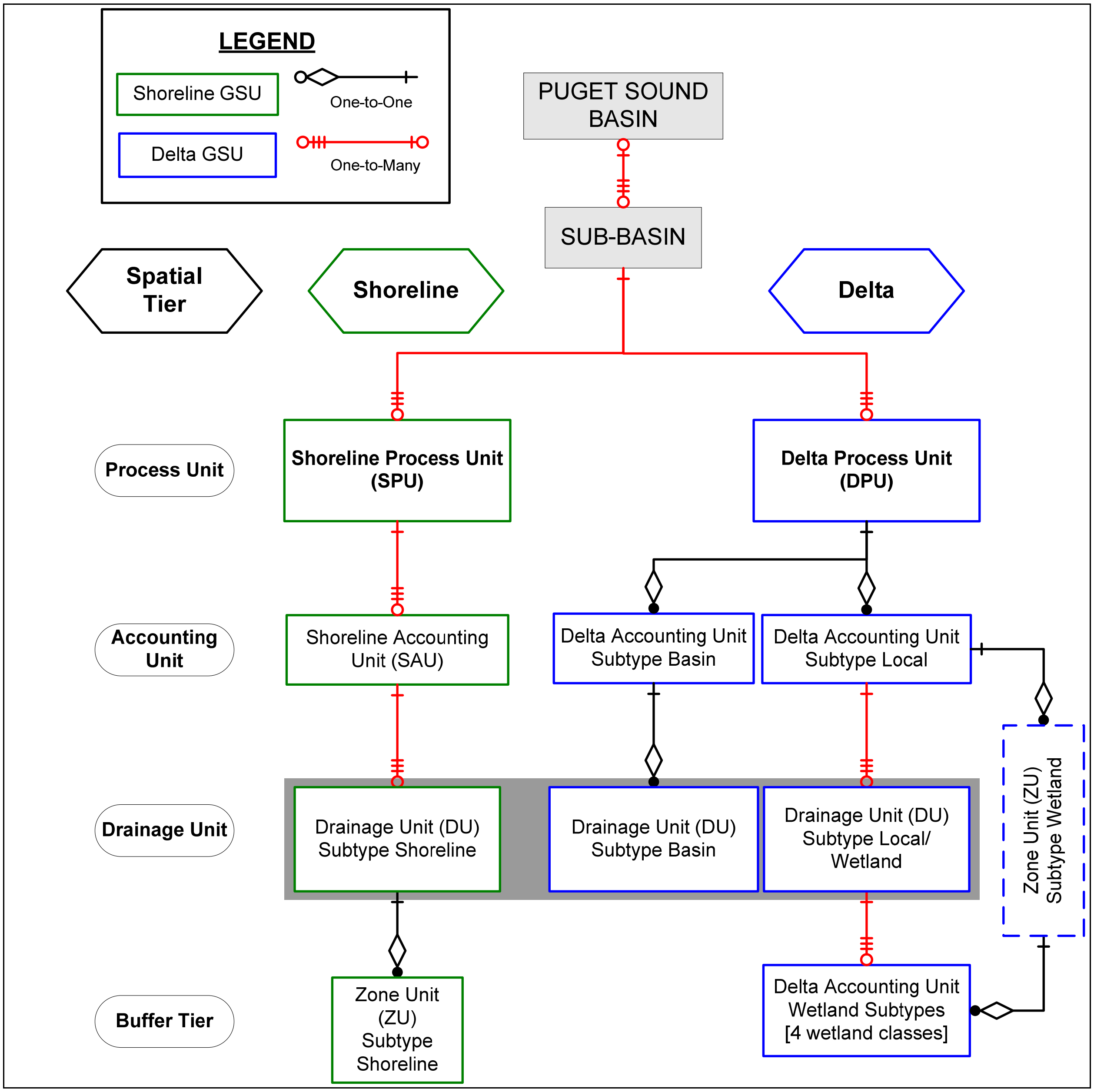


Figure 3-3
Spatial Hierarchy of Nested GSUs for the Shoreline and Delta Environments

3.2.1 Shoreline GSUs

The Drainage Unit (DU) defines the natural watersheds, or drainage areas constrained by topography and drift cells. The drift cell dataset (Johannessen and MacLennan 2008 update of Ecology) and a Digital Elevation Model (DEM) are used as the primary inputs for creation of the shoreline-related GSUs. The components that make up the drift cell include:

- Left to right (LtoR) net shore-drift (facing shoreline from an offshore position)
- Right to left (RtoL) net shore-drift (facing shoreline from an offshore position)
- Convergence zone (CZ)
- Divergence zone (DZ)
- No appreciable drift (NAD)

The Shoreline Accounting Unit (SAU) is aggregated over all DUs that relate to a single drift cell component, and may encompass one or more complete DUs. The Shoreline Process Unit (SPU) is then aggregated over the SAUs that represent a single drift cell, and may contain one or more SAUs. In areas of drift divergence or convergence, and in some cases no appreciable drift, there will be two SPUs that share the same drift cell component, and therefore share the attributes of an SAU.

The Zone Unit (ZU) delineates sub-areas within the other GSUs based on their adjacency to the shoreline. There are three Zone Units defined for both delta and shoreline GSUs:

- Waterward areas, extending to the 10-meter depth contour or the adjacent GSU (ZU = 2)
- Landward areas, within 200-meters of the shoreline (ZU = 1)
- Non-adjacent regions within the drainage (ZU = 0)

Queries involving the ZU are used for Tier 2 (when normalizing by aquatic area) and Tier 3 (when normalizing by shoreline-adjacent areas, both waterward and landward) analyses.

In summary, the shoreline GSUs are:

- SPU: Shoreline Process Unit
- SAU: Shoreline Accounting Unit
- DU: Drainage Unit (Subtype: Shoreline)
- ZU: Zone Unit (Subtype: Shoreline)

3.2.2 Delta GSUs

The delta consists of three overall areas that are structurally constrained in the database:

- Wetland: The area in the estuary section of the delta encompassing four possible wetland classes.
- Local: The local drainage surrounding and influencing the wetlands.
- Basin: The large area upland of the delta that encompasses all of the drainage that flows into the delta.

The delta areas are classified as subtypes in the database, and are defined in the Delta Accounting Unit (DAU). The DAU represents the different types and scales of environments in the delta, and will allow querying at different scales of drainage into the delta. There are six subtypes of DAU in the delta environment:

- Basin: A single Basin-type DAU represents one upland basin DU
- Local: A single Local-type DAU represents multiple drainage units that surround the wetlands area
- Wetland-EU: The wetland class, Euryhaline Unvegetated (EU)
- Wetland-EM: The wetland class, Estuarine Mixing (EM)
- Wetland-OT: The wetland class, Oligohaline Transition (OT)
- Wetland-TF: The wetland class, Tidal Freshwater (TF)

The Delta Process Unit (DPU) is aggregated over the six types of DAUs. In the rare occurrence where two deltas overlap, the attributes are shared between two DPUs.

The ZU in the delta extends landward beyond the boundaries of the wetlands, and is defined by a buffer from the wetland boundary that extends beyond the shoreline. These intertwining environments result in a complex hierarchal structure for the delta GSUs.

In summary, the Delta GSUs are:

- DPU: Delta Process Unit
- DAU: Delta Accounting Unit (Subtypes: Basin, Local, and four Wetland types [EU, EM, OT, and TF])
- DU: Drainage Unit (Subtypes: Basin, Local, Wetland)
- ZU: Zone Unit (Subtype: Delta)

3.2.3 Shoreline and Delta Overlap

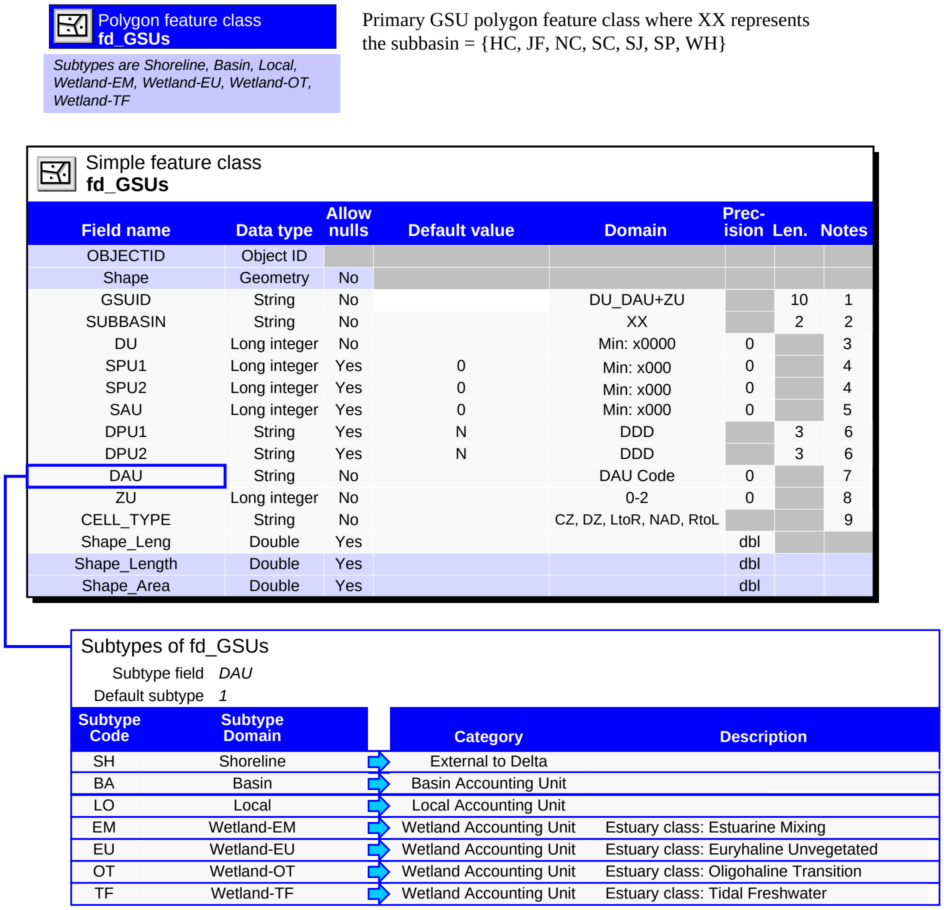
In addition to the overlap of GSUs in the shoreline environment, the delta and shoreline GSUs may overlap. Spatially, the Delta Process Units are delineated by shoreline areas of No Appreciable Drift (NAD) that are associated with the river mouth, as well as any adjacent areas of expansive, historic intertidal area. However, these additional intertidal regions are also adjacent to shorelines with active net shore-drift, and therefore, are also part of a SPU.

3.2.4 GSU Table Structure

Each sub-basin has the same database structure so that all of the sub-basin geodatabases can be combined and served as a single database, queryable by sub-basin. The workhorse table of each geodatabase is the table of Geographical Scale Units (GSUs; Figure 3-4). A single table defines all of the GSU polygons in order to constrain the relationships between and among each GSU type. Both shoreline and delta GSUs are in the table to enable querying in both environments at the same time. Caution is advised for these queries as certain areas with shared attributes will summarize data in different ways depending on the construction of the query.

The key field for the table is the GSU_ID, which is a concatenation of the DU, DAU, and the ZU. This single key field, as well as all the other GSU attributes, is available within the Change Analysis datasets once they have been intersected with GSU polygons. The DU polygons are comprehensive and exclusive (no overlapping polygons) throughout each sub-basin.

In some cases, there are process units that are partially located in two different sub-basins. Because of this, the sub-basin code in the GSU table was developed to maximize the flexibility of summarizing information over a sub-basin. If the process unit is located completely within one sub-basin, the sub-basin code will consist of a two-digit code representing that sub-basin (HC, JF, NC, SC, SJ, SP, WH; see definitions in Figure 3-2). If the unit is located in two different sub-basins, the primary sub-basin will be the first part of the code, followed by the shared sub-basin. As an example, if a unit is located in Hood Canal sub-basin, and is shared by the Strait of Juan de Fuca sub-basin, the code would be "HC|JF."



Polygon feature class
fd_GSUs

Subtypes are Shoreline, Basin, Local, Wetland-EM, Wetland-EU, Wetland-OT, Wetland-TF

Primary GSU polygon feature class where XX represents the subbasin = {HC, JF, NC, SC, SJ, SP, WH}

Simple feature class
fd_GSUs

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Len.	Notes
OBJECTID	Object ID						
Shape	Geometry	No					
GSUID	String	No		DU_DAU+ZU		10	1
SUBBASIN	String	No		XX		2	2
DU	Long integer	No		Min: x0000	0		3
SPU1	Long integer	Yes	0	Min: x000	0		4
SPU2	Long integer	Yes	0	Min: x000	0		4
SAU	Long integer	Yes	0	Min: x000	0		5
DPU1	String	Yes	N	DDD		3	6
DPU2	String	Yes	N	DDD		3	6
DAU	String	No		DAU Code	0		7
ZU	Long integer	No		0-2	0		8
CELL_TYPE	String	No		CZ, DZ, LtoR, NAD, RtoL			9
Shape_Leng	Double	Yes			dbl		
Shape_Length	Double	Yes			dbl		
Shape_Area	Double	Yes			dbl		

Subtypes of fd_GSUs

Subtype field *DAU*
Default subtype *1*

Subtype Code	Subtype Domain	Category	Description
SH	Shoreline	External to Delta	
BA	Basin	Basin Accounting Unit	
LO	Local	Local Accounting Unit	
EM	Wetland-EM	Wetland Accounting Unit	Estuary class: Estuarine Mixing
EU	Wetland-EU	Wetland Accounting Unit	Estuary class: Euryhaline Unvegetated
OT	Wetland-OT	Wetland Accounting Unit	Estuary class: Oligohaline Transition
TF	Wetland-TF	Wetland Accounting Unit	Estuary class: Tidal Freshwater

Notes

[1] **Primary key** (GSU_ID): Nine digit string created from "DU_" + DAU + ZU where DAU = {SH, BA, LO, EM, EU, OT, TF}
[2] Subbasin code: Two digit code for the subbasin = {HC, JF, NC, SC, SJ, SP, WH}
[3] Drainage Unit: Range of integers where x = different value for each subbasin (e.g., HC = {10000, 10001, 10002...n})
[4] Shoreline Process Unit [1,2]: Range of integers where x = different value for each subbasin (e.g., HC = {1000, 1001, 1002...n})
[5] Shoreline Accounting Unit: Range of integers where x = different value for each subbasin (e.g., HC = {1000, 1001, 1002...n})
[6] Delta Process Unit [1,2]: Three-digit delta code
[7] Delta Accounting Unit: Subtype (Two-digit code)
[8] Buffer Tier Zone Unit: Where 0 = not shoreline zone; 1 = landward zone area; 2 = waterward zone area
[9] Drift cell type: Code for drift cell = {Convergence Zone; Divergence Zone; Left to Right, No Appreciable Drift; Right to Left)

Figure 3-4
Geographical Spatial Unit (GSU) Table Design

3.3 Geodatabase Architecture

The geodatabases are consistent with ESRI™ (Environmental Systems Research Institute, Inc.) ArcGIS 9.x and contained within a personal geodatabase (Microsoft™ Access). The advantage of Microsoft™ Access is that it is accessible to all users of ArcGIS, and has a client interface for writing spatial and non-spatial queries. Because Access has limitations on storage size, a modular framework was created to store and deliver data, allowing relatively simple re-compilation into other formats if necessary. There is a separate geodatabase

(*.mdb) for each of the seven sub-basins because of file size limits on personal geodatabases. Puget Sound Basin (Sound-wide) queries are run on a personal geodatabase containing compiled attribute tables from each of the sub-basin datasets, plus compiled Sound-wide spatial datasets for GSUs, current shoreline, and shoreform change. Each sub-basin geodatabase can be connected to ArcGIS using an Object Linking and Embedding Database (OLE DB) connection, allowing real-time query creation and editing and map updates.

Each sub-basin geodatabase includes the GSU table, spatial datasets, and summary queries developed for the Change Analysis. Additional customized queries and data summary tabulations were developed as separate databases linked to each primary sub-basin geodatabase. Each sub-basin geodatabase contains the organizational unit data required for the queries (GSUs, user-defined units), supporting lookup tables that are used for calculations or normalization, links to the supporting feature datasets (depending on the analysis), and the queries used to generate results.

3.4 Long-Term Database Support

The project architecture has been designed to be modular, so that additional geodatabases, features, or rasters can easily be added. A new spatial dataset can be added by first intersecting the data with the unique GSU identifier for each sub-basin. If a dataset is edited or updated, it can replace the original in the architecture without disrupting the query chain of commands, assuming the same nomenclature and file paths are used.

Note: as of this writing the data is housed in ArcGIS 9.3 “personal geodatabases” (*.mdb). ArcGIS 9.2 users can access these geodatabases if ArcGIS 9.2 Service Packs 5 and/or 6 are installed. These service packs were released on March 26, 2008, and July 21, 2008, respectively, and are available on the ESRI™ website.

The long-term goal for the database is for it to be served by the Corps’ information management system. The project architecture presented above has been developed so that it can be compiled and delivered to the Corps. The database will be compatible with the Corps’ system, which includes ArcGIS, as well as an SDE-Oracle server. The nomenclature of each individual sub-basin geodatabase is consistent so that each geodatabase can be imported and combined into a single enterprise geodatabase, but still retain uniqueness based on the sub-basin identifier. As the geodatabase is implemented, the structure can be exported as an XML document that can be used to develop a parallel structure in Oracle or another enterprise Relational Database Management System (RDBMS).

4 DATA DEVELOPMENT AND SYNTHESIS

This section describes the Data Development and Data Synthesis steps of the Change Analysis datasets for a general reader. The Data Development and Data Synthesis steps are presented in flowchart Figures 4-1 and 4-2, respectively. Additional information about data processing and synthesis for a geographic information systems (GIS) practitioner is provided in Appendix C.

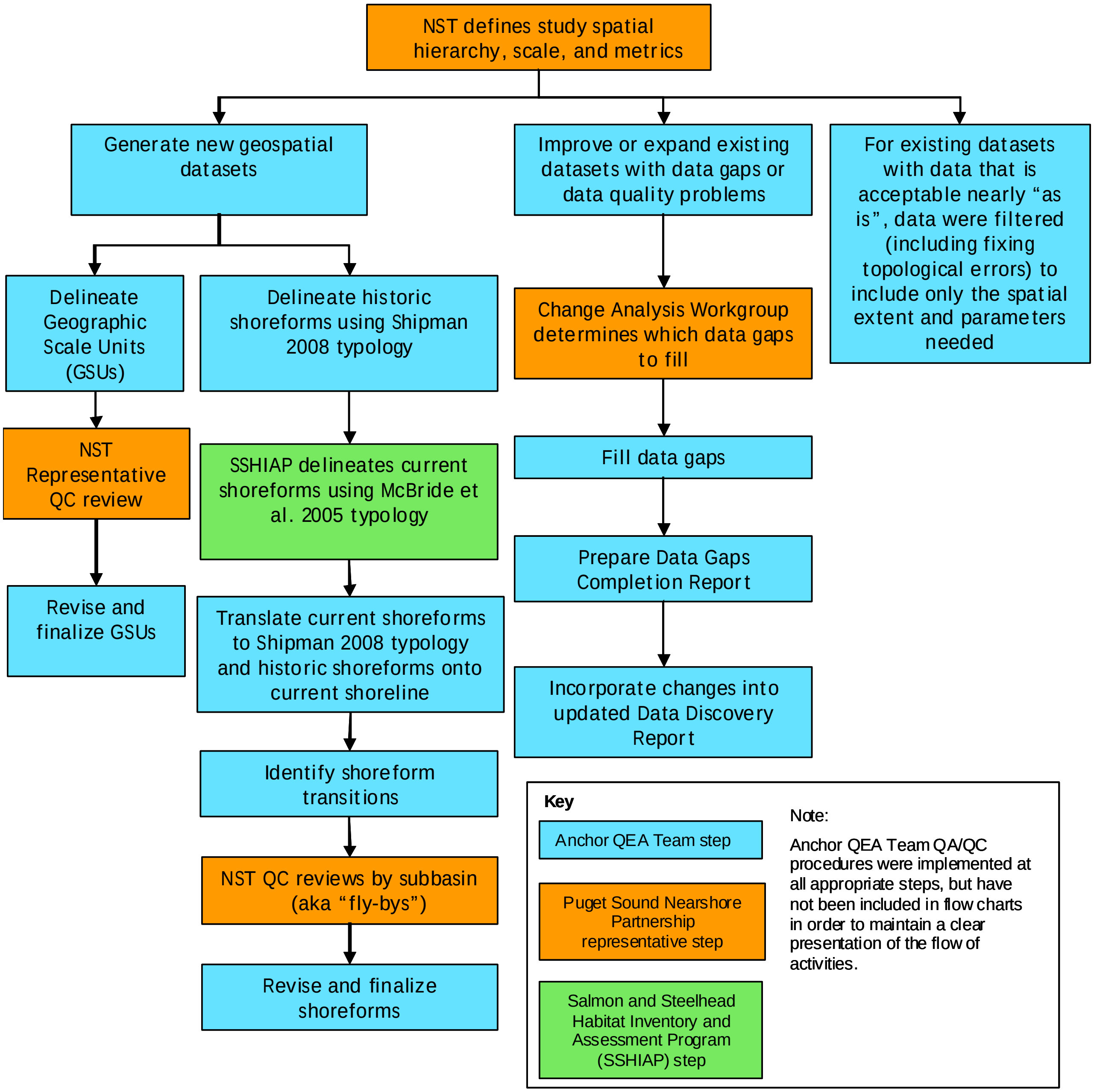


Figure 4-1
Data Development

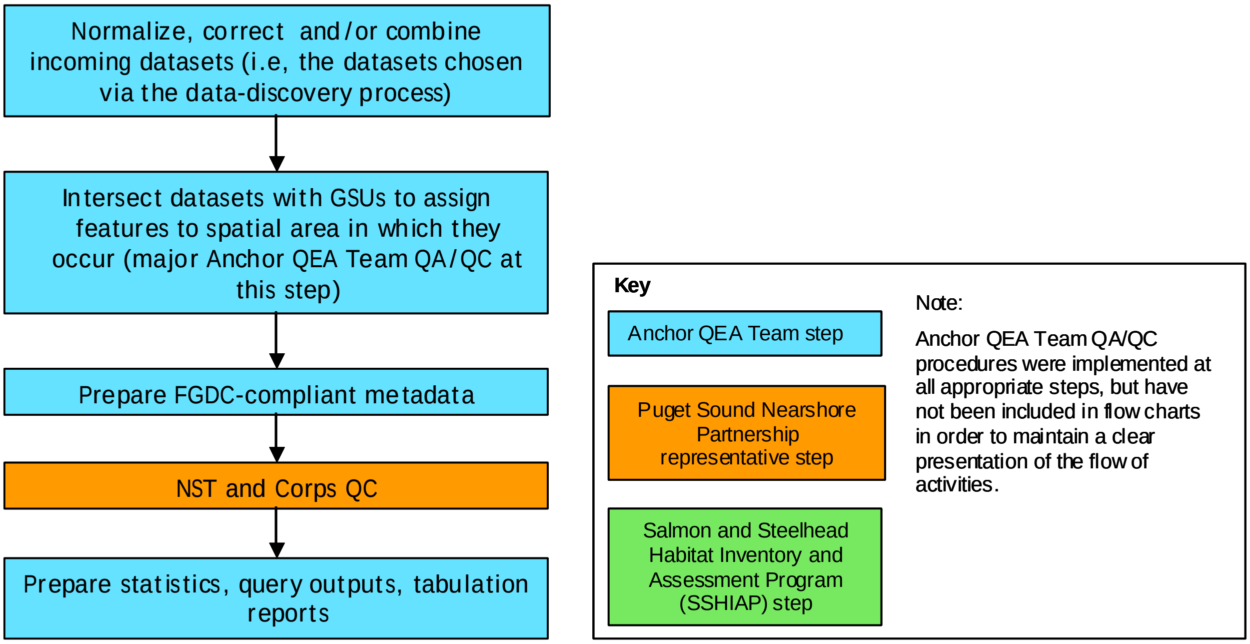


Figure 4-2
Data Synthesis

Several datasets fundamental to the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) General Investigation (GI) Study needed to be developed specifically for this project. These created datasets were:

- the delineation of the contributing watersheds of the Puget Sound planning area into the spatial assessment units, Geographic Scale Units (GSUs)
- the delineation of current and historic shoreforms using *A Geomorphic Classification of Puget Sound Nearshore Landforms* (Shipman 2008)
- the synthesis of current and historic shoreforms into a shoreform change dataset

The GSUs and historic shoreforms were delineated by the Anchor QEA Consultant Team as directed by the Nearshore Science Team (NST). Current shoreforms were delineated by Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) using an independent shoreform typology (McBride et al. 2005, as adapted by SSHIAP [Todd et al. 2009]) and translated into the Shipman (2008) classification system by the Anchor QEA Consultant Team as directed by the NST. Shoreform change was synthesized by the Anchor QEA Consultant Team with significant oversight from the NST. The current and historic shoreforms were considered intermediate data sets, whereas the GSUs and the shoreform change datasets were delivered as final data products. Because these datasets are the foundation of the Change Analysis, and because they were developed specifically for this project, the methods for data development are described in a higher level of detail in Section 4 than the other data sets.

Some datasets were acquired from other data sources, but required significant modifications or updating prior to their use in the Change Analysis. These datasets included:

- drift cells (net shore-drift)
- shoreline armoring
- breakwaters/jetties
- marinas
- nearshore fill
- tidal barriers (surrogate for levees/dikes)

These datasets were identified as having data gaps to fill in the Data Discovery process. The drift cells (net shore-drift) dataset required quality control improvements that were begun immediately by the Anchor QEA Team. The net shore-drift dataset revisions corrected the following four types of errors (Johannessen and MacLennan 2008, provided as Appendix D):

- Areas mapped as "unidentified" (UN), where no previous mapping existed
- Blank areas where there was a complete absence of data
- Drift mapped throughout regions where no net shore-drift occurs, areas of "no appreciable drift" (NAD)
- Other general misinterpretations of the original mapping units

A PSNERP sub-group convened a meeting to determine which of the remaining data gaps to fill and to define possible method options that could be used to fill data gaps. During this meeting, it was decided that methods to fill data gaps should be further explored for: shoreline armoring, breakwaters/jetties and marinas, levees/dikes, and nearshore fill. A *Data Gaps Work Plan* (Anchor Environmental Consultant Team 2008b) was prepared to describe possible methods that could be used to fill each of the data gaps, present the advantages and disadvantages of the identified possible methods, and estimate the level of effort and time period necessary to complete each data gap.

Data gaps for shoreline armoring, breakwaters/jetties and marinas, and intertidal fill were filled by the Anchor QEA Consultant Team. The outputs of this work were GIS feature classes and metadata for each data type. This work is documented in a Data Completion Report (Anchor Environmental Consultant Team 2008c, provided as Appendix E). The levees/dikes data gap was addressed by a delineation of tidal barriers conducted by SSHIAP of the Northwest Indian Fisheries Commission and Point-No-Point Treaty Council (NWIFC/PNPTC).

A number of datasets were not significantly modified from the original source, but were spatially subset, filtered using attributes in a table, grouped or classified by attributes, and/or buffered. The filtering activities also included fixing any topological errors in source data. This was especially needed for the parcels and overwater structures datasets. The datasets in this category were:

- current shoreline
- dams
- fish passage barriers
- impervious surfaces
- land cover
- land ownership
- overwater structures
- parcels
- protected lands
- roads
- stream crossings
- stream mouths
- wetlands, historic
- wetlands, current

After developing, modifying, and assembling the relevant datasets for Change Analysis, the data were compiled and synthesized into the GIS database structure described in Section 3. After all other data creation and preparation steps, all datasets were intersected with the seven sub-basin GSUs in order to:

- subset the data to the spatial extent of each sub-basin,
- facilitate queries developed outside of the GIS environment, and
- allow querying and summarizing of the data according to the analysis tier.

The step of intersecting with the GSUs was performed for all data sets, so this specific processing step is not listed for each individual dataset within Section 4.

Data were also combined into a single, sound-wide dataset. After data development and data synthesis, a sequence of spatial and tabular quality assurance steps were conducted. The overall process to assure data quality is described in Section 5 and detailed Quality Assurance/Quality Control (QA/QC) steps are provided in Appendix C.

With the completion of the data development and synthesis described above, the datasets included in the database include the point, line, and polygon spatial data shown in Table 4-1. Table 4-1 summarizes the data type, description, data sources, as well as the final metrics and tiers of analysis for which the data are used. The order of the datasets in the table and ensuing text is based on the tiers of analysis the datasets are used for. Within each tier, datasets are ordered alphabetically.

A Nearshore Model Certification Plan Criteria Table as required by the Corps Planning Centers of Expertise is provided as Appendix F.

Table 4-1
PSNERP Datasets for Change Analysis

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Geographic Scale Units	4.1	Polygon, Nested spatial units based on net shore-drift, topography/hydrology, and bathymetry	• USGS, 10-meter resolution DEM • Natural Resources Canada DEM, variable resolution (15-m by 23-m pixels in region of interest). • Ecology, Net Shore-Drift in Washington State, Updated by Corps/Coastal Geologic Services • University of Washington, Finlayson bathymetry, 2000 and 2005 • University of Washington, Puget Sound River History Project Geodatabase • WDNR, Hydrography Data • U.S. Department of Agriculture, National Aerial Imagery Program (NAIP) color orthophotos, 2006 • Ecology, Oblique Aerial Photographs, 2005-2006 • WDNR, ShoreZone Inventory	1852 – 2006	All	No metrics related to GSUs only. Used as spatial summary units for all metrics, primarily by Process Unit and Sub-basin

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Historic Shoreform	4.2	Line, Historic shoreline with Shipman shoreform type	• University of Washington, Puget Sound River History Project Geodatabase • Washington Department of Ecology, Net Shore-Drift in Washington State, Updated by U.S. Army Corps of Engineers/Coastal Geologic Services • University of Washington, Finlayson bathymetry, 2000 and 2005 • Washington Department of Natural Resources, Hydrography Data • U.S. Department of Agriculture, National Aerial Imagery Program (NAIP) color orthophotos, 2006 • Washington Department of Ecology, Oblique Aerial Photographs, 2005-2006 • Washington Department of Natural Resources, Hydrography Data • Washington Department of Natural Resources, Geology Data	1852 – 1926	None	An intermediate data set used to create Shoreform Change data; not included in geodatabases
Current Shoreline	4.3	Line, ShoreZone shoreline	• WDNR, Washington State ShoreZone Inventory	1994 – 2000	Used to normalize metrics for Tier 2	• Total shoreline length • Net shore-drift length

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Shoreform Change	4.4	Line, relative to current ShoreZone, including current, historic, and transition	• University of Washington, Puget Sound River History Project Geodatabase and historic T-sheet maps • Historic Shoreform, Corps/Anchor (intermediate dataset not included in geodatabases, see Section 4.2) • Current Shoreform, SSHIAP • WDNR, ShoreZone Inventory	1852 – 2008	1	• Count of shoreforms • Shoreform length • Transition matrices • (Historic shoreform length – current shoreform length) / historic wetland area

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Armoring	4.5	Line, showing extent of shoreline armoring, in relationship to ShoreZone	• WDNR, ShoreZone Inventory • City of Bainbridge Island, Nearshore Structure Inventory (2003) • Point No Point Treaty Council, Shoreline Alterations in Hood Canal and the Eastern Strait of Juan de Fuca (2003) • Island County Washington State University Beach Watchers Volunteer Survey • Kitsap County • King County • Skagit River System Cooperative (2000–2003) • Snohomish County, Marine Resources Committee • South Puget Sound Salmon Enhancement Group and Nisqually Indian Tribe (2008) • Thurston Regional Planning Council • Whatcom County • U.S. Department of Agriculture, NAIP color orthophotos (2006) • Ecology, Oblique Aerial Photographs (2005–2006) • Corps/Anchor Environmental Consultant Team	1994 – 2008	2	• Armoring length / current shoreline length

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Breakwaters/Jetties	4.6	Line	• WDNR, Overwater Structures, modified by Corps/Anchor QEA Consultant Team. • U.S. Department of Agriculture, NAIP color orthophotos, 2006 • Ecology, Oblique Aerial Photographs, 2005–2006	2002 – 2006	2	• Structure length / current shoreline length • Count of breakwaters/jetties
Marinas	4.7	Polygon, represents marina footprint, unique marinas are indicated by a unique identifier	• WDNR, Overwater Structures, modified by Corps/Anchor QEA Consultant Team. • U.S. Department of Agriculture, NAIP color orthophotos, 2006 • Ecology, Oblique Aerial Photographs, 2005–2006	2002 – 2006	2 Tabulations	• Marina (footprint) area / aquatic area • Count of marinas
Nearshore Fill	4.8	Polygon	• Ecology, Coastal Zone Atlas • USGS, Digital Raster Graphics (DRG)	1978 – 1980	2	• Nearshore fill area / aquatic area

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Overwater Structures	4.9	Polygon	• WDNR, Overwater Structures, modified by Corps/Anchor QEA Consultant Team. • U.S. Department of Agriculture, NAIP color orthophotos, 2006 • Ecology, Oblique Aerial Photographs, 2005–2006	2002 – 2006	2 Tabulations	• Overwater structure area / aquatic area • Count of overwater structures
Railroads, Abandoned (Nearshore Only)	4.10	Line, abandoned railroad lines within 25m of current shoreline	• Washington Department of Transportation, Railroads Abandoned in Washington State	1996	2	• Railroad length / current shoreline length
Railroads, Active (Nearshore Only)	4.11	Line, active railroad lines within 25m of current shoreline	• Washington Department of Transportation, Railroads Active in Washington State • Geological Survey Branch, Ministry of Energy and Mines, Province of British Columbia, Digital Geology Map of British Columbia: Tile NM10 Southwest B.C., "NM10_rail_utm,"	1996, 2005	2	• Railroad length / current shoreline length
Roads (Nearshore Only)	4.12	Line, roads within 25m of current shoreline	• WDNR, Transportation Data	2007	2	• Road length / current shoreline length

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Tidal Barriers	4.13	Line representing levees and dikes	• Corps Levees and Dikes data for Puget Sound nearshore • Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP), Tidal Barriers	1997 – 2008	2	• Tidal barrier length / current shoreline length
Wetlands, Historic	4.14	Polygon based on NST wetland class types	• University of Washington: Puget Sound River History Project Geodatabase and historic T-sheet maps • Historic H-sheet maps	1852 – 1926	2	• (Historic wetland area – current wetland area) / historic wetland area, calculated for each wetland class
Wetlands, Current	4.15	Polygon based on NST four wetland class types	• University of Washington: Puget Sound River History Project Geodatabase	1998 – 2004	2	• (Historic wetland area – current wetland area) / historic wetland area, calculated for each wetland class
Impervious Surfaces	4.16	Polygon created from processed raster, categorized by class (percent impervious surface)	• Multi-Resolution Land Characteristics Consortium (MRLC), 2001 National Land Cover Dataset (NLCD)	2001	3, 4	• Area of each impervious class / upland nearshore zone area • Area of each impervious class / upland drainage area

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Land Cover	4.17	Polygon created from processed raster, categorized by class	• Multi-Resolution Land Characteristics (MRLC) Consortium, National Land Cover Data (NLCD) • Province of British Columbia, Ministry of Sustainable Resource Management, Geographic Data BC, Baseline Thematic Mapping, Present Land Use Mapping	1999 – 2001	3, 4	• Total area of each land cover type / upland nearshore zone area • Total area of each land cover type / upland drainage area
Railroads, abandoned (watershed wide)	4.18	Polygons, buffered by standard width	• Washington Department of Transportation, Railroads Abandoned in Washington State	1996	3, 4	• Railroad area / upland nearshore zone area • Railroad area / upland drainage area
Railroads, active (watershed wide)	4.19	Polygons, buffered by standard width	• Washington Department of Transportation, Railroads Active in Washington State • Geological Survey Branch, Ministry of Energy and Mines, Province of British Columbia, Digital Geology Map of British Columbia: Tile NM10 Southwest B.C., "NM10_rail_utm,"	1996, 2005	3, 4	• Railroad area / upland nearshore zone area • Railroad area / upland drainage area
Roads (watershed wide)	4.20	Polygons, buffered by width class	• WDNR, Transportation Data	2007	3, 4	• Road area / upland nearshore zone area • Road area / upland drainage area

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Stream Crossings (polygons)	4.21	Polygon describing stream/road intersections buffered by road width class	• WDNR, Transportation Data • WDNR, Hydrography Data • Canada National Hydro Network (NHN) data from GeoBase • Canada National Roads Network (NRN) data from GeoBase	1994 – 2007	3, 4	• Stream crossing area / zone area • Stream crossing area / upland drainage area
Dams	4.22	Point, includes attributes that describe the area of furthest downstream dam	• Ecology, Dams data from Dams Safety Office • Canada National Hydro Network (NHN) data from GeoBase	2006	4 Tabulations	• Dam impoundment area / upland drainage area • Count of dams
Historic Drainages	4.23	Polygon describing entire delta drainage area	• USGS, 10-meter DEM • Natural Resources Canada DEM, variable resolution (15-m by 23-m pixels in region of interest) • WRIA 9 Habitat Inventory Factors and Reconnaissance Assessment Report (Kerwin and Nelson 2000)	1852 – 2008	4	• Current upland drainage (DPU) area / historic upland drainage area
Drift Cells	4.24	Line, assigned LtoR, RtoL, CZ, DZ, or NAD drift type	• Washington Department of Ecology • Updated by Corps/Coastal Geologic Services	1970 – 2007	None	For reference only; net shore-drift calculated from shoreline, current.

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Fish Passage Barriers	4.25	Point	• Washington Department of Fish and Wildlife, Fish Passage Barrier Inventory	1971 – 2007	Tabulations	• Count of fish passage barriers
Land Ownership	4.26	Polygon, categorized as public, private, and tribal	• The Nature Conservancy (TNC), Conservation Management Status database	2007	Tabulations	• Area of each ownership class / drainage area
Parcel Lines	4.27	Line, waterfront edge of parcel, unique parcels are indicated by a unique identifier	• Puget Sound Action Team (Clallam, Island, Jefferson, King, Kitsap, Mason, Pierce, San Juan, Skagit, and Snohomish counties) • Mason County • Island County	2004 – 2007	Tabulations	• Count of waterfront parcels per 10,000 meters of total parcel waterfront length
Protected lands	4.28	Polygon, categorized as Poor/Fair or Good/Very Good	• The Nature Conservancy (TNC), Conservation Management Status database	2007	Tabulations	• Area of protected lands / nearshore zone area • Area of protected lands / drainage area
Stream Crossings (points)	4.29	Stream/road intersection points (used to generate polygon file)	• WDNR, Transportation Data • WDNR, Hydrography Data • Canada National Hydro Network (NHN) data from GeoBase • Canada National Roads Network (NRN) data from GeoBase	1994 – 2007	Tabulations	• Count of stream crossings

Dataset	Report Section	Description	Data Sources	Date of Content	Tier(s)	Analysis Metric(s)
Stream Mouths	4.30	Point, stream mouths snapped to ShoreZone	• WDNR, Hydrography • WDNR, ShoreZone Inventory	2001 – 2008	Tabulations	• Count of stream mouths • Count of stream mouths per current shoreform

4.1 Geographic Scale Units (GSUs)

4.1.1 Description

As described in Section 3, the purpose of the Geographic Scale Units (GSUs) is to provide a spatial framework and summary unit for the Change Analysis. This spatial framework was developed to support the process-based assessment and analysis at multiple geographic scales.

The boundaries of the GSUs were designed to coincide with the boundaries of features that influence or indicate physical processes. The primary features that drive the GSU delineation are upland watersheds and shoreline drift cells. The spatial hierarchy of the nested GSUs is shown in Figure 4-3.

The fundamental spatial analysis unit is the Drainage Unit (DU). DUs were developed by creating drainage basins from the U.S. Geological Survey (USGS) 10-meter DEM and aggregating them in cases where numerous small drainages result. The DUs are aggregated or split, as necessary, to correspond to a shoreline drift cell component or a portion thereof. The DUs also include the adjacent waterward area out to a depth of 10 meters. Ancillary datasets, including aerial photos, hillshade images, Washington Department of Natural Resources' (WDNR) hydrology and ShoreZone shoreline, were used to aid in decision-making regarding DU aggregation or division because of their higher spatial resolution than the shoreline used to delineate drift cells. The direct association of the DUs and the drift cell components maintains the nested structure of the analyses as the DUs are rolled up into the larger units. DUs are spatially distinct and comprehensive for the Puget Sound region. The DUs range in size from 0.002 square kilometers to 7,060 square kilometers.

The remaining GSUs are Accounting Units, Process Units, and Zone Units. As described previously, these larger units are defined differently in areas dominated by shoreline processes (Shoreline Accounting Units, Shoreline Process Units) as compared to areas estuarine/delta-forming processes (Delta Accounting Units, Delta Process Units).

4.1.1.1 GSUs for the Shoreline Environment

A Shoreline Accounting Unit (SAU) is the set of DUs associated with a single drift cell component, (Convergence Zone (CZ), Divergence Zone (DZ), Left-to-Right transport (LtoR), Right-to-Left transport (RtoL), or No Appreciable Drift (NAD)). A SAU comprises one or more DU(s). In Puget Sound, the SAUs range in size from 0.002 square kilometers to 1,560 square kilometers and consist of 1 to 161 DUs.

A Shoreline Process Unit (SPU) is the group of Shoreline Accounting Units associated with a single drift cell. In general, a drift cell is composed of a directional drift component (LtoR or RtoL) and any adjacent DZ , CZ , or NAD component(s). Because divergence, convergence, and NAD components are associated with the directional drift components on either side, the DUs (and SAUs) associated with the DZ, CZ, and some NAD component types are shared between adjacent SPUs.

Zone Units (ZUs) delineate sub-areas in the DU based on proximity to the shoreline. The waterward Zone Unit is the waterward area from the ShoreZone shoreline to 10 meters in depth, and is sometimes referred to as the aquatic zone. This zone, combined with the ShoreZone shoreline, comprises the region of interest in Tier 2 of the Change Analysis, and is used in all Tier 2 area-based normalizations. The shoreward Zone Unit is the landward area within 200-meters of the ShoreZone shoreline. This nearshore influence which is the region of interest for Tier 3 of the Change Analysis and is used in nearshore zone normalization metrics.

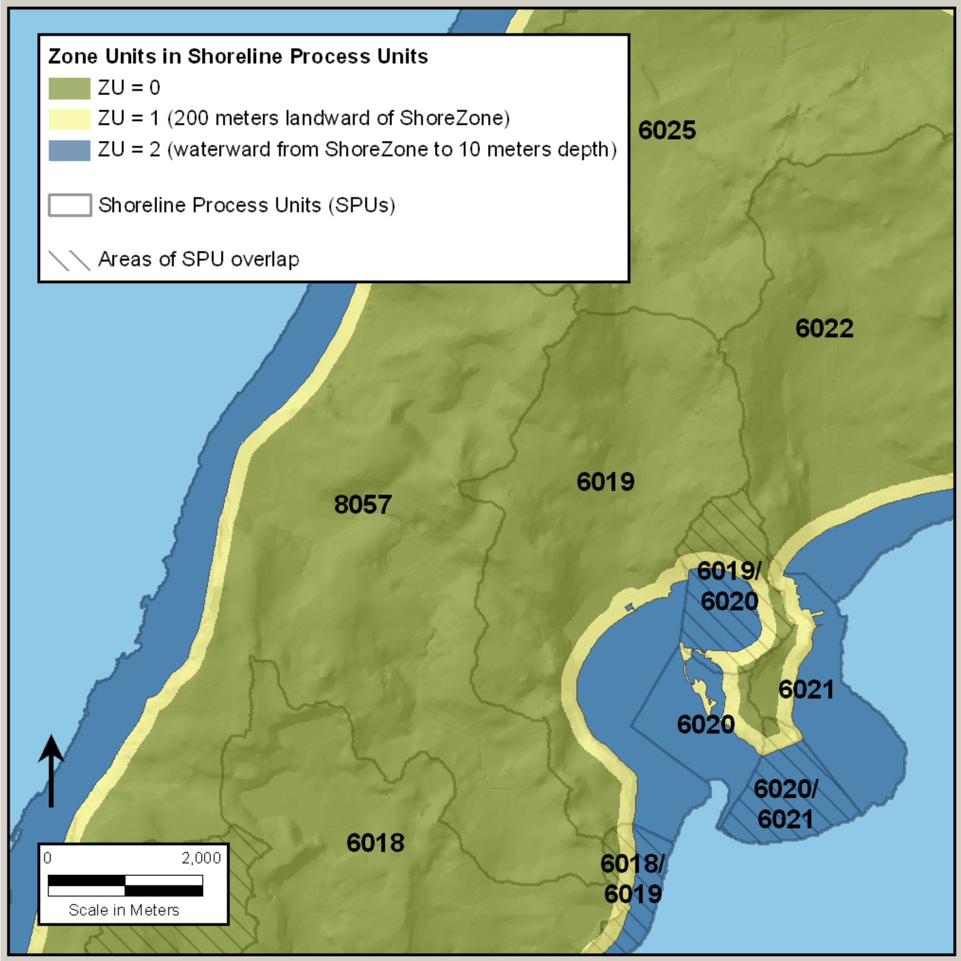


Figure 4-3
Example of Zone Unit Designations in Shoreline Process Units

4.1.1.2 GSUs for the Delta Environment

For the Change Analysis, the NST identified sixteen major river deltas to be delineated as Delta Process Units (DPUs; Table 4-2). These rivers were included because their drainage areas are depicted by Fifth Level watersheds (based on hydrologic units, or HUCs) as single drainages. If the Fifth Level HUC watersheds contained multiple large rivers, the dominant river in the watershed was selected as the major river delta to be designated a DPU. For example, the Quilcene delta is fed by both the Big and Little Quilcene rivers, but the Big Quilcene is the dominant river in the system and therefore the one selected for DPU designation.

Table 4-2
River Systems Delineated As Delta Process Units

River	DPU Code	Sub-basin
Dosewallips	DOS	Hood Canal
Duckabush	DUC	Hood Canal
Hamma Hamma	HAM	Hood Canal
Big Quilcene	QUL	Hood Canal
Skokomish	SKO	Hood Canal
Dungeness	DUN	Strait of Juan de Fuca
Elwha	ELW	Strait of Juan de Fuca
Duwamish/Green/White/ Cedar/Black/ Lake Washington/ Sammamish Rivers	DUW	South Central Puget Sound
Puyallup	PUY	South Central Puget Sound
Nooksack	NKS	San Juan Islands and Georgia Strait
Samish	SAM	San Juan Islands and Georgia Strait
Deschutes	DES	South Puget Sound
Nisqually	NSQ	South Puget Sound
Skagit	SKG	Whidbey Island
Snohomish	SNH	Whidbey Island
Stillaguamish	STL	Whidbey Island

Delta-associated DUs are those that drain to the river and its associated tidal wetlands and intertidal areas. Due to the extensive anthropogenic alteration in many of the deltas, the historic wetlands and intertidal areas were used to delineate the extent of DUs in deltas. The overall boundaries of the delta GSUs are controlled by the upland drainage extent, the lack of sediment transport (NAD) along the shoreline, and any extensive intertidal area at the mouth of the river.

DU delineation in the delta differs from the shoreline environment because of the importance of the historic tidal wetlands. In general, there is one very large drainage basin that encompasses the majority of upland area draining to the river. This drainage is referred to as the “Basin” DU. All of the other DUs that drain directly to the historic wetlands or the adjacent shoreline associated with the delta are referred to as “Local” DUs. The historic wetlands within the delta are grouped into their own DU.

For areas in the DPUs, but outside of historic wetlands, a Delta Accounting Unit (DAU) is a nesting of one or more DUs into the "Basin" or "Local" DAU. There is a single Basin DU per delta, so the DU and DAU are identical. There can be one or more Local DUs that are nested into the "Local" DAU.

For the historical wetland areas within the DPU, a DAU is a grouping of all polygons of a particular wetland type into one of four DAUs: Tidal Freshwater (TF), Oligohaline Transition (OT), Estuarine Mixing (EM), or Euryhaline Unvegetated (EU). In contrast to the hierarchy used in the shoreline environment, in this case the Accounting Units are subsets of a DU. The DU that contains all of the historic wetlands is subdivided into one to four DAUs.

A DPU is the group of all DUs within the upland and waterward region associated with that river. The DUs to be included in the DPU are those that encompass the historic Delta shoreforms (defined as the extent of NAD), and any adjacent shorelines with a wide expanse of historic intertidal area (Figure 4-4).

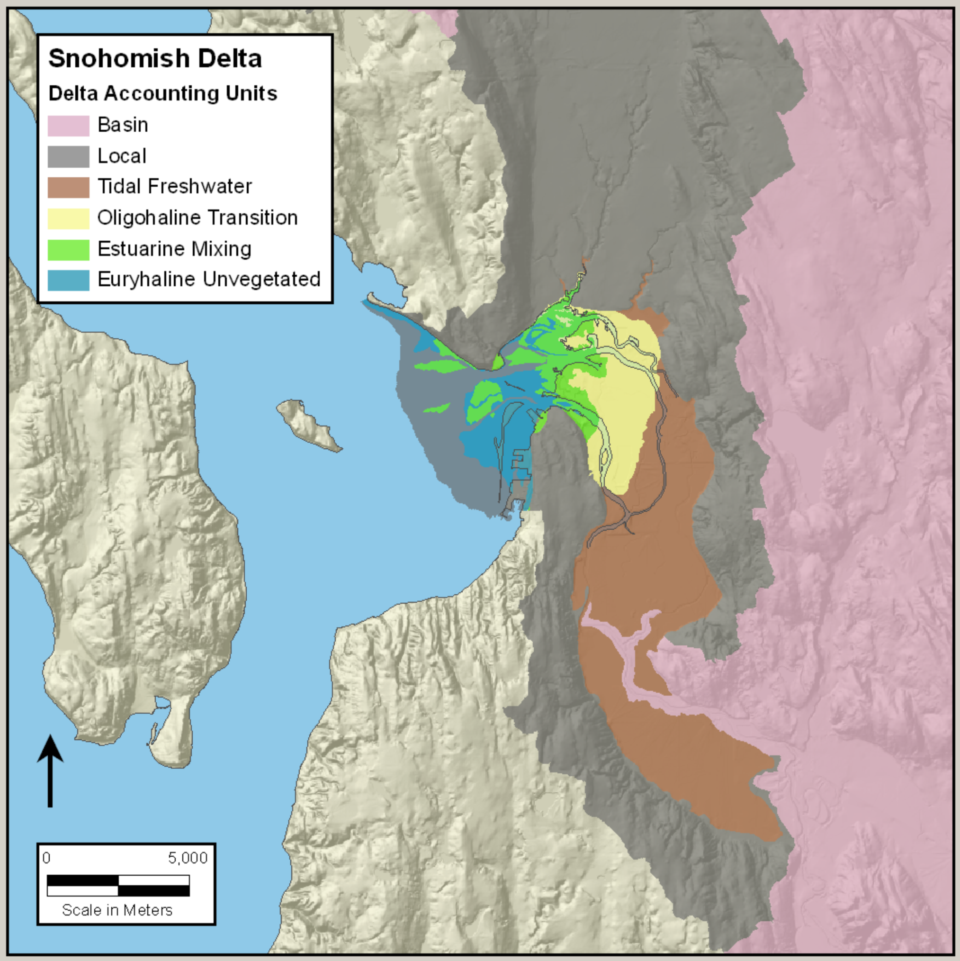


Figure 4-4
Example of Location of Intertidal Wetlands in Delta Process Units

Zone Units in the deltas delineate regions relative to the landward boundary of the historic wetlands (Figure 4-5). The waterward Zone Unit in the delta is the waterward area from the upland boundary of the tidal wetlands, including the wetlands, to 10 meters in depth. The shoreward Zone Unit is the landward area within 200 meters of the landward boundary of the historic wetlands. As in the SPUs, the aquatic zone is used in the calculation of area-based Tier 2 normalizations, and the landward nearshore zone is used in the calculation of Tier 3 normalizations.

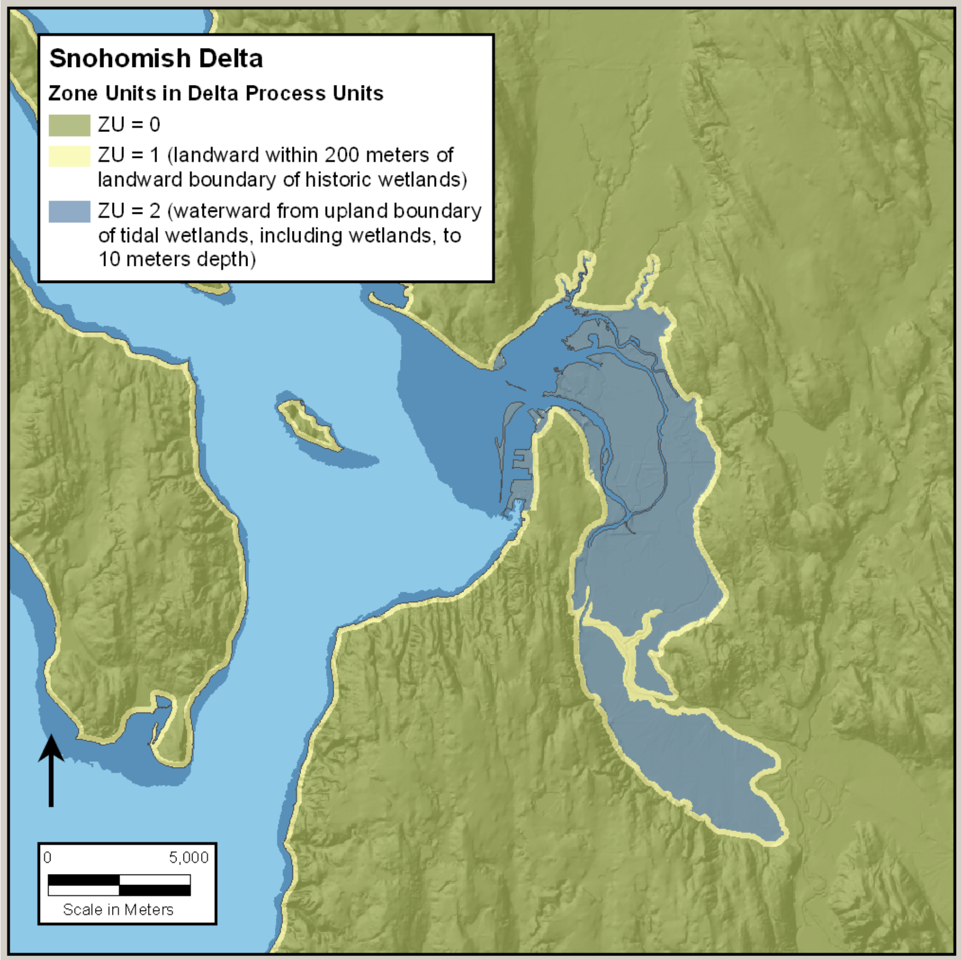


Figure 4-5
Example of Zone Unit Designations in Delta Process Units

4.1.1.3 Overlap of Geographic Scale Units

The process-based approach to Change Analysis required a set of spatial analysis units that are not spatially discrete. These overlaps occurred between the SPUs, in one case between DPUs, and between SPUs and DPUs.

In the shoreline environment, a SPU encompasses an entire drift cell, which includes a directional transport (RtoL or LtoR) component, as well as any adjacent CZs, DZs, and NAD areas. The CZ , DZ and NAD segments are shared by the adjacent drift cells. Therefore, in these areas, the DUs draining to the CZ, DZ, or NAD shorelines are shared by adjacent SPUs (Figure 4-6).

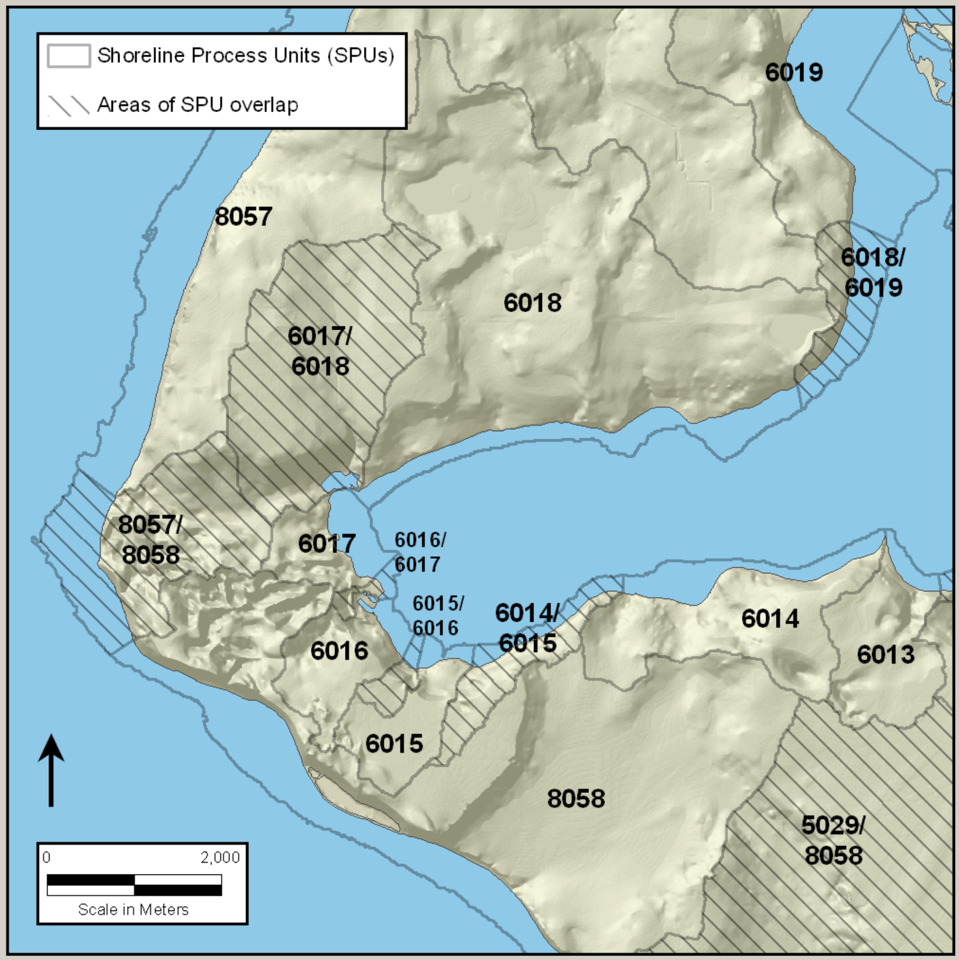


Figure 4-6
Example of Overlap Among Shoreline Process Units

In the delta environment, there are two deltas that have an area of shared influence, the Skagit and Stillaguamish DPUs. The DUs in this region are included in both DPUs. All other DPUs are spatially discrete from the other DPUs.

There are also shared regions between the shoreline and delta environment. Each DPU includes all NAD shorelines associated with the river mouth, and any additional shorelines, with active sediment transport, that have a broad intertidal area. The delta shoreline segments with sediment transport are a component of a drift cell, and as such, are part of a SPU as well as the DPU. Exceptions to this general rule of DPU/SPU overlap occurred for deltas with more exposed shorelines (Straits of Juan de Fuca and Hood Canal), that have active sediment transport along their entire shoreline. In these cases, none of the Delta DUs were shared with the adjacent SPUs.

4.1.2 Data Processing

The ESRI™ ArcGIS (v.9.2) Spatial Analyst Extension Hydrology Toolbox was used to generate drainage basins and "forced" watersheds at the end points of the drift cells. Both the basin and watershed rasters were exported as non-generalized polygons, leaving the sharp square edges of each pixel in the raster data.

Basins were then grouped by drift cell component segments or portions of segments, retaining well-defined hydrography basins as-is. Where a basin overlapped more than one line segment, the "forced" watersheds, aerial imagery, hillshaded topography, WDNR hydrography, ShoreZone shoreline and any other information necessary were used to estimate the best place to divide that basin into portions associated with each separate drift component. Each of these lumped or split polygons were then assigned a unique DU integer ID.

The following set of interpretation rules were used during DU delineation to resolve conflicting data sources:

a. Where a delineated stream in the WDNR hydrology layer crossed into another basin, the stream layer did not necessarily override the basin created by Spatial Analyst. In some cases it was necessary to heads-up digitize a new basin boundary, considering as many pieces of information (hydrology, hillshade, flow direction) as possible.
b. Areas with a well-defined incised channel merged with lots of smaller short intermittent channels retained their basin as a single DU.
c. Human-made ditches are often quite contrary to the basins created from the DEM. Therefore, the DEM was used as the primary source for grouping basins and the hydrology as a secondary source.
d. Basins that are sinks (like isolated lakes) were merged with an adjacent basin. This decision was based on looking at elevation and flow-accumulation raster data to determine the direction of flow if the sink were filled with water.

e. Small spits were generally split in half longitudinally (still breaking at drift cell transitions, which are usually at the tips of spits) when basin watersheds, hydrology, hillshade, and flow direction give no other direction.
f. Offshore islands without drift cells become their own DU and were be grouped with the nearest SAU and SPU.
g. Where the historic drift cell line were significantly different from the current shoreline (e.g., Elliott Bay Marina – Smith Cove), ignored the breaks between drift cell components and created a DU that represents the approximate historical drainage basin of the area
h. Where a change in drift cell component appeared in the middle of an obvious river delta (e.g., Dosewallips River), the break between drift cell components was ignored and the delta was kept together based on its wide expanse of historic intertidal area.

To extend the DUs waterward and capture the aquatic zone boundary, both the 2000 and 2005 Finlayson DEMs containing bathymetry were reclassified using the range of the highest elevation to -10 meters (-100 decimeters), with all other ranges reclassified as "NoData." Each recassification was converted to non-generalized polygons, which were used to delineate a 10-meter-depth waterward boundary. The 2000 and 2005 were combined using the UNION function with preference given to the newest (2005) data.

In the Rosario Strait and Bellingham Channel areas, the Finlayson DEMs have no bathymetry; this gap was filled with a DEM made from soundings taken primarily in the 1930s and 1940s. Again, preference was always given to newest data.
The DU polygons were dissolved, and the dissolved area was used to erase areas of overlap from the polygons created by the union of the 2000/2005 bathymetry, and trimmed the bathymetry polygons to each analysis basin (e.g., Hood Canal). What remained was a polygon extending out in a waterward direction from the DU polygons. This 10-meter-depth waterward boundary polygon was merged with the DUs in each analysis basin.

Attributes were assigned to each DU to indicate membership within Accounting Units and Process Units.

4.1.2.1 Shoreline Attributes

The DU's that correspond to a single SAU were assigned a unique identifier. SAUs are defined as the DU or DUs that correspond to a single drift cell component (LtoR, RtoL, CZ, DZ, NAD). A single SAU can contain one or multiple DUs.

The following rules were used to assign the SPU attributes:

a. Unique integer values were assigned for each SPU. Because of the occurrence of DUs belonging to two SPUs, there are two SPU attribute columns, SPU1 and SPU2. For ease of querying, a particular SPU identifier was assigned, consistently to either SPU1 or SPU2, but not both. For DUs that belong to only one SPU, only one column contains a value and the other is null.
b. DUs contributing to CZs and DZs were assigned two SPU codes, as they contribute to the drift process found on either side.
c. Areas of NAD that are bounded on either side by opposing drift directions were treated as either CZ (e.g., – LtoR → NAD ← RtoL) or DZ (e.g., ← RtoL – NAD – LtoR →) depending on the direction of sediment transport, and were assigned the attributes of Process Units on either side. Therefore, both the SPU1 and SPU2 fields were attributed.
d. Areas of NAD that are bounded on either side by a single drift direction (example: LtoR → NAD → LtoR → NAD → LtoR) were be assigned to a single SPU containing the directional drift. In these cases, only one SPU field (either SPU1 or SPU2) was attributed.

The Zone Units were created by the generation of a 200-meter landward buffer from the ShoreZone shoreline. Waterward of the shoreline, the polygon delineating the area out to the 10-meter depth zone was created using the Finlayson (2000, 2005) bathymetry data. Boundaries dividing the waterward sections of each GSU were delineated with straight line segments drawn as perpendicular from the shoreline as possible (as estimated visually). These landward and waterward polygons were intersected with the DUs to create the Zone Units within each GSU. The area waterward of the shoreline was assigned ZU = 2, and the area landward, within 200 meters distance, was assigned ZU = 1. All remaining areas were ZU = 0.

4.1.2.2 Delta Attributes

After the preliminary grouping of DUs, described in Section 4.1.2, the largest drainage basin to the river was identified as the "Basin" DAU. This DU was modified, if necessary, to terminate at the upstream edge of the historic wetlands.

All other DUs were identified as "Local" DAUs. The waterward extent of the Local DUs is to 10 meters in depth – the same waterward boundary used for Shoreline DUs. Depending on the delta-specific shoreline and wetland configurations, Local DUs that are not shared with SPUs may not necessarily have areas waterward of the historic wetlands.

The historic wetland polygons were classified into one of four wetland classes: tidal freshwater, oligohaline transition. Estuarine mixing, and euryhaline unvegetated. See Section 4.14 for the translation table for assigning the wetland classes. The wetland polygons were then combined with the Delta DUs, using the UNION function.

Some of the extensive intertidal areas associated with deltas were not included in the University of Washington Puget Sound River History Project data. Specifically, the intertidal areas in Samish Bay, Padilla Bay, Skagit Bay, Stillaguamish Delta, and Snohomish Delta were digitized from historic H-sheets (Appendix C Wetlands section). These intertidal areas were assigned to the euryhaline unvegetated class and combined with the rest of the historic wetland polygons.

The entire historic wetland area was buffered by 200 meters. The wetland buffer and the wetlands were combined using the UNION function, and then clipped with the outer boundary of the DPU. The waterward portion of the buffer was removed since the waterward extent of the DPU is delineated by the 10-meter depth contour.

Delta attributes were assigned according to the following rules:

- Delta Process Units (DPU1, DPU2): All DUs within the DPU are assigned a three letter code corresponding to the river that it is associated with (see

Table 4-2). In one case, an area is shared between two DPUs. This DU was assigned two DPU codes.

- Shoreline Process Unit (SPU1,SPU2) and Shoreline Accounting Unit (SAU): DUs in a DPU that do not overlap with the Delta shoreform are also considered shoreline DUs and are shared by the adjacent DPU and SPU. These DUs were assigned the numeric identifier of the adjacent SPU If the DUs are part of an adjacent SAU (i.e., part of a contiguous drift cell component), they were assigned the identifier of the adjacent SAU. If it was a distinct SAU (i.e., a different drift cell component for the adjacent area), it was assigned a unique SAU identifier.
- Delta Accounting Unit (DAU): DUs were assigned to on of the six DAU types based on the criteria described above. The DAU codes are:
  - Basin drainage = BA
  - Local drainage = LO
  - Euryhaline Unvegetated = EU
  - Estuarine Emergent = EM
  - Oligohaline Transition = OT
  - Tidal Freshwater = TF

  Note that the waterward portion of a DU is a Local DAU, assigned the same DU identifier as its corresponding upland DAU, even though it may be discontinuous due to the presence of historic wetlands
- Zone Unit (ZU): The Zone Unit value was assigned as follows:
  - 0 = The upland area above the historic wetlands and their 200-m buffer around the total wetland area
  - 1 = 200-m landward buffer from historic wetlands
  - 2 = historic wetlands and waterward region
- DU: Each DU was assigned a unique numeric identifier.
- For DUs within a DPU that are not shared with an SPU, the DUs delineated by the ArcMap Basin tool may be spatially discontinuous with the waterward area due the presence of the historic wetlands as their own DU. All wetland polygons within the DPU, but not shared with an SPU, were assigned a single, unique identifier. All other DUs were numbered in a manner analogous to the methods used for assigning DU identifiers in the shoreline

environment. For a DU that is shared with a Shoreline Process Unit, the DU numbering scheme is the same as the numbering in the SPU context: the contiguous drainage area from upland to waterward zone, including any historic wetland polygons, were assigned a unique identifier.

The GSUs have undergone extensive QA/QC as described in Appendix C. This QA/QC process included following the detailed procedures and rule sets described in this section. The QC process applied after delineation of the GSUs included review of spatial characteristics and tabular queries to identify incorrect or anomalous values. In addition, all GSUs were reviewed by the GIS Technical Liaison to the NST.

4.1.3 Data Quality

Attribute data quality is expected to be quite high, due to exhaustive, iterative QC procedures. Spatial data quality is based on source datasets, particularly the DEMs, drift cells, and historic wetlands. .

4.2 Historic Shoreform

4.2.1 Description

Historic shoreforms are the geomorphic classes assigned to homogeneous segments of the historic shoreline. Shipman's (2008) *A Geomorphic Classification of Puget Sound Nearshore Landforms* is the guiding document for characterization of historic shoreforms[1]. Shipman's geomorphic classes represent the variety of shoreforms occurring in Puget Sound. The system is based on the premise that the dynamic geomorphic processes are difficult to map, but that nearshore process can be inferred from the associated shoreform.

Shipman's (2008) classification divides Puget Sound shoreforms into four general geomorphic systems:

- Rocky Coasts
- Beaches
- Protected Embayments

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[1] Shipman generally uses the term "landform", whereas the term "shoreform" is used throughout this document to refer to these shoreline-specific landforms

- Large River Deltas

Each of these geomorphic systems is further subdivided into shoreforms depending upon local patterns of sediment deposition, erosion or lack of sediment. Shoreforms refer to the entire cross-section of beach from backshore to .subtidal. Mapping of historic shoreforms for change analysis was undertaken at the shoreform level. Table 4-3 presents an overview of the Shipman (2008) shoreform classification system to the shoreform level.

Table 4-3
Summary of Geomorphic Classification System Developed by Shipman (2008)

Systems	Shoreforms
River Deltas • Long-term deposition of fluvial sediment at river mouths	**River-dominated deltas** • Extensive alluvial valleys with multiple distributaries and significant upstream tidal influence **Wave-dominated deltas** • Deltas heavily influenced by wave action, typically with barrier beaches defining their shoreline **Tide-dominated deltas** • Deltas at heads of bays where tidal influence is much more significant than fluvial factors, typically with wedge-shaped estuary **Fan deltas** • Steep , often coarse-grained deltas with limited upstream tidal influence
Rocky Coast • Resistant bedrock with limited upland erosion	**Plunging** • Rocky shores with minimal erosion/ deposition and no erosional bench or platform
	Platform • Wave-eroded platform/ramp, but no beach
	Pocket Beaches • Isolated beaches contained by rocky headlands
Beaches • Shorelines consisting of loose sediment and under the influence of wave action	**Bluffs** • Formed by landward retreat of the shoreline
	Barriers • Formed where sediment accumulates seaward of earlier shoreline
Embayments • Protected from wave action by small size and sheltered configuration	**Open Coastal Inlets** • Small inlets protected from wave action by their small size or shape, but not significantly enclosed by a barrier beach
	Barrier estuaries • Tidal inlet largely isolated by a barrier beach and with a significant input of freshwater from a stream or upland drainage
	Barrier lagoons • Tidal inlet largely isolated by a barrier beach and with no significant input of freshwater
	Closed lagoons and marshes • Back-barrier wetlands with no surface connection to the Sound

The general process for historic shoreform classification is summarized in a graphic decision tree (Figure 4-7). Each shoreform type is given a code in the database, which is indicated in parentheses after the shoreform name in Figure 4-7. A summary, paraphrased description of each shoreform type is provided below for quick reference. Please refer to Shipman (2008) for complete shoreform descriptions.

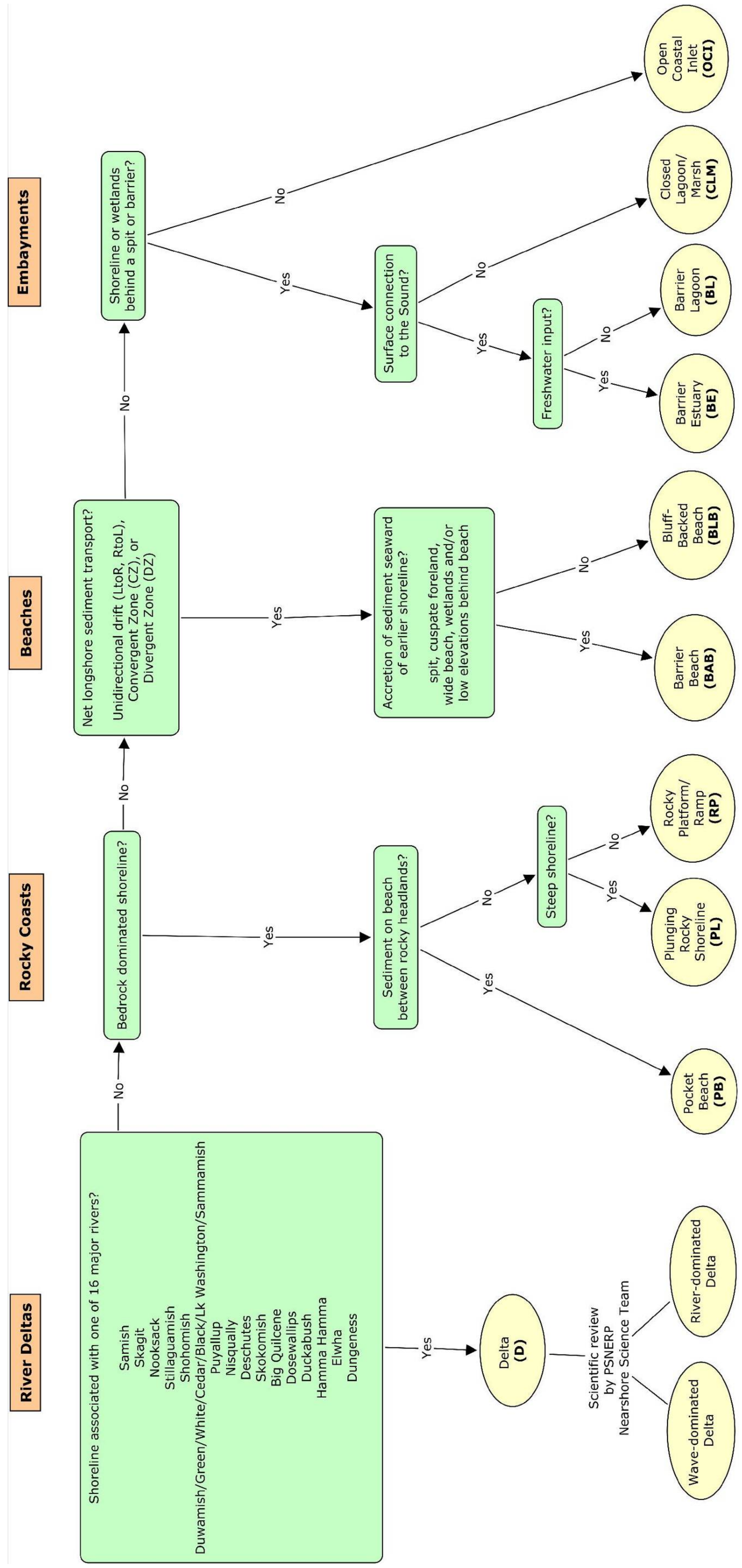

Figure 4-7
Decision Tree to Determine Shipman (2008) Geomorphic Shoreform Classification

4.2.1.1 Deltas

Deltas typically consist of several major geomorphic components: a delta front, a delta plain, distributary channels, and a variety of tidal channels (Figure 4-8). The delta front normally refers to where the flat-lying portion of the delta drops steeply into deeper water offshore. Deltas typically have extensive estuarine wetlands with well-developed tidal and distributary channels. Extensive freshwater marshes and freshwater tidal channels are often associated with these delta systems.

Figure 4-8
Delta

For this project, large river systems with a significant delta system at their mouth are the systems that fit this typology. Smaller streams of the Puget Lowlands that flow from watersheds that lie a few kilometers from the Sound have typically small sediment yields, and are often dominated by tidal or wave processes. For the purpose of this project, these smaller systems are considered as components of either beaches or embayment shoreform types depending on the net shore-drift.

The PSNERP NST has chosen to include river deltas that are within large watersheds as identified by Fifth Level Hydrologic Unit Codes (HUC). If more than one Fifth

Level HUC watershed feeds the same region of shoreline, the dominant river was retained as the DPU and delta shoreform. The saltwater shorelines associated with the following rivers are assigned the Delta shoreform type:

- Nooksack River
- Samish River
- Skagit River
- Stillaguamish River
- Snohomish River
- Duwamish/Green/White/Cedar/Black/Lake Washington/Sammamish Rivers
- Puyallup River
- Nisqually River
- Deschutes River
- Skokomish River
- Hamma Hamma River
- Duckabush River
- Dosewallips River
- Big Quilcene River
- Dungeness River
- Elwha River

The NAD section of shoreline depicted in the drift cell dataset is assigned the Delta shoreform. The further distinction between types of deltas, wave-dominated, river-dominated, tide-dominated, and fan, is not applied to these data.

4.2.1.2 Rocky Coasts

Rocky coasts occur where resistant bedrock occurs at the coastline, with little or slow erosion rates. Rocky shorelines are often irregular in shape, located along older geologic units, (i.e., units prior to Quaternary period).

Rocky coasts are relatively easy to identify using aerial photographs (orthophotos and oblique photos) supplemented by upland geologic mapping of bedrock areas. Rocky shores were also frequently mapped on the historic T-sheets. In general, drift cell data indicates NAD along rocky coasts. This is not due to lack of wave energy for longshore sediment transport, rather, due to the absence of sediment to be transported.

4.2.1.2.1 Plunging Rocky Shores

Plunging rocky shores are those rocky coasts with no significant intertidal or subtidal platforms (Figure 4-9). Plunging rocky shorelines drop directly into deeper water with little break in slope.

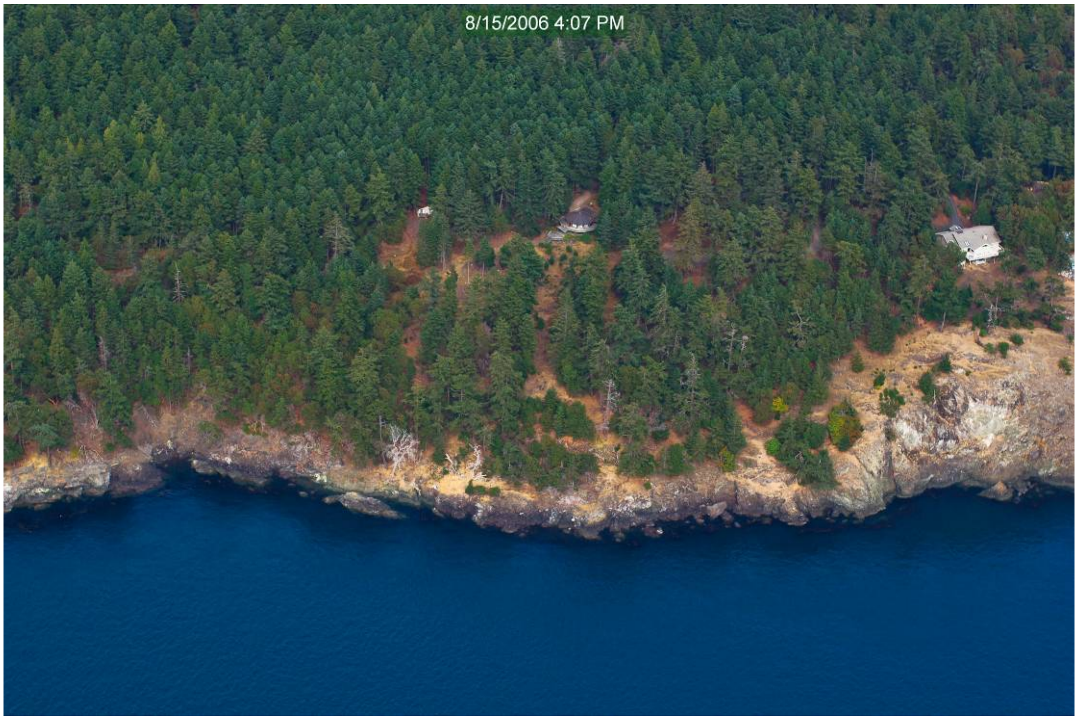

Figure 4-9
Plunging Rocky Shore

4.2.1.2.2 Rocky Platforms/Ramps

Rocky platform/ramp shoreforms have exposed bedrock that is of low gradient and intertidal/subtidal surfaces formed by wave erosion (Figure 4-10). There may be some unconsolidated material (cobbles, boulders), but it usually lacks fine sediment.

Figure 4-10
Rocky Platform/Ramp

4.2.1.2.3 Pocket Beaches

Pocket beaches are sediment beaches isolated from longer reaches of shoreline by rocky headlands or promontories that restrict longshore sediment transport (Figure 4-11). Pocket beaches are generally oriented perpendicular to the major direction of wave approach (swash-aligned). Although sediment may be moved in a longshore direction within pocket beaches (or brought into a "pocket" during high energy wave events), the net transport is generally zero.

Figure 4-11
Pocket Beach

4.2.1.3 Beaches

Beaches occur along shorelines with (1) an abundant supply of sand or gravel and (2) sufficient wave action to rework this material. The source of sediment might not be in the immediate vicinity, but transported into the area and deposited/reworked. "The predominant geomorphic process associated with beaches is sediment movement by wave action" (Shipman 2008). For this project, active longshore sediment transport, as depicted in the drift cell data, is required to identify a segment of shore as a one of two beach shoreform types, bluff-backed beach or barrier beach.

4.2.1.3.1 Bluff-Backed Beaches

Erosion by wave action, mass wasting of bluff sediments, and resulting sediment transport along the shoreline are typical processes associated with shoreline characterized as bluff-backed beach (Figure 4-12). The term "bluff" is broad and "is used here to describe any shoreline where the upland rises directly landward of the beach. This includes both high, steep cliffs (although not rock), as well as more gentle slopes that intersect the shoreline with little historic erosion" (Shipman 2008). Bluffs and bluff-backed beaches are formed by the landward retreat of the shoreline due to erosion.

Figure 4-12
Bluff-Backed Beach

4.2.1.3.2 Barrier Beaches

Barrier beaches result from accumulation of sediment seaward of a previous coastline as a consequence of longshore transport (Figure 4-13). Barrier beaches often form across embayments along the coastline, at distinct bends in the shoreline, or where sediment transported alongshore converges from two directions. Barrier beaches are often identified by the occurrence of wetlands and/or low elevations landward of the beach berm.

Figure 4-13
Barrier Beach

4.2.1.4 Embayments

Embayments are protected shoreforms that are exposed to minimal wave energy or beach processes due to their limited connection to the larger water bodies in Puget Sound proper. Embayments encompass a wide range of scales, and are the shoreforms that are partially or completed enclosed by barriers or otherwise protected from wave action due to size or configuration.

For mapping purposes, the embayment shoreforms are delineated using the extent of NAD as mapped by the drift cell dataset. Three factors (presence of a barrier, degree of tidal connection, and freshwater input) are used to distinguish between the four embayment types: open coastal inlet, barrier estuary, barrier lagoon, and closed lagoon/marsh.

For three of the four embayment types (barrier estuary, barrier lagoon and closed lagoon/marsh), the historic shoreline is supplemented with any additional coastal wetlands from the historic land cover data that are associated with that shoreform. These areas may be outside of the area depicted by the drift cell dataset, but the wetland boundaries are added in order to delineate the full extent of the shoreform.

4.2.1.4.1 Open Coastal Inlets

Open coastal inlets are usually associated with valleys in the terrestrial landscape and can be associated with a coastal stream or river mouth (Figure 4-14). Open coastal inlets are the only embayment shoreforms that lack a barrier to significantly enclose them, but their size or configuration minimizes wave action.

Figure 4-14
Open Coastal Inlet

4.2.1.4.2 Barrier Estuaries

Barrier estuaries are the shoreforms consisting of inlets, lagoons, and/or marshes behind a barrier and having significant freshwater input (Figure 4-15). These may include wetlands formed on cuspate forelands (a triangular, accretionary shoreform), wetlands within an embayment, or wetlands along an unembayed coastline. Barrier estuaries are partially isolated from open marine water by a barrier, with tidal exchange occurring through a narrow entrance channel. The wetland itself may include open water, a stream channel, tidal channels, and salt marshes.

Figure 4-15
Barrier Estuary

4.2.1.4.3 Barrier Lagoons

Barrier lagoons are tidal embayments, similar in many ways to barrier estuaries, but lacking a significant freshwater source (i.e., a perennial stream; Figure 4-16).

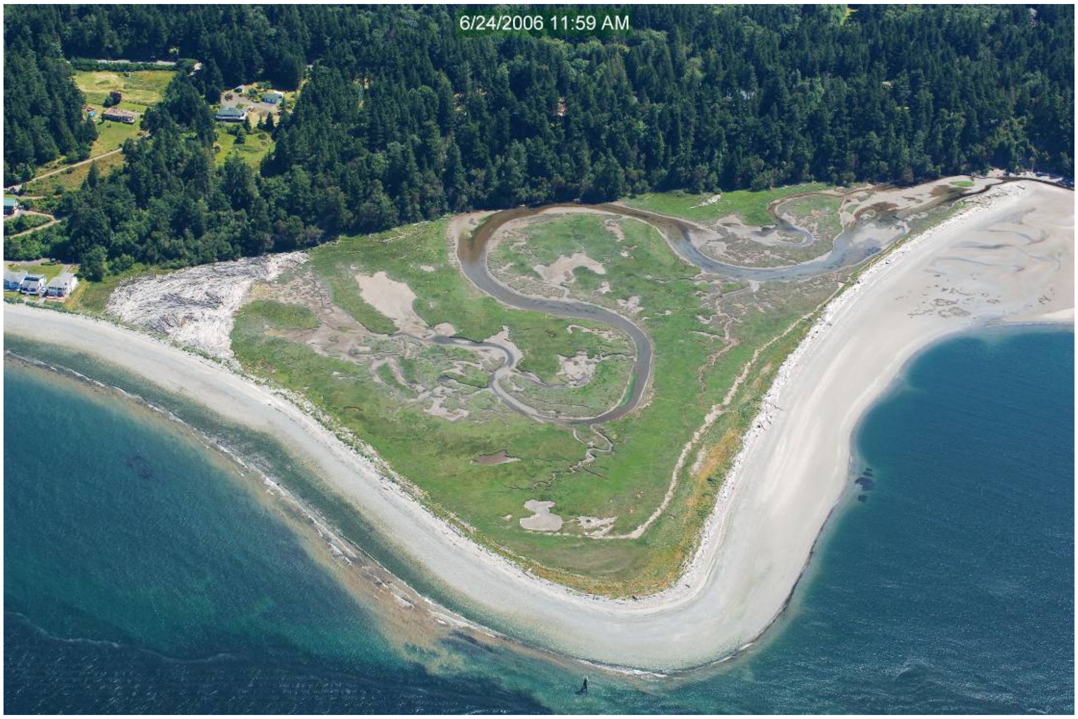

Figure 4-16
Barrier Lagoon

4.2.1.4.4 Closed Lagoons/Marshes

Closed lagoons/marshes are back-barrier wetlands that typically have a subsurface hydrologic linkage with marine waters, but lack a persistent tidal channel opening to Puget Sound (Figure 4-17). The main characteristic of this shore type is the presence of a lagoon, wetland, pond, or marsh completely enclosed by a barrier beach or pocket beach. Closed lagoons may be subject to periodic saltwater inundation during storms or periodic breaching of the barrier, but do not maintain a persistent connection to Puget Sound.

Figure 4-17
Closed Lagoon/Marsh

4.2.2 *Data Processing*

This section describes the detailed protocols used for mapping historic shoreforms with available Sound-wide GIS datasets. Because the shoreform classification was completed by multiple analysts, protocols were developed to minimize subjective decision-making. However, shoreform mapping and classification is necessarily an interpretive process that requires decisions about where to place boundaries between shoreforms as well as assigning a classification when the supporting data are inadequate or contradictory. All questionable shoreform interpretations were reviewed by a geomorphologist who provided a cohesive perspective across all sub-basins.

4.2.2.1 General Interpretation Methods and Guidelines

- The shoreline from the University of Washington Puget Sound River History Project (RHP) historical shoreline dataset is the foundation layer for assigning historic shoreforms. This line was extracted from their dataset with the query: [LULC] = “shoreline%”. (In other words, extract any entries in the land use/land cover field that start with the word “shoreline”).
- The decision tree (Figure 4-7) was used to guide the shoreform classification. The historic shoreline was segmented or combined, depending on the extent of each shoreform, and assigned a shoreform code. Shoreform types and their codes are listed in Table 4-4. The shape or configuration of the historic shoreline was not modified.
- Data were edited while viewing at a scale of approximately 1:2,000. Some review was required at smaller scales in order to evaluate the landscape context of the feature, or to identify larger features, such as very long barrier beaches.
- Features in the RHP data were used to set the minimum mapping unit for historic shoreforms. If a shoreform was not uniquely depicted in the RHP data, a minimum mapping unit of approximately 100 meters was used to differentiate shoreforms. One exception is a rocky shoreform that is needed to contain a pocket beach – often these are very small features, but were mapped for logical consistency and their importance along a rocky shoreline.
- If the shoreform is one of the embayment types that is behind a barrier, (barrier estuary, barrier lagoon, or closed lagoon/marsh), additional wetland linework associated with that shoreform was imported from the historic wetland boundaries. Table 4-5 lists the land cover classes from the RHP data that are appropriate for inclusion. Wetland linework was minimized to include only the outer boundary of all discrete wetland features.
- For shoreline areas that were already significantly modified by humans in the RHP data, a code of “ART” (for artificial) was assigned to the shoreform.

- If the modification is a single overwater structure, it was assigned the same shoreform as the adjacent shoreline sections.
- A confidence level code was assigned to each shoreform: high (H), medium (M), or low (L). If all rules and criteria were met, the confidence level was high. If the data were conflicting or inadequate to be certain of the historic shoreform, a medium or low confidence was assigned.
- All shoreforms with low or medium confidence were reviewed by the geomorphologist. After review, the geomorphologist assigned their recommended shoreform classification for that shoreline segment.
- The system level code could be assigned in cases of extremely low confidence (Table 4-4).
- Any additional information about the shoreform, especially for low or medium confidence interpretations, was entered in the free-text field, "Notes."

Table 4-4
Historic Shoreform Codes

System	System Code	Shoreform	Shoreform Code
Delta	D	Delta	D
Rocky Coast	R	Plunging Rocky Shore	PL
		Rocky Platform/Ramp	RP
		Pocket Beach	PB
Beach	B	Bluff-Backed Beach	BLB
		Barrier Beach	BAB
Embayment	E	Open Coastal Inlet	OCI
		Barrier Estuary	BE
		Barrier Lagoon	BL
		Closed Lagoon/Marsh	CLM
N/A		Artificial (Anthropogenic modifications)	ART

Table 4-5
Land Use / Land Cover Classes Used in Embayment Shoreform Delineation

Simenstad Intertidal Wetland Classification	RHP Land Use / Land Cover Class	Description
Tidal freshwater (TF)	CH/TF	Tidal-fresh channel
	CH/TF/BAR	Tidal-fresh channel/Bar
	CH/TF/WOOD	Tidal-fresh channel/Wood
	REM	Riverine-tidal emergent wetland
	RFO	Riverine-tidal forested wetland
	RSS	Riverine-tidal scrub-shrub wetland
Oligohaline transition (OT)	CH/ESS	Estuarine scrub-shrub wetland
	CH/ESS/BAR	Estuarine scrub-shrub wetland/Bar
	CH/ESS/WOOD	Estuarine scrub-shrub wetland/Wood
	ESS	Estuarine scrub-shrub wetland
Estuarine mixing (EM)	CH/EEM	Estuarine emergent wetland channel
	CH/EEM/BAR	Estuarine emergent wetland channel/Bar
	CH/EEM/IT	Estuarine emergent wetland channel/Intertidal
	CH/EEM/WOOD	Estuarine emergent wetland channel/Wood
	EEM	Estuarine emergent wetland
	EEM_LOW	Submerged Estuarine emergent wetland
	LAG-C	Closed lagoon
	LAG-O	Open lagoon
	LAG/EEM-C	Closed lagoon enclosed by estuarine emergent wetland
	LAG/EEM-O	Open lagoon enclosed by estuarine emergent wetland
Euryhaline unvegetated (EU)	CH/ST	Sub-tidal channel
	CH/ST/BAR	Sub-tidal channel/Bar
	COB/BL	Cobblestone, below low-water
	COB/BS	Cobblestone, below shoreline
	GR/BL	Gravel, below low-water
	GR/BS	Gravel, below shoreline
	IT	Intertidal
	IT/BAR	Intertidal/Bar
	IT/WOOD	Intertidal/Wood
	MUD/BS	Mud, below shoreline
	REEF	Reef
	SND/BL	Sand, below low-water

4.2.2.2 Interpretation Procedures by Shoreform Type

4.2.2.2.1 Deltas

Criteria:

- River systems that qualify as deltas were determined by the NST and are listed in the decision tree (Figure 4-7).

Supporting Evidence and Interpretation Guidelines:

- NAD drift cell data and bathymetry may assist in determining the beginning and end of the shoreform.

Mapping Protocol:

- Attribute the shoreline associated with the river mouth to the extent of the NAD zone depicted in the drift cell data and upstream to include any estuarine and tidal freshwater channels (CH) from the RHP shoreline data.
- Supplemental historic wetland linework is not included in the delta shoreform linework.
- Delta shoreforms without NAD along the shore (such as Elwha and Dungeness) are delineated based on the extent of the wide, historic intertidal areas.

4.2.2.2.2 Plunging Rocky Shores

Criteria:

- WDNR’s 100K Geology dataset shows bedrock along the shore. (This includes any geologic map symbols encountered within the Puget Sound area that do not begin with "Q").
- Steep rocky shores, without a significant platform, are visually evident on Ecology’s oblique aerial photographs or NAIP orthophotographs.

Supporting Evidence and Interpretation Guidelines:

- RHP line data show an irregular shoreline.
- RHP polygon data with “rocky’ or “kelp” land cover may indicate presence of bedrock.

- Drift cell data is predominantly NAD, but you may see drift as well, especially along promontories.
- Oblique photos show bedrock outcroppings with no rocky ledges or rocky areas that descend straight into the water.
- Oblique photos may also depict strong currents moving along the shoreline.
- LiDAR, DEMs, and bathymetry data (if resolution is fine enough) may help distinguish between plunging and platform rocky shores by depicting steep sides in plunging rocky shorelines.

Mapping Protocol:

- Begin and end the shoreform shoreline segment where drift cell NAD, RHP “rocky” polygons, bathymetry, oblique photos, and irregular shoreline orientation suggest plunging rock.

4.2.2.2.3 Rocky Platforms/Ramps

Criteria:

- WDNR’s 100K Geology dataset shows bedrock along the shore. (This includes any geologic map symbols encountered within the Puget Sound area that do not begin with "Q").
- Rocky shores with an intertidal platform are visually evident on Ecology’s oblique aerial photographs.

Supporting Evidence and Interpretation Guidelines:

- RHP line data show irregular shoreline.
- RHP poly data with “rocky’ or “kelp” may indicate presence of bedrock.
- Drift cell data is predominantly NAD but you may see drift as well, especially along promontories.
- Oblique photos show bedrock outcroppings of exposed bedrock, with intertidal/subtidal platform at the surface (beach).
- Oblique photos may show some accumulation of larger unconsolidated materials.
- LIDAR, DEMs, and bathymetry data may help distinguish between plunging and platform rocky shores (if resolution is fine enough).

Mapping Protocol:

- Begin and end the shoreform where NAD, RHP "rocky" polygons, bathymetry, oblique photos, and irregular shoreline orientation suggest rocky platform or ramp.

4.2.2.2.4 Pocket Beaches

Criteria:

- Isolated sediment (sand/gravel) beaches located between bedrock shoreforms.
- Oblique photos or orthophotos confirm presence of a sediment (sand/gravel) beach between bedrock shoreforms.

Supporting Evidence and Interpretation Guidelines:

- RHP line data indicate a small section of smooth shoreline between irregular shoreline.
- RHP data delineate a wetland behind the beach.
- Drift is predominantly NAD, but drift may be present.
- Consider the larger picture instead of isolated segments at a time to distinguish between pocket beaches and bluff-back beaches. If bedrock is predominant along the shoreline, then it is more likely to be a pocket beach than a bluff-backed beach if all other guidelines are met from above.

Mapping Protocol:

- Break the segment where smooth lines become more irregular or between RHP "rocky" polygons.
- If needed, use the oblique photos to determine the end points of the pocket beach shoreform.
- Use the RHP polygons to determine the minimum mapping unit for pocket beaches—if it was mapped by the RHP, then include it in the historic shoreform delineation. If it was not mapped by the RHP, include it in the historic shoreform delineation if the beach is longer than 100 meters.

4.2.2.2.5 Bluff-Backed Beaches

Criteria:

- A sediment-dominated beach that has net longshore drift (LtoR, RtoL, DZ, CZ) and does not meet the criteria for delta, rocky coast, or barrier beach shoreforms.

Supporting Evidence and Interpretation Guidelines:

- RHP polygon dataset maps a "bluff" Land Use/Land Cover (LULC) class.
- Oblique photos show slope along the shoreline in the upland areas. The slope can be steep or very gentle.
- DEM and LiDAR show elevation at the nearshore or indicate hill slope mass-wasting and erosion towards upland.
- If a CZ is present, check that guidelines for barrier beach are not present.

Mapping Protocol:

- Drift cells are the primary data for determining the boundary between bluff-backed beaches and shoreforms of the other systems (rocky coast, delta, and embayments)—specifically, a change between directional drift (CZ, DZ, LtoR, RtoL) and NAD.
- Change in elevation and/or vegetation type is used to delineate the boundary between bluff-backed and barrier beaches.

4.2.2.2.6 Barrier Beaches

Criteria:

- A sediment-dominated beach that has net longshore drift (LtoR, RtoL, DZ, CZ) and shows indications of accretion of sediment seaward of a previous shoreline, including: cuspate forelands, spit, wetlands behind the beach, and/or low elevations behind the beach.

Supporting Evidence and Interpretation Guidelines:

- RHP data or oblique or orthophotos show embayments such as lagoons, marshes, ponds, tidal embayments, or other low lying wetland/aquatic feature in the backshore.

- DEM or LiDAR show flat topography behind the beach.
- RHP polygon data show an accumulation of sand or gravel at the intertidal, especially within a convergence zone.
- CZs are often barrier beaches.
- Barrier beaches are common where streams and rivers enter Puget Sound.

Mapping Protocol:

- Drift cells are the primary data for determining the boundary between barrier beaches and shoreforms of the other systems (rocky coast, delta, and embayments), specifically, a change between directional drift (CZ, DZ, LtoR, RtoL) and NAD.
- Change in elevation and/or vegetation type is used to delineate the boundary between bluff-backed and barrier beaches.
- Drift cell CZs or a change in shoreline geometry can also be used to delineate the end points of a barrier beach.

4.2.2.2.7 Open Coastal Inlets

Criteria:

- Lack of longshore drift (NAD).
- Protected, basin-like geometry.
- No barrier present.

Supporting Evidence and Interpretation Guidelines:

- A stream or river mouth may be present.
- Open coastal inlets may occur at a wide range of scales.

Mapping Protocol:

- The shoreform is delineated by the extent of NAD in the drift cell data, even if the area that is shaped like an embayment encompasses a longer stretch of shoreline.

4.2.2.2.8 Barrier Estuaries

Criteria:

- Lack of longshore drift (NAD).

- Presence of a barrier enclosing the embayment.
- Surface connection to the salt water of Puget Sound.
- Significant input of fresh water from a stream or river

Supporting Evidence and Interpretation Guidelines:

- Drift cell data indicates drift is associated with the barrier beach on the seaward side of the estuary, but no drift (NAD in drift cell data) within the embayment.
- Stream input determined using the WDNR watercourse data and “intermittent channel” or “channel” LULC in the RHP MEGA_T line feature dataset.
- RHP line and polygon data show presence of any lagoon, pond, tidal embayment, or other low-lying wetland/aquatic feature with a barrier beach along the seaward side.
- RHP line data indicate spit or barrier features across the seaward side of the wetland feature(s).
- Use aerial photos (oblique and orthophotos) to determine the connectivity of the embayment to salt water of Puget Sound.

Mapping Protocol:

- The barrier estuary is delineated by the extent of NAD along the section of the shore that is behind the barrier.
- Include the outer extent of any associated estuarine wetland features from the RHP data.

4.2.2.2.9 Barrier Lagoons

Criteria:

- Lack of longshore drift (NAD).
- Presence of a barrier enclosing the embayment.
- Surface connection to the salt water of Puget Sound.
- Lack of significant input of fresh water from a stream or river.

Supporting Evidence and Interpretation Guidelines:

- Drift cell data indicates drift is associated with the barrier beach on the seaward side of the estuary, but no drift (NAD in drift cell data) within the embayment.
- Absence of stream input determined using the WDNR watercourse data and "intermittent channel" or "channel" LULC in the RHP MEGA_T line feature dataset.
- RHP line and polygon data show presence of any lagoon, pond, tidal embayment, or other low-lying wetland/aquatic feature with a barrier beach along the seaward side.
- RHP line data indicate spit or barrier features across the seaward side of the wetland feature(s).
- Use aerial photos (oblique and orthophotos) to determine the connectivity of the embayment to salt water of Puget Sound.

Mapping Protocol:

- The barrier lagoon is delineated by the extent of NAD along the section of the shore that is behind the barrier.
- Include the outer extent of any associated estuarine wetland features from the RHP data.

4.2.2.2.10 Closed Lagoons/Marshes

Criteria:

- Lack of longshore drift (NAD).
- Presence of a barrier completely enclosing the embayment.
- No surface connection to the salt water of Puget Sound.

Supporting Evidence and Interpretation Guidelines:

- Drift cell data indicates drift is associated with the barrier beach on the seaward side of the embayment, but no drift is mapped within the embayment itself. (It is "off-line").
- RHP line and polygon data show presence of any lagoon, pond, tidal embayment, or other low-lying wetland/aquatic feature with a barrier beach along the seaward side.

- RHP line data indicate spit or barrier features across the seaward side of the wetland feature(s).
- Use aerial photos (oblique and orthophotos) to determine the connectivity of the embayment to salt water of Puget Sound.

Mapping Protocol:

- The closed lagoon/marsh is delineated by the extent of estuarine wetlands behind the barrier beach as mapped by the RHP
- Include the outermost extent of the estuarine wetland features from the RHP data.

4.2.3 Data Quality

Data quality by shoreform is indicated in the confidence intervals. Most shoreforms were indicated to have high confidence, but some areas have conflicting information from the various sources. To increase data quality and accuracy, shoreforms with low and medium confidence were reviewed by a coastal geomorphologist. Due to the use of historical maps, positional accuracy is known to be low, but is expected to have internal consistency.

4.3 Current Shoreline

4.3.1 Description

This dataset contains the current ShoreZone shoreline. It was used as the geometry for the current shoreforms, shoreform change, armoring, and as the shoreline delineation within the GSUs.

4.3.2 Data Processing

The ShoreZone line was overlaid with the GSU boundaries.

4.3.3 Data Quality

The ShoreZone shoreline is the most commonly used shoreline delineation in Puget Sound. Because it was used as the base for numerous project data sets, its use provides internal consistency between datasets. The locational accuracy is adequate for project analyses.

4.4 Shoreform Change

4.4.1 Description

The shoreform change data are a compilation of current and historic shoreforms applied to the ShoreZone shoreline. Historic and current shoreforms in Puget Sound were independently delineated and combined onto a single shoreline (ShoreZone) to provide a comparison of historic to current conditions.

4.4.2 Data Processing

4.4.2.1 Translation of Current Shoreform to Shipman Type

The current ShoreZone shoreline was classified according to a geomorphic classification system developed by McBride et al. (2005) and applied by SSHIAP (Todd et al. 2009). Because the shoreform classification system chosen for the Change Analysis is Shipman (2008), the current shoreline types (GeoUnits) had to be cross-walked to the corresponding Shipman types. Some of the SSHIAP types may correspond to more than one Shipman type, so a first-cut, automated translation was performed. The Shipman type assigned during the automated translation was the class expected to be correct most of time. Table 4-6 shows the SSHIAP GeoUnit and the preliminary Shipman shoreform assigned to that segment of shoreline. Note that there is no SSHIAP GeoUnit that corresponds to Shipman's Open Coastal Inlet (OCI) shoreform in the automated translation process.

Table 4-6
SSHIAP GeoUnit and Preliminary Shipman Shoreform Type

SSHIAP GeoUnit	Shipman Shoreform	Shoreform Code
Tidal Channel Marsh	Barrier Estuary	BE
Tidal Channel Lagoon	Barrier Estuary	BE
Drowned Channel	Delta	D
Drowned Channel Lagoon	Barrier Estuary	BE
Tidal Delta	Delta	D
Tidal Delta Lagoon	Barrier Estuary	BE
Delta	Delta	D
Delta Lagoon	Bluff-backed Beach	BLB
Pocket Beach Estuary	Barrier Estuary	BE
Pocket Beach Lagoon	Barrier Lagoon	BL

SSHIAP GeoUnit	Shipman Shoreform	Shoreform Code
Pocket Closed Lagoon and Marsh	Closed Lagoon and Marsh	CLM
Pocket Beach	Pocket Beach	PB
Closed Lagoon and Marsh	Closed Lagoon and Marsh	CLM
Longshore Lagoon	Barrier Lagoon	BL
Beach Seep	Bluff-backed Beach	BLB
Depositional Beach	Bluff-backed Beach	BLB
Sediment Source Beach	Bluff-backed Beach	BLB
Barrier Beach	Barrier Beach	BAB
Plunging Sediment Bluff	Bluff-backed Beach	BLB
Rocky Shoreline*	Rocky Platform	RP
Veneered Rock Platform	Rocky Platform	RP
Plunging Rocky Shoreline	Plunging Rocky Shoreline	PL
Modified	Artificial	ART

Note:
* In Whidbey and South Central sub-basins, Rocky Beach = Rocky Shoreline.

This automated translation was followed by a visual review of all current shoreforms to make any necessary modifications to the current shoreform type.

4.4.2.2 Simultaneous Review of Current and Historic Shoreforms

After translation of the current shoreline type into the Shipman type, both current and historic shoreforms were displayed using the same symbology and edited as necessary. This review was performed in order to:

- Assign the correct type to the current shoreform for GeoUnit types that may correspond to more than one Shipman type.
- QC current and historic shoreform types and modify values as necessary.
- Split historic shoreform segments when necessary to correspond to a region of change from historic to current.

The review of historic and current shoreforms was guided by a list of expected shoreform transitions (Table 4-7). These expected transitions were based on Shipman's Transition Narrative (7/31/2007) and review of results in Whidbey and South Puget Sound sub-basins. Any shoreform change not specified on this list was subject to additional scrutiny.

Table 4-7
Expected Shoreform Transitions

TO Shipman Shoreform

FROM Shipman Shoreform

	BLB	BAB	OCI	BE	BL	CLM	D	PL	RP	PB	MOD
BLB	Y	Y	N	N	N	N	N	N	N	N	Y
BAB	Y	Y	N	N	N	N	N	N	N	N	Y
OCI	N	N	Y	Y	N	N	N	N	N	N	Y
BE	N	N	N	Y	Y	Y	N	N	N	N	Y
BL	N	N	N	Y	Y	Y	N	N	N	N	Y
CLM	N	N	N	N	Y	Y	N	N	N	N	Y
D	N	N	N	N	N	N	Y	N	N	N	Y
PL	N	N	N	N	N	N	N	Y	N	N	Y
RP	N	N	N	N	N	N	N	N	Y	M	Y
PB	N	N	N	N	N	N	N	N	M	Y	Y
MOD	N	N	N	N	N	N	N	N	N	N	Y

Notes:
(Y)es (N)o (M)aybe

Because of the difference in approaches and classification methods, if there were ambiguities in classification, it was more important to determine whether a section of shoreline had changed than to try to determine the "correct" type. The following general rules were applied:

- If there was clearly no shoreline change, but the two shoreform types differed, the historic shoreform type was used for both current and historic.
- If there was a question about where to place breaks for shoreline change, (because only part of a contiguous shoreform type had changed), the current shoreline was used as a guide.
- Unless there was a shoreform change or obvious error, segment end point locations, in both the current and historic shoreline, were not changed.

4.4.2.3 Attribute Transfer from Historic to Current Shoreline

After historic and current linework were reviewed, the attributes from the historic shoreform data were transferred to the corresponding segments of the current shoreline. Once this process was complete, and the final data were intersected with the GSUs, it was possible to query each segment of the current shoreform data and find the historic shoreform type and its full length, or the length that was included within a specific GSU.

This process entailed the following:

- Assignment of a unique identifier to each section of contiguous historic shoreform.
- Assignment of a unique identifier to each section of historic shoreline that will correspond to a section of current. (A contiguous section of a single shoreform type may be split due modification of part of that shoreline in modern times.)
- Assignment of a unique identifier to each section of current shoreform.
- Transfer of the historic shoreform type and its length to attributes in the corresponding current shoreline segment.

4.4.2.3.1 On-line and Off-line Embayments

The current shoreline (ShoreZone) does not depict all of the current estuarine wetlands or embayments (BE, BL, CLM). To handle this discrepancy, an additional attribute in the current linework indicates the presence of these features as "off-line" wetlands and identifies their shoreform type.

If the current embayment was delineated by the shoreline linework, the corresponding historic embayment attributes were transferred to the primary ("on-line") historic shoreform fields. If the current embayment was not delineated by the shoreline linework, the corresponding historic embayment attributes were transferred to the embayment ("off-line") shoreform columns.

The length of the current off-line embayment was transferred from the University of Washington Puget Sound River History Project current wetlands data. The criteria for including a wetland boundary as part of the historic embayment were based on the same rules used for historic shoreform delineation.

Off-line embayment attributes were assigned to an entire homogeneous section of shoreline. The on-line shoreform was not split to indicate exactly where the off-line embayment occurs. It was adequate to know that there was (or is) an embayment associated with that stretch of beach.

4.4.2.4 NST Review (Fly-Bys)

Shoreform change data for each sub-basin were reviewed during a half-day meeting with a minimum of three NST members present, as well as participants from SSHIAP. The participants viewed current shoreforms, historic shoreforms, and the combined data with ancillary and source datasets, including historic T-sheets, aerial photos, and historic and current wetlands data. The reviews, called "fly-bys," had the following objectives:

- Provide the NST with an understanding of the historic and current shoreform data and the process used to develop shoreform change data.
- Get input from the NST on question areas, either site-specific or general methodological questions.
- Review all areas of shoreform transition as a QC measure.
- Review any other areas of interest specified by the NST.
- Develop or refine rules for situations of ambiguity in shoreform classification or shoreform change data development

Overall, the NST reviewed approximately 58 percent (2,250 km) of the total shoreline length. The discussions at these meetings were iterative, and sometimes a general rule developed at a previous meeting was reversed in a later meeting as participants became more familiar with the data, the process, and had more examples for consideration. The general rules and methods that came out of these fly-bys are described below.

4.4.2.4.1 Expected Transitions Matrix

The NST representatives reviewed a matrix of expected shoreform transitions at the first fly-by. Transitions that were not in this matrix were flagged during the QC process, and were given particular attention during review. The NST approved this list and it was subsequently updated in later fly-bys. Table 4-7 is the final approved matrix.

4.4.2.4.2 Barrier Beach Merge or Split

For barrier beaches that were discontinuous in one dataset (due to an on-line embayment) and continuous in the other (due to an off-line embayment), the

NST representatives approved this general rule: if the drift is the same direction, merge the discontinuous segments into one; if the drift is in opposite directions, split the continuous segment into two.

4.4.2.4.3 Created Shoreform

It was acceptable to have shoreline in the current shoreform that was not in the historic. These were assigned the Artificial (ART) shoreform. Examples in Whidbey sub-basin include Jetty Island at the mouth of the Snohomish River and a small "island" (of dredge material) at the southern end of the Swinomish Slough.

4.4.2.4.4 Current Shoreline Position

Sometimes the current shoreline (ShoreZone) mapped the backshore area, and the on-line and off-line shoreforms were the opposite of how they were mapped in the historic. When this occurred, they were swapped so that the beach shoreform was assigned to the line, and any embayment shoreform was off-line.

4.4.2.4.5 Rocky Shoreline in Current, not Historic

Often there were small bedrock islands that were mapped in the current shoreform, but not in the historic. It was assumed that the rock existed previously, but was not mapped on the historic T-sheets. Therefore, it was not a true transition. The NST requested that shoreforms stay the same to reflect the source data (rocky in current and none in historic), but that it should not show up as a transition.

4.4.2.4.6 Artificial/Modified Shoreline

There was extensive discussion regarding the definition of an artificial or modified shoreline. It was decided that the term Artificial was preferred to Modified. The definition is not based on function, rather it is based on the extent of obvious modification, such as dredging and fill. This extent can be determined by use of ancillary layers showing fill, or by areas where the shape and location of the shoreline has changed significantly. (Significant change was not rigorously defined, so some subjectivity is involved in classification of

Artificial shoreforms.) In the case of railroads, although there may have been some fill involved, in many cases, these shoreforms were not significantly changed in location, shape, or visible processes from the historic shoreform, and therefore were classified as a non-artificial beach type (such as Bluff-backed Beach). Road causeways that were commonly built along former spits across the mouths of embayments were mapped as Artificial (ART) along the outside and the inside of the causeway. If the rest of the embayment was not artificial, it was mapped as the appropriate embayment type.

4.4.3 Data Synthesis

After the review meeting, any changes requested during the fly-by were implemented. The changes were documented in a notes field in the attribute table.

Two fields were added to aid in the display of on- and off-line transitions.

Once the historic and current shoreform typologies on the current shoreline were finalized, the data were intersected with the GSU data. Because the shoreform delineation was an independent process from the GSUs, the lengths of each feature split up by the GSUs was calculated after this intersection step using lengths stored in the attribute table prior to intersection. The proportional lengths apply to both current and historic shoreforms, both on and off the ShoreZone shoreline. To accomplish this, the following calculations were performed:

- Current on-line shoreform GSU lengths are equal to the Shape Length calculated by the geodatabase. (C_LenGSU = Shape_Length)
- Current off-line embayment shoreform lengths are equal to the pre-intersection total embayment length multiplied by the pre-and post-intersection length ratio (C_LenEmbGSU = C_LenEmb * C_LenGSU / C_LenFull)
- Historic on-line shoreform GSU lengths are equal to the transferred continuous shoreform length multiplied by the pre-and post-intersection length ratio (H_LenGSU = H_LenFull * C_LenGSU / C_LenFull)
- Historic off-line embayment shoreform lengths are equal to the pre-intersection total embayment length multiplied by the pre-and post-intersection length ratio (C_LenEmbGSU = C_LenEmb * C_LenGSU / C_LenFull)

These GSU lengths are ultimately used to calculate historic and current shoreform lengths at multiple scales. During QC, these fields were also compared against the historic shoreform data in a series of tabular queries to verify that all historic shoreforms and their lengths were correctly transferred into the shoreform change attribute table (Appendix C).

Fields representing the percent change in length for both on- and off-line features were calculated as follows:

- Chg_PropLen_OnLine = (C_LenFull – H_LenFull)/H_LenFull
- Chg_PropLen_OffLine = (C_LenEmb – H_LenEmb/H_LenEmb

These percent changes in length reflect complete losses of shoreforms as well as lost lengths in shoreform.

Example Shoreform Transition Matrix

The primary output from the combined shoreform change dataset is the transition matrix, which itemizes the number of segments that have changed from the historic to current times (Table 4-8).

Table 4-8
Example Shoreform Transition Matrix

		Current Shoreform												Total
	Shoreform Type	BLB	BAB	D	BE	BL	CLM	OCI	PL	RP	PB	ART	None	
Historic Shoreform	Bluff-Backed Beach (BLB)		8									7		15
	Barrier Beach (BAB)	3										3		6
	Delta (D)											3		3
	Barrier Estuary (BE)													0
	Barrier Lagoon (BL)											4		4
	Closed Lagoon/Marsh (CLM)											1		1
	Open Coastal Inlet (OCI)													0
	Plunging Rocky Shoreline (PL)													0
	Rocky Platform (RP)													0
	Pocket Beach (PB)													0
	Artificial (ART)													0
	Shoreform Not Present (None)					1						5		6
	Total	**3**	**8**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**23**	**0**	**35**

4.4.4 Data Quality

The extensive review and QC applied to these data indicate that they are quite accurate and consistent between sub-basins. The shoreform data were developed specifically for the Change Analysis, so will be appropriate for project-specific analyses.

4.5 Armoring

4.5.1 Description

These data depict armored shoreline segments (bulkheads, riprap, concrete walls, etc.) delineated on the ShoreZone shoreline. Unlike most of the other data sets, there was no acceptable comprehensive dataset to delineate armoring throughout Puget Sound. The ShoreZone armoring data are comprehensive for the Puget Sound region, but the dataset does not locate the start and end points of armored sections of shoreline, rather it indicates the percentage of armoring along a geomorphic shoreline units.

The NST determined that, because information about shoreline armoring was so important for the Change Analysis, it was appropriate to gather data sets from numerous sources and synthesize them onto a single shoreline. Data were compiled from numerous county and regional surveys of shoreline armoring. In areas where data were lacking, ShoreZone armoring data were used and limited photo interpretation supported by field surveys were conducted (Anchor Environmental Consultant Team 2008c, provided as Appendix E).

4.5.2 Data Processing

Existing datasets depicting shoreline armoring locations in Puget Sound were gathered and compiled (Anchor Environmental Consultant Team 2008a, provided as Appendix A). For regions that did not have local mapping data, the ShoreZone shoreline was queried for segments that were completely unarmored (SM_TOT_PCT = 0) and segments that were completely armored (SM_TOT_PCT = 100). These datasets were combined and synthesized onto the ShoreZone shoreline. These data covered 92 percent of the shoreline in Puget Sound.

For the remaining shoreline of Puget Sound without armoring data (8 percent of Puget Sound shoreline), shoreline armoring locations were mapped using NAIP orthophotos and Ecology's oblique shoreline photos. A minimum mapping resolution of 30 meters was used during this assessment. In addition, a confidence level (low, medium, high) was assigned to each segment. Field verification, by boat, was conducted on most low and medium confidence segments (Anchor Environmental Consultant Team 2008c).

After the relevant source and field armoring data was synthesized onto the ShoreZone shoreline, a separate calculation of continuous armored and unarmored shoreline lengths was added to the spatial data, before the armoring lines were intersected with the GSU boundaries. This "hard-coding" of continuous length allows calculations of contiguous armoring length associated with a Process Unit, even if a portion of the armoring extends beyond the bounds of that PU.

4.5.3 Data Quality

Due to the variation in source datasets, data quality is variable throughout the Sound. Because most of the existing surveys were completed for regional projects, and usually included some field work, it is expected that these datasets are quite accurate. The ShoreZone assessment is a bit dated, and the shorelines indicated as having 0 percent armored could have been armored since the data were developed, but this dataset is appropriate for a regional assessment. Field assessment of the data developed for this project indicated a high level of accuracy.

4.6 Breakwaters/Jetties

4.6.1 Description

This dataset shows structures in the marine environment, usually rock fill, that are used to block waves. Typically, jetties are attached to the shore and perpendicular to longshore drift, and breakwaters are offshore and perpendicular to onshore drift.

4.6.2 Data Processing

WDNR's overwater structure data were reviewed and the data were updated with additional breakwaters/jetties based on interpretation of 2006 NAIP color orthophotos, supplemented by Ecology's oblique shoreline photos. In addition, breakwaters/jetties were reviewed with the ShoreZone shoreline to identify structures that were previously missed. Boundaries of existing breakwaters/jetties were corrected as necessary, and topological errors (such as duplicated polygons) were corrected.

The breakwater/jetty lines were spatially joined with shoreform change data to identify and attribute the closest shoreform segment to each breakwater/jetty.

4.6.3 Data Quality

Delineation and identification of breakwaters and jetties were improved, for project-specific purposes, through modifications of WDNR's source data by the Anchor QEA Consultant Team. The incoming WDNR overwater structure data contained numerous topological problems and inconsistencies in attribution. All topological errors and most attribution errors/inconsistencies were addressed, but a comprehensive assessment and correction of the dataset was considered outside of scope. Data are limited to those structures present prior to 2006, the most recent date of the source aerial photography, and features are limited to those that can be visually identified with 1-meter resolution color photography.

4.7 Marinas

4.7.1 Description

This dataset includes overwater structures, jetties/breakwaters, and adjacent aquatic areas providing facilities for boaters. The data include marinas that have at least 10 boat slips.

4.7.2 Data Processing

WDNR overwater structures polygon data were updated using 2006 NAIP color orthophotos and oblique aerial photos to identify marinas. Footprints of marinas with 10 or more boat slips were improved, all boat slips were included as part of the marina's overwater coverage (i.e., it was assumed all boat slips were filled), and unshaded water areas at marinas were added as part of the marina footprint. Breakwaters/jetties associated with the marina were also included as part of the marina footprint. The marina polygons were spatially joined with shoreform change data to identify and attribute the closest shoreform segment to each marina.

4.7.3 Data Quality

Delineation and identification of marinas were improved through modifications of WDNR's source data by Anchor QEA Consultant Team. The incoming WDNR overwater structure data contained numerous topological problems and inconsistencies in attribution. All topological errors and most attribution errors/inconsistencies were addressed, but a comprehensive assessment and correction of the dataset was considered outside of scope. Data are limited to those marinas present prior to 2006, the most recent date of the source aerial photography, and features are limited to those that can be visually identified with 1-meter resolution color photography.

4.8 Nearshore Fill

4.8.1 Description

This polygon feature class depicts areas of anthropogenic nearshore fill within 200 meters of the current shoreline. The 200 meter boundary is due to the mapping extent of source data, Department of Ecology's Coastal Zone Atlas.

4.8.2 Data Processing

These data were derived from scanned images of the hard-copy Coastal Zone Atlas pages. In the source data, artificial fill polygons were hand-drawn onto 1:24,000 scale USGS topographic maps. The scanned images were georeferenced to USGS Digital Raster Graphics (georeferenced images of topographic maps). Areas marked with "af" (artificial fill) were digitized from the georeferenced maps, projected to the project's coordinate system, and intersected with the GSU dataset. Areas marked "af" that were determined to be levees/dikes were not included, as those structures are characterized in the Tidal Barriers dataset.

4.8.3 Data Quality

The spatial accuracy of the source data, and thus the digital version is highly variable. Because the 1:24K DRGs have been updated since 1980, not every Coastal Zone Atlas page lined up perfectly when georeferencing. Differences were not often substantial overall but in some case shorelines had changed considerably due to erosion and deposition. An attempt was made to keep the root mean square error as close to 0 as possible and always below 5 when georeferencing but in some instances corrections from the 1980 topography maps to the 2008 topography maps were dramatic. These situations were usually due to misalignments of portions of the 1980 topography maps. When these situations were encountered, considerably more control points were used in order to align all portions of the topography maps accurately. This sometimes led to root mean square errors above 5 but resulted in georeferencing that appeared visually appropriate based on alignment of features between the 1980 topography maps and the 2008 versions.

The extent of nearshore fill is limited to the area that was mapped by the Coastal Zone Atlas – regions within 200 meters of the shoreline. Therefore, areas with extensive fill, such as urban areas and deltas, may not show all areas that have been filled. Some areas classified as nearshore fill may overlap areas classified as overwater structures; the two datasets are of independent origin and were not evaluated for overlap.

4.9 Overwater Structures

4.9.1 Description

This dataset delineates structures that extend over marine and estuarine waters of Puget Sound, including docks, bridges, marinas, buoys, and ferry terminals. Marinas' unshaded water areas are not included, unlike in the marinas dataset.

4.9.2 Data Processing

WDNR's overwater structure data were reviewed and the data were updated with additional overwater structures based on interpretation of 2006 NAIP color orthophotos, supplemented by Ecology's oblique shoreline photos. Boundaries of existing overwater structures were corrected as necessary, and extensive topological errors (such as duplicate overlapping polygons) were corrected.

After the updates, the relevant overwater structures were extracted using attributes from the source data and the updated data. From WDNR source data, the following structure types (St_Type) were removed: Building or Fill. In addition, structures identified as Aquaculture, Breakwater/Riprap, Building, Clustered Pilings, Landfill (in OS_Detail2), were omitted from the final data. From the updated data attributes, the following structure types (in a temporary field, "NEW_ST_TYPE") were included: Null, BREAKWATER, WOOD, FLOATING, BRIDGE, COLLAPSED DOCK, DOCK, DOCK/PIER, FERRY TERMINAL, FLOATING DOCK, FOOTBRIDGE, MARINA, COVERED DECKS/SLIPS, DECKS/SLIPS, PIER, PILING, PRIVATE DOCK, RAFT, RAILROAD TRACKS, and STAIRS. These structures were then grouped into one of the six final structure types: Bridge, Buoy/Float, Dock/Pier, Ferry Terminal, Marina, and Other.

4.9.3 Data Quality

Delineation and identification of overwater structures was improved through modifications to WDNR's source data by the Anchor QEA Consultant Team. The incoming WDNR overwater structure data contained numerous topological problems and inconsistencies in attribution. All topological errors and most attribution errors/inconsistencies were addressed, but a comprehensive assessment and correction of the dataset was considered outside of scope. Data are limited to those structures present prior to 2006, the most recent date of the source aerial photography, and features are limited to those that can be visually identified with 1-meter resolution color photography. Some areas classified as overwater structures may overlap areas classified as nearshore fill; the two datasets are of independent origin and were not evaluated for overlap.

4.10 Railroads, Abandoned (Nearshore Only)

4.10.1 Description

This dataset includes abandoned railroad track locations within 25 meters of the ShoreZone shoreline.

4.10.2 Data Processing

The WDOT railroad data were spatially subset to include only railways within 25 meters of the ShoreZone shoreline. Due to spatial inconsistencies between the railroads dataset and the shoreline, railroads that appear to be in the waterward area of the GSUs were retained.

4.10.3 Data Quality

Source data from WDOT are over 10 years old, and were originally digitized from 1:24,000 quadrangle maps. However, these are the only comprehensive data depicting railroads in the region of interest. Locations and use of rail lines are not that dynamic, and therefore, these data should be acceptable for project purposes.

4.11 Railroads, Active (Nearshore Only)

4.11.1 Description

This dataset includes railroad track locations, currently in use, within 25 meters of the ShoreZone shoreline.

4.11.2 Data Processing

The WDOT railroad data were spatially subset to include only railways within 25 meters of the ShoreZone shoreline. Due to spatial inconsistencies between the railroads dataset and the shoreline, railroads that appear to be in the waterward area of the GSUs were retained.

4.11.3 Data Quality

Source data from WDOT are over 10 years old, and were originally digitized from 1:24,000 quadrangle maps. However, these are the only comprehensive data depicting railroads in the region of interest. Locations and use of rail lines are not that dynamic, and therefore, these data should be acceptable for project purposes.

4.12 Roads (Nearshore Only)

4.12.1 Description

This dataset includes roads within 25 meters of the ShoreZone shoreline as line features, with the WDNR road-class field retained in the dataset.

4.12.2 Data Processing

The WDNR road data was subset to include only roads within 25 meters of the ShoreZone shoreline. Due to spatial inconsistencies between the roads dataset and the shoreline, roads that appear to be in the waterward area of the GSUs were retained.

4.12.3 Data Quality

The WDNR transportation dataset includes many smaller roads and forest roads that are not in other roads datasets. Because these data are comprehensive for the region of interest and are extensively used by numerous natural resource agencies, it is expected that their data quality is of a level that is acceptable to support project analyses.

4.13 Tidal Barriers

4.13.1 Description

This dataset delineates dikes, levees, roads, and other man-made structures that impede tidal hydrology such that historic wetlands are lost or become isolated from nearshore waters.

4.13.2 Data Processing

SSHIAP used LiDAR, ortho and aerial oblique photos, transportation layers and an existing levee dataset to identify and digitize dikes, levees, roads and other man-made structures that impede tidal hydrology such that historic wetlands become lost or isolated from Puget Sound nearshore waters. This inventory was limited to the 16 large river deltas, barrier estuaries, barrier lagoons, and open coastal inlets that contain historic wetland among the 4 NST designated classes (according to the historic shoreform typology).

Only the outermost tidal barriers in an embayment, defined as those barriers which would be encountered first by an incoming tide, were digitized for the Change Analysis.

Areas of fill were excluded except in two situations. First, if the fill was contiguous with a tidal barrier, the outer boundary of fill was digitized such that tidal barrier line could be "closed" to infer an area impounded from tidal influence. Second, if a road, railroad, or other topographically elevated structure was evident in front of the fill, the outer boundary of fill was digitized.

4.13.3 Data Quality

Data quality for tidal barriers is indicated by confidence intervals (low, medium, high). Tidal barrier structures identified have a relatively high level of temporal accuracy because of the recent content dates of the spatial data used in the digitization effort. Because digitization efforts were limited to the intertidal areas associated with the embayment and delta classes of historic shoreforms, these data do not represent a complete sound-wide tidal barriers dataset.

4.14 Wetlands, Historic

4.14.1 Description

This dataset consists of historic tidal wetlands (circa late 1800s), developed from interpretation of historic surveys (T-sheets and General Land Office surveys). The wetland classes from the source data were grouped into four categories using the NST's salinity-based classification (ordered from greatest salinity to least): euryhaline unvegetated (EU), estuarine mixing (EM), oligohaline transition (OT), and tidal freshwater (TF).

4.14.2 Data Processing

The University of Washington Puget Sound River History Project developed the source data from historic T-sheets, supplemented with field notes and plat maps from 19th century government land survey and various other sources including other early maps, aerial photographs, early text sources, and recent data including high-resolution DEMs.

Some of the extensive intertidal areas associated with deltas were not included in the University of Washington Puget Sound River History Project data. Specifically, the intertidal areas in Samish Bay, Padilla Bay, Skagit Bay, Stillaguamish Delta, and Snohomish Delta were digitized from historic H-sheets. These intertidal areas were assigned to the euryhaline unvegetated class and merged with the rest of the historic wetland polygons.

The historic LULC classes were grouped into one of the four estuarine wetland categories according to the scheme, defined by a subset of the NST, presented in Table 4-9.

Table 4-9
Wetland Categories Assigned to Historic Land Use/Land Cover Classifications

RHP LULC	Wetland Class
CH/EEM	Estuarine mixing
CH/EEM/BAR	Estuarine mixing
CH/EEM/IT	Estuarine mixing
CH/EEM/WOOD	Estuarine mixing
CH/ESS	Oligohaline transition
CH/ESS/BAR	Oligohaline transition
CH/ESS/WOOD	Oligohaline transition
CH/ST	Euryhaline unvegetated
CH/ST/BAR	Euryhaline unvegetated
CH/TF	Tidal freshwater
CH/TF/BAR	Tidal freshwater
CH/TF/WOOD	Tidal freshwater
COB/BL	Euryhaline unvegetated
COB/BS	Euryhaline unvegetated
EEM	Estuarine mixing
EEM_LOW	Estuarine mixing
ESS	Oligohaline transition
GR/BL	Euryhaline unvegetated
GR/BS	Euryhaline unvegetated
IT	Euryhaline unvegetated
IT/BAR	Euryhaline unvegetated
IT/WOOD	Euryhaline unvegetated
LAG-C	Estuarine mixing
LAG-O	Estuarine mixing
LAG/EEM-C	Estuarine mixing
LAG/EEM-O	Estuarine mixing
MUD/BS	Euryhaline unvegetated
REEF	Euryhaline unvegetated
REM	Tidal freshwater
RFO	Tidal freshwater
RSS	Tidal freshwater
SND/BL	Euryhaline unvegetated

In generating Delta Process Units (DPUs) only, historic wetland types outside the main delta wetland body were assumed to be above head of tide and removed from the GSUs. However, those intertidal wetlands outside the main wetland body of the

DPU—technically falling within the "Basin" drainage of the DPU—were retained in the historic wetlands data.

Particularly pertinent were areas typed as CH/* ("Channel/...") which can extend far inland above head of tide on some T-sheets. Channel "CH" types not listed in Table 4-9 were deemed to lack tidal influence and were removed from the Change Analysis databases.

4.14.3 Data Quality

Details of data development are described in Collins and Sheikh (2005). This is the only comprehensive dataset delineating historic wetlands in Puget Sound. Historic maps have a lower positional accuracy than modern maps, and it is difficult to validate an historic classification with other datasets from modern times. Both the current and historic wetlands data were developed by the same project, so they are consistent and comparable for an assessment of wetland change. Geo-referenced Hydrographic sheets (H-sheets) from the same era as the T-sheets were used to provide a "low-water" line in deltas where the T-sheets and the River History Project data did not have one (see Appendix C, wetlands section).

4.15 Wetlands, Current

4.15.1 Description

This dataset depicts current tidal wetlands mapped from orthophotos, National Wetlands Inventory and other sources. The wetland classes from the source data were grouped into four categories using the NST's salinity- based classification (ordered from greatest salinity to least): euryhaline unvegetated (EU), estuarine mixing (EM), oligohaline transition (OT), and tidal freshwater (TF).

4.15.2 Data Processing

The University of Washington Puget Sound River History Project developed the source data by digitizing orthophotos from 1998-2004, supplemented with reference to the digital National Wetlands Inventory and other sources, including ShoreZone shoreline, oblique photos, LiDAR, and DLG data.

The current LULC classes were grouped into one of the four estuarine wetland categories according to the scheme, defined by a subset of the NST, presented in Table 4-10.

Table 4-10
Wetland Categories Assigned to Current Land Use/Land Cover Classifications

RHP LULC	Wetland Class
CH\EEM	Estuarine mixing
CH\ESS	Oligohaline transition
EEM	Estuarine mixing
EEM\ESS	Estuarine mixing
EEM\GRA	Estuarine mixing
EEM\PEM	Estuarine mixing
EEM\PEM\WOOD	Estuarine mixing
EEM\WOOD	Estuarine mixing
EEM\WOOD\SGR	Estuarine mixing
EEM_LOW	Estuarine mixing
ESS	Oligohaline transition
ESS\GRA	Oligohaline transition
ESS\WOOD	Oligohaline transition
EST	Estuarine mixing
EST\AGR	Estuarine mixing
EST\CH	Estuarine mixing
EST\LAG\EEM-O	Estuarine mixing
EST\MUDFLAT	Estuarine mixing
EST\SGR	Estuarine mixing
GRA\EEM	Estuarine mixing
GRA\REM	Tidal freshwater
INT	Euryhaline unvegetated
INT\EST	Estuarine mixing
LAG-C	Estuarine mixing
LAG-C\PFO	Estuarine mixing
LAG-C\PON	Estuarine mixing
LAG-C\WOOD	Estuarine mixing
LAG-O	Estuarine mixing
LAG-O\EST	Estuarine mixing
LAG\EEM-C	Estuarine mixing
LAG\EEM-O	Estuarine mixing
LAG\EEM-O\EST	Estuarine mixing

RHP LULC	Wetland Class
LAG\EEM-O\WOOD	Estuarine mixing
LAG\WOOD	Estuarine mixing
PON\RES	Tidal freshwater
REM	Tidal freshwater
REM\RFO	Tidal freshwater
REM\RSS	Tidal freshwater
RES	Tidal freshwater
RES\DI	Tidal freshwater
RFO	Tidal freshwater
RFO\ESS	Tidal freshwater
RFO\RSS	Tidal freshwater
RSS	Tidal freshwater
RSS\REM	Tidal freshwater
RSS\RFO	Tidal freshwater
RSS\SGR	Tidal freshwater
RSS\SS	Tidal freshwater
SALMON BAY	Estuarine mixing
SALTPOND\LAG\EEM-C	Estuarine mixing
SGR\EEM	Estuarine mixing
SS\REM	Tidal freshwater
WOOD\LAG-C	Estuarine mixing
WOOD\LAG\EEM-C	Estuarine mixing
WOOD\LAG\EEM-O	Estuarine mixing
WOOD\SGR\EEM	Estuarine mixing

4.15.3 Data Quality

Details of data development are described in Collins and Sheikh (2005). This is a comprehensive dataset delineating current wetlands in Puget Sound. The advantage of using this dataset for current wetlands is that both the current and historic wetlands data were developed by the same project, so they are consistent and comparable for an assessment of wetland change.

4.16 Impervious Surfaces

4.16.1 Description

This dataset depicts estimated percentages of impervious surface by 30-meter pixel, grouped into 4 ranges, 0-10 percent, 10-30 percent, 30-50 percent and 50-100 percent.

4.16.2 Data Processing

As part of the source NLCD data methods, imperviousness percentage values for each pixel were derived from 30-meter Landsat TM satellite imagery. The method employed to map percent imperviousness for NLCD 2001 mapping (in zone 01) consisted of three key steps: deriving reference data of imperviousness from high spatial resolution images, calibrating density prediction models using reference data and Landsat spectral bands, and extrapolating the developed models spatially to map per-pixel imperviousness. This method is described in detail in Yang et al. (2003). Space Imaging applied this method to mapping zone 01, which includes the Puget Sound project area.

Original percent impervious values were grouped into 4 classes: 0-10 percent, 10-30 percent, 30-50 percent, and 50-100 percent. Raster data were converted to vector data.

4.16.3 Data Quality

The Landsat TM imagery is slightly dated, especially considering the amount of recent development in the Puget Sound area. Despite the age of the data, it is a good relative characterization of percent impervious surface. No formal accuracy assessment was completed by MRLC, but a cross-validation was done that indicated an accuracy of 86.2 percent.

4.17 Land Cover

4.17.1 Description

This dataset depicts National Land Cover Data (NLCD; Homer et al. 2004 and 2007, and Huang et al. 2002) land cover classes as derived from satellite data and classified into one of 16 classes (Table 4-11).

Table 4-11
Land Cover Classes

Land Cover Classes
Developed, High Intensity
Developed, Medium Intensity
Developed, Low Intensity
Developed, Open Space
Emergent Herbaceous Wetlands
Woody Wetlands
Herbaceous
Evergreen Forest
Deciduous Forest
Mixed Forest
Scrub/Shrub
Open Water
Perennial Snow/Ice
Cultivated Crops
Hay/Pasture
Barren Land

4.17.2 Data Processing

The source land cover raster was converted to vector format and the feature class was reprojected to NAD-83 UTM Zone 10N, meters. For a small area in Canada, Canadian land cover classes were cross-walked to the NLCD 16 land cover classes and combined with the U.S. land cover data (Table 4-12).

Table 4-12
United States and Canadian Land Cover Classes

Canada		United States	
BTM Code	**BTM Classification**	**NLCD Code**	**NLCD Classification**
NONE	Outside B.C.	0	--
LAKE	Lakes	1	Open Water
RIV	Rivers, double line	1	Open Water
WFRE	Fresh water	1	Open Water
WSAL	Salt Water	1	Open Water
ICE	Glaciers and Snow	2	Perennial Snow/Ice
TRAN	Transmission line corridor	3	Developed, Open Space
HWY	Highways	4	Developed, Low Intensity
URB	Urban	4	Developed, Low Intensity
BARE	Barren Surfaces	7	Barren Land
BURN	Recently Burned	7	Barren Land
MINE	Mining	7	Barren Land
FO	Old forest	10	Mixed Forest
FY	Young forest	10	Mixed Forest
LOG	Recently Logged	10	Mixed Forest
LOGS	Selectively Logged	10	Mixed Forest
REC	Recreation activities	10	Mixed Forest
SHRB	Shrubs	11	Shrub/Scrub
ALP	Alpine	12	Herbaceous
AVA	Sub alpine Avalanche Chutes	12	Herbaceous
AGMX	Residential Agriculture Mixtures	13	Hay/Pasture
RANG	Range lands	13	Hay/Pasture
AGR	Agriculture	14	Cultivated Crops
EST	Estuaries	16	Emergent Herbaceous Wetlands
WET	Wetlands	16	Emergent Herbaceous Wetlands

4.17.3 Data Quality

The imagery used for these data sources are a bit dated (1999–2001), but are the only comprehensive land cover data that cover the region of interest. According to an accuracy assessment performed by Space Imaging on the original NLCD, the overall classification accuracy is 86.1 percent and 85.0 percent Kappa. This assessment was based on field and photo-interpreted validation points. There were 1,043 validation points located in Washington.

4.18 Railroads, Abandoned (Watershed Wide)

4.18.1 Description

This dataset depicts abandoned railroad track locations buffered to the average right-of-way width.

4.18.2 Data Processing

The linework was buffered to create a polygon dataset depicting an average railroad right-of-way width (20 meters).

4.18.3 Data Quality

Source data from WDOT are over 10 years old, and were originally digitized from 1:24,000 quadrangle maps. However, these are the only comprehensive data depicting railroads in the region of interest. Locations and use of rail lines are not that dynamic, and therefore, these data should be acceptable for project purposes.

4.19 Railroads, Active (Watershed Wide)

4.19.1 Description

This dataset includes railroad track locations, currently in use, buffered to right-of-way width.

4.19.2 Data Processing

The linework was buffered to create a polygon dataset depicting an average railroad right-of-way width (20 meters).

4.19.3 Data Quality

Source data from WDOT are over 10 years old, and were originally digitized from 1:24,000 quadrangle maps. However, these are the only comprehensive data depicting railroads in the region of interest. Locations and use of rail lines are not that dynamic, and therefore, these data should be acceptable for project purposes.

4.20 Roads (Watershed Wide)

4.20.1 Description

This dataset depicts roads buffered with widths that correspond to the estimated mean road width according to road class.

4.20.2 Data Processing

WDNR road class code was used to determine approximate road widths. WDNR road classification codes (ROAD_CLASS_CD) were based on generalized USGS road classification codes. The mean road widths were from Hawbaker and Radelhoff (2004).

- USGS 1 = WDNR ROAD_CLASS_CD 1: mean road width (m) = 32.0: Primary highway/all-weather/hard surface.
- USGS 2 = WDNR ROAD_CLASS_CD 2: mean road width (m) = 32.0: Secondary highway/ all-weather/ hard surface.
- USGS 3 = WDNR ROAD_CLASS_CD 3: mean road width (m) = 15.7: Light-duty road/ all-weather/ improved surface.
- USGS 4 = WDNR ROAD_CLASS_CD 4: mean road width (m) = 9.9: Unimproved road/ fair or dry weather.
- USGS 5 = WDNR ROAD_CLASS_CD 9: mean road width (m) = 4.8: WDNR's "Unknown" (very few roads are attributed as such)

Lines were eliminated where WDNR ROAD_CLASS_CD = NULL because lines assigned a NULL value appeared to be some railroads, (accounted for in a separate, dedicated, and more comprehensive dataset), and some trails. Canadian road categories were mapped to the same classification as the WDNR data using the scheme presented in Table 4-13.

Table 4-13
WDNR Road Classification Assigned to Each Canadian Road Class

CANADA_ROADCLASS	WDNR_ROAD_CLASS	Mean Width (m)
Freeway	1	32.0
Expressway / Highway	2	32.0
Arterial	2	32.0
Collector	3	15.7
Local / Street	3	15.7
Local / Strata	3	15.7
Local / Unknown	3	15.7
Alleyway / Lane	4	9.9
Ramp	3	15.7
Resource / Recreation	5	4.8
Rapid Transit	3	15.7
Service Lane	4	9.9
Winter	5	4.8

The road lines were buffered to form polygons with widths based on these road classes.

4.20.3 Data Quality

The WDNR transportation dataset includes many smaller roads and forest roads that are not in other roads datasets. Because these data are comprehensive for the region of interest and are extensively used by numerous natural resource agencies, it is expected that their data quality is of a level that is acceptable to support project analyses.

4.21 Stream Crossings (polygons)

4.21.1 Description

This dataset depicts the area where roads cross over streams, based on WDNR's transportation and hydrography data sets. These data were created by buffering the stream mouth points according to the estimated road width.

4.21.2 Data Processing

Road data were intersected with hydrography data to output point locations for stream crossings. These points were buffered to create a circular polygon with a diameter equal to the width of the road crossing it (based on WDNR road classes). Stream crossing buffers that overlapped were combined into single polygons.

4.21.3 Data Quality

Data quality of the stream crossings is dependent upon the source layers. The WDNR transportation dataset includes many smaller roads and forest roads that are not in other roads datasets. For the hydrography data, out of three data layers evaluated, the WDNR data was the most consistent and is updated monthly. Because these layers are comprehensive for the region of interest and are extensively used by numerous natural resource agencies, it is expected that their data quality is of a level that is acceptable to support project analyses.

4.22 Dams (Impoundments)

4.22.1 Description

These data depict point locations of dams that capture and store at least 10 acre-feet of water. The size is based on the criteria used to develop the source data sets.

4.22.2 Data Processing

Points were removed from the source Ecology dams point file that were duplicates, including those that overlapped or were multiple parts of the same dam complex. Dams were removed that were clearly in the wrong place, as determined from available LiDAR, aerial imagery, or other information.

The dam that was the furthest downstream on a particular stream fork was visually determined and assigned “Y” to Downstream attribute. All dams were retained in order to be counted in the tabulations. However, for quantifying the total drainage area that was impounded within a Process Unit, it was necessary to use only the drainage area from the dam that was furthest downstream because these values were cumulative for each dam.

4.22.3 Data Quality

The dam data were thoroughly reviewed and modified for project-specific purposes, and therefore the data quality was improved. The values for impoundment area are from the source data and were not evaluated for accuracy, so the quality is dependent upon source data. The data are statewide, but include only larger dams.

4.23 Historic Drainages

4.23.1 Description

This dataset is a delineation of the historic drainage boundaries for the sixteen large river deltas in Puget Sound. The drainage for the Duwamish and Puyallup River deltas were significantly modified from historic to current times. All other drainages are delineated identically for historic and current eras.

4.23.2 Data Processing

In South Central Puget Sound, the replumbing of several rivers has altered the river systems to which portions of watersheds contribute. Modifications to the boundaries of the GSUs were made to reflect the following changes:

1. The rerouting of the White River to flow into the Puyallup River instead of the Green River
2. The rerouting of the Cedar and Black Rivers to force the Cedar River flow into Lake Washington and the Black River to become a tributary to the Duwamish River

Maps and descriptions of the historic river routes presented in Collins and Sheikh (2002, 2003, 2004, 2005) were used to interpret historic drainages prior to the river routing modifications/changes in the Green, White, Black, Cedar and Duwamish river systems.

To reflect the historic watershed of the Cedar River contributing to the Duwamish River DPU, the entire Lake Washington DU that was originally derived from the DEM was assigned to the Duwamish River rather than its current flow path out Lake Union and the Ballard Ship Canal. For all other sub-basins, no major rivers have been re-routed to warrant similar adjustments to the historic drainage area.

4.23.3 Data Quality

Drainage delineation is based on 10-meter DEM and interpretation of historic river drainage maps. Therefore, delineations are only as accurate as these sources. The DEMs are known to have some inaccuracies, but are adequate for the scale of this analysis.

4.24 Drift Cells

4.24.1 Description

This dataset is a characterization of net shore-drift in Puget Sound. The drift cell data represents the sediment transport processes along the shoreline. Net shore-drift is assigned to one of five categories: Right-to-Left (RtoL), Left-to-Right (LtoR), Convergence Zone (CZ), Divergence Zone (DZ), or NAD (No Appreciable Drift). A single drift cell usually contains several components: a directional drift component (RtoL or LtoR) and one or more other components (CZ, DZ, and NAD). CZ and DZ components are shared by adjacent drift cells, and NAD may be shared, depending on the direction of net shore-drift of the adjacent components.

The drift cell dataset is one of the foundation layers for the development of the Geographic Scale Units (GSUs). The end points of each drift cell component were used to guide the boundaries for the GSUs, however, due to imprecision of the drift cell geometry, the GSU boundaries, by design, do not align precisely with the drift cell end points.

4.24.2 Data Processing

The Department of Ecology's source dataset is a digitized version of net shore-drift mapping conducted by approximately ten graduate students of Dr. Maurice Schwartz at Western Washington University. The mapping was conducted between the late 1970s and early 1990s.

In 2008, for this project, the Corps contracted Coastal Geologic Services (CGS) to revise the Ecology drift cell dataset in the following ways:

3. Fill in data gaps in areas mapped as UN (undefined) or blank
4. Correct data in areas where net shore-drift was mapped in regions where no net shore-drift occurs

5. Interpret historic net shore-drift for those areas characterized in Ecology based on current drift conditions caused by large anthropogenic alterations (e.g., jetties, dikes, and dredge/fill)

Detailed information about the processing completed by CGS is provided in Appendix D.

4.24.3 Data Quality

Because different regions were developed by different individuals, the data quality varies between regions. Source data were compiled onto 1:24,000 quadrangle maps and transferred to the 1:24,000 marine shoreline, so positional accuracy and alignment with the current shoreline data is variable. In some places the data is coarser than others; some smaller soft sediment embayments are simply swept up with the prevailing directional drift, while others are singled out and given NAD values. Because of the relatively coarse horizontal accuracy of the source data, the drift cells are included in the geodatabase for reference purposes, not for calculations. The "Current Shoreline" feature (Section 4.3) is used to calculate the "Drift component length/Shoreline length" metric.

The review and modifications by CGS validated and improved the overall attribute accuracy of the data. These modifications were not a comprehensive QA/QC of the drift cell dataset, which has numerous errors resulting from misinterpreting coarse-scaled original mapping, occasional errors or inconsistencies in original mapping, frequent digitizing errors (including some small topological gaps between segments), and a lack of geomorphic oversight or QA/QC during the digitization process. However, the CGS work focused on correcting the most common problems in the existing digital net shore-drift database. For the broad scale analysis of the Change Analysis, the Corps and the NST determined that any shortcomings of the dataset were acceptable and would not affect the Change Analysis interpretation of nearshore conditions.

4.25 Fish Passage Barriers

4.25.1 Description

This dataset includes location, type, and status of road-based stream crossing structures, dams, and miscellaneous instream structures that prevent or inhibit fish passage as surveyed and identified in the Washington Department of Fish and Wildlife's Fish Passage Barrier Inventory.

4.25.2 Data Source(s)

Washington Department of Fish and Wildlife, Fish Passage Barrier Inventory

4.25.3 Data Processing

Source data are a subset of data from Washington Department of Fish and Wildlife's (WDFW) Fish Passage and Diversion Screening Inventory (FPDSI) database. The data were collected according to the Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual (WDFW, 2000). This manual is available in PDF format at <http://wdfw.wa.gov/hab/engineer/fishbarr.htm>. Detailed descriptions and definitions for the attributes contained in this dataset may be found in the manual. Additionally, the manual explains the fish passage barrier assessment process and what constitutes a barrier for selected feature types.

For project purposes, all fish passage inventory points (Dams, Misc_Barriers, Road_Crossings) were combined into one dataset. Points having a Barrier Status of "Yes" or "Unknown" were retained.

4.25.4 Data Quality

The WDFW's Fish Passage Barrier data are statewide in scope but do not represent a comprehensive or complete inventory of fish passage barriers. The dataset is updated continually as inventory efforts are ongoing. Recent positional data is collected using GPS technology and has an accuracy of 5 meters or better. Prior to GPS use, data were plotted using 1:24000 USGS quadrangle maps and these locations have an accuracy of 100 meters or better.

4.26 Land Ownership (Public, Private, Tribal)

4.26.1 Description

This dataset is a delineation of public, private, and tidal uplands, compiled by The Nature Conservancy as part of their Conservation Management Status database.

4.26.2 Data Processing

To develop the source data, the TNC synthesized land ownership and conservation status from various sources, including: the WDNR Non-DNR Major Public Lands (NDMPL) database, CommEn Space's Protected Lands database, WDNR CADASTRE.PARCEL data, and NOAA's Marine Managed Areas of the United States: State of Washington Digital Boundaries.

For the Change Analysis, TNC's ownership attributes were grouped into three classes: Public (Owner = Federal, State, County, or Municipal), Private (Owner = Private), Tribal (Owner = Tribal). Any areas without data were assumed to be private lands and were categorized as such.

4.26.3 Data Quality

Due to the compilation of multiple input datasets with inaccuracies in boundary delineation, the source data contained numerous, small overlapping polygon "slivers." Using ArcGIS topology tools, these slivers were removed in order to avoid double-counting of these small areas.

Although these data are the most current compilation of the multiple datasets depicting land ownership, there are some discrepancies between these data and current WDNR cadastre datasets. The data are also lacking current WDNR aquatic ownership parcels. The data are not comprehensive – there were many areas that were not mapped that are expected to be primarily private land, but may contain some public ownership areas. Therefore, these data should not be used as a definitive spatial delineation of land ownership. As a relative assessment of public, private, and tribal ownership area, the data are of acceptable quality.

4.27 Parcels

4.27.1 Description

These data depict the waterward boundary line of upland land ownership parcels. The purpose for creating this dataset was to provide an estimate of the density of waterfront parcels.

4.27.2 Data Processing

Parcel polygons were converted to lines, and all lines were removed except for the lines corresponding to the waterfront edge of the parcel. Short lines representing road ends were added where necessary. (These road ends, and various odd parcel ends and corners, make for a few very short line lengths in some places). A unique identifier was assigned to each source parcel line in order to facilitate the parcel count.

For parcels in the DPU areas, the agricultural parcels that were created through tidal barriers (levees, dikes) were removed. To identify agriculture, raster land cover values of "Hay/Pasture" or "Cultivated Crops", or zoning or land use attributes in the parcels themselves that might identify agricultural use were reviewed. Tidal barrier delineation datasets from SSHIAP were also used and compared against historic T-sheet polygons.

4.27.3 Data Quality

Parcel data quality varies from county to county, but is expected to be at an accuracy that is appropriate for calculating the described metric.

4.28 Protected Lands

4.28.1 Description

This dataset includes land protection status grouped into two classes, (Poor/Fair or Good/Very Good), as determined by TNC. These are the same areas that were delineated for Land Ownership, with protection status categorization applied.

4.28.2 Data Processing

To develop the source data, the TNC synthesized land ownership and conservation status from various sources, including: the WDNR Non-DNR Major Public Lands (NDMPL) database, CommEn Space's Protected Lands database, WDNR

CADASTRE.PARCEL data, and NOAA's Marine Managed Areas of the United States: State of Washington Digital Boundaries.

TNC's CONSTAT attribute is a measure of the potential for protection and management activities on lands and waters to secure biodiversity to persist. This measure takes into account the protection or management intent, duration and authorization, and the potential for management to be effective for biodiversity and threats.

For the Change Analysis, TNC's CONSTAT attributes were grouped into two classes: Poor/Fair and Good/Very Good.

4.28.3 Data Quality

Due to the compilation of multiple input datasets with inaccuracies in boundary delineation, the source data contained numerous, small overlapping polygon "slivers" Using ArcGIS topology tools, these slivers were removed in order to avoid double-counting of these small areas. Although these data are the most current compilation of the multiple datasets depicting land ownership, there are some discrepancies between these data and current WDNR cadastre datasets. The data are also lacking current WDNR aquatic ownership parcels. The data are not comprehensive – there were many areas that were not mapped. Therefore these data should not be used as a definitive spatial delineation of land ownership.

4.29 Stream Crossings (points)

4.29.1 Description

This dataset depicts the point locations where roads cross over streams, based on WDNR's transportation and hydrography data sets.

4.29.2 Data Processing and QA/QC

Road data were intersected with hydrography data to output point locations for stream crossings. These points were buffered to create a circular polygon with a diameter equal to the width of the road crossing it. Stream crossing buffers that overlapped were combined into single polygons.

4.29.3 Data Quality

Data quality of the stream crossings is dependent upon the source layers. The WDNR transportation dataset includes many smaller roads and forest roads that are not in other roads datasets. For the hydrography data, out of three data layers evaluated, the WDNR data was the most consistent and is updated monthly. Because these layers are comprehensive for the region of interest and are extensively used by numerous natural resource agencies, it is expected that their data quality is of a level that is acceptable to support project analyses.

4.30 Stream Mouths

4.30.1 Description

This point feature class depicts the location of stream mouths where they intersect with the ShoreZone shoreline.

4.30.2 Data Processing

Stream lines were intersected with the ShoreZone shoreline, retaining points where they cross. Those streams that did not intersect the ShoreZone shoreline, (due to occasional slight spatial inconsistencies between the datasets), were collected manually.

4.30.3 Data Quality

Please refer to the WDNR Hydrography and ShoreZone Inventory metadata for detailed accuracy and completeness report. Intersecting streams with the ShoreZone dataset creates spatial consistency with other datasets developed and used for the Change Analysis.

5 QUALITY ASSURANCE AND QUALITY CONTROL

A detailed Quality Assurance and Quality Control (QA/QC) program was implemented throughout the development of the Change Analysis database in order to ensure high quality and accurate datasets were used.

5.1 Quality Control

Quality Control (QC) refers to the system of routine technical activities to control the quality of database as it was being developed. QC procedures were conducted to evaluate, review, and error-check the datasets after they were developed, processed, and/or compiled.

QC procedures were established and conducted on each dataset included in the spatial analysis database. In general, QC procedures included a sequence of visual spatial review, topology validation, spatial and tabular queries to check for anomalous and erroneous data elements. QC procedures were implemented by the Anchor QEA Consultant Team and the geographic information systems (GIS) Technical Liaison to the Nearshore Science Team (NST). As necessary, QC was also conducted by members of the NST. Specifically, for the synthesis of current and historic shoreforms, meetings (called "fly-bys") were convened with members of the NST for their review of: (a) shoreforms that had changed from historic to current shoreline, (b) anomalous areas, and (c) specific areas of interest to NST. Overall, the NST reviewed approximately 58 percent of the total shoreline length. The NST review clarified delineation rules that were applied to the entire shoreline. The QC procedures are briefly described for Geographic Scale Units (GSUs) and each dataset in Section 5, and in more detail in Appendix C.

Documentation of QC notes during the finalization of datasets that were developed by the Anchor QEA Consultant Team (e.g., GSUs, historic shoreforms, shoreform transitions) was included in the database. This documentation explains whether any change was made and the reason for consideration of the change. This serves to document instances in which the QC steps identified errors or differences in interpretation.

5.1.1 Visual Spatial Review

Each sound-wide and sub-basin feature class was mapped and reviewed in GIS to ensure complete spatial coverage for the entire study area. In addition, the results of any tabular queries were verified using a visual inspection of spatial features to ensure results accurately reflected mappable data.

5.1.2 Verification of Topological Integrity

The integrity in the topology of spatial data is recognized as an integral part of consistency among datasets. Because topological errors in line and polygon geometries can quickly compound when performing any calculations or metrics using those geometries' lengths or areas, the finalization of each dataset involved using the ESRI™ ArcGIS Topology tools to locate and correct spatial errors, such as self-intersections, dangles, and overlap within the line and polygon datasets. Such errors most often occurred when intersecting the GSUs with any feature falling exactly on the shoreline, and the use of topology rules was crucial to identifying and correcting geometric errors. These topology tools were also used to identify and remove any features that may have fallen outside the delineated GSUs.

5.1.3 Spatial and Tabular Queries

Spatial and tabular queries in the QC process fall into three categories: queries that check attribute table integrity, queries that check for complete spatial coverage, and queries that check the results of other written queries. Query development to sum and normalize the various data at multiple scales was conducted in parallel, primarily independent efforts by members of the Anchor QEA Consultant Team to provide a means for all query results from one effort could be compared against query results written by an independent party. These queries supported efforts to ensure all metrics derived from the Change Analysis databases were accurate and addressed the requests of the NST.

5.1.3.1 Attribute Table Integrity

The shoreform change dataset was extensively queried against the historic shoreform change dataset to ensure accurate transfer of historic information onto the current shoreform line geometry. Queries were developed to ensure accurate counts, lengths, and IDs of historic shoreforms populated in the final shoreform change attribute table, and to check for any duplicate shoreform IDs in both the historic and current lines. After intersection with the GSUs, the calculated GSU lengths were summed by both historic ID and total sub-basin shoreform lengths to verify the proportional GSU lengths were correct.

5.1.3.2 Complete Spatial Coverage

The GSU-normalized percentages of all land cover and impervious classes were verified to add up to 100 percent of the GSU. This tabular query checked both spatial and attribute table integrity.

5.1.3.3 Query Result Comparisons

Exa Data was responsible for developing queries to generate the tabulation reports at Process Unit (PU), sub-basin, and Sound-wide scales. For this effort, queries were developed independently by other members of the Anchor QEA Consultant Team to check the tabulation reports as they were generated. The queries were grouped to correspond to each page of the report at the given geographic scale. For PU tabulations, a "10 percent" check was done, taking the largest PUs equal to 10 percent of the sub-basin by PU count. It was inferred that the largest PUs would be the most complex and have the highest probability of having metrics derived from each spatial dataset, therefore ensuring metrics derived from each dataset received QC.

5.2 Quality Assurance

Quality Assurance (QA) refers to the planned system of review procedures that was conducted to ensure that the spatial analysis database includes the best available data describing nearshore conditions. The QA was done within the Anchor QEA Consultant Team, as well as by the GIS Technical Liaison from the NST and the U.S. Army Corps of Engineers (Corps).

The QA procedures for Change Analysis datasets were divided into two components: (a) review of existing datasets and (b) development of new datasets.

The review of existing datasets is described in more detail in Section 4 and Appendix A, the *Data Discovery Report*. In brief, the Anchor QEA Consultant Team conducted a thorough review of existing datasets relevant to nearshore processes, including source documentation, and assessed each dataset's suitability for use in the Change Analysis. The outcome of the review was a recommendation on which dataset to use, any caveats, and data gaps. The recommendations of this assessment were reviewed and approved by a subset of the PSNERP NST. This process ensured that the datasets of the best quality, given the limitations inherent in using existing datasets not developed for the specific project purposes, were incorporated into the spatial analysis database.

For development of new datasets, QA included (a) development of detailed rule sets for interpretive processes, (b) development and documentation of step-by-step GIS procedures for data development and synthesis, and (c) use of experienced GIS analysts who are knowledgeable in both GIS procedures and the Puget Sound nearshore environment.

At the project outset, preliminary GIS procedures were developed by the GIS Technical Liaison to the NST. Training in these methods was provided to all project GIS analysts. As the project progressed and GIS methods were tested and refined, some procedures were co-developed by the Anchor QEA Consultant Team. All procedures were reviewed by the GIS Technical Liaison to the NST, and, as appropriate, members of the NST.

For interpretive processes, such as historic shoreform classification, a detailed set of rules was developed for all analysts to follow. Any exceptions to these rules were reviewed by the GIS Technical Liaison to the NST. When appropriate, review by a scientific expert, such as a geomorphologist, was included in the data development procedures.

QA oversight by the GIS Technical Liaison to the NST and the Corps was conducted through weekly meetings during the preparation of the datasets. These meetings focused on resolving any issues identified during QA/QC review steps.

5.3 Error Tracking

As described in the QC section above, the database includes documentation of the rationale for delineation decisions made in the shoreform transition analysis. In addition, the database tracks changes made to historic and current shoreforms during the QC reviews within the Anchor QEA Consultant Team as well as by the NST in the fly-bys. During the interpretation of historic shoreforms, confidence was assigned as high, medium, or low.

This served to track data quality and point out shoreline areas requiring more oversight by a geomorphologist and the NST. Among the nearly 6,000 shoreform segments delineated, 94 percent were assigned a high confidence level. At this stage, 1 percent was assigned medium confidence and 5 percent was assigned a low confidence. Following the geomorphologist and NST review, 96 percent were assigned high confidence, 3 percent were assigned medium confidence, and less than 1 percent were assigned low confidence.

6 REFERENCES

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APPENDIX A

DATA DISCOVERY SUMMARY REPORT

(Erratum: Section 12.3 and Page 4 of the Data Discovery Summary Table – The Aquascape database referred to is still in development)

DATA DISCOVERY SUMMARY REPORT

PUGET SOUND NEARSHORE ECOSYSTEM RESTORATION PROJECT

Prepared for

U.S. Army Corps of Engineers, Seattle District
4735 East Marginal Way South
Seattle, Washington 98124

Prepared in Support of

PUGET SOUND
NEARSHORE
PARTNERSHIP

RESTORING OUR
ECOSYSTEM HEALTH

Prepared by

Anchor Environmental, L.L.C., Consultant Team
1423 Third Avenue, Suite 300
Seattle, Washington 98101

Including

LeeSaa Consulting, Inc.
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EXECUTIVE SUMMARY

This Data Discovery Summary Report describes the availability and suitability of datasets identified for use in the Change Analysis that is being completed as part of the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) General Investigation Study and the Puget Sound Nearshore Partnership. The Change Analysis is defined here as a measurement of changes between historic (pre-1900) and current conditions (circa 2000) of shoreline and estuarine landscape features. The data discovery information is presented as a report and in table format as Appendix A. The 27 datasets of interest in this data discovery effort were identified by a subset of the PSNERP Nearshore Science Team and are listed below:

- Shoreline
- Bathymetry
- Digital Elevation Model (DEM)
- Drift cells
- Geology
- Slope stability
- Hydrographic sheets (H-sheets)
- Puget Sound River History Project data
- High resolution aerial imagery
- Oblique aerial imagery
- LIDAR (terrestrial)
- Streams
- Overwater structures
- Marinas
- Armoring
- Breakwaters/jetties
- Groins
- Levees/dikes
- Dams
- Nearshore fill
- Land cover
- Parcels
- Impervious surfaces
- Roads
- Railroads
- Aquaculture
- Protected Lands

The data discovery investigation focused on identifying sources for readily available datasets that covered all or nearly all of the Soundwide project area. For each data source identified for a given dataset, the availability of data was assessed, as well as its geographic extent, data quality, availability of Federal Geographic Data Committee (FGDC) compliant metadata, compatibility with other data sources, and other advantages or disadvantages associated with using the data. Based on this assessment, a recommendation is provided as to which data source or combination of data sources to use for each dataset. To help inform the assessment of each dataset, a subset of the PSNERP Nearshore Science Team identified the purpose, analyses, and metrics of interest for the Change Analysis.

1 SHORELINE

Purpose: Base layer

Analyses: Attributed with shoreform

Metrics at the Geographic Scales: Percent length by shoreform

1.1 Washington Department of Natural Resources ShoreZone Inventory

Source: Washington Department of Natural Resources (WDNR) ShoreZone Inventory

Description: The ShoreZone Inventory describes the physical and biological characteristics of intertidal and shallow subtidal areas throughout Puget Sound and the outer coast of Washington. Data are presented for discrete assessment reaches. The ShoreZone Inventory can be used to better understand and manage Washington's coastal ecosystem.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: 1994 to 2000

Scale/Resolution: 1:24,000

Data Format: Line shapefile

Assessment of Dataset: The ShoreZone Inventory includes a shoreline shapefile of the estimated mean higher high water (MHHW) line. There are some small areas of discrepancy where the shoreline is too far inland or offshore, but in general, the shapefile adequately depicts the shoreline configuration.

1.2 Washington Department of Ecology

Source: Washington Department of Ecology (WDOE)

Description: The WDOE shoreline shapefile was developed as a cartographic background dataset for Geographic Information Systems (GIS) coastal projects—specifically, updates to local Shoreline Management Plans. The dataset also shows the area of the marine (saltwater) shorelines of

Washington State that fall under Shoreline Management Act jurisdiction. The shoreline shapefile depicts the estimated location of the ordinary high water mark (OHWM).

Data in Hand:	Yes
Metadata:	FGDC format metadata available
Geography:	Soundwide
Date of Content:	1996 to 2005
Scale/Resolution:	1:24,000
Data Format:	Line shapefile

Assessment of Dataset: The WDOE shoreline shapefile depicts the estimated location of the OHWM along the marine (saltwater) shorelines of the state. The dataset has many discrepancies throughout the shoreline.

1.3 Recommendation

The WDNR ShoreZone Inventory shoreline provides a better shoreline to use as a base map in the Change Analysis. The WDNR ShoreZone Inventory shoreline has fewer discrepancies and more detail of coastal features than the WDOE shoreline. In addition, the ShoreZone Inventory has been used by the Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP) for a geomorphic typology base layer. Using the same shoreline as SSHIAP will facilitate easier cross-walk during the upcoming typology assessment.

2 BATHYMETRY

Purpose: Primary

Analyses: To generate waterward edge of drainage units

Metrics at the Geographic Scales: None

2.1 University of Washington (Finlayson) 2005

Source: University of Washington (UW) School of Oceanography (Finlayson graduate work)

Description: This is a general purpose DEM of bathymetry and topography in the Puget lowland. The dataset was designed to address the needs of researchers and managers considering the terrestrial and marine topography as a seamless unit. It represents a composite of data sources.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide, except no data for the San Juan Islands sub-basin and western half of Strait of Juan de Fuca sub-basin

Date of Content: 2000 to 2005

Scale/Resolution: 30 feet

Data Format: ESRI GRID

Assessment of Dataset: This dataset represents a composite of the best available bathymetry and topography for Puget Sound, Hood Canal, Lake Washington, and the surrounding lowlands as of January 2005. A drawback is the incomplete geographic extent of the dataset. It is important to note that the dataset is a compilation of sources providing data of variable scales and accuracies. This may be less important for the intended uses of the bathymetric data, but may limit its suitability as a topographic DEM data source (see Section 4). Another limitation for using the topographic portion of the dataset is that the LIDAR-derived data are expected to be too precise to be incorporated into the drainage unit (DU) delineation.

2.2 University of Washington (Finlayson) 2000

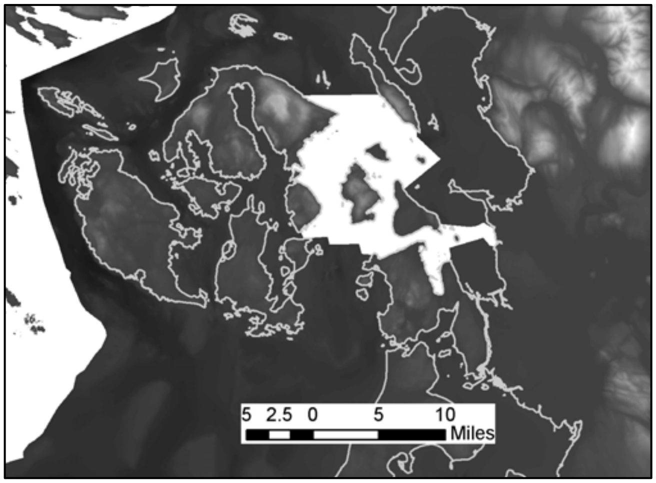
Source: UW School of Oceanography (Finlayson graduate work)

Description: This is a general purpose DEM of bathymetry and topography for most of western Washington.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide, except for a hole between eastern San Juan Islands and western shoreline of Lummi Island, Guemes Island, and Fidalgo Island (see map below)



Date of Content: Circa 2000

Scale/Resolution: 30 meter

Data Format: ESRI GRID

Assessment of Dataset: This is a Soundwide dataset for bathymetry and topography, including those areas not included in the 2005 dataset. This 2000 dataset is at a lower (poorer) resolution than the 2005 dataset described above.

2.3 WDFW and NOAA National Ocean Service

Source: WDFW and NOAA National Ocean Service

Description: This DEM was derived from 930,967 soundings taken primarily between 1934 and 1943. The sounding data were originally distributed by NOAA National Ocean Service (NOAA NOS; Dale Gombert, personal communication,WDFW 2008). The DEM is currently available at the NOAA NOS website (http://egisws01.nos.noaa.gov/servlet/BuildPage?template=bathy.txt&B1=Submit&parm1=P290). WDFW hired a private contractor to use that sounding data to generate an ESRI GRID DEM. The data are referenced to mean low water.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: Primarily between 1934 and 1943, but up to 1982.

Scale/Resolution: 30 meter pixels

Data Format: ESRI GRID

Assessment of Dataset: The DEM is derived from 88 surveys dating as far back as 1934. Some unknown variability in data accuracy is acknowledged in the metadata due to grid spacing of the soundings, resolution of the soundings, and to changes in technology. In some regions, the only source data were at fathom (6 feet) resolution. In general, most source surveys were certified to 1 foot or better by NOAA NOS. The vertical datum would need to be converted to North American Vertical Datum (NAVD) 88 for use with the other DEMs.

2.4 Recommendation

A composite of multiple sources should not limit the dataset's usefulness for characterizing the offshore limit of DUs. The UW 2005 dataset is recommended as the primary bathymetry dataset. It is a compilation of the best available data within the geographic area included in the dataset. The UW 2000 dataset is useful as a supplemental bathymetry dataset. It can be used to fill gaps in the 2005 data, except in the area just east of the San Juan Islands. The WDFW and NOAA NOS dataset is useful to fill the remaining gap that neither of the UW DEMs covered. For any given area within Puget Sound, if more than one bathymetry DEM data source is available, it is recommended that the dataset providing the most recent data is used. In this way, data preference would be in the following order: UW (Finlayson) 2005, UW (Finlayson) 2000, and the WDFW/NOAA NOS.

3 DIGITAL ELEVATION MODEL

Purpose: Primary

Analyses: To generate DUs and topology

Metrics at the Geographic Scales: None

3.1 U.S. Geological Survey

Source: U.S. Geological Survey (USGS)

Description: This is a general purpose Digital Elevation Model (DEM) of topography throughout the State of Washington.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: 2001

Scale/Resolution: 10 meter

Data Format: Raster

Assessment of Dataset: This is a statewide DEM with good resolution that will be adequate for use in deriving measurement units. The USGS DEM leaves some gaps between the edge of the dataset and the ShoreZone Inventory shoreline.

3.2 Natural Resources Canada

Source: Government of Canada, Natural Resources Canada

Description: This is a general purpose DEM of topography throughout western Canada.

Data in Hand: No, but available online

Metadata: Canadian equivalent of FGDC format metadata available

Geography: Canadian portion of watersheds flowing into Puget Sound

Date of Content: 1996

Scale/Resolution: Variable throughout spatial extent, but roughly 15-meter-wide by 23-meter-high pixels in the area of interest

Data Format: Raster

Assessment of Dataset: This DEM has lower resolution than the USGS DEM for Washington.

3.3 Recommendation

The USGS DEM is an adequate primary DEM dataset. Areas of gaps between the USGS DEM and the ShoreZone shoreline can be supplemented using the UW 2005 bathymetry and topography DEM dataset. The coupling of these two datasets for this purpose is expected to be seamless. The USGS DEM dataset can also be supplemented by the Canadian DEM to allow for comprehensive delineation of DUs in Process Units that extend into Canada.

4 DRIFT CELLS

Purpose: Primary

Analyses: To support typology and geographic scale delineation

Metrics at the Geographic Scales: None

4.1 Washington Department of Ecology (Schwartz)

Source: WDOE

Description: This dataset is a digitized version of net shore-drift mapping conducted by approximately ten graduate students of Dr. Maurice Schwartz at Western Washington University. The mapping was conducted between the late 1970s and early 1990s.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: 1970 to 1980

Scale/Resolution: The original maps were created at a variety of scales and formats, and later aligned to a 1:24,000 scale marine shoreline coverage.

Data Format: Line shapefile

Assessment of Dataset: This dataset is the only Soundwide characterization of net-shore drift. It is widely used in shoreline planning efforts, including Shoreline Master Plan updates. The multiple authors and incomplete quality control of the dataset have resulted in some resolution and completeness inconsistencies among areas that have been carried forward through WDOE's digitization of the dataset.

4.2 U.S. Army Corps of Engineers

Source: U.S. Army Corps of Engineers (Corps)

Description: The Corps contracted Coastal Geologic Services to revise the WDOE drift cell dataset in the following ways:

1. Fill in data gaps in areas mapped as UN (unidentified) or blank
2. Correct data in areas where net shore-drift was mapped in regions where no net shore-drift occurs

3. Interpret historic net shore-drift for those areas characterized in WDOE based on current drift conditions caused by large anthropogenic alterations (e.g., jetties, dikes, and dredge/fill)

Data in Hand: Yes

Metadata: FGDC format metadata available for original, methods documentation report for recent revisions

Geography: Soundwide

Date of Content: 1970 to 1980

Scale/Resolution: The original maps were created at a variety of scales and formats, and later aligned to a 1:24,000 scale marine shoreline coverage.

Data Format: Line shapefile

Assessment of Dataset: This dataset provides an improved version of the original WDOE drift cell dataset.

4.3 Recommendation

The Corps corrected version of the WDOE drift cell dataset fixes some of the errors in the original dataset. The dataset is the best available characterization of net shore-drift in Puget Sound.

5 GEOLOGY

Purpose: Primary

Analyses: To support typology

Metrics at the Geographic Scales: None

5.1 WDNR Geology Dataset

Source: WDNR

Description: This is a statewide geology dataset.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: 1984 to 2002

Scale/Resolution: 1:100,000

Data Format: Polygon shapefile

Assessment of Dataset: This dataset contains polygons that identify the extent and type of each geologic unit. It is a coarse resolution geology dataset, but it covers all of Puget Sound and will be useful in the delineation of current typology.

5.2 WDNR Miscellaneous Compilation

Source: WDNR

Description: This is a compilation of all previous WDNR mapping indexes of geologic and geophysical mapping.

Data in Hand: No

Metadata: Unknown

Geography: Incomplete data in all sub-basins

Date of Content: 1949 to 1999

Scale/Resolution: Variable

Data Format: Unknown

Assessment of Dataset: The usefulness of this dataset is limited because it is not available Soundwide.

5.3 Recommendation

The 1:100,000 scale WDNR geology dataset is the best Soundwide dataset available in digital format.

6 SLOPE STABILITY

Purpose: Primary

Analyses: To support typology

Metrics at the Geographic Scales: None

6.1 Washington Department of Ecology Coastal Zone Atlas

Source: WDOE

Description: This is a digitized version of the slope stability maps in the WDOE Coastal Zone Atlas.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide for areas under direct State of Washington jurisdiction. Federal military installations and Indian reservations are not included. The dataset extends only 2,000 feet inland from the Puget Sound shoreline.

Date of Content: Mid-1970s

Scale/Resolution: 1:24,000

Data Format: Polygon shapefile

Assessment of Dataset: This dataset provides slope stability information for general reference. These maps indicate the relative stability of coastal slopes as interpreted by geologists based on aerial photographs, geological mapping, topography, and field observations. The methods are standard but may occasionally result in some unstable areas being overlooked and in some stable areas being incorrectly identified as unstable. Further inaccuracies are introduced to the data through the process of converting the published maps into digital format. This dataset should not be used as a substitute for site-specific studies carried out by qualified geologists and engineers, but for the purposes of this analysis, this dataset provides adequate information.

6.2 Washington Department of Natural Resources Forest Practices Division

Source: WDNR Forest Practices Division

Description: This dataset depicts outputs of predictive shallow-rapid slope stability using one or more calibrated GIS-based models.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: 2000

Scale/Resolution: 10 meter

Data Format: ESRI Grid

Assessment of Dataset: The model outputs contained in this dataset are intended to be used for pre-classification screening of forest practices applications and screening for slope stability concerns on managed timberlands.

6.3 Recommendation

Though the WDOE Slope Stability dataset has many limitations on quality, it is a useful representation of the state of anthropogenic modification in the 1970s. This dataset is useful as a secondary dataset for all analyses in the project, and it is useful for shoreline typology analysis. The WDNR Forest Practices dataset is a predictive layer and less useful for the analysis.

7 HYDROGRAPHIC SHEETS

Purpose: Primary

Analyses: To support typology

Metrics at the Geographic Scales: None

7.1 U.S. Coast and Geodetic Survey Historic Digitized Hydrographic Sheets

Source: National Oceanic and Atmospheric Administration (NOAA)

Description: The U.S. Coast and Geodetic Survey (USCGS) historic digitized hydrographic sheets (H-sheets) are good historic maps of hydrographic soundings and bathymetric points around Puget Sound.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: Late 1800s

Scale/Resolution: Variable, no worse than 1:100,000 (between 1:10,000 and 1:20,000 among H-sheets to be used in this analysis)

Data Format: TIFs/GeoTIFs

Assessment of Dataset: The USCGS was in the forefront of new surveying innovations, using schooners to perform surveys, lead lines to measure soundings, and astronomic fixes and dead reckoning to position a survey ship when out of sight of land on the first hydrographic surveys in late 1834 and early 1835. In addition to hydrographic soundings and bathymetric points, the H-sheet maps are also useful for digitizing eelgrass and general intertidal areas around deltas. The maps are scanned but not geo-rectified.

7.2 Recommendation

The H-sheets are good historic maps to use as a primary dataset of historic conditions.

8 PUGET SOUND RIVER HISTORY PROJECT DATA

Purpose: Primary

Analyses: To support typology

Metrics at the Geographic Scales: Percent area

8.1 University of Washington Puget Sound River History Project Historic Digitized Topography Sheets

Source: UW Puget Sound River History Project

Description: This is a dataset of the digitized historic topography sheets (T-sheets) prepared by the USCGS.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: 1852 to 1926

Scale/Resolution: 1:100,000

Data Format: Geodatabase

Assessment of Dataset: Provides digitized historic T-sheets for all of Puget Sound and the Strait of Juan de Fuca. GIS data were developed by the UW Puget Sound River History Project for an assessment of historical change to nearshore environments in the Puget Sound region.

8.2 University of Washington Puget Sound River History Project Historic Nearshore

Source: UW Puget Sound River History Project

Description: Historic data of Puget Sound nearshore derived from historic T-sheets, supplemented with field notes and plat maps from 19th century government land survey and various other sources including other early maps, aerial photographs, early text sources, and recent data including high-resolution DEMs.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: Approximately 1850

Scale/Resolution: 1:100,000

Data Format: Geodatabase

Assessment of Dataset: The historic nearshore dataset is the best GIS historic dataset for the Puget Sound nearshore. The GIS data were developed by the UW Puget Sound River History Project for an assessment of historical change to nearshore environments in the Puget Sound region.

8.3 Recommendation

The UW Puget Sound River History Project datasets are essential datasets for the upcoming analysis.

9 HIGH RESOLUTION AERIAL IMAGERY

Purpose: Primary

Analyses: To support multiple datasets

Metrics at the Geographic Scales: None

9.1 USGS National Agriculture Imagery Program 2006

Source: USGS National Agriculture Imagery Program (NAIP)
Description: Recent high resolution imagery for Washington State
Data in Hand: Yes
Metadata: No formal metadata; online description available
Geography: Soundwide
Date of Content: 2006
Scale/Resolution: 1-meter pixels; color
Data Format: MrSIDs

Assessment of Dataset: The USGS aerial imagery is the best available Soundwide dataset.

9.2 Recommendation

The USGS photographs are the best available with a Soundwide extent. Imagery from various other sources (e.g., counties) is available for subsets of the Puget Sound region, but this imagery is not Soundwide or more current.

10 OBLIQUE AERIAL IMAGERY

Purpose: Ancillary

Analyses: To support multiple datasets

Metrics at the Geographic Scales: None

10.1 Washington Department of Ecology 2005-2006

Source: WDOE

Description: Recent aerial oblique photographs along marine shorelines of Washington State

Data in Hand: No, but it has been requested

Metadata: No formal metadata; online description available

Geography: Soundwide, except Whatcom and Snohomish Counties, which have not yet been released

Date of Content: 2005 to 2006

Scale/Resolution: Variable; generally, one photograph shows approximately 1,000 lineal feet of shoreline

Data Format: Hyperlinked GIS point file with JPG and TIF images

Assessment of Dataset: Good quality oblique photographs taken during summer low tide events. Photographs were taken to optimize sun angle, shoreline orientation, and low tides. The oblique photographs are useful for interpreting bluff geology and land-sliding, riparian vegetation, and shoreline modifications, such as bulkheads and seawalls.

10.2 Washington Department of Ecology 2000-2002

Source: WDOE

Data in Hand: Yes

Metadata: No formal metadata; online description available

Geography: Soundwide

Date of Content: 2000 to 2002

Scale/Resolution: Variable; generally, one photograph shows approximately 1,000 lineal feet of shoreline

Data Format: Hyperlinked GIS point file with JPG and TIF images

Assessment of Dataset: Good quality oblique photographs taken during summer low tide events. Photographs were taken to optimize sun angle, shoreline orientation, and low tides. The oblique photographs are useful for interpreting bluff geology and land-sliding, riparian vegetation, and shoreline modifications, such as bulkheads and seawalls.

10.3 Recommendation

The 2005-2006 oblique photographs will be useful to support interpretation of high resolution aerial orthogonal photography and shoreline information. The 2000-2002 data will be a good backup dataset.

11 LIDAR (TERRESTRIAL)

Purpose: Ancillary

Analyses: To support multiple datasets

Metrics at the Geographic Scales: None

11.1 Puget Sound LIDAR Consortium

Source: Puget Sound LIDAR Consortium (PSLC)

Description: The Light Distance and Ranging (LIDAR) dataset of bare earth DEMs is a representation of the earth's surface where all constructed structures and vegetation have been removed. The PSLC is an informal group of local agency staff and Federal research scientists devoted to developing public-domain high-resolution LIDAR topography and derivative products for the Puget Sound region.

Data in Hand: Yes

Metadata: No formal metadata; online description available

Geography: Soundwide, except for the western half of the Strait of Juan de Fuca, Bellingham area of San Juan Islands, and a small area along the southern end of Whidbey Island Basin

Date of Content: 2000 to 2006

Scale/Resolution: 6-foot pixels

Data Format: ArcInfo Coverage files

Assessment of Dataset: The LIDAR bare earth DEMs are comparable to the USGS DEMs (described in Section 4.1), but are of much higher accuracy and can be used at a larger scale up to 1:12,000 (1 inch = 1,000 feet). The LIDAR bare earth DEMs have a wide range of uses such as earthquake hazard studies, hydrologic modeling, forestry, coastal engineering, roadway and pipeline engineering, flood plain mapping, wetland studies, geologic studies, and a variety of analytical and cartographic projects. The precision of the LIDAR-derived portion of the dataset would produce overly complex DU delineations, which would then require extra work to simplify.

11.2 Recommendation

Because of the incomplete geographic extent of this dataset, it is recommended that the LIDAR dataset be used to supplement the USGS DEM dataset and for cartographic purposes. If there is an interest in developing more LIDAR data, the WDNR Geologic Division is looking for cost-share partners.

12 STREAMS

Purpose: Analytical

Analyses: To analyze with shoreline; analyze with roads

Metrics at the Geographic Scales: Count of stream mouths; count of stream intersections with roads

12.1 Washington Department of Natural Resources Watercourse Hydrography

Source: WDNR

Description: Statewide dataset of watercourses that represent streams, ditches, or pipelines, or as centerlines through water body polygons such as double-banked streams, lakes, impoundments, reservoirs, wet areas, or glaciers.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: August 2007, but updated monthly

Scale/Resolution: 1:24,000

Data Format: Coverages converted to Geodatabase

Assessment of Dataset: This dataset is the most consistent Soundwide hydrology layer. It has many more stream courses mapped than the USGS National Hydrologic Dataset described below. The dataset is updated monthly by WDNR. The WDNR dataset classifies waterbodies into the following eight types:

- Ditch/canal
- Impounded wet areas
- Impoundments/inundated areas
- Lakes/ponds
- Pipeline
- Side channels to rivers/streams
- Streams or rivers
- Unclassified

12.2 U.S. Geologic Survey National Hydrologic Dataset

Source: USGS

Description: Nationwide stream dataset

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: Not specified

Scale/Resolution: Originally developed at 1:100,000 nationwide; some unspecified areas may be of higher resolution (1:24,000 or 1:12,000)

Data Format: Geodatabase, line feature class

Assessment of Dataset: Not as detailed as the WDNR Streams dataset**.** The USGS National Hydrologic Dataset (NHD) classifies waterbodies into the following seven types:

- Stream/river
- Shoreline
- Pipeline
- Coastline
- Connector
- Canal/ditch
- Artificial path

12.3 Salmon and Steelhead Habitat Inventory and Assessment Project

Assessment of Dataset: SSHIAP is currently developing a compilation of hydrologic and stream datasets to support analyses conducting the watershed data to the marine environment. This layer will be linked to the ShoreZone Inventory shoreline data in a relational database called “Aquascape.” It was not determined whether the dataset is available at this time.

12.4 Recommendation

The WDNR watercourse hydrography appears to be the best dataset for the analysis of road crossings. It is a widely used dataset, including use by other state agencies to support various mapping efforts. The dataset does not extend into Canada; therefore, it will be necessary to obtain available data from Canada if DU delineations are to extend beyond the U.S.-Canada border.

13 OVERWATER STRUCTURES

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Area

13.1 Washington Department of Natural Resources

Source: WDNR

Description: This is a dataset of overwater structures in Puget Sound and the Strait of Juan de Fuca. Structure attribute information indicates whether structure decking is complete or partial due to construction or decay, as well as whether the structure includes multiple structure types (e.g., a dock and building together). Boats are sometimes included in the structure boundary. Some structures (approximately 10 percent of the 9,327 polygons) include additional detail, classified with the following categories: road, train, pedestrian, other function, dams/locks, building, dock, marina, pier, breakwater/riprap, causeway, support, landfill, boat ramp, float, nautical aid, aquaculture, clustered pilings, and log booms,

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Marine waters statewide

Date of Content: 2002 to 2003 and 2005 to 2006

Scale/Resolution: Digitized from 1-meter orthophotos; 3-meter horizontal accuracy

Data Format: Polygon shapefile

Assessment of Dataset: This dataset marks the outline (footprint) of overwater structures throughout Puget Sound. The most reliably and comprehensively mapped structures in this dataset are docks/piers, bridges, buildings, and floats. There are also data on structures such as buoys and fills, but these were not comprehensively mapped by all cartographers.

13.2 Recommendation

This is a Soundwide standardized dataset that will be useful for this project.

14 MARINAS

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Area

14.1 Washington Department of Natural Resources

Source:	WDNR
Description:	The WDNR overwater structures dataset described above includes marinas.
Data in Hand:	Yes
Metadata:	FGDC format metadata available
Geography:	Marine waters statewide
Date of Content:	2002 to 2003 and 2005 to 2006
Scale/Resolution:	Digitized from 1-meter orthophotos; 3-meter horizontal accuracy
Data Format:	Polygon shapefile

Assessment of Dataset: This dataset marks the outline (footprint) of overwater structures, including marinas, throughout Puget Sound. The dataset is approximately 80 percent complete and would require some refinement of the line work.

14.2 NOAA Environmental Sensitivity Index

Source:	NOAA, Office of Restoration and Response, Environmental Sensitivity Index (ESI)
Description:	This is a dataset documenting marina locations.
Data in Hand:	Yes
Metadata:	FGDC format metadata available
Geography:	Soundwide
Date of Content:	1985 to 2005
Scale/Resolution:	1:24,000
Data Format:	Geodatabase, point feature class

Assessment of Dataset: Marina locations are identified in the point file, but no information is provided about the marinas' on-water footprints. The locations were based on information from a variety of sources and were adjusted to align with shoreline.

14.3 U.S. Army Corps of Engineers

Source: Corps

Description: The Corps contracted Anchor Environmental, L.L.C. (Anchor), to revise the marina dataset included in the WDNR overwater structure dataset. This entailed scanning shoreline imagery to ensure that all marinas of sufficient size (10 or more slips) were included in the dataset and that the linework was accurate. Marinas were delineated using aerial photography interpretation techniques. Polygons were created to delineate the shape of overwater structures (i.e., docks) in marinas. Boats in slips were considered overwater structures in this delineation. The polygon shapes were created assuming every boat slip was filled with a boat. For marinas with an associated breakwater/jetty, separate polygons were created for the overwater structures within the marina, the breakwater/jetty, and the unshaded aquatic area enclosed within the breakwater/jetty.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Marine waters of Puget Sound planning area

Date of Content: 2002 to 2003, 2005 to 2006, and 2008

Scale/Resolution: Digitized from 1-meter orthophotos; 3-meter horizontal accuracy

Data Format: Polygon shapefile

Assessment of Dataset: This is a comprehensive dataset of marinas containing 10 or more slips in the Puget Sound planning area. The dataset allows for calculation of overwater structure area in marinas assuming every slip in the marina is occupied. For marinas with associated jetties/breakwaters, the dataset allows for calculation of the entire aquatic area of the marina complex, (i.e., overwater structure area, jetty/breakwater, and unshaded aquatic area sheltered within the jetty/breakwater).

14.4 Recommendation

The Corps-enhanced version of the marinas portion of the WDNR overwater structures dataset will be suitable for calculation marina areas. As described above, the dataset allows for two separate calculations of marina size: 1) the area with overwater structures and 2) the aquatic area encompassed by the marina complex.

15 ARMORING

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Length

15.1 Puget Sound Partnership and U.S. Army Corps of Engineers Compilation

Source: Corps for final compilation; Puget Sound Partnership (PSP) for an interim compilation

Description: The PSP prepared a compilation of available shoreline armoring data throughout Puget Sound and Strait of Juan de Fuca. The Corps contracted Anchor to acquire additional datasets that became available after the PSP compilation effort.

Data in Hand: Yes

Metadata: Incomplete among contributing datasets

Geography: Incomplete; of the 2,479 miles of shoreline in the project area, 905 miles of shoreline have not been surveyed, which includes approximately:

- 127 miles in the Strait of Juan de Fuca sub-basin
- 550 miles in San Juan Islands/Georgia Strait sub-basin
- 55 miles in South Central Puget Sound sub-basin
- 234 miles in South Puget Sound sub-basin

Date of Content: 1999 to 2005

Scale/Resolution: Variable and not well documented in the metadata; some datasets were collected in the field, while others were interpreted off of aerial photographs and oblique photographs.

Data Format: Mix of ESRI Geodatabase, line shapefiles, polygon shapefiles

Assessment of Dataset: The available armoring data were gathered using a variety of field and/or photograph interpretation techniques and do not cover the full spatial extent of the project area. Following is a brief summary of available armoring data (other than the ShoreZone Inventory) in each sub-basin. The PSP assessment of the data available at the end of their compilation efforts is provided as Appendix B.

15.1.1 Strait of Juan de Fuca Sub-basin

In the 204 miles of shoreline in this sub-basin, this armoring compilation has no information for 127 miles of shoreline.

No shoreline armoring data are available between Cape Flattery and the Dungeness Spit. From the Dungeness Spit east to Point Wilson, the shoreline was assessed by the Point No Point Treaty Council using a global positioning system (GPS) on a boat as well as a high precision GPS and laser range finder from fixed offshore positions. The dataset in this area describes the bulkhead type and indicates whether the bulkhead elevation is at or below the OHWM.

15.1.2 Hood Canal Sub-basin

The entire Hood Canal shoreline was assessed by Point No Point Treaty Council using GPS on a boat as well as a high precision GPS and laser range finder from fixed offshore positions. The dataset in this area describes the bulkhead type and indicates whether the bulkhead elevation is at or below the OHWM.

15.1.3 North Central Puget Sound Sub-basin

The entire sub-basin has been assessed for armoring distribution. The western side of the sub-basin between Point Wilson and Tala Point was assessed by Point No Point Treaty Council using GPS on a boat as well as a high precision GPS and laser range finder from fixed offshore positions. The dataset in this area describes the bulkhead type and indicates whether the bulkhead elevation is at or below the OHWM.

Southwest shoreline of Whidbey Island from Point Partridge to Possession Point was assessed by Island County Washington State University Beach Watchers Volunteer Survey Team using GPS and walking on the shoreline. The assessment only recorded altered shoreline and unaltered sections of shoreline. The linear distances were estimated using a map wheel and topographic maps. Modification descriptions are considered questionable.

15.1.4 South Central Puget Sound Sub-basin

In the 377 miles of shoreline in this sub-basin, this armoring compilation has no information for 55 miles of shoreline.

The King County shoreline was assessed by Anchor via photograph interpretation and later field checked to discern modification type and to determine whether the modification extends below, at, or above the OWHL. Coastal Geologic Services conducted a field survey of armoring in King County and identified all armored shorelines.

Armoring data for Bainbridge Island were provided by the City of Bainbridge Island. Kitsap County data were provided by Kitsap County. Other than armoring data between Point Defiance and the southern boundary of the sub-basin, no armoring assessments were identified for Pierce County.

15.1.5 South Puget Sound Sub-basin

In the 445 miles of shoreline in this sub-basin, this armoring compilation has no information for 234 miles of shoreline.

The South Puget Sound Salmon Enhancement Group and Nisqually Indian Tribe assessed armoring between the Nisqually River and Point Defiance. Elsewhere in Thurston County, armoring has been identified along the shoreline by the Thurston Regional Planning Council based on an inventory of County-issued permits for bulkheads. The geospatial accuracy of this dataset has been validated by aerial photograph interpretation.

No available armoring assessments were identified for Pierce County or Mason County.

15.1.6 San Juan Islands/Georgia Strait Sub-basin

In the 715 miles of shoreline in this sub-basin, this armoring compilation has no information for 550 miles of shoreline.

WRIA 1 and Whatcom County shoreline armoring was assessed for the 2005 to 2006 SMP updates by Whatcom County. Individual line datasets were created for each modification type. No local assessment has been conducted on the shorelines of San Juan County or the Skagit County portion of the sub-basin.

15.1.7 Whidbey Basin Sub-basin

The entire sub-basin has been assessed for armoring distribution. Camano Island and 125 miles of Whidbey Island were surveyed by WSU Beach Watchers Program using GPS. Methodology is described in the armoring assessment report prepared by Tim Strickler of PSP and provided in Appendix B.

The northeast shoreline of Whidbey Island (Crescent Harbor northward) and Northwest Skagit County (Deception Pass to Skagit Bay) was mapped by Skagit River System Cooperative between 2000 and 2003 using a combination of GPS field observations and aerial photograph interpretation. The dataset identifies the type of modification.

The Snohomish County shoreline was assessed on the ground using GPS by the County's Marine Resources Committee.

15.2 Washington Department of Natural Resources ShoreZone Inventory

Source: WDNR

Description: The WDNR ShoreZone Inventory identifies shoreline modifications (armoring) by type; percent of shoreline armored; and linear feet of the primary, secondary, and tertiary modifications in discrete assessment reaches demarcated by geomorphologic characteristics.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: 1994 to 2000

Scale/Resolution: 1:24,000

Data Format: Line shapefile

Assessment of Dataset: The ShoreZone Inventory is not an adequate source of armoring data for this analysis because the assessment unit scale of the data is not detailed enough to adequately characterize the amount of armoring within individual delineated drainage units. As noted by Tim Strickler of the Puget Sound Partnership, ShoreZone Inventory assessment units with 0 percent or 100 percent armoring provide acceptable data to fill data gaps where other local assessments (described above) have not been conducted. Comparing these areas with 0 percent or 100 percent armoring to the data gaps of local assessments provides armoring data for all shorelines except approximately:

- 16 miles in the Strait of Juan de Fuca sub-basin
- 44 miles in San Juan Islands/Georgia Strait sub-basin
- 34 miles in South Central Puget Sound sub-basin
- 96 miles in South Puget Sound sub-basin

15.3 U.S. Army Corps of Engineers

Source: Corps

Description: The Corps contracted Anchor to fill the gaps in armoring data described above. Shoreline armoring was delineated using aerial photograph interpretation techniques.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Fills data gaps remaining from other local assessments and WDNR ShoreZone Inventory:

- 16 miles in the Strait of Juan de Fuca sub-basin
- 44 miles in San Juan Islands/Georgia Strait sub-basin
- 34 miles in South Central Puget Sound sub-basin
- 96 miles in South Puget Sound sub-basin

Date of Content: 2008

Scale/Resolution: Approximately 1:1,500; delineation captured only armoring sections greater than 30 meters long

Data Format: Line shapefile

Assessment of Dataset: The armoring data were collected using aerial photography interpretation techniques and limited ground-truthing. The data are suitable for use in analyses of armoring location and length.

15.4 Recommendation

The conglomeration of the three data sources above provide a complete armoring dataset for the Puget Sound planning area. The dataset is suitable for use in analyses of armoring location and length.

16 BREAKWATERS/JETTIES

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Length

16.1 Washington Department of Natural Resources ShoreZone Inventory

Source: WDNR

Description: The ShoreZone Inventory describes the physical and biological characteristics of intertidal and shallow subtidal areas throughout Puget Sound and the outer coast of Washington. Data are presented for discrete assessment reaches. The ShoreZone Inventory indicates only which shoreline assessment reaches include breakwaters or jetties.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: 1994 to 2000

Scale/Resolution: 1:24,000

Data Format: Line shapefile

Assessment of Dataset: The ShoreZone Inventory does not provide the desired information about breakwaters and jetties.

16.2 U.S. Army Corps of Engineers

Source: Corps

Description: The Corps contracted Anchor to prepare a breakwaters/jetties dataset. The dataset delineates the polygon outline of all breakwaters/jetties. The dataset attribute table will also identify the material or type (e.g., rock, pier pile, or floating). The delineation was based on interpretation of ortho and aerial oblique photographs.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Marine waters of Puget Sound planning area

Date of Content: 2002 to 2003, 2005 to 2006, and 2008

Scale/Resolution: Digitized from 1-meter orthophotos; 3-meter horizontal accuracy

Data Format: Polygon shapefile

Assessment of Dataset: This is a comprehensive dataset of breakwaters/jetties in the Puget Sound planning area.

16.3 Recommendation

The Corps breakwaters/jetties dataset was created to provide the information requested for the change analysis.

17 GROINS

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Length

17.1 Assessment of Available Data

No available Soundwide dataset delineating groins was identified. Some of the armoring datasets delineate some groins and would provide length information.

17.2 Recommendation

It is recommended that either groins are not included in the analysis or the analysis continues with a partial dataset that could be created. There is a wide range of variability in the proximity to MHHW, size, and condition of groins, which makes it a very challenging shoreline feature to assess. The aerial photographs available Soundwide are not of sufficient resolution to support a photograph interpretation to create a comprehensive dataset; instead, an extensive field-based inventory during summer low tides would be necessary.

If a partial dataset using the aerial photographs is sufficient, then aerial (orthogonal and oblique) photograph interpretation techniques can be conducted to create the dataset. Ground-truthing would be prudent for quality control and to provide a more comprehensive dataset; however, the need for daytime low tides greatly limits what could be accomplished in the winter. If aerial photograph interpretation of groins is conducted, then the establishment of interpretation rules will be very important because there is more subjectivity for what appears to be a groin in aerial photographs than there is for other physical features.

18 LEVEES/DIKES

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Length

18.1 U.S. Army Corps of Engineers

Source: Corps

Description: This dataset was created for the change analysis and delineates the approximate centerline of levees affecting or near the Puget Sound Nearshore.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide, major levees only

Date of Content: 2007

Scale/Resolution: 1:24,000

Data Format: Line shapefile

Assessment of Dataset: The levee data was digitized from topographic maps, aerial imagery, and LIDAR data (showing the crowns of levees). As such, it is not considered a complete dataset of levees, but one that is representative of one type of anthropogenic feature disconnecting the Puget Sound nearshore environment from upland areas.

18.2 Salmon and Steelhead Habitat Inventory and Assessment Project Hood Canal Hydromodifications

Source: SSHIAP

Description: This SSHIAP hydromodifications dataset delineates the approximate centerline of levees and other structures throughout most of the Hood Canal sub-basin and part of the Strait of Juan de Fuca sub-basin. Levees were delineated based on aerial photograph interpretation coupled with a significant field verification effort. The analysis included large and small river systems in the analysis area. Channel gradient and confinement data in the SSHIAP stream segment dataset were useful information for identifying river systems most likely to have levees.

Data in Hand: Yes

Metadata: Incomplete

Geography: Hood Canal and a small part of the Strait of Juan de Fuca sub-basin

Date of Content: 2001

Scale/Resolution: Unspecified

Data Format: Line shapefile

Assessment of Dataset: The SSHIAP dataset provides field verified levee data for the area surveyed, including large and small river systems.

18.3 National Wildlife Federation Dike Impoundment

Source: National Wildlife Federation (NWF)

Description: The NWF dike impoundment area dataset was created for an analysis of sea-level rise impacts (NWF 2007). The NWF dataset estimates the areas impounded by dikes, but it does not explicitly delineate dikes. NWF identified impounded areas on agriculture lands using topographic maps and an elevation analysis. Some U.S. Geological Survey topographic maps that show dikes were used to verify the created impoundment dataset and provided some information used to reduce the patchiness of the impoundment dataset.

Data in Hand: Yes

Metadata: Incomplete

Geography: Based on the geographic extent described in NWF (2007), the analysis covered 10 areas within Puget Sound:

- Nooksack Delta, Lummi Bay, and Bellingham Bay
- Padilla Bay, Skagit Bay, and Port Susan Bay
- Whidbey Island, Port Townsend, and Admiralty Inlet
- Snohomish Estuary and Everett
- Ediz Hook, Dungeness Spit, and Sequim Bay
- Dyes Inlet, Sinclair Inlet, and Bainbridge Island
- Elliott Bay to the Duwamish Estuary
- Annas Bay and Skokomish Estuary
- Commencement Bay, Tacoma, and Gig Harbor
- Olympia, Budd Inlet, and Nisqually Delta

Date of Content: 2001

Scale/Resolution: Unspecified

Data Format: Raster

Assessment of Dataset: The NWF dataset estimates the areas impounded by dikes, but it does not explicitly delineate dikes. The characterization of impoundment areas is further limited because they were only identified on agricultural lands. The dataset is inadequate to support a levee analysis, although the approach to determining impoundment areas could be expanded upon and applied Soundwide if impoundment areas become of interest.

18.4 Salmon and Steelhead Habitat Inventory and Assessment Project Tidal Barriers

Source: SSHIAP

Description: SSHIAP prepared this tidal barriers dataset to support the Puget Sound Nearshore Partnership change analysis. SSHIAP delineated dikes, levees, roads, and other constructed structures that impede tidal hydrology such that historic wetlands become lost or isolated from Puget Sound nearshore waters. This inventory was limited to selected tidal wetland classes within large river deltas, barrier estuaries, barrier lagoons, and open coastal inlets as identified by PSNERP NST. The delineation was based on LIDAR, ortho and aerial oblique photographs, transportation layers, and the Corps levee dataset described above.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide in selected shoreforms

Date of Content: 2002 to 2003, 2005 to 2006, and 2008

Scale/Resolution: Unspecified

Data Format: Line shapefile

Assessment of Dataset: The SSHIAP tidal barriers dataset was created based on the direction of the PSNP in order to support the change analysis.

18.5 Recommendation

The SSHIAP tidal barriers dataset was created to provide the information requested for the change analysis.

19 DAMS

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Count

19.1 Washington Department of Ecology Dams Dataset

Source: WDOE

Description: This is a statewide dataset of dams that capture and store at least 10 acre-feet (about 3.2 million gallons) of water or watery materials.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 2006

Scale/Resolution: No metadata information on positional accuracy, but contact suggested some may be off by as much as 1,000 feet

Data Format: Point shapefile

Assessment of Dataset: For dams of adequate size to be included in the dataset (capture and store at least 10 acre-feet of water or watery materials), information is provided on dam size, purpose, material, year built, discharge capacity, storage, and drainage area above the dam.

19.2 Washington Department of Fish and Wildlife Fish Passage Barrier Inventory

Source: Washington Department of Fish and Wildlife (WDFW)

Description: The focus of this inventory is dams that are barriers to fish passage according to the guidelines in WDFW's *Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual*

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 1971 to 2007

Scale/Resolution: Positional accuracy of 5 meters to 100 meters, depending on source of data (either GPS or USGS 1:24,000 topographic map)

Data Format: Point shapefile

Assessment of Dataset: The dataset includes information on dam purpose and fish barrier status. Most dams in this dataset are too small to be included in the WDOE dataset described above. Therefore, the two datasets could be complementary.

19.3 Recommendation

Use both datasets to characterize the number of dams. A quality control review of the two datasets would be necessary to avoid double-counting dams that may be included in both datasets.

20 NEARSHORE FILL

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Area

20.1 Washington Department of Ecology Coastal Zone Atlas

Source: WDOE

Description: WDOE Coastal Zone Atlas data on geology includes a category for artificial fill (af). Corps contracted Anchor to digitize the af polygons. The af polygons that were found to be dikes or levees were not digitized as that information is captured in a separate dataset.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Marine waters of Puget Sound planning area

Date of Content: 1980

Scale/Resolution: 1:24,000

Data Format: Polygon shapefile

Assessment of Dataset: This dataset provides a sufficiently consistent nearshore fill throughout the Puget Sound planning area. It does not delineate all areas of nearshore fill, but it is a consistent Soundwide dataset.

20.2 Recommendation

The nearshore fill data in the WDOE dataset will provide adequate information to support the change analysis.

21 LAND COVER

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Percent land cover

21.1 University of Washington Puget Sound Regional Synthesis Model

Source: UW Puget Sound Regional Synthesis Model (PRISM)

Description: This dataset delineates land cover classifications through interpretation of satellite imagery.

Data in Hand: Yes

Metadata: No formal metadata, but description available

Geography: Soundwide

Date of Content: 2002

Scale/Resolution: 30 meter

Data Format: ESRI Grid

Assessment of Dataset: The PRISM dataset extends to the ShoreZone Inventory shoreline and would be a good primary dataset. The dataset identifies the following 17 land cover classifications:

- Dense urban
- Light-medium urban
- Bare ground
- Dry ground
- Native grass
- Grass/shrub/crops
- Mixed/deciduous forest
- Conifer forest
- Re-growing vegetation
- Clear-cut forest
- Snow/rock/ice
- Wetlands
- Shoreline
- Water
- Clouds
- No data
- No data – steep slopes

21.2 NOAA Coastal Change Analysis Program

Source: NOAA Coastal Change Analysis Program (C-CAP)

Description: This dataset delineates land cover classifications through interpretation of satellite imagery.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide

Date of Content: 2000

Scale/Resolution: 30 meter

Data Format: Raster (.img)

Assessment of Dataset: This dataset is not clipped to the ShoreZone Inventory shoreline which could present difficulties for use in the analysis. The dataset identifies the following 25 land cover classifications:

- High Intensity Developed
- Medium Intensity Developed
- Low Intensity Developed
- Developed Open Space
- Cultivated
- Pasture/Hay
- Grassland
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Scrub/Shrub
- Palustrine Forested Wetland
- Palustrine Scrub/Shrub Wetland
- Palustrine Emergent Wetland
- Estuarine Forested Wetland
- Estuarine Scrub/Shrub Wetland
- Estuarine Emergent Wetland
- Unconsolidated Shore
- Bare Land
- Water
- Palustrine Aquatic Bed
- Estuarine Aquatic Bed
- Tundra
- Snow/Ice
- Unclassified

21.3 Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Data

Source: Multi-Resolution Land Characteristics (MRLC) Consortium National Land Cover Data (NLCD)

Description: NLCD 2001 is a land-cover database comprised of three elements: land cover, impervious surface, and canopy density. These characteristics are interpreted for each 30 meter pixel using Landsat TM imagery.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 1999 to 2002

Scale/Resolution: 30-meter pixel

Data Format: IMAGINE raster (.img)

Assessment of Dataset: The Landsat TM imagery is slightly dated, especially considering the amount of recent development in the Puget Sound area. Despite the age of the data, it is a good characterization of land cover. The dataset identifies the following 16 land cover classifications:

- Developed, High Intensity
- Developed, Medium Intensity
- Developed, Low Intensity
- Developed, Open Space
- Emergent Herbaceous Wetlands
- Woody Wetlands
- Herbaceous
- Evergreen Forest
- Deciduous Forest
- Mixed Forest
- Scrub/Shrub
- Open Water
- Perennial Snow/Ice
- Cultivated Crops
- Hay/Pasture
- Barren Land

21.4 Recommendation

The NOAA C-CAP dataset is useful as the primary land cover dataset. The NOAA C-CAP dataset provides preferred coastal wetland land cover classes to those provided by the UW PRISM and NLCD datasets.

22 PARCELS

Purpose: Analytical

Analyses: To extract shoreline parcels only

Metrics at the Geographic Scales: Density – the number of parcels along a length of shoreline, may differentiate between commercial and residential

22.1 Puget Sound Action Team Compilation

Source: Puget Sound Action Team (PSAT)

Description: This compilation of parcels was prepared to support an analysis to identify underdeveloped and un-developed parcels.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Soundwide, except Island and Mason Counties

Date of Content: 2004 to 2005

Scale/Resolution: Parcel level

Data Format: ESRI Geodatabase

Assessment of Dataset: This is an acceptably recent dataset that provides nearly complete coverage of the project area, except for Island and Mason Counties. The data can be used for the density metric as well as the differentiation of commercial and residential properties.

22.2 Washington Department of Natural Resources Cadastre for Parcels

Source: WDNR

Description: This data contains ownership parcels for WDNR managed lands.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 2005

Scale/Resolution: Parcel level

Data Format: Polygon Shapefile

Assessment of Dataset: This is an acceptably recent dataset that provides a coverage of WDNR managed lands only in Washington state.

22.3 Parcels – University of Washington Statewide Cadastre for Parcels

22.3.1 Description of Available Data

Luke Rogers at UW is in the process of developing a statewide cadastre for all parcel data (39 counties) that will be standardized and will update these data for all counties. Incorporating the PLDB classification into the standard parcel data is also underway. The timeline for this cadastre data is uncertain.

22.3.2 Assessment of Available Data

The standardization of the parcel data is an important and useful effort.

22.4 Recommendation

The contents of the county parcels datasets are highly variable and have multiple topological errors. The datasets are adequate for investigating parcel density, but incomplete information is available to investigate other aspects of parcels (e.g., ownership groups and land values).

23 IMPERVIOUS SURFACES

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Percent

23.1 University of Washington Puget Sound Regional Synthesis Model

Source: UW PRISM

Description: This dataset delineates percent impervious surfaces through interpretation of satellite imagery. This dataset is being prepared to support the Future With/Without Project.

Data in Hand: No

Metadata: Unknown

Geography: Soundwide

Date of Content: Unknown

Scale/Resolution: Unknown

Data Format: Unknown

Assessment of Dataset: The PRISM dataset is expected to be an excellent dataset for the analysis, but no information was available for it.

23.2 Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Data

Source: MRLC Consortium NLCD 2001

Description: NLCD 2001 is a land-cover database comprised of three elements: land cover, impervious surface, and canopy density. These characteristics are interpreted for each 30 meter pixel using Landsat TM imagery.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 1999 to 2002

Scale/Resolution: 30-meter pixel

Data Format: IMAGINE raster (.img)

Assessment of Dataset: The Landsat TM imagery is slightly dated, especially considering the amount of recent development in the Puget Sound area. Despite the age of the data, it is a good characterization of percent impervious surface. No formal accuracy assessment was completed, but a cross-validation was done that indicated an accuracy of 86.2 percent.

23.3 Washington State Department of Transportation (ps_impsurf)

Source: Washington State Department of Transportation (WSDOT) (ps_impsurf)

Description: This dataset interprets the percent impervious surface for each 10 meter pixel using SPOT imagery.

Data in Hand: Yes

Metadata: Report, but no formal FGDC metadata

Geography: Limited spatial extent available; dataset includes almost all of the South Central Puget Sound sub-basin and parts of South Puget Sound and Hood Canal sub-basins

Date of Content: Not specified

Scale/Resolution: 10-meter pixel

Data Format: ESRI Grid

Assessment of Dataset: Usefulness of dataset is limited because of incomplete coverage of project area. The report accompanying the dataset concluded that for regional-level assessments of impervious surfaces, the WSDOT Landsat analysis described below performed as well as this higher resolution SPOT imagery dataset.

23.4 Washington State Department of Transportation (psimpsurf2004)

Source: WSDOT (psimpsurf2004)

Description: This dataset interprets the percent impervious surface for each 30 meter pixel using Landsat imagery.

Data in Hand: Yes

Metadata: Report, but no formal FGDC metadata

Geography: Limited spatial extent available; dataset includes all of South Central Puget Sound sub-basin and parts of Whidbey Basin, North Central Puget Sound, Hood Canal, and South Puget Sound sub-basins

Date of Content: 2004

Scale/Resolution: 30-meter pixel

Data Format: ESRI Grid

Assessment of Dataset: The data are more recent than the MRLC impervious surface data described above, but the usefulness of the dataset is limited because of its incomplete coverage of the project area.

23.5 Recommendation

Use MRLC NLCD data until the UW PRISM impervious dataset is available. Using the UW PRISM dataset would provide more consistency with the Future With/Without Project Analysis.

24 ROADS

Purpose: Analytical

Analyses: Apply a width according to road class

Metrics at the Geographic Scales: Area by road class in buffer according to frequency distribution; area by road class in drainage units

24.1 ESRI 2007 Street Map

Source: ESRI's 2007 Street Map

Description: This is the Washington portion of a nationwide roads dataset.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Nationwide

Date of Content: 2003

Scale/Resolution: 1:100,000; the horizontal positional accuracy is 167 feet

Data Format: Clipped data to go into an ESRI Geodatabase

Assessment of Dataset: This dataset provides an extensive catalog of roads that would be useful for road area calculations. There is no consistent relationship between this ESRI dataset and the WDNR dataset described below because each dataset includes roads that the other does not. The ESRI dataset appears more comprehensive in urban areas, but overall is less comprehensive than the WDNR dataset. The ESRI dataset categorizes roads into the following 16 types:

- Primary limited access or interstate
- Primary U.S. and state highways
- Secondary state and county highways
- Local, neighborhood, rural or city street
- 4WD
- Other ramp
- Cul-de-sac
- Traffic circle
- Freeway ramp
- Service road
- Ferry
- Other thoroughfare
- Pedestrian walkway
- Alley
- Driveway
- Parking area road

24.2 Washington Department of Natural Resources Transportation Dataset

Source: WDNR

Description: This dataset represents roads, railroads, trails, and other land and water transportation routes existing within the State of Washington. It was developed to support WDNR's forest practice regulation, Timber, Fish & Wildlife (TFW) planning and analysis applications, natural resource planning, and general cartography.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 1994 to present

Scale/Resolution: Two sources: USGS 7.5 minute quadrangles: 1:24,000; WDNR Orthophotos: 1:36,000

Data Format: Clipped data to go into an ESRI Geodatabase

Assessment of Dataset: This dataset provides an extensive catalog of roads that would be useful for road area calculations. There is no consistent relationship between this WDNR dataset and the ESRI dataset described above because both datasets include roads that the other does not. The WDNR dataset includes many forest roads and is more comprehensive than the ESRI dataset. The WDNR dataset categorizes roads into the following five types:

- Primary highway/all-weather/hard surface
- Secondary highway/ all-weather/ hard surface
- Light-duty road/ all-weather/ improved surface
- Unimproved road/ fair or dry weather
- Unknown road classification

24.3 Recommendation

It is recommended that only one of the available roads datasets is used, because it does not appear that the two datasets are satisfactorily compatible to merge together. Some assumptions of road width would be necessary with either the ESRI or the WDNR dataset. The WDNR dataset is recommended as the better dataset for this analysis because it is more comprehensive and includes more small roads occurring along the Puget Sound shoreline.

25 RAILROADS

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Area; same analyses as roads

25.1 Washington State Department of Transportation Active Railroads

Source: WSDOT

Description: This dataset catalogs active railroads as of December 1996.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 1996

Scale/Resolution: 1:24,000

Data Format: Line coverage with annotation

Assessment of Dataset: This dataset is a good inventory of active railroads, although the only associated information provided is the rail owner and there is not a full description of how this dataset was originally created.

25.2 Washington State Department of Transportation Abandoned Railroads

Source: WSDOT

Description: This dataset catalogs railroads that have been abandoned since 1953.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: Unspecified

Scale/Resolution: 1:24,000

Data Format: Line coverage with annotation

Assessment of Dataset: This dataset is a good inventory of abandoned railroads, although the only associated information provided is the rail owner. Mainline railroads are shown with high reliability, but minor railroads in remote areas (e.g., logging rail lines) are of questionable quality. The routes shown represent abandoned rights of way, whether or not tracks currently exist, and whether or not rights of way are currently owned by a railroad operator.

25.3 Recommendation

Both railroad datasets are good information sources for this analysis.

26 AQUACULTURE

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Area

26.1 Washington Department of Health Commercial Shellfish Growing Areas

Source: WDOH

Description: This dataset shows the boundaries of commercial shellfish growing areas for Puget Sound and Washington coastal areas. It is used to communicate closures and restrictions to commercial harvesters, and to validate license renewals for the Office of Shellfish and Water Protection.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 2006

Scale/Resolution: Positional accuracy estimated at 50 meters

Data Format: Polygon shapefile

Assessment of Dataset: Polygons are labeled with classes defined as “Approved: Commercial harvesting approved,” “Conditional: harvest is conditional upon rainfall and other factors,” Prohibited: harvest is prohibited,” “Restricted: harvest is restricted to species dependent on water quality conditions,” and “Unclassified: unclassified areas.” A growing area is determined by sanitary surveys, based on water quality samples, pollution sources, and weather conditions. This dataset’s resolution may be too broad for parcel-level analyses since it relies on spreading out sampling stations over a large area to measure for health concern contaminants. Thus, specific farmed acreage is not measured out.

26.2 Washington Department Natural Resources Successful Geoduck Leases for 2006-2007

Source: Washington Department Natural Resources (WDNR)

Description: It is worth noting that no geoduck aquaculture currently occurs on state-owned aquatic lands—all existing geoduck aquaculture occurs on privately owned lands. However, WDNR's Geoduck Aquaculture Program is in its early implementation phase, and there are now 16 successful permits issued for geoduck culture on state-owned lands. This is a database of those 16 successful leases, with latitude/longitude coordinates and acreage information.

Data in Hand: Yes

Metadata: No

Geography: Puget Soundwide

Date of Content: 2006 to 2007

Scale/Resolution: No positional accuracy was given

Data Format: Point shapefile

Assessment of Dataset: This dataset can be a good addition to any other species-specific culture datasets; however, no boundary extent is available at this time.

26.3 Pacific Shellfish Institute Shellfish Growers

Source: Pacific Shellfish Institute

Description: PSI has been collecting and updating individual growers using data from DOH management areas, WDNR's aquatic lease information, and county parcel data to get at specific farmed acreage from individual growers. There are 17 records in the dataset that they provided, ranging from South Puget Sound, to areas in the Hood Canal, and a single farm in San Juan Island. Contact says that this is an ongoing project that takes a bit of effort and time to compile and verify the growing extent.

Data in Hand: Yes

Metadata: No

Geography: Puget Soundwide

Date of Content: 2006 and ongoing

Scale/Resolution: No positional accuracy was given

Data Format: Polygon shapefile

Assessment of Dataset: This dataset is probably the best fit for the analysis, but is incomplete to date.

26.4 Recommendation

The PSI and WDNR lease information may be the best resolution datasets that exist, but are incomplete and cannot support a Soundwide change analysis.

27 PROTECTED LANDS

Purpose: Analytical

Analyses: Inventory

Metrics at the Geographic Scales: Area

27.1 Washington State Non-DNR Major Public Lands

Source: WDNR

Description: The Washington State Non-DNR Major Public Lands (NDMPL) dataset contains ownership parcels for federal, state (excluding WDNR), county and city lands within the State of Washington. It also includes tribal administrative boundaries.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 2005

Scale/Resolution: Ownership Parcel level

Data Format: Polygon Shapefile

Assessment of Dataset: This is an acceptably recent dataset that provides good coverage of non-DNR protected lands in Washington state; however, the information may be out-of-date and incomplete.

27.2 Washington Department of Natural Resources Cadastre for Parcels

Source: WDNR

Description: This data contains ownership parcels for WDNR managed lands.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 2005

Scale/Resolution: Parcel level

Data Format: Polygon Shapefile

Assessment of Dataset: This is an acceptably recent dataset that provides a coverage of WDNR managed lands only in Washington state.

27.3 CommEn Space Washington Protected Lands Database

Source: CommEn Space

Description: This dataset contains location, conservation status, and other information on both public and private protected lands in the State of Washington. This shapefile contains publicly and privately protected lands in Washington State.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 2004

Scale/Resolution: Parcel level

Data Format: Polygon Shapefile

Assessment of Dataset: This complete dataset of both public and private protected lands for Washington; however, it is 4 years old.

27.4 The Nature Conservancy Washington State Conservation Management Status Database

Source: The Nature Conservancy

Description: Conservation Management Status (CMS) is a measure of the potential for protection and management activities of lands and waters to secure biodiversity to persist. This measure takes into account the protection or management intent, duration and authorization, and the potential for the management of these activities to be effective at conserving biodiversity and abating threats.

Data in Hand: Yes

Metadata: FGDC format metadata available

Geography: Statewide

Date of Content: 2007

Scale/Resolution: Parcel level

Data Format: Polygon Shapefile

Assessment of Dataset: This dataset provides the most up to date and complete information on publicly and privately protected lands in Washington State. Both the Washington Department of Natural Resources NDMPL database and

CommEn Space's Protected Lands database served as the primary sources of spatial and attribute data used in the Washington Conservation Management Status database. These data sources were determined to be more accurate than the current snapshot of the Conservation Biology Institute Protected Areas Database (CBI PAD).

27.5 Recommendation

The TNC's Washington Conservation Management Status database is the most current and comprehensive dataset to support the change analysis.

APPENDIX A

DATA DISCOVERY SUMMARY TABLE

Data Discovery Summary Table

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
Shoreline	Base layer	Attributed with shoreform	Percent length by shoreform	WDNR ShoreZone Inventory	Washington Department of Natural Resources (WDNR) ShoreZone Inventory	The ShoreZone Inventory describes the physical and biological characteristics of intertidal and shallow subtidal areas throughout Puget Sound and the outer coast of Washington. Data are presented for discrete assessment reaches. The ShoreZone Inventory can be used to better understand and manage Washington's coastal ecosystem.	Yes	FGDC format metadata available	Soundwide	1994 to 2000	1:24,000	Line shapefile	The ShoreZone Inventory includes a shoreline shapefile of the estimated mean higher high water (MHHW) line. There are some small areas of discrepancy where the shoreline is too far inland or offshore, but in general, the shapefile adequately depicts the shoreline configuration.	The WDNR ShoreZone Inventory shoreline provides a better shoreline to use as a base map in the Change Analysis. The WDNR ShoreZone Inventory shoreline has fewer discrepancies and more detail of coastal features than the WDOE shoreline. In addition, the ShoreZone Inventory has been used by the Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP) for a geomorphic typology base layer. Using the same shoreline as SSHIAP will facilitate easier cross-walk during the upcoming typology assessment.
				WDOE	Washington Department of Ecology (WDOE)	The WDOE shoreline shapefile was developed as a cartographic background dataset for Geographic Information Systems (GIS) coastal projects—specifically, updates to local Shoreline Management Plans. The dataset also shows the area of the marine (saltwater) shorelines of Washington State that fall under Shoreline Management Act jurisdiction. The shoreline shapefile depicts the estimated location of the ordinary high water mark (OHWM).	Yes	FGDC format metadata available	Soundwide	1996 to 2005	1:24,000	Line shapefile	The WDOE shoreline shapefile depicts the estimated location of the OHWM along the marine (saltwater) shorelines of the state. The dataset has many discrepancies throughout the shoreline.	
Bathymetry	Primary	To generate waterward edge of drainage units	None	UW (Finlayson) 2005	University of Washington (UW) School of Oceanography (Finlayson graduate work)	This is a general purpose DEM of bathymetry and topography in the Puget lowland. The dataset was designed to address the needs of researchers and managers considering the terrestrial and marine topography as a seamless unit. It represents a composite of datasources.	Yes	FGDC format metadata available	Soundwide, except no data for the San Juan Islands sub-basin and western half of Strait of Juan de Fuca sub-basin	2000 to 2005	30 feet	ESRI GRID	This dataset represents a composite of the best available bathymetry and topography for Puget Sound, Hood Canal, Lake Washington, and the surrounding lowlands as of January 2005. A drawback is the incomplete geographic extent of the dataset. It is important to note that the dataset is a compilation of sources providing data of variable scales and accuracies. This may be less important for the intended uses of the bathymetric data, but may limit its suitability as a topographic DEM data source (see Section 4). Another limitation for using the topographic portion of the dataset is that the LIDAR-derived data are expected to be too precise to be incorporated into the drainage unit (DU) delineation.	A composite of multiple sources should not limit the dataset's usefulness for characterizing the offshore limit of DUs. The UW 2005 dataset is recommended as the primary bathymetry dataset. It is a compilation of the best available data within the geographic area included in the dataset. The UW 2000 dataset is useful as a supplemental bathymetry dataset. It can be used to fill gaps in the 2005 data, except in the area just east of the San Juan Islands. The WDFW and NOAA NOS dataset is useful to fill the remaining gap that neither of the UW DEMs covered. For any given area within Puget Sound, if more than one bathymetry DEM data source is available, it is recommended that the dataset providing the most recent data is used. In this way, data preference would be in the following order: UW (Finlayson) 2005, UW (Finlayson) 2000, and the WDFW/NOAA NOS.
				UW (Finlayson) 2000	University of Washington (UW) School of Oceanography (Finlayson graduate work)	This is a general purpose DEM of bathymetry and topography for most of western Washington.	Yes	FGDC format metadata available	Soundwide, except for a hole between eastern San Juan Islands and western shoreline of Lummi Island, Guemes Island, and Fidalgo Island	Circa 2000	30 meter	ESRI GRID	This is a Soundwide dataset for bathymetry and topography, including those areas not included in the 2005 dataset. This 2000 dataset is at a lower (poorer) resolution than the 2005 dataset described above.	
				WDFW and NOAA National Ocean Service	WDFW and NOAA National Ocean Service	This DEM was derived from 930,967 soundings taken primarily between 1934 and 1943. The sounding data were originally distributed by NOAA National Ocean Service (NOAA NOS; personal communication Dale Gombert, WDFW 2008). The DEM is currently available at the NOAA NOS website (http://egisws01.nos.noaa.gov/servlet/BuildPage?template=bathy.txt&B1=Submit&parm1=P290). WDFW hired a private contractor to use that sounding data to generate an ESRI GRID DEM. The data are referenced to mean low water.	Yes	FGDC format metadata available	Soundwide	Primarily between 1934 and 1943, but up to 1982.	30 meter pixels	ESRI GRID	The DEM is derived from 88 surveys dating as far back as 1934. Some unknown variability in data accuracy is acknowledged in the metadata due to grid spacing of the soundings, resolution of the soundings, and to changes in technology. In some regions, the only source data were at fathom (6 feet) resolution. In general, most source surveys were certified to 1 foot or better by NOAA NOS. The vertical datum would need to be converted to North American Vertical Datum (NAVD) 88 for use with the other DEMs.	
Digital Elevation Model (DEM)	Primary	To generate DUs and topology	None	USGS	U.S. Geological Survey (USGS)	This is a general purpose Digital Elevation Model (DEM) of topography throughout the State of Washington.	Yes	FGDC format metadata available	Soundwide	2001	10 meter	Raster	This is a statewide DEM with good resolution that will be adequate for use in deriving measurement units. The USGS DEM leaves some gaps between the edge of the dataset and the ShoreZone Inventory shoreline.	The USGS DEM is an adequate primary DEM dataset. Areas of gaps between the USGS DEM and the ShoreZone shoreline can be supplemented using the UW 2005 bathymetry and topography DEM dataset. The coupling of these two datasets for this purpose is expected to be seamless. The USGS DEM dataset can also be supplemented by the Canadian DEM to allow for comprehensive delineation of DUs in Process Units that extend into Canada.
				Natural Resources Canada	Government of Canada, Natural Resources Canada	This is a general purpose DEM of topography throughout western Canada.	No, but available online	Canadian equivalent of FGDC format metadata available	Canadian portion of watersheds flowing into Puget Sound	1996	Variable throughout spatial extent, but roughly 15-meter-wide by 23-meter-high pixels in the area of interest	Raster	This DEM has lower resolution than the USGS DEM for Washington.	

Data Discovery Summary Table

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
Drift Cells	Primary	To support typology and geographic scale delineation	None	WDOE (Schwartz)	WDOE	This dataset is a digitized version of net shore-drift mapping conducted by approximately ten graduate students of Dr. Maurice Schwartz at Western Washington University. The mapping was conducted between the late 1970s and early 1990s.	Yes	FGDC format metadata available	Soundwide	1970 to 1980	The original maps were created at a variety of scales and formats, and later aligned to a 1:24,000 scale marine shoreline coverage.	Line shapefile	This dataset is the only Soundwide characterization of net-shore drift. It is widely used in shoreline planning efforts, including Shoreline Master Plan updates. The multiple authors and incomplete quality control of the dataset have resulted in some resolution and completeness inconsistencies among areas that have been carried forward through WDOE's digitization of the dataset.	The Corps corrected version of the WDOE drift cell dataset fixes some of the errors in the original dataset. The dataset is the best available characterization of net shore-drift in Puget Sound
				U.S. Army Corps of Engineers	U.S. Army Corps of Engineers (Corps)	The Corps contracted Coastal Geologic Services to revise the WDOE drift cell dataset in the following ways: 1. Fill in data gaps in areas mapped as UN (unidentified) or blank 2. Correct data in areas where net shore-drift was mapped in regions where no net shore-drift occurs 3. Interpret historic net shore-drift for those areas characterized in WDOE based on current drift conditions caused by large anthropogenic alterations (e.g., jetties, dikes, and dredge/fill)	Yes	FGDC format metadata available for original, methods documentation report for recent revisions	Soundwide	1970 to 1980	The original maps were created at a variety of scales and formats, and later aligned to a 1:24,000 scale marine shoreline coverage.	Line shapefile	This dataset provides an improved version of the original WDOE drift cell dataset.	
Geology	Primary	To support typology	None	WDNR Geology Dataset	WDNR	This is a statewide geology dataset.	Yes	FGDC format metadata available	Soundwide	1984 to 2002	1:100,000	Polygon shapefile	This dataset contains polygons that identify the extent and type of each geologic unit. It is a coarse resolution geology dataset, but it covers all of Puget Sound and will be useful in the delineation of current typology.	The 1:100,000 scale WDNR geology dataset is the best Soundwide dataset available in digital format.
				WDNR Miscellaneous Compilation	WDNR	This is a compilation of all previous WDNR mapping indexes of geologic and geophysical mapping.	No	Unknown	Incomplete data in all sub-basins	1949 to 1999	Variable	Unknown	The usefulness of this dataset is limited because it is not available Soundwide.	
Slope Stability	Primary	To support typology	None	WDOE Coastal Zone Atlas	WDOE	This is a digitized version of the slope stability maps in the WDOE Coastal Zone Atlas.	Yes	FGDC format metadata available	Soundwide for areas under direct State of Washington jurisdiction. Federal military installations and Indian reservations are not included. The dataset extends only 2,000 feet inland from the Puget Sound shoreline.	Mid-1970s	1:24,000	Polygon shapefile	This dataset provides slope stability information for general reference. These maps indicate the relative stability of coastal slopes as interpreted by geologists based on aerial photographs, geological mapping, topography, and field observations. The methods are standard but may occasionally result in some unstable areas being overlooked and in some stable areas being incorrectly identified as unstable. Further inaccuracies are introduced to the data through the process of converting the published maps into digital format. This dataset should not be used as a substitute for site-specific studies carried out by qualified geologists and engineers, but for the purposes of this analysis, this dataset provides adequate information.	Though the WDOE Slope Stability dataset has many limitations on quality, it is a useful representation of the state of anthropogenic modification in the 1970s. This dataset is useful as a secondary dataset for all analyses in the project, and it is useful for shoreline typology analysis. The WDNR Forest Practices dataset is a predictive layer and less useful for the analysis.
				WDNR Forest Practices Division	WDNR Forest Practices Division	This dataset depicts outputs of predictive shallow-rapid slope stability using one or more calibrated GIS-based models.	Yes	FGDC format metadata available	Soundwide	2000	10 meter	ESRI Grid	The model outputs contained in this dataset are intended to be used for pre-classification screening of forest practices applications and screening for slope stability concerns on managed timberlands.	
Hydrographic Sheets	Primary	To support typology	None	USCGS Historic Digitized Hydrographic Sheets	National Oceanic and Atmospheric Administration (NOAA)	The U.S. Coast and Geodetic Survey (USCGS) historic digitized hydrographic sheets (H-sheets) are good historic maps of hydrographic soundings and bathymetric points around Puget Sound.	Yes	FGDC format metadata available	Soundwide	Late 1800s	Variable, no worse than 1:100,000 (between 1:10,000 and 1:20,000 among H-sheets to be used in this analysis)	TIFs/GeoTIFs	The USCGS was in the forefront of new surveying innovations, using schooners to perform surveys, lead lines to measure soundings, and astronomic fixes and dead reckoning to position a survey ship when out of sight of land on the first hydrographic surveys in late 1834 and early 1835. In addition to hydrographic soundings and bathymetric points, the H-sheet maps are also useful for digitizing eelgrass and general intertidal areas around deltas. The maps are scanned but not geo-rectified.	The H-sheets are good historic maps to use as a primary dataset of historic conditions.

Data Discovery Summary Table

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
Puget Sound River History Project Data	Primary	To support typology	Percent area	UW Puget Sound River History Project Historic Digitized Typography Sheets	UW Puget Sound River History Project	This is a dataset of the digitized historic topography sheets (T-sheets) prepared by the USCGS.	Yes	FGDC format metadata available	Soundwide	1852 to 1926	1:100,000	Geodatabase	Provides digitized historic T-sheets for all of Puget Sound and the Strait of Juan de Fuca. GIS data were developed by the UW Puget Sound River History Project for an assessment of historical change to nearshore environments in the Puget Sound region.	The UW Puget Sound River History Project datasets are essential datasets for the upcoming analysis.
				UW Puget Sound River History Project Historic Nearshore	UW Puget Sound River History Project	Historic data of Puget Sound nearshore derived from historic T-sheets, supplemented with field notes and plat maps from 19th century government land survey and various other sources including other early maps, aerial photographs, early text sources, and recent data including high-resolution DEMs.	Yes	FGDC format metadata available	Soundwide	Approximately 1850	1:100,000	Geodatabase	The historic nearshore dataset is the best GIS historic dataset for the Puget Sound nearshore. The GIS data were developed by the UW Puget Sound River History Project for an assessment of historical change to nearshore environments in the Puget Sound region.	
High Resolution Aerial Imagery	Primary	To support multiple datasets	None	USGS NAIP 2006	USGS National Agriculture Imagery Program (NAIP)	Recent high resolution imagery for Washington State	Yes	No formal metadata; online description available	Soundwide	2006	1-meter pixels; color	MrSIDs	The USGS aerial imagery is the best available Soundwide dataset.	The USGS photographs are the best available with a Soundwide extent. Imagery from various other sources (e.g., counties) is available for subsets of the Puget Sound region, but this imagery is not Soundwide or more current.
Oblique Aerial Imagery	Ancillary	To support multiple datasets	None	WDOE 2005-2006	WDOE	Recent aerial oblique photographs along marine shorelines of Washington State	No, but it has been requested	No formal metadata; online description available	Soundwide, except Whatcom and Snohomish Counties, which have not yet been released	2005 to 2006	Variable; generally, one photograph shows approximately 1,000 lineal feet of shoreline	Hyperlinked GIS point file with JPG and TIF images	Good quality oblique photographs taken during summer low tide events. Photographs were taken to optimize sun angle, shoreline orientation, and low tides. The oblique photographs are useful for interpreting bluff geology and land-sliding, riparian vegetation, and shoreline modifications, such as bulkheads and seawalls.	The 2005-2006 oblique photographs will be useful to support interpretation of high resolution aerial orthogonal photography and shoreline information. The 2000-2002 data will be a good backup dataset.
				WDOE 2000-2002	WDOE		Yes	No formal metadata; online description available	Soundwide	2000 to 2002	Variable; generally, one photograph shows approximately 1,000 lineal feet of shoreline	Hyperlinked GIS point file with JPG and TIF images	Good quality oblique photographs taken during summer low tide events. Photographs were taken to optimize sun angle, shoreline orientation, and low tides. The oblique photographs are useful for interpreting bluff geology and land-sliding, riparian vegetation, and shoreline modifications, such as bulkheads and seawalls.	
LIDAR (terrestrial)	Ancillary	To support multiple datasets	None	PSLC	Puget Sound LIDAR Consortium (PSLC)	The Light Distance and Ranging (LIDAR) dataset of bare earth DEMs is a representation of the earth's surface where all constructed structures and vegetation have been removed. The PSLC is an informal group of local agency staff and Federal research scientists devoted to developing public-domain high-resolution LIDAR topography and derivative products for the Puget Sound region.	Yes	No formal metadata; online description available	Soundwide, except for the western half of the Strait of Juan de Fuca, Bellingham area of San Juan Islands, and a small area along the southern end of Whidbey Island Basin	2000 to 2006	6-foot pixels	ArcInfo Coverage files	The LIDAR bare earth DEMs are comparable to the USGS DEMs (described in Section 4.1), but are of much higher accuracy and can be used at a larger scale up to 1:12,000 (1 inch = 1,000 feet). The LIDAR bare earth DEMs have a wide range of uses such as earthquake hazard studies, hydrologic modeling, forestry, coastal engineering, roadway and pipeline engineering, flood plain mapping, wetland studies, geologic studies, and a variety of analytical and cartographic projects. The precision of the LIDAR-derived portion of the dataset would produce overly complex DU delineations, which would then require extra work to simplify.	Because of the incomplete geographic extent of this dataset, it is recommended that the LIDAR dataset be used to supplement the USGS DEM dataset and for cartographic purposes. If there is an interest in developing more LIDAR data, the WDNR Geologic Division is looking for cost-share partners.

Data Discovery Summary Table

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
Streams	Analytical	To analyze with shoreline; analyze with roads	Count of stream mouths; count of stream intersections with roads	WDNR Watercourse Hydrography	WDNR	Statewide dataset of watercourses that represent streams, ditches, or pipelines, or as centerlines through water body polygons such as double-banked streams, lakes, impoundments, reservoirs, wet areas, or glaciers.	Yes	FGDC format metadata available	Soundwide	August 2007, but updated monthly	1:24,000	Coverages converted to Geodatabase	This dataset is the most consistent Soundwide hydrology layer. It has many more stream courses mapped than the USGS National Hydrologic Dataset described below. The dataset is updated monthly by WDNR. The WDNR dataset categorizes waterbodies into 8 types (see report text for types).	The WDNR watercourse hydrography appears to be the best dataset for the analysis of road crossings. It is a widely used dataset, including use by other state agencies to support various mapping efforts. The dataset does not extend into Canada; therefore, it will be necessary to obtain available data from Canada if DU delineations are to extend beyond the U.S.-Canada border.
				USGS National Hydrologic Dataset	USGS	Nationwide stream dataset	Yes	FGDC format metadata available	Statewide	Not specified	Originally developed at 1:100,000 nationwide; some unspecified areas may be of higher resolution (1:24,000 or 1:12,000)	Geodatabase, line feature class	Not as detailed as the WDNR Streams dataset. The USGS National Hydrologic Dataset (NHD) classifies waterbodies into the following seven types (see report text for types).	
				Salmon and Steelhead Habitat Inventory and Assessment Project									SSHIAP is currently developing a compilation of hydrologic and stream datasets to support analyses conducting the watershed data to the marine environment. This layer will be linked to the ShoreZone Inventory shoreline data in a relational database called "Aquascape." It was not determined whether the dataset is available at this time.	
Overwater Structures	Analytical	Inventory	Area	WDNR	WDNR	This is a dataset of overwater structures in Puget Sound and the Strait of Juan de Fuca. Structure attribute information indicates whether structure decking is complete or partial due to construction or decay, as well as whether the structure includes multiple structure types (e.g., a dock and building together). Boats are sometimes included in the structure boundary. Some structures (approximately 10 percent of the 9,327 polygons) include additional detail, classified with categories described in report text.	Yes	FGDC format metadata available	Marine waters statewide	2002 to 2003 and 2005 to 2006	Digitized from 1-meter orthophotos; 3-meter horizontal accuracy	Polygon shapefile	This dataset marks the outline (footprint) of overwater structures throughout Puget Sound. The most reliably and comprehensively mapped structures in this dataset are docks/piers, bridges, buildings, and floats. There are also data on structures such as buoys and fills, but these were not comprehensively mapped by all cartographers.	This is a Soundwide standardized dataset that will be useful for this project.
Marinas	Analytical	Inventory	Area	WDNR	WDNR	The WDNR overwater structures dataset described above includes marinas.	Yes	FGDC format metadata available	Marine waters statewide	2002 to 2003 and 2005 to 2006	Digitized from 1-meter orthophotos; 3-meter horizontal accuracy	Polygon shapefile	This dataset marks the outline (footprint) of overwater structures, including marinas, throughout Puget Sound. The dataset is approximately 80 percent complete and would require some refinement of the line work.	The Corps-enhanced version of the marinas portion of the WDNR overwater structures dataset will be suitable for calculation marina areas. As described above, the dataset allows for two separate calculations of marina size: 1) the area with overwater structures and 2) the aquatic area encompassed by the marina complex.
				NOAA ESI	NOAA, Office of Restoration and Response, Environmental Sensitivity Index (ESI)	This is a dataset documenting marina locations.	Yes	FGDC format metadata available	Soundwide	1985 to 2005	1:24,000	Geodatabase, point feature class	Marina locations are identified in the point file, but no information is provided about the marinas' on-water footprints. The locations were based on information from a variety of sources and were adjusted to align with shoreline.	
				U.S. Army Corps of Engineers	Corps	The Corps contracted Anchor Environmental, L.L.C. (Anchor), to revise the marina dataset included in the WDNR overwater structure dataset. This entailed scanning shoreline imagery to ensure that all marinas of sufficient size (10 or more slips) were included in the dataset and that the linework was accurate. Marinas were delineated using aerial photography interpretation techniques. Polygons were created to delineate the shape of overwater structures (i.e., docks) in marinas. Boats in slips were considered overwater structures in this delineation. The polygon shapes were created assuming every boat slip was filled with a boat. For marinas with an associated breakwater/jetty, separate polygons were created for the overwater structures within the marina, the breakwater/jetty, and the unshaded aquatic area enclosed within the breakwater/jetty.	Yes	FGDC format metadata available	Marine waters of Puget Sound planning area	2002 to 2003, 2005 to 2006, and 2008	Digitized from 1-meter orthophotos; 3-meter horizontal accuracy	Polygon shapefile	This is a comprehensive dataset of marinas containing 10 or more slips in the Puget Sound planning area. The dataset allows for calculation of overwater structure area in marinas assuming every slip in the marina is occupied. For marinas with associated jetties/breakwaters, the dataset allows for calculation of the entire aquatic area of the marina complex, (i.e., overwater structure area, jetty/breakwater, and unshaded aquatic area sheltered within the jetty/breakwater).	

Data Discovery Summary Table

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
Armoring	Analytical	Inventory	Length	WDNR ShoreZone Inventory	WDNR	The WDNR ShoreZone Inventory identifies shoreline modifications (armoring) by type; percent of shoreline armored; and linear feet of the primary, secondary, and tertiary modifications in discrete assessment reaches demarcated by geomorphologic characteristics.	Yes	FGDC format metadata available	Soundwide	1994 to 2000	1:24,000	Line shapefile	The ShoreZone Inventory is not an adequate source of armoring data for this analysis because the assessment unit scale of the data is not detailed enough to adequately characterize the amount of armoring within individual delineated drainage units. As noted by Tim Strickler of the Puget Sound Partnership, ShoreZone Inventory assessment units with 0 percent or 100 percent armoring provide acceptable data to fill data gaps where other local assessments (described above) have not been conducted. Comparing these areas with 0 percent or 100 percent armoring to the data gaps of local assessments provides armoring data for all shorelines except approximately (see report text for details).	The conglomeration of the three data sources above provide a complete armoring dataset for the Puget Sound planning area. The dataset is suitable for use in analyses of armoring location and length.
				PSP and Corps Compilation	Corps for final compilation; Puget Sound Partnership (PSP) for an interim compilation	The PSP prepared a compilation of available shoreline armoring data throughout Puget Sound and Strait of Juan de Fuca. The Corps contracted Anchor to acquire additional datasets that became available after the PSP compilation effort.	Yes	Incomplete among contributing datasets	Incomplete; of the 2,479 miles of shoreline in the project area, 905 miles of shoreline have not been surveyed (see report text for details).	1999 to 2005	Variable and not well documented in the metadata; some datasets were collected in the field, while others were interpreted off of aerial photographs and oblique photographs.	Mix of ESRI Geodatabase, line shapefiles, polygon shapefiles	The available armoring data were gathered using a variety of field and/or photograph interpretation techniques and do not cover the full spatial extent of the project area. Following is a brief summary of available armoring data (other than the ShoreZone Inventory) in each sub-basin. The PSP assessment of the data available at the end of their compilation efforts is provided as Appendix B.	
				Corps	Corps	The Corps contracted Anchor to fill the gaps in armoring data described above. Shoreline armoring was delineated using aerial photograph interpretation techniques.	Yes	FGDC format metadata available	Fills data gaps remaining from other local assessments and WDNR ShoreZone Inventory (see report text for details).	2008	Approximately 1:1,500; delineation captured only armoring sections greater than 30 meters long	Line shapefile	The armoring data were collected using aerial photography interpretation techniques and limited ground-truthing. The data are suitable for use in analyses of armoring location and length.	
Breakwaters/ Jetties	Analytical	Inventory	Length	WDNR ShoreZone Inventory	WDNR	The ShoreZone Inventory describes the physical and biological characteristics of intertidal and shallow subtidal areas throughout Puget Sound and the outer coast of Washington. Data are presented for discrete assessment reaches. The ShoreZone Inventory indicates only which shoreline assessment reaches include breakwaters or jetties.	Yes	FGDC format metadata available	Soundwide	1994 to 2000	1:24,000	Line shapefile	The ShoreZone Inventory does not provide the desired information about breakwaters and jetties.	The Corps breakwaters/jetties dataset was created to provide the information requested for the change analysis.
				Corps	Corps	The Corps contracted Anchor to prepare a breakwaters/jetties dataset. The dataset delineates the polygon outline of all breakwaters/jetties. The dataset attribute table will also identify the material or type (e.g., rock, pier pile, or floating). The delineation was based on interpretation of ortho and aerial oblique photographs.	Yes	FGDC format metadata available	Marine waters of Puget Sound planning area	2002 to 2003, 2005 to 2006, and 2008	Digitized from 1-meter orthophotos; 3-meter horizontal accuracy	Polygon shapefile	This is a comprehensive dataset of breakwaters/jetties in the Puget Sound planning area.	

Data Discovery Summary Table

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
Groins	Analytical	Inventory	Length										No available Soundwide dataset delineating groins was identified. Some of the armoring datasets delineate some groins and would provide length information.	It is recommended that either groins are not included in the analysis or the analysis continues with a partial dataset that could be created. There is a wide range of variability in the proximity to MHHW, size, and condition of groins, which makes it a very challenging shoreline feature to assess. The aerial photographs available Soundwide are not of sufficient resolution to support a photograph interpretation to create a comprehensive dataset; instead, an extensive field-based inventory during summer low tides would be necessary. If a partial dataset using the aerial photographs is sufficient, then aerial (orthogonal and oblique) photograph interpretation techniques can be conducted to create the dataset. Ground-truthing would be prudent for quality control and to provide a more comprehensive dataset; however, the need for daytime low tides greatly limits what could be accomplished in the winter. If aerial photograph interpretation of groins is conducted, then the establishment of interpretation rules will be very important because there is more subjectivity for what appears to be a groin in aerial photographs than there is for other physical features.
Levees/ Dikes	Analytical	Inventory	Length	Corps	Corps	This dataset was created for the change analysis and delineates the approximate centerline of levees affecting or near the Puget Sound Nearshore.	Yes	FGDC format metadata available	Soundwide, major levees only	2007	1:24,000	Line shapefile	The levee data was digitized from topographic maps, aerial imagery, and LIDAR data (showing the crowns of levees). As such, it is not considered a complete dataset of levees, but one that is representative of one type of anthropogenic feature disconnecting the Puget Sound nearshore environment from upland areas.	The SSHIAP tidal barriers dataset was created to provide the information requested for the change analysis.
				Salmon and Steelhead Habitat Inventory and Assessment Project Hood Canal Hydromodifications	SSHIAP	This SSHIAP hydromodifications dataset delineates the approximate centerline of levees and other structures throughout most of the Hood Canal sub-basin and part of the Strait of Juan de Fuca sub-basin. Levees were delineated based on aerial photograph interpretation coupled with a significant field verification effort. The analysis included large and small river systems in the analysis area. Channel gradient and confinement data in the SSHIAP stream segment dataset were useful information for identifying river systems most likely to have levees.	Yes	Incomplete	Hood Canal and a small part of the Strait of Juan de Fuca sub-basin	2001	Unspecified	Line shapefile	The SSHIAP dataset provides field verified levee data for the area surveyed, including large and small river systems.	
				National Wildlife Federation Dike Impoundment	National Wildlife Federation (NWF)	The NWF dike impoundment area dataset was created for an analysis of sea-level rise impacts (NWF 2007). The NWF dataset estimates the areas impounded by dikes, but it does not explicitly delineate dikes. NWF identified impounded areas on agriculture lands using topographic maps and an elevation analysis. Some U.S. Geological Survey topographic maps that show dikes were used to verify the created impoundment dataset and provided some information used to reduce the patchiness of the impoundment dataset.	Yes	Incomplete	Based on the geographic extent described in NWF (2007), the analysis covered 10 areas within Puget Sound (see report text for the areas).	2001	Unspecified	Raster	The NWF dataset estimates the areas impounded by dikes, but it does not explicitly delineate dikes. The characterization of impoundment areas is further limited because they were only identified on agricultural lands. The dataset is inadequate to support a levee analysis, although the approach to determining impoundment areas could be expanded upon and applied Soundwide if impoundment areas become of interest.	

Data Discovery Summary Table

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
				Salmon and Steelhead Habitat Inventory and Assessment Project Tidal Barriers	SSHIAP	SSHIAP prepared this tidal barriers dataset to support the Puget Sound Nearshore Partnership change analysis. SSHIAP delineated dikes, levees, roads, and other constructed structures that impede tidal hydrology such that historic wetlands become lost or isolated from Puget Sound nearshore waters. This inventory was limited to selected tidal wetland classes within large river deltas, barrier estuaries, barrier lagoons, and open coastal inlets as identified by PSNERP NST. The delineation was based on LIDAR, ortho and aerial oblique photographs, transportation layers, and the Corps levee dataset described above.	Yes	FGDC format metadata available	Soundwide in selected shoreforms	2002 to 2003, 2005 to 2006, and 2008	Unspecified	Line shapefile	The SSHIAP tidal barriers dataset was created based on the direction of the PSNP in order to support the change analysis.	

Data Discovery Summary Table

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
Dams	Analytical	Inventory	Count	WDOE Dams Dataset	WDOE	This is a statewide dataset of dams that capture and store at least 10 acre-feet (about 3.2 million gallons) of water or watery materials.	Yes	FGDC format metadata available	Statewide	2006	No metadata information on positional accuracy, but contact suggested some may be off by as much as 1,000 feet	Point shapefile	For dams of adequate size to be included in the dataset (capture and store at least 10 acre-feet of water or watery materials), information is provided on dam size, purpose, material, year built, discharge capacity, storage, and drainage area above the dam.	Use both datasets to characterize the number of dams. A quality control review of the two datasets would be necessary to avoid double-counting dams that may be included in both datasets.
				WDFW Fish Passage Barrier Inventory	Washington Department of Fish and Wildlife (WDFW)	The focus of this inventory is dams that are barriers to fish passage according to the guidelines in WDFW's *Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual*	Yes	FGDC format metadata available	Statewide	1971 to 2007	Positional accuracy of 5 meters to 100 meters, depending on source of data (either GPS or USGS 1:24,000 topographic map)	Point shapefile	The dataset includes information on dam purpose and fish barrier status. Most dams in this dataset are too small to be included in the WDOE dataset described above. Therefore, the two datasets could be complementary.	
Nearshore Fill	Analytical	Inventory	Area	Washington Department of Ecology Coastal Zone Atlas	WDOE	WDOE Coastal Zone Atlas data on geology includes a category for artificial fill (af). Corps contracted Anchor to digitize the af polygons. The af polygons that were found to be dikes or levees were not digitized as that information is captured in a separate dataset.	Yes	FGDC format metadata available	Marine waters of Puget Sound planning area	1980	1:24,000	Polygon shapefile	This dataset provides a sufficiently consistent nearshore fill throughout the Puget Sound planning area. It does not delineate all areas of nearshore fill, but it is a consistent Soundwide dataset.	The nearshore fill data in the WDOE dataset will provide adequate information to support the change analysis.
Land Cover	Analytical	Inventory	Percent land cover	UW Puget Sound Regional Synthesis Model	UW Puget Sound Regional Synthesis Model (PRISM)	This dataset delineates land cover classifications through interpretation of satellite imagery.	Yes	No formal metadata, but description available	Soundwide	2002	30 meter	ESRI Grid	The PRISM dataset extends to the ShoreZone Inventory shoreline and would be a good primary dataset. The dataset identifies 17 land cover classifications (see report text for classifications).	The NOAA C-CAP dataset is useful as the primary land cover dataset. The NOAA C-CAP dataset provides preferred coastal wetland land cover classes to those provided by the UW PRISM and NLCD datasets
				NOAA Coastal Change Analysis Program	NOAA Coastal Change Analysis Program (C-CAP)	This dataset delineates land cover classifications through interpretation of satellite imagery.	Yes	FGDC format metadata available	Soundwide	2000	30 meter	Raster (.img)	This dataset is not clipped to the ShoreZone Inventory shoreline which could present difficulties for use in the analysis. The dataset identifies 25 land cover classifications (see report text for classifications).	
				Multi-Resolution Land Characteristics Consortium National Land Cover Data (NLCD)	Multi-Resolution Land Characteristics (MRLC) Consortium	NLCD 2001 is a land-cover database comprised of three elements: land cover, impervious surface, and canopy density. These characteristics are interpreted for each 30 meter pixel using Landsat TM imagery.	Yes	FGDC format metadata available	Statewide	1999 to 2002	30-meter pixel	IMAGINE raster (.img)	The Landsat TM imagery is slightly dated, especially considering the amount of recent development in the Puget Sound area. Despite the age of the data, it is a good characterization of land cover. The dataset identifies 16 land cover classifications (see report text for classifications).	

Data Discovery Summary Table

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
Parcels	Analytical	To extract shoreline parcels only	Density – the number of parcels along a length of shoreline, may differentiate between commercial and residential	Puget Sound Action Team Compilation	Puget Sound Action Team (PSAT)	This compilation of parcels was prepared to support an analysis to identify underdeveloped and un-developed parcels.	Yes	FGDC format metadata available	Soundwide, except Island and Mason Counties	2004 to 2005	Parcel level	ESRI Geodatabase	This is an acceptably recent dataset that provides nearly complete coverage of the project area, except for Island and Mason Counties. The data can be used for the density metric as well as the differentiation of commercial and residential properties.	The contents of the county parcels datasets are highly variable and have multiple topological errors. The datasets are adequate for investigating parcel density, but incomplete information is available to investigate other aspects of parcels (e.g., ownership groups and land values).
				Washington Department of Natural Resources Cadastre for Parcels	WDNR	This data contains ownership parcels for WDNR managed lands.	Yes	FGDC format metadata available	Statewide	2005	Parcel level	Polygon Shapefile	This is an acceptably recent dataset that provides a coverage of WDNR managed lands only in Washington state.	
				Parcels - UW Statewide Cadastre for Parcels		Luke Rogers at UW is in the process of developing a statewide cadastre for all parcel data (39 counties) that will be standardized and will update these data for all counties. Incorporating the PLDB classification into the standard parcel data is also underway. The timeline for this cadastre data is uncertain.							The standardization of the parcel data is an important and useful effort.	
Impervious Surfaces	Analytical	Inventory	Percent	UW PRISM	UW PRISM	This dataset delineates percent impervious surfaces through interpretation of satellite imagery. This dataset is being prepared to support the Future With/Without Project.	No	Unknown	Soundwide	Unknown	Unknown	Unknown	The PRISM dataset is expected to be an excellent dataset for the analysis, but no information was available for it.	Use MRLC NLCD data until the UW PRISM impervious dataset is available. Using the UW PRISM dataset would provide more consistency with the Future With/Without Project Analysis.
				MRLC Consortium 2001 NLCD	MRLC Consortium NLCD 2001	NLCD 2001 is a land-cover database comprised of three elements: land cover, impervious surface, and canopy density. These characteristics are interpreted for each 30 meter pixel using Landsat TM imagery.	Yes	FGDC format metadata available	Statewide	1999 to 2002	30-meter pixel	IMAGINE raster (.img)	The Landsat TM imagery is slightly dated, especially considering the amount of recent development in the Puget Sound area. Despite the age of the data, it is a good characterization of percent impervious surface. No formal accuracy assessment was completed, but a cross-validation was done that indicated an accuracy of 86.2 percent.	
				WSDOT (ps_impsurf)	Washington State Department of Transportation (WSDOT) (ps_impsurf)	This dataset interprets the percent impervious surface for each 10 meter pixel using SPOT imagery.	Yes	Report, but no formal FGDC metadata	Limited spatial extent available; dataset includes almost all of the South Central Puget Sound sub-basin and parts of South Puget Sound and Hood Canal sub-basins	Not specified	10-meter pixel	ESRI Grid	Usefulness of dataset is limited because of incomplete coverage of project area. The report accompanying the dataset concluded that for regional-level assessments of impervious surfaces, the WSDOT Landsat analysis described below performed as well as this higher resolution SPOT imagery dataset.	
				WSDOT (psimpsurf2004)	WSDOT (psimpsurf2004)	This dataset interprets the percent impervious surface for each 30 meter pixel using Landsat imagery.	Yes	Report, but no formal FGDC metadata	Limited spatial extent available; dataset includes all of South Central Puget Sound sub-basin and parts of Whidbey Basin, North Central Puget Sound, Hood Canal, and South Puget Sound sub-basins	2004	30-meter pixel	ESRI Grid	The data are more recent than the MRLC impervious surface data described above, but the usefulness of the dataset is limited because of its incomplete coverage of the project area.	

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
Roads	Analytical	Apply a width according to road class	Area by road class in buffer according to frequency distribution; area by road class in drainage units	ESRI 2007 Street Map	ESRI's 2007 Street Map	This is the Washington portion of a nationwide roads dataset.	Yes	FGDC format metadata available	Nationwide	2003	1:100,000; the horizontal positional accuracy is 167 feet	Clipped data to go into an ESRI Geodatabase	This dataset provides an extensive catalog of roads that would be useful for road area calculations. There is no consistent relationship between this ESRI dataset and the WDNR dataset described below because each dataset includes roads that the other does not. The ESRI dataset appears more comprehensive in urban areas, but overall is less comprehensive than the WDNR dataset. The ESRI dataset categorizes roads into 16 types (see report text for types).	It is recommended that only one of the available roads datasets is used, because it does not appear that the two datasets are satisfactorily compatible to merge together. Some assumptions of road width would be necessary with either the ESRI or the WDNR dataset. The WDNR dataset is recommended as the better dataset for this analysis because it is more comprehensive and includes more small roads occurring along the Puget Sound shoreline.
				WDNR Transportation Dataset	WDNR	This dataset represents roads, railroads, trails, and other land and water transportation routes existing within the state of Washington. It was developed to support WDNR's forest practice regulation, Timber, Fish & Wildlife (TFW) planning and analysis applications, natural resource planning, and general cartography.	Yes	FGDC format metadata available	Statewide	1994 to present	Two sources: USGS 7.5 minute quadrangles: 1:24,000; WDNR Orthophotos: 1:36,000	Clipped data to go into an ESRI Geodatabase	This dataset provides an extensive catalog of roads that would be useful for road area calculations. There is no consistent relationship between this WDNR dataset and the ESRI dataset described above because both datasets include roads that the other does not. The WDNR dataset includes many forest roads and is more comprehensive than the ESRI dataset. The WDNR dataset categorizes roads into five types (see report text for types).	
Railroads	Analytical	Inventory	Area; same analysis as roads	WSDOT Active Railroads	WSDOT	This dataset catalogs active railroads as of December 1996.	Yes	FGDC format metadata available	Statewide	1996	1:24,000	Line coverage with annotation	This dataset is a good inventory of active railroads, although the only associated information provided is the rail owner and there is not a full description of how this dataset was originally created.	Both railroad datasets are good information sources for this analysis.
				WSDOT Abandoned Railroads	WSDOT	This dataset catalogs railroads that have been abandoned since 1953.	Yes	FGDC format metadata available	Statewide	Unspecified	1:24,000	Line coverage with annotation	This dataset is a good inventory of abandoned railroads, although the only associated information provided is the rail owner. Mainline railroads are shown with high reliability, but minor railroads in remote areas (e.g., logging rail lines) are of questionable quality. The routes shown represent abandoned rights of way, whether or not tracks currently exist, and whether or not rights of way are currently owned by a railroad operator.	
Aquaculture	Analytical	Inventory	Area	Washington Department of Health Commercial Shellfish Growing Areas	WDOH	This dataset shows the boundaries of commercial shellfish growing areas for Puget Sound and Washington coastal areas. It is used to communicate closures and restrictions to commercial harvesters, and to validate license renewals for the Office of Shellfish and Water Protection.	Yes	FGDC format metadata available	Statewide	2006	Positional accuracy estimated at 50 meters	Polygon shapefile	Polygons are labeled with classes defined as "Approved: Commercial harvesting approved," "Conditional: harvest is conditional upon rainfall and other factors," Prohibited: harvest is prohibited," "Restricted: harvest is restricted to species dependent on water quality conditions," and "Unclassified: unclassified areas." A growing area is determined by sanitary surveys, based on water quality samples, pollution sources, and weather conditions. This dataset's resolution may be too broad for parcel-level analyses since it relies on spreading out sampling stations over a large area to measure for health concern contaminants. Thus, specific farmed acreage is not measured out.	The PSI and WDNR lease information may be the best resolution datasets that exist, but are incomplete and cannot support a Soundwide change analysis.
				Washington Department Natural Resources Successful Geoduck Leases for 2006-2007	Washington Department Natural Resources (WDNR)	It is worth noting that no geoduck aquaculture currently occurs on state-owned aquatic lands—all existing geoduck aquaculture occurs on privately owned lands. However, WDNR's Geoduck Aquaculture Program is in its early implementation phase, and there are now 16 successful permits issued for geoduck culture on state-owned lands. This is a database of those 16 successful leases, with latitude/longitude coordinates and acreage information.	Yes	No	Puget Soundwide	2006 to 2007	No positional accuracy was given	Point shapefile	This dataset can be a good addition to any other species-specific culture datasets; however, no boundary extent is available at this time.	
				Pacific Shellfish Institute Shellfish Growers	Pacific Shellfish Institute	PSI has been collecting and updating individual growers using data from DOH management areas, WDNR's aquatic lease information, and county parcel data to get at specific farmed acreage from individual growers. There are 17 records in the dataset that they provided, ranging from South Puget Sound, to areas in the Hood Canal, and a single farm in San Juan Island. Contact says that this is an ongoing project that takes a bit of effort and time to compile and verify the growing extent.	Yes	No	Puget Soundwide	2006 and ongoing	No positional accuracy was given	Polygon shapefile	This dataset is probably the best fit for the analysis, but is incomplete to date.	

Data Discovery Summary Table

Data	Purpose	Analyses	Metrics at the geographic scales	Dataset Name	Data Source	Description	Data in Hand	Metadata	Geography	Date of Content	Scale/ Resolution	Data Format	Assessment of Dataset or Available Data	Recommendation
Protected Lands	Analytical	Inventory	Area	Washington State Non-DNR Major Public Lands	WDNR	The Washington State Non-DNR Major Public Lands (NDMPL) dataset contains ownership parcels for federal, state (excluding WDNR), county and city lands within the State of Washington. It also includes tribal administrative boundaries.	Yes	FGDC format metadata available	Statewide	2005	Ownership Parcel level	Polygon Shapefile	This is an acceptably recent dataset that provides good coverage of non-DNR protected lands in Washington state; however, the information may be out-of-date and incomplete.	The TNC's Washington Conservation Management Status database is the most current and comprehensive dataset to support the change analysis.
				Washington Department of Natural Resources Cadastre for Parcels	WDNR	This data contains ownership parcels for WDNR managed lands.	Yes	FGDC format metadata available	Statewide	2005	Parcel level	Polygon Shapefile	This is an acceptably recent dataset that provides a coverage of WDNR managed lands only in Washington state.	
				CommEn Space Washington Protected Lands Database	CommEn Space	This dataset contains location, conservation status, and other information on both public and private protected lands in the State of Washington. This shapefile contains publicly and privately protected lands in Washington State.	Yes	FGDC format metadata available	Statewide	2004	Parcel level	Polygon Shapefile	This complete dataset of both public and private protected lands for Washington; however, it is 4 years old.	
				The Nature Conservancy Washington State Conservation Management Status Database	The Nature Conservancy	Conservation Management Status (CMS) is a measure of the potential for protection and management activities of lands and waters to secure biodiversity to persist. This measure takes into account the protection or management intent, duration and authorization, and the potential for the management of these activities to be effective at conserving biodiversity and abating threats.	Yes	FGDC format metadata available	Statewide	2007	Parcel level	Polygon Shapefile	This dataset provides the most up to date and complete information on publicly and privately protected lands in Washington State. Both the Washington Department of Natural Resources NDMPL database and CommEn Space's Protected Lands database served as the primary sources of spatial and attribute data used in the Washington Conservation Management Status database. These data sources were determined to be more accurate than the current snapshot of the Conservation Biology Institute Protected Areas Database (CBI PAD).	

APPENDIX B

PUGET SOUND PLANNING AREA SHORELINE ARMORING ASSESSMENTS

TIM STRICKLER, PUGET SOUND PARTNERSHIP, 2007

Puget Sound Planning Area Shoreline Armoring Assessments

This summary is meant to describe past, current, and in-work efforts to identify and quantify armoring along the shoreline in the Puget Sound Planning Area. It is also meant to identify data that has been acquired for use and made available to PSNER for use in its nearshore change or list primary custodians that will be able to provide this information in the regions were data has not been provided, but collected.

Regional Efforts

Two Puget Sound regional assessments have been completed or are in work that identifies armoring along the shoreline. The first is the DNR Shorezone assessment completed between 1997 and 2000. The assessment was completed by helicopter and identifies primary, secondary, tertiary percentages of shoreline modifications based on segments demarcated by geomorphologic characteristics. The next regional modification identification effort is through the NWIFC where they are characterizing the shoreline of WRIAs 1-19. I am assuming there has been some conversation between PSNER and NWIFC to see what if any results of this work can be used in the change analysis.

Local efforts

Currently three of the seven basins proposed by PSNER have had complete shoreline modification assessments between 1999- and the present date, two other basins have had a majority of the shoreline assessed for armoring, and the remaining two are unique in that a majority of the shoreline has not been assessed (other than the DNR shorezone data), but have a geomorphology of a type where regional efforts could suffice.

Armoring Projects by Basin

Strait of Juan de Fuca

Shorezone appears to be the only known armoring assessment between Cape Flattery and the Dungeness Spit. After conversations with a number of persons with first hand knowledge of the area there are three major divisions of the shoreline that should be taken into account in this area:

- WRIA 19 - Cape Flattery to the Elwha River – The majority of the shoreline is of a geology that would have little armoring and would most likely be adequately represented by shorezone data;
    - Exceptions - Developed bays (Neah Bay and Clallam Bay) would be likely to have soft, armored shorelines and should be further investigated;
        - One approach, if using shorezone explicitly in this area does not meet the current needs, might be to only investigate the shoreline for armoring in areas that shorezone identifies already as armored or identifies shoreline segments with soft beach/substrate types.
- Elwha River to Dungeness Spit – This shoreline division would include the majority of WRIA 18Port Angeles would be the primary concern along this stretch of shoreline, but as you move east the potential for soft shorelines increases;

- Dungeness spit to Point Wilson – The remaining eastern portion of WRIA 18 and all of WRIA 17 shoreline was assessed in the 2003 Shoreline Alterations in Hood Canal and the Eastern Strait of Juan de Fuca technical report[1] put out by the Point No Point Treaty Council;

North Central Puget Sound

The west side of North Central Puget Sound (WRIA 17 between Point Wilson and Tala Point) was assessed under the Point No Point Project. Southwest shoreline of Whidbey Island and discussed from Point Partridge to Possession Point was assessed in 1999 outlined in a Survey of Shoreline Armoring A Protocol for Volunteers that was overseen by Island County WSU Beach Watchers' Shoreline Survey Team[2]. Both of these methodologies will be discussed in detail in other sections of the armoring summary.

Hood Canal Basin

The entire Hood Canal basin shoreline was assessed by boat between 1999 and 2000 the results were published in 2003 Point No Point Treaty Council Technical report. This project gives the best overall description of methodologies, and observations on other approaches that could be used and that were investigated by the principles in this project to identify shoreline alterations. This included:

- On the ground GPS foot assessments
    - This was the preferred option, but was determined to be unreasonable based on access to privately owned shorelines (which accounts for a majority of the shoreline in Puget sound), physical access, and extensive survey distances;
- A combination of aerial oblique photos from the DOE website and georectified aerial photography. This was not considered to be a feasible approach because of the oblique photos not being rectified to the shoreline and vegetation obscuring the extent of individual incidences of armoring. Two general observations about this approach that may help future iterations of this type of assessment:
    - The oblique photos from Ecology were accessed via the website and were a low resolution version of the photos and much higher resolution photos are currently available;
    - It may make sense to investigate the feasibility of having a set of aerial photos flown in the winter months along the shoreline to be better able to identify physical features on the shoreline during leaf off seasons;
- Boat Assessments that included a high-precision GPS and laser range finder to map shoreline features from fixed positions offshore;
    - This was rejected based on equipment costs and the required man power, but was rethought at the time of the writing of the technical document. The belief that this would have noticeably increased the overall precision of the mapping and decreased the overall data processing time to an extent that would have offset the cost and manpower limitations.

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[1] See the Hood Canal summary for a discussion of the technical report

[2] See Whidbey Basin summary for a discussion of the Beach Watcher document

Based on time, manpower, and budget constraints it was decided to use a small boat with an outboard motor and a mounted Trimble, GeoExploer II to map the shoreline at an average distance that varied between 30 to 100 meters off shore depending on the tide.

This was one of the few assessment efforts that attempted any type of error analysis to validate the results. The results of the assessment compared values assessed on shore to the boat assessment and estimated that 19% of bulkhead features were omitted by and linear distances were underestimated by 23% of the actual length. However, the results may not be a true representation of error because only two segments totaling 10 km or just over 1% of the total shoreline were assessed for accuracy.

San Juan Basin

I am not aware of any armoring assessments in the San Juan Archipelago region of this basin other than the shore zone work. However, this region is similar to the geology in the western portion of the Strait of Juan de Fuca. Again it might make sense to either use shorezone data explicitly in this region or to only investigate shoreline segments that are identified as either armored or having a higher probability to be armored based on shore type similar to the suggestion for the western part of the Strait of Juan de Fuca basin.

WRIA 1 and the Samish basin portion of WRIA 3 (Whatcom County) account for the rest of San Juan basin and have used georectified, aerial oblique photography to identify armoring. The photos were at a two foot resolution and taken in late winter early spring February and March of 2004. No other accuracy information was provided and an accuracy assessment needs to be completed on this data. I would assume that the majority of the deciduous vegetation would be leaf off during these months making armoring identification easier, but still not anymore accurate than a boat assessment at 30-100 meters done in Hood Canal.

Whidbey Island

- Island County –
  - 125 miles of the estimated 145 mile shoreline of Whidbey Island was surveyed by Volunteers in 1999 and Camano Island was assessed in 2002/03* by volunteers using a GPS walking the shoreline;
    - These assessments did not have the same issues others had in regards to access to shorelines because the Beach Watchers marketed the assessment in such away that it was turning down homeowners volunteers along certain stretches of shoreline based on the numbers volunteering;
    - The assessment only recorded altered shoreline and unaltered sections of shoreline linear distances were estimated using a map wheel and topo maps.
      - A hard copy of the methods and report for the 1999 assessment will be sent out to Jen Burke at UW for

            PSNERP review, but this captures armoring quite accurately where it was assessed.
        - Acquisition of the data has been problematic for both the Whidbey and Camano Assessments from the WSU extension;
            - There is not a lot of expertise around spatial data internally at the extension. I have sent the GPS and GIS files that I have received to-date, but this is not all of what they have documented as collecting;
            - After a number of conversations with Don Meahan at the WSU extension I am not completely confident that email conversations will ever produce the entire data set. I suggest the next course of action would be to schedule a face to face meeting with Don at the Island County extension office and ask to meet with the person(s) that Don has been going through to get the data. He has been very guarded about letting them talk directly with anybody besides him.
    - Coastal Geologic Service has supposedly mapped armoring for the entire Island County between 2002-and 2003. I do not have any records of speaking to anybody affiliated with CGS and I am not sure if this effort overlapped any of the efforts implemented by Beach Watchers or the Skagit River Co-op. However, I am assuming that there were not three independent assessments going on in the same time covering the same geographies.

- Northeast Whidbey Island (Crescent Harbor northward); Northwest Skagit County (Deception Pass to Skagit Bay) –
    - The Skagit River System Cooperative (Andrea McBride) mapped northeast Whidbey Island and northwest Skagit County between 2000/2003 using a combination of GPS, foot assessments and aerial photo interpretation.
        - The line work is an approximation of extreme high water;
        - Data was differentially corrected to Skagit County's base station and are assumed to be with in one-meter of actual locations;
            - the accuracy of the shoreline will also be a function of the Skagit River Co-ops ability to accurately identify extreme high tide.

One spatial issue that will need to be addressed is the different definitions of demarcations between DNR's shorezone (the primary shoreline assessment information has been snapped to) and GPS assessments that map tidelines other than ordinary high water. It is unclear if the methods required the surveyors to map exact location of armoring or if it was attributed to the definition of extreme high-water, this should be followed up to better quantify uncertainty. It was estimated that 85% of the shoreline modifications were mapped by GPS (dikes were identified by aerial interpretation). I would suggest a cross validation to be preformed between the overlapping study areas between the Island County Beach Watchers work and this effort to investigate error and uncertainty within, and between, each effort.

- Snohomish County –
    - Most of this shoreline has supposedly been assessed on the ground using GPS;
        - Stef Frenzl of the Snohomish Marine Resource Committee is the primary contact for this data. Calls have been placed to acquire the data, but have not received the data as of yet.
    - It was my understanding that the reason that a ground assessment was successful in Snohomish County is that a majority of the shoreline was considered 100% armored based on the proximity of railroad tracks to the shoreline and were not actually assessed.

Central Puget Sound

Central Puget Sound was the pilot study area for the PSNERP change analysis so very little armoring research was done in this area. However, there does not appear to be any armoring assessments for the western portion of Central Puget Sound (eastern Kitsap and western Pierce County), or the WRIA 10[3] portion of eastern Central Sound. Pierce County did an evaluation of armoring along its shorelines, but it was an enhancement of DNR shorezone[4] that did not increase the spatial accuracy of armoring found in shore zone. The following description of applicable data collection efforts was provided by Kollin Higgins (King County)

WRIAs 8&9 including Maury and Vashon Islands
These WRIAs were assessed by CGS and Anchor Environmental separately. Both reports/efforts collected shoreline armoring data-in different ways. The Anchor Environmental work was done in a two part effort, with all of the original work being done in the office and then it was field checked. The first report http://dnr.metrokc.gov/Wrias/9/ShorelineInventory.htm Later they went out and added attributes as to if the armoring was above, at, or below OHW. There are two versions of data for shoreline armoring. The first one covers all of WRIA 9 and all of Seattle (in WRIA 8) and is not attributed with information on where the armoring falls in relation to the OWHM. The second data set includes the extra attributes but only includes WRIA 9 as far as I can remember. The link to the work by http://dnr.metrokc.gov/Wrias/9/NearshoreHabitatPrioritization.htm (note that the data collection description is in appendix A versus the body of the report which deals with how they applied the data)

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[3] The southern end of Central Puget Sound WRIA 12 has an armoring assessment in place that is discussed in South Puget Sound

[4] DNR shorezone has been assumed not to be of a fine enough resolution to be used in a Sound wide change analysis.

The method used by Coastal Geologic Services was done entirely in the field. You have to piece together the "armored" shoreline from both the "modified" shoreline and look closely at the different ways that Accretion shoreforms were attributed. The accretion shoreforms data includes information about if it was armored, if the armoring was located in the backshore, in high intertidal or deep intertidal. The other armoring data for "modified" does not have this extra info in it—it is merely "modified". This data set includes all of WRIA 9 and WRIA 8. The link to this report can be found at http://dnr.metrokc.gov/wlr/waterres/marine/reports/marine-shoreline.htm

South Sound

- Nisqually River to Point Defiance –
  - WRIA 12 and a majority of WRIA 11 are currently being assessed via ground assessments by the Nisqually Indian Tribe. It is estimated that this will be completed early this month and now is probably timely to follow up with these folks.
- Thurston County –
  - Armoring has been identified along the shoreline by the Thurston Regional Planning Council based on permitted alterations of the shoreline.
    - Geospatially this data has been validated by aerial photo interpretation.
    - The planning council cautions that this may under represent armoring because it does not consider non-permitted armoring
- Pierce County –
  - Pierce County completed an assessment of shoreline modifications for there critical area update that included the entire Pierce County shoreline
    - This was based on modification information contained in the DNR Shorezone data, which at the time was not considered an accurate enough source for PSNER needs and was not pursued;
- Greater Mason County –
  - An assessment was completed by Anchor Environmental for the Squaxin tribe that included most of Mason County shoreline outside of Hood Canal.
    - This project was based on the premise not all shoreline modifications have negative effects on the shoreline and the data is not representative of true shoreline conditions. It is unclear if there was an effort to collect armoring data locally then generalize it based on specific criteria. Anchor will probably be able to best evaluate this data to its usefulness.

At the start of this process I did not think that remote identification of armoring was going be able to accurately identify and measure linear distances of armoring and that at a minimum a boat assessment would be needed to meet these needs. However, I do not think that other options outside of boat assessments should be completely taken off the table. The Point-No-Point assessment is the only assessment that I can tell has attempted to quantify error both on its ability to identify and map linear distance of armoring, which on the surface would appear to be similar to the error you would expect to find using photo interpretation of high resolution photos.

One suggestion would be to develop a basic error analysis using stratified random sampling to compare the different approaches that were used across the Planning Area (Photo Interpretation, ground assessments, and boat assessments) to see if there is a major difference in the approaches before settling on a preferred method. Also, I think that at a minimum shorezone can be used to target stretches of shoreline to be assessed. Based on the comparisons between the DNR effort and the Whidbey ground assessment this information would most likely be able to mask out areas with zero armoring in the remaining shoreline and to include areas that were 100% armored further reducing the remaining amount of shoreline to be mapped.

Conclusion

Regional Data

The DNR survey has been considered not to be able to locate armoring to the precision needed by PSNER. However, I would caution against discounting it completely. It has been my feeling that the methodology has not been completely assessed and the way that the data reports armoring fully understood.

In the Puget Sound Planning Area there are approximately 6945 DNR ShoreZone segments that identify shoreline modifications by type, percent armored, and linear feet of primary as well as secondary and tertiary modifications were applicable. A majority of these segments are very small with the average shoreline segment in the planning area being 0.3542 of a mile and the median shoreline segment being 0.2352 of a mile. However, 324 of the ShoreZone segments are over one mile, and 64 segments are greater than two miles. The shortest of these segments is 0.1176 of a mile and the longest being over 8 and half miles. It is my understanding that armoring data will be used to make inferences about how near shore processes (i.e. sediment transport based on drift cell mapping) have been or could be disrupted based on armoring. It is also my understanding that: 1) most drift cells are much larger than the average DNR shoreline segment in the Puget Sound Planning Area; 2) Drift cell mapping, like most geographic information, is a generalization of the real world process with fuzzy boundaries. I believe based on this that a majority of the ShoreZone segments will be at a discrete/appropriate enough size/resolution to identify armoring that will affect sediment transport. I think this is even further supported when looking at how well local methods have identified armoring and the cost/benefit of using some of the more accurate assessment methods. This is especially the case when considering that in 2000 DNR assessed their results against the Island County Beach Watchers' shoreline modification ground assessment and found them to be very comparable with DNR reporting 20% of the 155 mile shoreline to be modified compared to the ground survey that found 22% of the 125 miles of shoreline surveyed to be armored[5] . It should be noted that there was some initial concerns about the differences between DNR data and Skagit River Co-op

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[5] The Island County Beach Watcher's assessment only used GPS where shoreline was armored. Linear measures of shoreline that were unaltered were made using a map wheel and topo maps after the fact and may account for much of the 2% difference.

information along the Skagit Mudflats. On first glance it appeared that the while the co-op was showing a 100% unaltered shoreline at extreme high water DNR was representing 100% armoring assumed to be a process much farther inland; however, on further investigation this was based on a misinterpretation of the data and DNR was representing the area to be a fill modification and not armoring.

Local Data

Local efforts have identified armoring along 51% (1275 miles) of the 2470 mile Puget Sound Shoreline. 1195 miles of shoreline have not been surveyed, which include (approximations):

- 127 miles in the Strait of Juan de Fuca;
- 550 miles in San Juan Island;
- 210 miles in Central Puget Sound, and;
- 308 miles in South Puget Sound.

Local surveys have included two types of boat surveys, various ground surveys, and two different photo interpretations. In general ground surveys have been assumed to be the most accurate way to identify and quantify armoring followed by the boat survey methods used by Coastal Geological Services, Point No Point Boat Survey methods, and the least photo interpretations. With the amount of shoreline left to survey, the local topography of the remaining areas, and the time constraints ground surveys and very near shore boat surveys are most likely unfeasible. The next most accurate methodology has been assumed to be the Point No Point treaty effort. This is also the only local assessment that has documented an attempt to both quantify error in the identification and linear distance of armoring. Again as reported earlier this compared values assessed on shore to the boat assessment and estimated that 19% of bulkhead features were omitted and linear distances were underestimated by 23% of the actual length. I think it is now very questionable how much less accurate photo interpretations will be compared to the Point No Point Methodology, or to the ShoreZone Regional assessment. I suggest that a very basic error/accuracy assessment be made based on the needs of this data by PSNER to more comprehensively identify the most efficient approach.

Regardless of the outcome of this assessment the results of the DNR shorezone validation on Whidbey Island at minimum segments that are identified as 100% armored should be representative of location and segments that show no armoring can be masked out. Using this approach almost all of the 127 miles in the Straits and the 550 miles in the San Juans will not need further assessments reducing the percent of shoreline left to map to just under 23% or 570 linear miles

Data Availability

Regional

DNR ShoreZone – Included - Helen Berry;

NWIFC – In work, Ron McFarland, Steve Todd

Local

Straits of Juan de Fuca

Point No Point – Included- Steve Todd

North Central Puget Sound
Western region - Point No Point – Included – Steve Todd
Whidbey Island – WSU extension – Included*- Don Meahan
Geological Coastal Services – Jim Johansson

Hood Canal
Point No Point – Included – Steve Todd

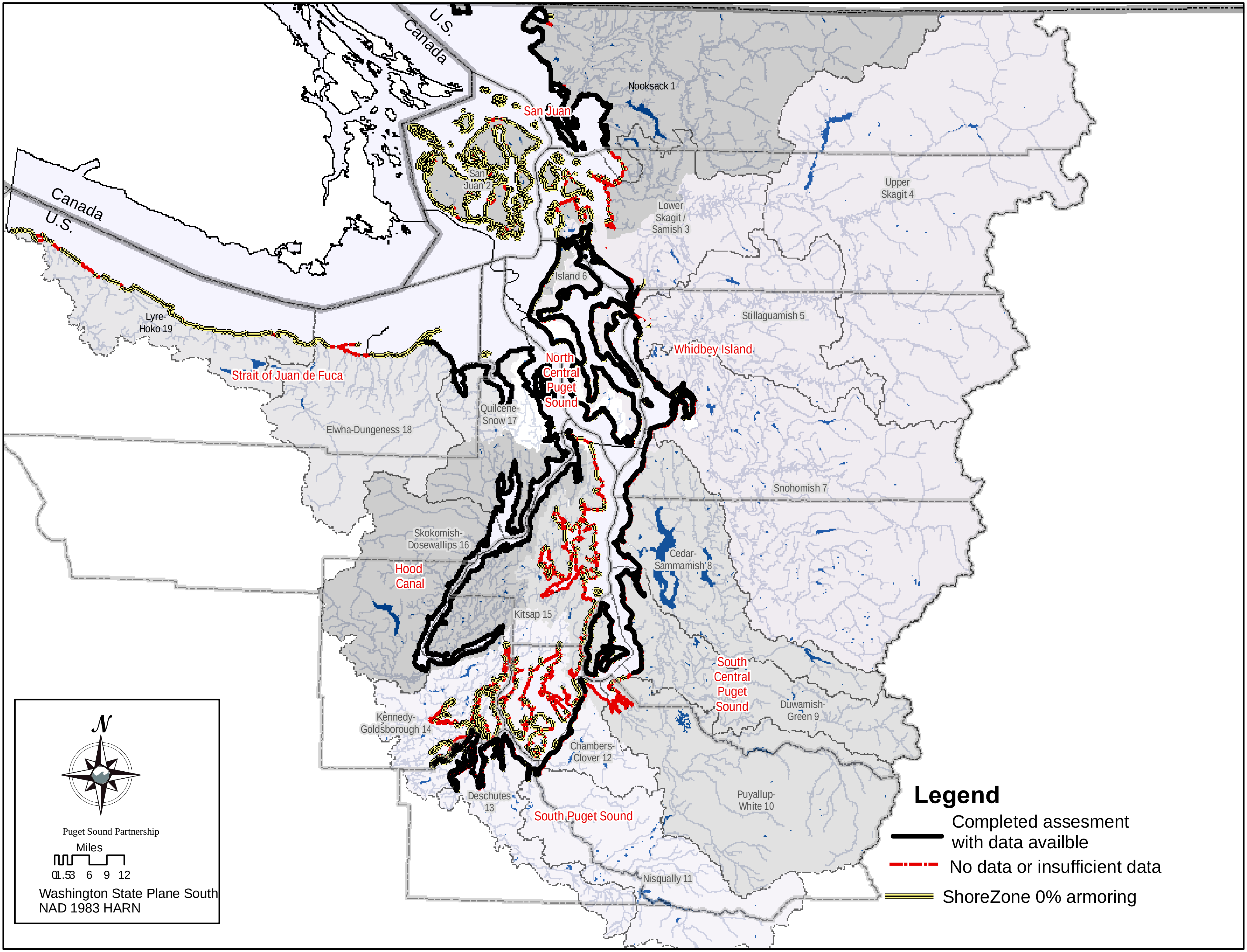
San Juan
Whatcom County – Included – Peter Gill (Whatcom County PDS)
San Juan Island – N/A

Whidbey Island
Whidbey Island – WSU extension – Included*- Don Meahan
Skagit River Co-op – Included- Andrea McBride
Geological Coastal Services – Jim Johansson
Skagit County – Skagit County Co-op – Included-Andrea McBride
Snohomish County – Snohomish County MRC- Stef Frenzl

Central Puget Sound
WRIA 8 & 9 – Kollin Higgins (King County)

South Puget Sound
Point Defiance to Nisqually River – Nisqually Indian Tribe – In work – Sayre Hodgeson

Thurston County – Thurston Regional Planning Council – Included - Scott Carte


U.S.
Canada
Canada
U.S.
Nooksack 1
San Juan
San Juan 2
Upper Skagit 4
Lower Skagit / Samish 3
Island 6
Lyre-Hoko 19
Stillaguamish 5
Whidbey Island
North Central Puget Sound
Strait of Juan de Fuca
Quilcene-Snow 17
Elwha-Dungeness 18
Snohomish 7
Skokomish-Dosewallips 16
Cedar-Sammamish 8
Hood Canal
Kitsap 15
South Central Puget Sound
Duwamish-Green 9
Kennedy-Goldsborough 14
Chambers-Clover 12
Deschutes 13
South Puget Sound
Puyallup-White 10
Nisqually 11
N
Puget Sound Partnership
Miles
0 1.5 3 6 9 12
Washington State Plane South
NAD 1983 HARN
Legend
Completed assesment with data availble
No data or insufficient data
ShoreZone 0% armoring

APPENDIX B

DATABASE STRUCTURE REPORT

DRAFT GEODATABASE STRUCTURE REPORT

PUGET SOUND NEARSHORE ECOSYSTEM RESTORATION PROJECT

Prepared for
U.S. Army Corps of Engineers, Seattle District
4735 East Marginal Way South
Seattle, Washington 98124

Prepared in Support of
PUGET SOUND
NEARSHORE
PARTNERSHIP

RESTORING OUR
ECOSYSTEM HEALTH

Prepared by
Exa Data & Mapping Services, Inc.

Under Contract to Anchor Environmental, L.L.C.

January 2009

Table of Contents

1 Goals and Requirements for the PSNERP Geodatabase

Geodata are in the process of being inventoried, collected and generated to support a systematic Change Analysis, defined as a measurement of change between historic (pre-1900) and current (circa 2000) conditions of shoreline and delta landscape features for the Puget Sound nearshore. This analysis will inform a strategic assessment of Puget Sound restoration needs as part of the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) General Investigation (GI) Study and the Puget Sound Nearshore Partnership. The Seattle District of the U.S. Army Corps of Engineers (USACE) and the Washington Department of Fish and Wildlife are partners in the project; the USACE will ultimately house the database.

The overall goal of this document is to support a consistent and standardized geodatabase system, and subsequent spatial analyses and geoprocessing, in support of analytical queries and summaries. The structure, methods, and deliverables will be compatible with the goals of the SNAR (Strategic Needs Assessment Report), as well as used for reporting purposes by the Puget Sound Nearshore Partnership.

1.1 STUDY HIERARCHY, SCALE, AND METRICS

There are four tiers of change that will be measured:

- ☐ Tier 1: Shoreform transition
- ☐ Tier 2: Shoreline modifications
- ☐ Tier 3: Nearshore Zone modifications
- ☐ Tier 4: Drainage (watershed/drainage) area modifications

The modifications will be reported in metrics on the level of *Process Unit* (defined in Section 1.3) for both the shoreline and delta environments.

Puget Sound has been divided into seven sub-basins, and each sub-basin will be analyzed separately; all methods will be applied consistently across sub-basin (Figure 1-1). The database, however, must also allow querying at the Puget Sound level; a summary database linking all of the sub-basin databases will allow basin-wide queries.

Queries will be developed to generate summary metrics for the four tiers and at multiple scales. Some queries will be developed within the geodatabase (e.g., multivariate summaries). Additional query databases will be created to contain queries or data summaries (e.g., Tabulations). Below the level of sub-basin, the database must support summarization of data over explicitly-defined nested units, as well as over user-defined spatial units (e.g., bays, islands, etc.) that are not yet defined. The metrics will be summarized over consistent spatial organizational units that are calculated differently for the shoreline and delta environments. Final scales of analysis and metrics are not yet determined; thus the data management model must be flexible and modular.

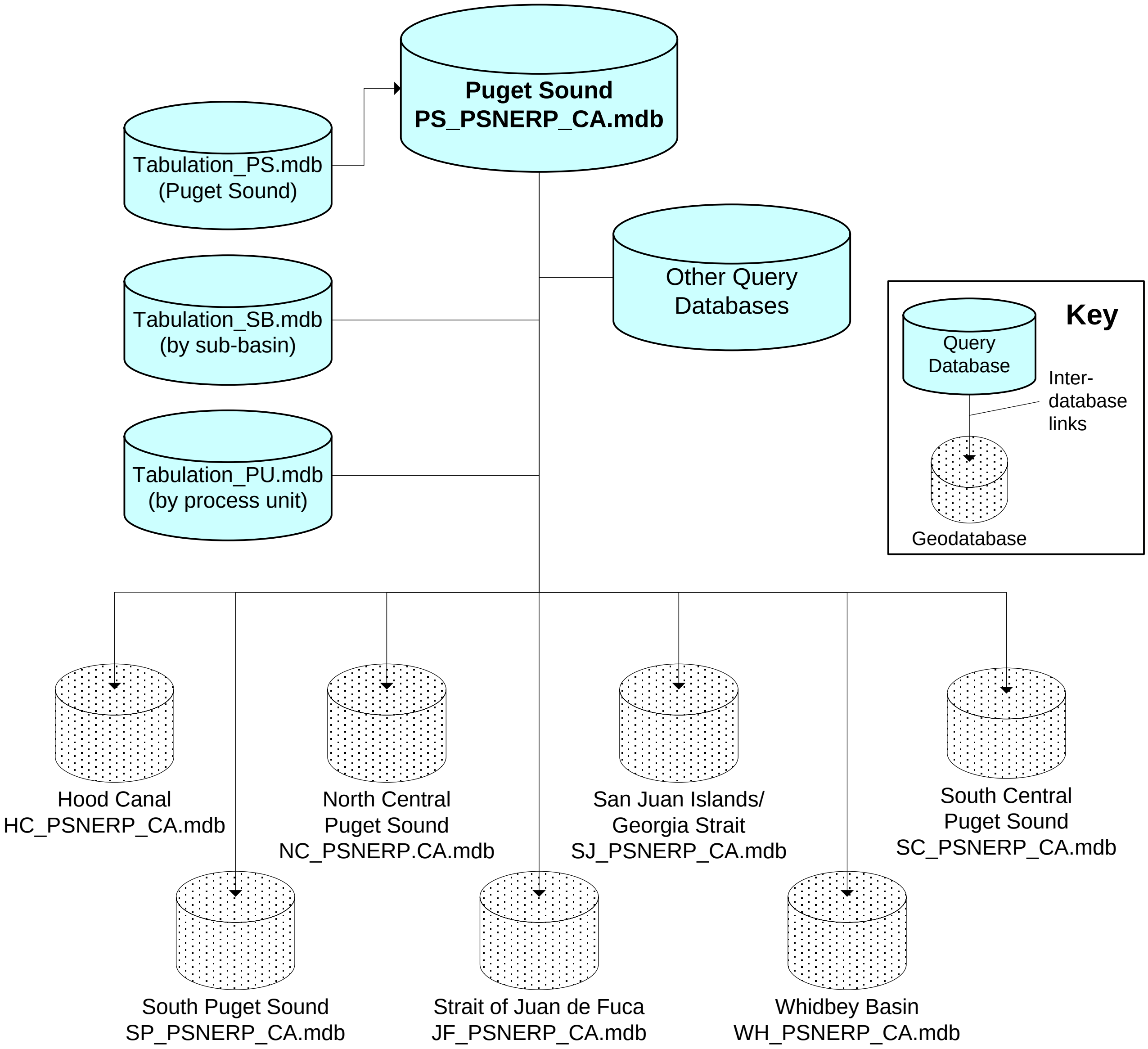


Figure 1-1. PSNERP framework for sub-basin geodatabases and related query databases.

1.2 REQUIREMENTS AND STANDARDS

Requirements

- Data will be summarized over the *Process Unit* scale (as defined below), compatible with the goals of the SNAR.
- All data used for the analysis must be available and generally consistently applied across Puget Sound.
- Every database must have metadata.
- The database must support the goals of the GI, and also support the larger user community.
- The database must be modular and expandable as spatial and measurement metrics are developed.
- Queries used for data processing and summarizing must be documented, and developed using consistent nomenclature.
- All data, queries, reports, and documentation need to be delivered regularly.

Standards

- The projection will be UTM NAD83, Zone 10, meter mapping units.
- The vertical datum standard will be NGVD29.
- Metadata will be compliant with the Federal Geographic Data Committee (FGDC 1998) standard.
- Units of measure will include linear (m^2), areal (m^3), percent, and count.
- GIS software for spatial analyses will be ESRI™ (Environmental Systems Research Institute, Inc.) ArcGIS 9.x.

1.3 TERMS AND ACRONYMS

Standard nomenclature and coding will be used for all database elements. The following codes have been developed to be used to identify datasets for each sub-basin. This list will become part of the project documentation, and added to as additional datasets, metrics, and spatial scales are developed. A brief explanation of the codes is provided below; a more detailed discussion of the GSUs and their interrelationships is provided in Section 4.

Basin

- Puget Sound BasinID (PS)

Sub-basin (Sub-Basin ID in parentheses)

- Hood Canal (HC)
- North Central Puget Sound (NC)
- San Juan Islands/Georgia Straits (SJ)
- South Central Puget Sound (SC)
- South Puget Sound (SP)
- Strait of Juan de Fuca (JF)
- Whidbey Basin (WH)

The set of organizational units being developed are called, as a whole, Geographic Scale Units (GSUs; Figure 1-2). The basic GSUs over which metrics will be summarized are the *Drainage Unit* (DU), the *Accounting Unit* (AU), the *Process Unit* (PU), and the *Zone Unit* (ZU). These units represent different physical constraints, therefore the GSUs are being developed using different methods for the shoreline and delta environments (specific geo-processing methods are available in Anchor et al. in prep.).

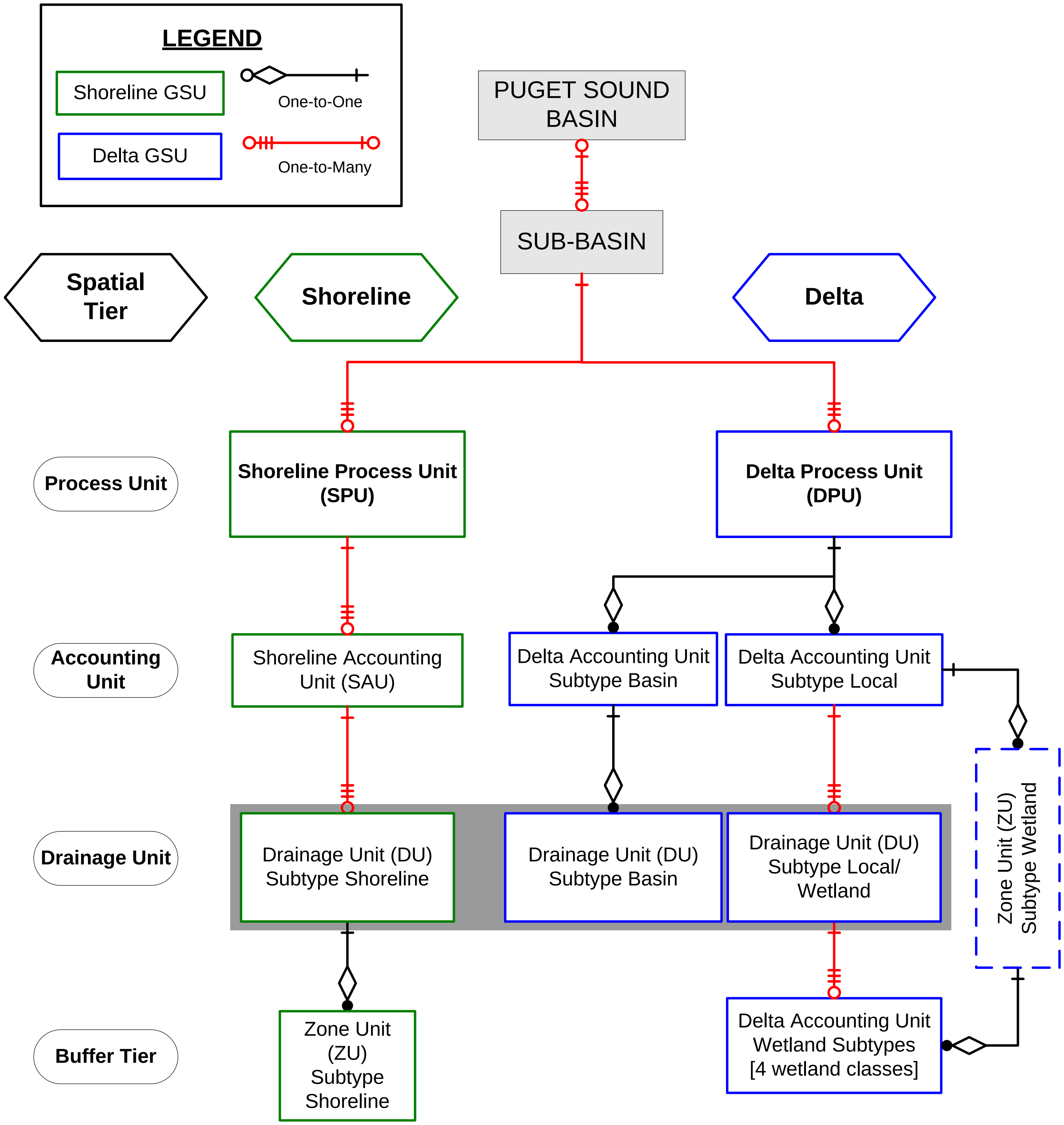


Figure 1-2. Spatial hierarchy of nested GSUs for the shoreline and delta environments.

1.3.1 Shoreline GSUs

The *Drainage Unit* defines the natural watersheds, or drainage areas constrained by topography and drift cells. The drift cell dataset (CGS 2008) is used as the baseline for creation of the shoreline-related GSUs. The components that make up the drift cell include:

- Left to right (L2R)
- Right to left (R2L)
- Convergent zone (CZ)
- Divergent zone (DZ)
- No appreciable drift (NAD)

The *Shoreline Accounting Unit* (SAU) is aggregated over all DUs that relate to a single drift cell component, and may encompass one or more complete DUs. The *Shoreline Process Unit* (SPU) is then aggregated over the SAUs that represent a single drift cell, and may contain one or more SAUs. In areas of divergence or convergence, and in some cases no appreciable drift, there will be two SPUs that share the same drift cell component, and therefore share the attributes of an SAU.

The Zone Unit (ZU) describes the nearshore area of influence on shoreline drainage that encompasses the landward and waterward extent of the shoreline, and will be used in Tier 3 analysis (nearshore zone modification). In summary, the shoreline GSUs are:

- SPU: Shoreline Process Unit
- SAU: Shoreline Accounting Unit
- DU: Drainage Unit (subtype Shoreline)
- ZU: Zone Unit (subtype Shoreline)

1.3.2 Delta GSUs

The delta consists of three overall areas that are structurally constrained in the database:

- Wetland: The area in the estuary section of the delta encompassing four possible wetland classes.
- Local: The local drainage surrounding and influencing the wetlands.
- Basin: Large area upland of the delta that encompasses all of the drainage that flows into the delta;

The delta areas are classified as subtypes in the database, and are defined in the *Delta Accounting Unit* (DAU). The DAU represents the different types and scales of environments in the delta, and will allow querying at different scales of drainage into the delta. There are six subtypes of DAU in the delta environment:

- Basin: A single Basin-type DAU represents one upland basin drainage unit (DU)
- Local: A single Local DAU represents multiple drainage units that surround the wetlands area
- Wetland-EM: The wetland class Estuary Mixing
- Wetland-EU: The wetland class Euryhaline Unvegetated
- Wetland-OT: The wetland class Oligohaline Transition
- Wetland-TF: The wetland class Tidal Freshwater

The *Delta Process Unit* (DPU) is aggregated over the six types of DAUs. In the rare occurrence where two deltas intersect, the attributes are shared between two DPUs.

The Zone Unit in the delta is extended landward beyond the boundaries of the wetlands, and is defined by the wetland boundary that extends beyond the shoreline. These intertwining environments result in a complex hierarchal structure for the delta GSUs.

In summary, the Delta GSUs are:

- DPU: Delta Process Unit
- DAU: Delta Accounting Unit (Subtypes: Basin, Local, Wetland-EM, EU, OT, and TF)
- DU: Drainage Unit (subtypes Basin, Local, Wetland)
- ZU: Zone Unit (subtype Delta)

1.3.3 Geodatabase Nomenclature

Naming conventions have been defined for the geodatabases and related datasets. Nomenclature for geodatabase elements have been designed to conform to the following rules:

- All feature, table, and query names should be independent of the specific sub-basin so they can be transferred easily between sub-basins and rolled up to Puget Sound level.
- The sub-basin identifier should be included in all tables and queries for cross-Puget Sound summary queries.
- Table and query names should start with a prefix that will allow sorting and quick reference for real-time analyses.
- Query names should include reference to the analysis Tier, summary metric, and query number if applicable.

Initial geodatabase processing includes object names that follow these conventions (Table 1-1); this table will be maintained as additional datasets are generated. Additional terms and acronyms also will be generated and documented during the project, including shoreform types and user-defined units of different spatial scales.

There are also terms that have been adopted as part of the Change Analysis that have specific definitions in the database. These terms include:

- Shoreline length – Tier 2 Shoreline analyses will be normalized by the relative scale of unit in question normalized to the shorezone.
- Zone of Influence - Tier 3 analyses will use the unit in question normalized to the landward and waterward extent from the shorezone, quantified as the Zone Unit.
- Aquatic Area – Some metrics will be calculated over this area, defined as the waterward zone of influence, and quantified as the Zone Unit = 2.
- Wetland Area – Some metrics will be calculated over this area, defined as the cumulative four wetland-type Delta Accounting Units.
- Watershed/drainage area – Tier 4 will normalize metrics by the entire area covered by the different types of Drainage Units.

Table 1-1. Selected Nomenclature Standards for PSNERP Geodatabases

Database Object	Prefix	Description	Example
Table	lut	Reference table (codes)	*lutDAU* (lookup table for codes used for Delta Accounting Units)
Table	fd	Feature dataset (GIS)	*fd_roads* (roads spatial dataset)
Query	refqry	Reference query (used as baseline calculations for other analysis queries)	*refqry_DPU_ShorelineLength* (calculates shoreline length by DPU for use in other queries)
Query	TierX	Tier-based pre-PRIMER analysis query	*Tier2_Breakwater_01* (first Tier 2 query to summarize breakwaters normalized over the shoreline)
Query	qryQA	QA/QC query	*qryQA_NullDU* (QA query that tests for presence of nulls in the required DU field)
Query	tabqry	Tabulation query	*tabqry_PU_DriftCellSummary* (tabulation query that summarizes the percent of each drift cell for a process unit)

2 Database Content Overview

The PSNERP project will be utilizing data in different stages and with different levels of processing. In order to meet the project objective of making the data accessible, all of these different types of datasets will be part of the overall geodatabase framework (Table 2-1).

An inventory of readily available data has been collected and reported previously (Anchor et al. 2008). The inventory contains information on the availability, geographic extent, and quality of the data, as well as availability of metadata in compliance with data requirements as listed above. The inventory will be used, in combination with metadata files, as a library to efficiently access and retrieve the datasets and metadata record. In addition to the collection of existing data, additional datasets will be generated in support of project goals (Section 2.2). A description of the generated datasets and the methods used is outside of the scope of this document.

Table 2-1. Components of the PSNERP Geodatabase Framework

Data Component	Data Type	Metadata	Framework Component	Technical Details
Existing Data Inventory[1]	Geodatabase, raster, shape files	As received	File-based, archival	Raw data will be stored and available in original formats.
Change Analysis Database	Spatial (geodatabase)	By database by reference[2]	Sub-basin geodatabase	Processed for each sub-basin, intersected with geodatabase GSUs.
Multivariate summary metrics	Tables	By database by reference[2]	Sub-basin geodatabase	Processed at GSU level (primarily Process Unit) for calculation of impairment; summary data tables can be joined to GSU spatial data.
Data summaries and queries	Reports, maps, graphs, tables	Documented as they are developed	Query databases, external file-based products	Tabulations will be created as reports by Process Unit; other queries and data products are to be defined.

[1] Anchor and LeeSaa 2007

[2] Anchor et al. 2008

2.1 INVENTORY AND METADATA

The current data inventory documents the source of the existing dataset. Existing metadata will be retained for the Change Analysis, and generated for new data (Table 2-1). General process description will be available in project documentation (Anchor et al. in prep.). Specific documentation will be provided with each sub-basin database that details specific processing steps for each dataset.

ESRI ArcCatalog will be used to generate some of the standard metadata; while specific process information will be developed separately and available for each geodatabase. A system of documenting accuracy and error will be developed. Queries and other data synthesis products will also include documentation as they are developed and standardized.

2.2 DATASETS

The datasets to be used for the Change Analysis include point, line, polygon, and raster spatial data; tabular data; and other associated graphics and summary data as they are generated. Each source spatial dataset will be intersected with the GSU data for Change Analysis queries (Table 2-2). Raster data will be converted to polygon feature classes and intersected with GSU features. Details of the datasets with attributes and attribute descriptions are included in Appendix A.

Table 2-2. PSNERP Datasets for Change Analysis

Dataset	Tier	Description
Geographical Scale Units	All	Polygon
Drift Cells	All	Line
Shoreline	Descriptive	Current shorezone shoreline intersected with the GSUs
Stream Mouths	Descriptive	Point, stream mouths snapped to shorezone
Shoreforms	1	Line, relative to current shorezone, including current, historic, and transition
Jetties, Breakwaters	2	Polygons
Marinas	2	Polygon represents marina footprint, unique marinas are indicated by a unique identifier
Nearshore Fill	2	Polygon
Nearshore roads, railroads (abandoned and active)	2	Lines within 150 m of the shorezone shoreline
Overwater Structures	2	Polygon
Shoreline Armoring	2	Line, in relationship to shorezone
Tidal Barriers	2	Lines representing levees and dikes
Wetlands (current and historic)	2	Polygon, current and historic based on Simenstad wetland class types
Historic Drainage Area	4	Polygon describing entire delta drainage area
Dams	3, 4	Point, includes attributes that describe the area of furthest downstream dam
Fish Passage Barriers	3, 4	Point
Impervious Surfaces	3, 4	Polygon created from processed raster, categorized by class
Land Cover	3, 4	Polygon created from processed raster, categorized by class
Ownership	3, 4	Polygon, categorized as public, private, and tribal
Parcel Lines	3, 4	Line, waterfront edge of parcel, unique parcels are indicated by a unique identifer
Protected lands	3, 4	Polygon
Roads, railroads (abandoned and active)	3, 4	Polygons, buffered by width class
Stream Crossings (points)	3, 4	Stream/road intersection points (used to generate polygon file)
Stream Crossings (polygons)	3, 4	Polygon describing stream/road intersections buffered by road width class

The primary data table will be the GSU data that will serve as the central organizational schema for each geodatabase. The structure of the GSU table is discussed fully in Section 4 of this document. Every additional existing and created data will be classified by the GSUs for queries, and joined for mapping.

Additional data include shoreform typology (Tier 1), shoreline, nearshore, and drainage modification datasets processed from the collected and inventoried data (Tier 2-4), results of statistical analyses from the PRIMER program, and finally summary queries, output tables, and graphics from the analyzed data.

Shoreform data have been developed from historic and current typology (Anchor et al. in prep.) and stored as intersected with the GSU table. User-defined units will be generated as a separate data table at a future time, and also intersected by GSU.

All datasets will be spatially intersected with the GSUs. In general, all of the original fields will be carried within the dataset. Some Tier 2 datasets also will be intersected with shoreforms in order to query these attributes over shoreform types.

3 Geodatabase Architecture

The architecture (hardware and software) of the geodatabase, as noted in the requirements, has to both support the near-term GI project goals, as well as be consistent and compatible with the ultimate storage and sharing plan for the data. Therefore, an architecture has been designed that can meet the project goals (Section 3.1), and also easily be integrated for delivery to the ultimate storage system (Section 3.2) at the USACE.

3.1 GENERAL INVESTIGATION PROJECT

The geodatabase architecture will include ESRI ArcGIS 9.x integrated with a personal geodatabase (Microsoft™ Access). Access is accessible to all users of ArcGIS, and has a client interface for easily writing spatial and non-spatial queries. Because Access has limitations on storage size, we have created a modular framework to store and deliver PSNERP data. There will be a separate geodatabase for each sub-basin (Figure 1-1) because of file size limits on personal geodatabases. Puget Sound Basin (Sound-wide) queries are run on a personal geodatabase containing compiled attribute tables from each of the sub-basin datasets, plus compiled sound-wide spatial datasets for GSUs, current shoreline, and shoreform change. Each geodatabase can be connected to ArcGIS using an OLE DB connection, allowing real-time query creation and editing and map updates.

Each sub-basin geodatabase will include the GSU table (Section 4), spatial datasets (Appendix A), and summary queries developed for Change Analysis. Additional queries and data summary tabulations will be developed as separate databases linked to the primary geodatabase. Some data, including summary graphics, will be stored externally and cataloged using a file-based approach.

Each sub-basin geodatabase (*.mdb) will contain the organizational unit data required for the queries (GSUs, user-defined units), supporting lookup tables that will be used for calculations or normalization, links to the supporting feature datasets (depending on the analysis), and the queries used to generate results.

3.2 LONG-TERM DATABASE SUPPORT

The project architecture has been designed to be modular, so that additional geodatabases, features, or rasters can be easily added. A new spatial dataset can be added by first intersecting the data with the unique GSU identifier for each sub-basin. If a dataset is edited or updated, it can replace the original in the architecture without disrupting the query chain of commands assuming the same nomenclature and file paths are used.

The long-term goal for the database is for it to be served by the USACE information management system. The project architecture presented above has been developed so that it can be compiled and delivered to the USACE. The database will be compatible with the USACE system, which includes ArcGIS, as well as an SDE-Oracle server. The database may also be available as individual geodatabases through an FTP download. The nomenclature of each individual sub-basin geodatabase will be consistent so that each geodatabase can be imported and merged into a single enterprise geodatabase, but still retain uniqueness based on the Sub-basin ID. As the geodatabase is implemented, the structure can be exported as an XML document that can be used to develop a parallel structure in Oracle or other enterprise system.

4 PSNERP General Investigation Geodatabase

4.1 GEOGRAPHICAL SCALE UNIT TABLE STRUCTURE

Each sub-basin will have the same database structure so that all of the sub-basin geodatabases can be merged, and served as a single database, queryable by sub-basin. The workhorse table of each geodatabase is the table of Geographical Scale Units (GSUs; Figure 4-1). A single table will define all of the GSU polygons in order to constrain the relationships between and among each GSU type. Both shoreline and delta GSUs are in the table to enable querying in both environments at the same time. Caution is advised for these queries as certain areas with shared attributes will summarize data in different ways depending on the construction of the query (Section 5).

The key field for the table is the GSU_ID, which is a concatenation of the Drainage Unit (DU), Delta Accounting Unit, and the Zone Unit (ZU) that specifies the location of the polygon within or outside of the shoreline zone of influence. This single key field will be used to intersect all of the other datasets to the GSU table.

The DU polygons are comprehensive and exclusive (no overlapping polygons) throughout each sub-basin. The DU is modified by the DAU field, allowing summarizing of data over the DU by the type of environment (shoreline, delta-basin, local or wetland). The DU is a 5-digit integer, and is numbered differently for each sub-basin, using the following convention:

- Strait of Juan de Fuca (JF; 1xxxx)
- Hood Canal (HC; 2xxxx)
- South Puget Sound (SP; 3xxxx)
- South Central Puget Sound (SC; 4xxxx)
- North Central Puget Sound (NC; 5xxxx)
- Whidbey Basin (WH; 6xxxxx)
- San Juan Islands/Georgia Straits (SJ; 7xxxxx)

The hierarchy of the nested GSUs is slightly different between the shoreline and delta environments (Figure 1-2), and will be discussed individually below.

4.1.1 Shoreline GSUs

The *Drainage Unit* defines the natural watersheds, or drainage areas constrained by topography and drift cells. The drift cell dataset is used as the baseline for creation of the shoreline-related GSUs. The components that make up the drift cell include:

- Left to right (L2R)
- Right to left (R2L)
- Convergent zone (CZ)
- Divergent zone (DZ)
- No appreciable drift (NAD)

The DUs in the shoreline environment are aggregated into the *Shoreline Accounting Unit* (SAU). The SAU is a four-digit integer using the same numbering scheme as the DU (e.g., 6xxx) and has a 1:many relationship to the shoreline DU (Figure 1-2). It is aggregated over all DUs that relate to a single drift cell component, and may encompass one or several DUs.

Polygon feature class
fd_GSUs

Subtypes are Shoreline, Basin, Local, Wetland-EM, Wetland-EU, Wetland-OT, Wetland-TF

Primary GSU polygon feature class where XX represents the subbasin = {HC, JF, NC, SC, SJ, SP, WH}

Simple feature class
fd_GSUs

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Len.	Notes
OBJECTID	Object ID						
Shape	Geometry	No					
GSUID	String	No		DU_DAU+ZU		10	1
SUBBASIN	String	No		XX		2	2
DU	Long integer	No		Min: x0000	0		3
SPU1	Long integer	Yes	0	Min: x000	0		4
SPU2	Long integer	Yes	0	Min: x000	0		4
SAU	Long integer	Yes	0	Min: x000	0		5
DPU1	String	Yes	N	DDD		3	6
DPU2	String	Yes	N	DDD		3	6
DAU	String	No		DAU Code	0		7
ZU	Long integer	No		0-2	0		8
CELL_TYPE	String	No		CZ, DZ, LtoR, NAD, RtoL			9
Shape_Leng	Double	Yes			dbl		
Shape_Length	Double	Yes			dbl		
Shape_Area	Double	Yes			dbl		

Subtypes of fd_GSUs

Subtype field *DAU*
Default subtype *1*

Subtype Code	Subtype Domain	Category	Description
SH	Shoreline	External to Delta	
BA	Basin	Basin Accounting Unit	
LO	Local	Local Accounting Unit	
EM	Wetland-EM	Wetland Accounting Unit	Estuary class: Estuarine Mixing
EU	Wetland-EU	Wetland Accounting Unit	Estuary class: Euryhaline Unvegetated
OT	Wetland-OT	Wetland Accounting Unit	Estuary class: Oligohaline Transition
TF	Wetland-TF	Wetland Accounting Unit	Estuary class: Tidal Freshwater

Notes

[1] **Primary key** (GSU_ID): Nine digit string created from “DU_” + DAU + ZU where DAU = {SH, BA, LO, EM, EU, OT, TF}
[2] Subbasin code: Two digit code for the subbasin = {HC, JF, NC, SC, SJ, SP, WH}
[3] Drainage Unit: Range of integers where x = different value for each subbasin (e.g., HC = {10000, 10001, 10002...n})
[4] Shoreline Process Unit [1,2]: Range of integers where x = different value for each subbasin (e.g., HC = {1000, 1001, 1002...n})
[5] Shoreline Accounting Unit: Range of integers where x = different value for each subbasin (e.g., HC = {1000, 1001, 1002...n})
[6] Delta Process Unit [1,2]: Three-digit delta code
[7] Delta Accounting Unit: Subtype (Two-digit code)
[8] Buffer Tier Zone Unit: Where 0 = not shoreline zone; 1 = landward zone area; 2 = waterward zone area
[9] Drift cell type: Code for drift cell = {Convergence Zone; Divergence Zone; Left to Right, No Appreciable Drift; Right to Left)

Figure 4-1. Geographical Spatial Unit (GSU) table design.

The SAUs are aggregated into the *Shoreline Process Unit* (SPU), and is a four-digit integer using the same schema as the SAU. The SPU is aggregated over the SAUs that represent a single drift cell, and has a 1:many relationship with the SAU. In areas of divergence or convergence, and in some cases no appreciable drift, there will be two SPUs that share the same drift cell component, and therefore share the attributes of an SAU. The GSU data table stores this information as two separate SPU fields (Figure 4-2; SPU1 and SPU2). The nomenclature of SPU1 and SPU2 are designed so that an SPU identifier is unique in each column for efficiency of querying and joining in ArcGIS.

The Zone Unit (ZU) describes the area that encompasses the landward and waterward extent of the shoreline and will be used in the Nearshore Zone modification (Tier 3). In the shoreline area, the DU, SAU, and SPU all contain the ZU, such that the ZU is the smallest unit in the shoreline schema (Figure 1-2). The shoreline-type DUs have a 1:1 parent-child relationship with the ZU, as the zone polygons are subdivided by DU by design. The Zone Unit is a required field, and is filled with 0, 1, or 2 as follows:

- ☐ 0 = Area is neither in the landward nor waterward zone of influence (all other uplands outside of the 200 meter zone);
- ☐ 1 = Area is within 200 meters landward of the shorezone or historic wetlands;
- ☐ 2 = Area is waterward of the shorezone (SPU) inclusive of wetlands (DPU).

4.1.2 Delta GSUs and SPU Overlap

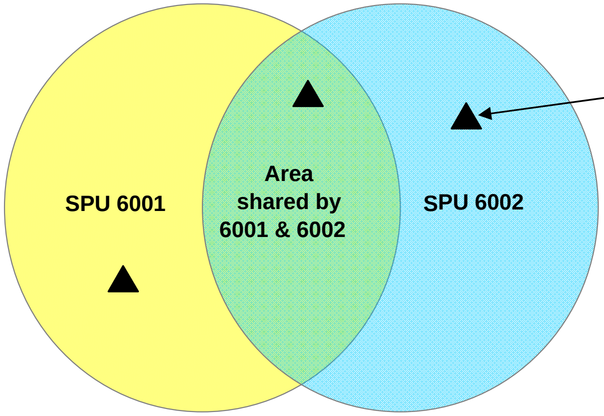
Deltas are created from wetland polygons (Anchor et al. in prep.); the full wetland complex is buffered in this processing. The historic wetland complex is used to isolate areas of potential Delta Process Unit (DPU). The previously-created DU boundary is used as the outer extent of the qualified Delta boundary, so that the DU boundaries reflect the wetland complex rather than the shoreline boundaries. In some areas, the shoreline area is nested among the delta units, so that there are also shared attributes between SPUs and DPUs.

The four types of wetland polygons created by this process are, by definition, four types of *Delta Accounting Units* (DAUs). The integration of these DAUs form a single drainage unit within the delta, such that the DU in the wetlands complex has a 1:many parent child relationship with the four wetland-type DAUs (Figure 1-2). The single DU encompassing all four wetland DAUs, however, is in the DPU-only area. In areas shared between the delta and shoreline process unit, the wetlands are assigned DU of the surrounding (local) area.

The other two types of DAUs include the Local DAU and the Basin DAU. The Basin DAU, reflecting the upland area of influence on a delta, is the most straightforward: it is upland of both the wetland complex and the shorezone. A DPU has a single Basin DAU, which in turn consists of a single Drainage Unit (associated with the DAU subtype ‘Basin’). Therefore, the DPU has a 1:1 parent-child relationship with the Basin DAU, which in turn has a 1:1 parent-child relationship with the DU (Figure 1-2).

In addition to the wetlands complex (DAU-wetlands) and the Basin, the remaining area of the DPU is made up of localized drainage that surrounds the wetlands; therefore these units are called Local and they have a complex relationship with the other two types of DAUs. The DPU has a single Local DAU that surrounds the wetland complex and is made up of numerous DUs that are associated with the subtype Local. Therefore, a DPU has a single

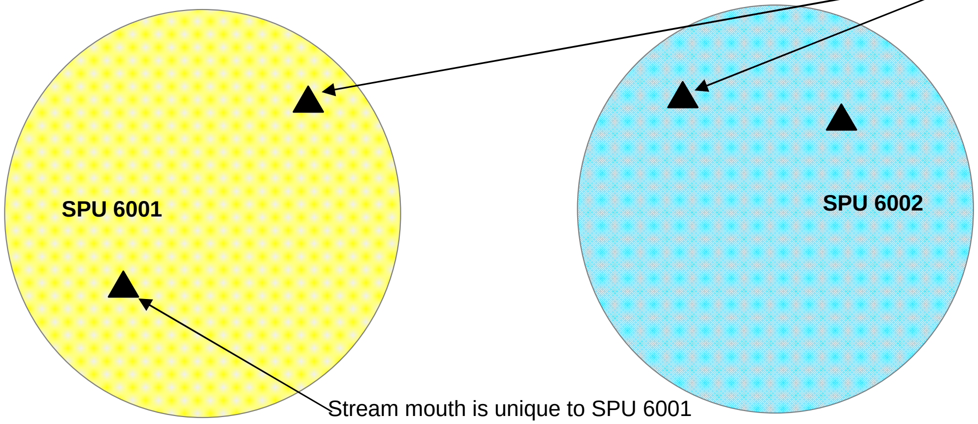
Diagram of spatial data



Single Stream Mouth

SPU1	SPU2	
6001		Area is unique to SPU 6001 only
6001	6002	Area falls within SPUs 6001 and 6002, and metrics will be need to be counted by both SPUs
	6002	Area is unique to SPU 6002 only

Dividing the diagram above into separate SPUs:



Spatially, these are the exact same physical stream mouth
that will be counted twice in any SPU summaries

Stream mouth is unique to SPU 6002

Stream mouth is unique to SPU 6001

SPU 6001 has two stream mouths

SPU 6002 has two stream mouths

SPU	StreamMouthCount
6001	2
6002	2

Local DAU that has a 1:many parent-child relationship between the Local DAU and the DU. In some cases, however, the DU that encompasses the wetland complex includes a Local component because of the complexities of the shapes of the wetlands. The DAU field is required, and is filled with a code for one of the six DAU subtypes in the delta environment, as defined in the GSU data table (Figure 4-1):

- Basin (“BA”): A single Basin-type DAU represents the upland basin drainage area;
- Local (“LO”): A single Local DAU represents multiple drainage units that surround the wetlands area; one Local DAU encompasses one or more Local drainage units.
- Wetland-EM (“EM”): The wetland class Estuary Mixing;
- Wetland-EU (“EU”): The wetland class Euryhaline Unvegetated;
- Wetland-OT (“OT”): The wetland class Oligohaline Transition;
- Wetland-TF (“TF”): The wetland class Tidal Freshwater.

Because the DAU field is required, it is also populated for the shoreline areas (“SH”).

The *Delta Process Unit* (DPU) is aggregated over the six types of DAUs. In the rare occurrence where two deltas intersect, the attributes will be shared between two DPUs. The GSU data table includes this information as two separate DPU fields (DPU1 and DPU2). The DPU field is populated with a three-digit code for the delta system.

4.1.3 GSU Structure within the Geodatabase

The GSU data table (fd_GSUs; Figure 4-3) is unique based on the single field of the GSU_ID. The table is related to several lookup tables for use in querying, including the sub-basin (lutSB), the Delta Accounting Unit (lutDAU), the Zone Unit (lutZU), and the drift cell type (lutDC). The table can be related or joined to any of the other spatial datasets by the single key field GSU_ID.

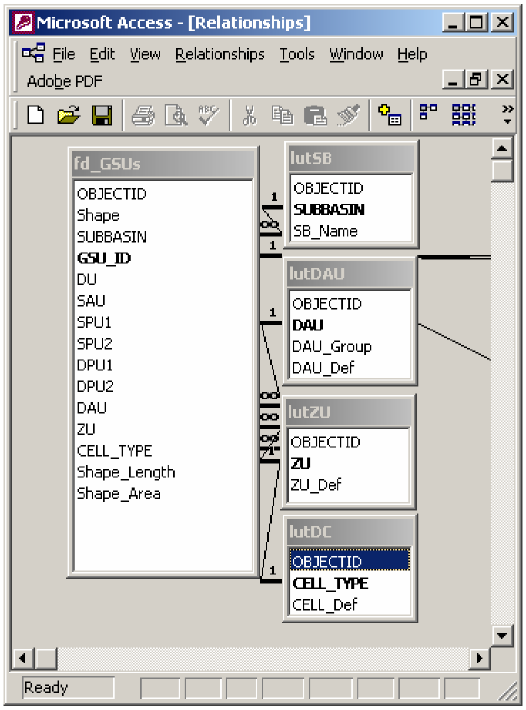


Figure 4-3. Structure of the GSU table.

4.2 DATASET TABLE STRUCTURE

Each sub-basin will have the same database structure so that all of the sub-basin geodatabases can be merged (in an enterprise geodatabase), and served as a single database, queryable by sub-basin. The attributes can also be merged in a personal geodatabase (but not the spatial data due to the limited capacity of the personal geodatabase).

4.2.1 Tier 1 Datasets: Shoreforms

The current and historic shoreforms are in the same data table (fd_shoreform_change; Figure 4-4). The table is unique on the GSU_ID field, as well as a unique identifier created during the processing of the historic and current shoreforms (SF_Change_ID; Anchor et al. in prep.). The table is related to the fd_GSUs table via the GSU_ID field; the historic (H_Type) and current (C_ID) shoreforms can be related to the shoreform lookup table (lutSF) for querying. The SF_Change_ID field was also used to intersect other Tier 2 datasets in order to be able to relate other stressors to the shoreform change.

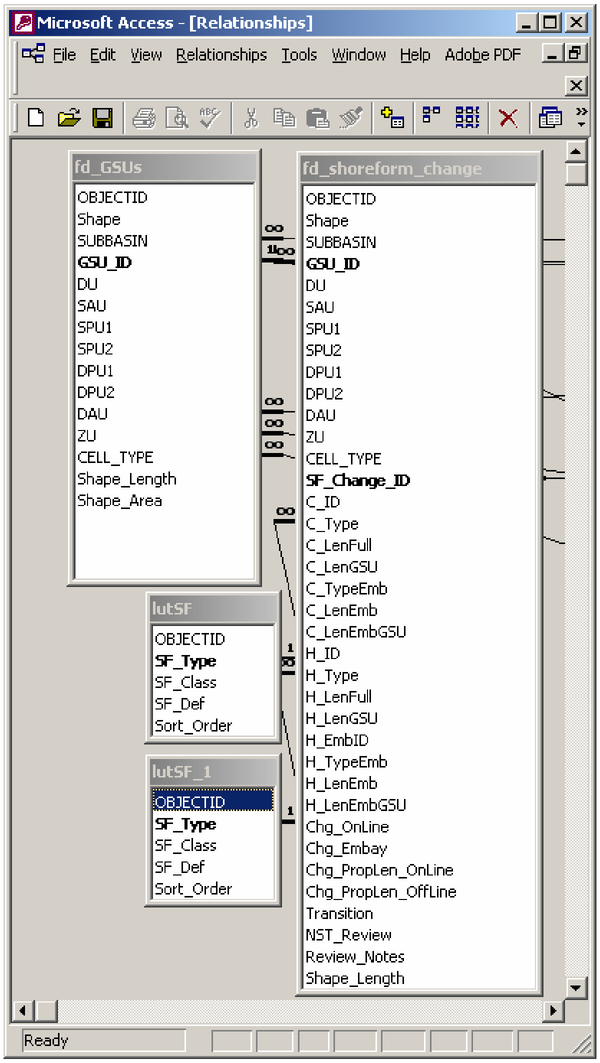


Figure 4-4. Structure of the shoreform table as related to the GSU table.

4.2.2 Tier 2 Datasets

The Tier 2 datasets (Table 2-2) all have been intersected with the GSU table via the GSU_ID field, and some also to the shoreform table via the SF_Change_ID field (Figure 4-5). Note all of the GSU fields have been carried through the tables in order to maximize the flexibility of querying. Most of the tables have retained fields from the original database. Attributes that must be counted have a created unique identifier (Unique_ID) or retain the unique ID that was in the original data (e.g., FED_NR for dams). Many of the tables are not unique on the GSU_ID because of the spatial nature of the source data (for example, non-contiguous polygons will have separate rows in the data table). General information is provided here to support querying of the datasets (Section 5) with some examples for specific datasets. Details on each dataset are in Appendix A as well as the project data processing document (Anchor et al. in prep.).

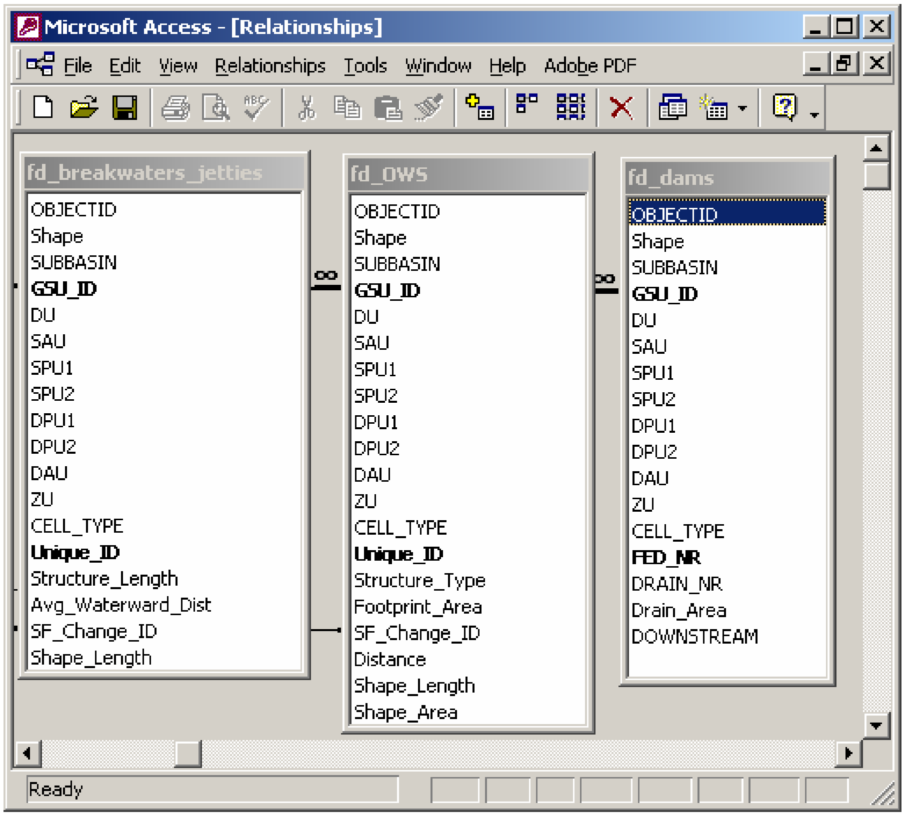


Figure 4-5. Example datasets showing unique identifiers and relationship to shoreform table (SF_Change_ID).

The breakwaters and jetties dataset (fd_breakwaters_jetties) has a Unique ID, as well as a field for the length of the structure and the distance (average) to the 10 meter in-water boundary within the DU. It has been intersected with the shoreform dataset via SF_Change_ID. To count breakwaters, a query should first group the data on the Unique_ID field. Similarly, the over-water structures dataset (fd_OWS) also has a Unique ID and SF_Change_ID. This dataset retains a list of normalized structure types (Bridge, Buoy/Float, Dock/Pier, Marina, Other), and the footprint area (in m). To count individual OWS, a query should first group the data on the Unique_ID field, although marinas should be calculated using the marinas dataset (fd_marinas) using the UniqueID field. Note that in the marinas dataset, the UniqueID sometimes refers to multiple polygons.

The tidal barriers and nearshore fill tables are polygon data that have been intersected with the GSUs and carry the original classification fields. Nearshore roads and active/abandoned railroads are line class tables that have been processed from the roads/railroads datasets that lie within 150 meters of the shorezone. The roads dataset has a lookup table that defines the road class (lutRC).

Wetlands are included in the database as two separate tables for current (fd_wetlands_current) and historic (fd_wetlands_historic); both are based on Simenstad four wetland classes (Anchor et al. in prep.). The class code is defined both in lutDAU (wetland type) and in a table called lutWC for summary queries (Section 5). The wetland DAUs in the GSU table is based on the historic wetlands (there may be some discrepancy between DAU and the historic wetland class field due to geo-processing methods).

4.2.3 Tier 3 and 4 Datasets

Roads and active/abandoned railroads for the Tier 3 and 4 analyses have also been processed as polygon class tables that have been buffered as a function of road class (roads) or the right-of-way width (railroads).

The dams dataset is used both for counting dams (on the unique ID FED_NR) as well as calculating the drainage area behind the dams. The drainage area is given in both square meters (Drain_Area) and square miles (DRAIN_NR). The Y/N field is used to indicate the furthest downstream to be used in the Tier 4 impoundment area metric.

Streams are reported in a number of datasets processed using different methods (Anchor et al. in prep.). Stream crossing points are points where streams and roads intersect (fd_stream_crossing_pts). These points are also reported as polygons, where the intersections have been buffered by the road width class (fd_stream_crossings). Finally, stream mouths are mouths of streams that have been geospatially snapped to the shorezone shoreline; each row is a unique stream mouth (point).

There are several datasets that provide information about land ownership properties. Parcels have been processed to a line file (fd_parcel_lines) that represent the waterfront edge of the parcel within the shorezone. Waterfront parcels can be counted as well, using the Unique_ID identifier (Section 5).

The protected lands (fd_protected_lands) dataset is a polygon file that includes the originally reported conservation status (Poor/Fair; Good/Very Good). Finally, the ownership status is available in the polygon class table fd_ownership classified to ownership class including private, public, and tribal.

Two datasets were originally raster and converted to polygons prior to intersection with the GSUs (fd_land cover, fd_impervious). Both datasets have been classified by a standard set of codes. Land cover (Table 4-1) has been categorized by class and also a land cover group used in summary queries (Natural and Developed). Impervious surfaces are categorized to four codes representing a range of imperviousness (Table 4-1).

Table 4-1. Landcover and Impervious Surface Code Defintions

Landcover			*Impervious Surface*	
LC_Class	**Sort_Order**	**LC_Group**	**Imperv_Code**	**TabCode**
Open Water	1	Natural	10	0-10
Perennial Snow/Ice	2	Natural	30	10-30
Developed, Open Space	3	Developed	50	30-50
Developed, Low Intensity	4	Developed	100	50-100
Developed, Medium Intensity	5	Developed		
Developed, High Intensity	6	Developed		
Barren Land	7	Natural		
Deciduous Forest	8	Natural		
Evergreen Forest	9	Natural		
Mixed Forest	10	Natural		
Shrub/Scrub	11	Natural		
Herbaceous	12	Natural		
Hay/Pasture	13	Developed		
Cultivated Crops	14	Developed		
Woody Wetlands	15	Natural		
Emergent Herbaceous Wetlands	16	Natural		

4.3 VALIDATION RULES AND QUALITY ASSURANCE/QUALITY CONTROL

The following validation rules have been developed and applied as QA/QC queries to the datasets developed to this point. This list will be updated and additional rules appended as the sub-basin GSU creation and queries are developed.

General rules, non-specific to environment or relative to both environments are provided below, followed by shoreline- and delta-specific rules.

- The GSU table should be unique based on the fields DU+DAU+ZU.
- Drainage Units are distinct and entirely encompassed within a sub-basin.
- The DU is spatially discrete and cannot be split between a DPU and an SPU.
- The DU field is required, and should be a six-digit number following the sub-basin numbering convention.
- The DU has one and only one drift cell component.
- ZU should be 0, 1, or 2
- If SPU1 and SPU2 are both null, then there must be a DPU.
- If an SAU is null, then there must be a DPU.

4.3.1 Shoreline

- ☐ The DU is spatially discrete and entirely encompassed within an SAU.
- ☐ The SAU has a 1:many parent-child relationship with DUs.
- ☐ The SAU should be related to one and only one drift cell.
- ☐ The SAU should be a five-digit number following the sub-basin numbering convention.
- ☐ The SAU is spatially discrete and entirely encompassed within an SPU.
- ☐ The SPU has a 1:many parent-child relationship with SAUs.
- ☐ Every SPU must have an SAU.
- ☐ There should be no duplicate SPU numbers that are reported in both SPU1 and SPU2.
- ☐ Shoreline data should be unique on DU+ZU (excluding DPU records).
- ☐ The ZU should be entirely encompassed within a shoreline DU (where SAU <> 0), such that the shoreline DU has a 1:1 parent-child relationship with the ZU.

4.3.2 Delta

- ☐ The DU is spatially discrete and entirely encompassed within a DPU, it cannot be split between DPUs or between a DPU and SPU.
- ☐ The DAU is a required field, and must consist of one of the 7 codes for DAU.
- ☐ The DAUs are spatially discrete and entirely encompassed within a DPU so that the DPU has a 1:many parent-child relationship with DAU (excluding DUs).
- ☐ If DPU1 is null, then DAU should be ‘SH’.
- ☐ Wetland DUs should consist only of wetland DAUs, local DUs should consist only of local DAUs, and basin DUs should consist only of basin DAUs.
- ☐ A DPU must have at least the Estuarine Mixing DAU and one other DAU polygon that is not Estuarine Forested/Tidal Freshwater present in the same area.
- ☐ The Basin DAU has a 1:1 parent-child with the basin-type DU.
- ☐ In a DPU that is not shared with an SPU, the Local DAU has a 1:many parent-child relationship with DU type Local.
- ☐ In a DPU that is not shared with an SPU, the DU in the NAD section of DPU consisting of the wetland DAUs should be just one DU.
- ☐ If DAU is EU, EM, OT or TF, ZU must be 1. Local or Basin DAUs can have a ZU of 0,1,or 2.
- ☐ The DU of the wetland/local type has a 1:1 parent-child relationship with the Wetland-class DAUs.

5 Queries and Tabulations

Standardized queries will be stored in each geodatabase, and will have the same naming conventions regardless of sub-basin.

- Quality Assurance/Quality Control: These queries, with a preface of ‘qaqry’ (Table 1-1), will be run after the creation of each GSU dataset to check for errors in the validation rules (Section 4.3).
- Reference: These queries, with a preface of ‘refqry’ (Table 1-1), will be used to normalize the feature data by the required spatial reference, either linear (shoreline length) or areal (aquatic, wetland, or total area).
- Tier queries: These queries are run to create the multivariate summary spreadsheets, and also tabulations, and are classified to Tier.
- Tabulation queries: These queries (‘tabqry’) are specific to tabulations.

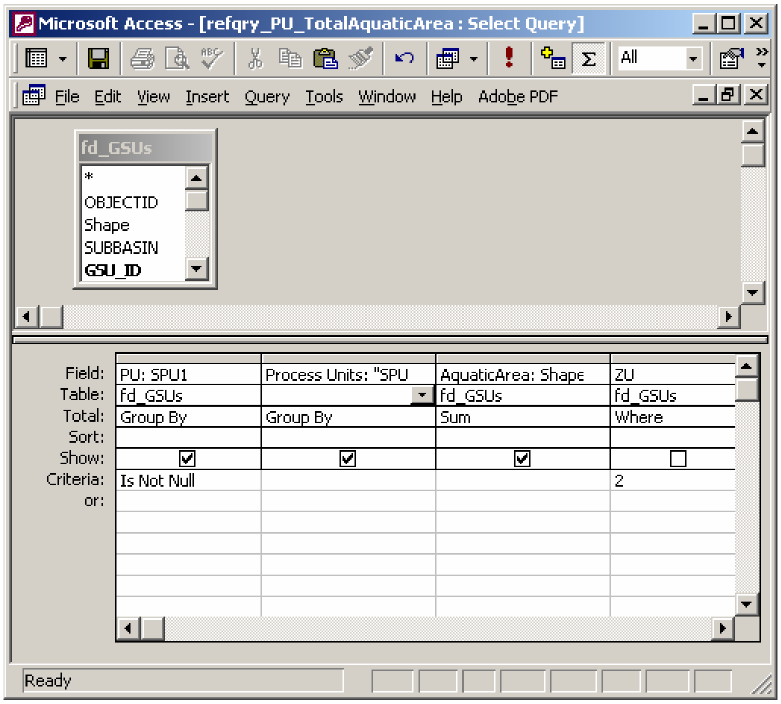
The spatial scales over which calculations are made are in the query name, including “PU” if the calculation is made over the process unit scale, or “SB” if over the sub-basin scale. Additional query nomenclature will be developed and documented as analyses proceed. All queries will require an understanding of how the database is structured for accurate querying. This section includes a description of these query standards, and provides some examples of how they are used in the Change Analysis queries and tabulations.

Most of the queries are analyzed on the Process Unit scale. Because of the database structure, process units sometimes share attributes (Section 4). Therefore, all of the queries must start with a union query that joins the attributes for SPU1, SPU2 for shoreline process units and DPU1, DPU2 for delta process units. In the example below (Figure 5-1), all of the unique process units are selected and named with the field “PU.” Note by creating a union of the SPUs (numeric field) and the DPUs (text field), the new field PU is text.

```
SELECT fd_GSUs.SPU1 AS PU
FROM fd_GSUs
GROUP BY fd_GSUs.SPU1
HAVING (((fd_GSUs.SPU1) is not null))
UNION
SELECT fd_GSUs.SPU2 AS PU
FROM fd_GSUs
GROUP BY fd_GSUs.SPU2
HAVING (((fd_GSUs.SPU2) is not null))
UNION
SELECT fd_GSUs.DPU1 AS PU
FROM fd_GSUs
GROUP BY fd_GSUs.DPU1
HAVING (((fd_GSUs.DPU1) is not null))
UNION
SELECT fd_GSUs.DPU2 AS PU
FROM fd_GSUs
GROUP BY fd_GSUs.DPU2
HAVING (((fd_GSUs.DPU2) is not null));
```

Figure 5-1. Example SQL statement to select a column of all of the process units through a UNION query.

Reference queries will be developed to calculate base summary metrics for the linear (e.g., shoreline length) and areal (e.g., GSUs over the Aquatic Area) measurements to be included in the Tier queries. For example, a reference query that calculates the total area, by SPU, over the Aquatic Area (ZU = 2) is shown in Figure 5-2. This shows only that for SPU1 (and would require a UNION query to call out all PUs as above).



Field:	PU: SPU1	Process Units: "SPU	AquaticArea: Shape	ZU
Table:	fd_GSUs		fd_GSUs	fd_GSUs
Total:	Group By	Group By	Sum	Where
Sort:				
Show:	☑	☑	☑	☐
Criteria:	Is Not Null			2
or:				

Figure 5-2. Example query in query design mode that sums the aquatic area (Zone Unit =2) for shoreline process unit SPU1.

The Tier queries range from simple to quite complex nested queries. Because of the nature of some of the process units sharing attributes in areas of spatial overlap between process units, the queries will result in different values depending on how the queries are structured. For example, in the Whidbey Island sub-basin, there are stream mouths that are shared between SPUs as well as between SPUs and DPUs (Table 5-1).

Table 5-1. Stream Mouth Count in the Whidbey Island Sub-basin

Process Unit	Stream Mouths
SPU1	88
SPU2	58
Total number in SPUs	146
DPU1	68
DPU2	35
Total number in DPUs	103
Total number in Whidbey Island by Process Unit	*249*
Actual total number in Whidbey Island	*227*

5.1 MULTIVARIATE QUERIES FOR CHANGE ANALYSIS

Within each geodatabase, there are standard queries that are used to develop the multivariate spreadsheets for the Change Analysis. Reference queries are named so as to be self-explanatory, ranging from length (refqry_PU_TotalCurrentShorelineLength) or area (refqry_PU_TotalCurentWetlandArea) calculations, to queries need for counting of unique attributes (e.g., refqry_PU_MarinaUniqueArea).

The multivariate calculations are generated for each Tier with the Tier number as the first part if the query name, the metric, and the query number for queries that require several nested queries. The preparatory queries are hidden for the final database, so that you may need to unhide them to see the detail (Tools/Options/View and check ‘Hidden Objects’).

Shoreforms (Tier 1) are the most complicated dataset to query, as it includes both current and historic shoreforms, as well as on- and off-line lengths (Anchor et al. in prep.), so will be used here to provide an example. The intent of the query is to calculate the total historic and current shoreform lengths, and then calculate a percent difference between them. The final query (Tier1_Shoreform_Final) is actually the last of a series of nested queries named from 01-03. The first UNION query (Tier1_Shoreform_01) calculates the sum of each type of length by shoreform type and for each process unit. This query extract shown below selects the current shoreform (“CurrSF”) for each the SPU1 unit, sums each length, including the on-line length (C_LenGSU), and the off-line (embayment) length (C_LenEmbGSU), and includes the shoreform type and sort order from the associated lookup table (lutSF):

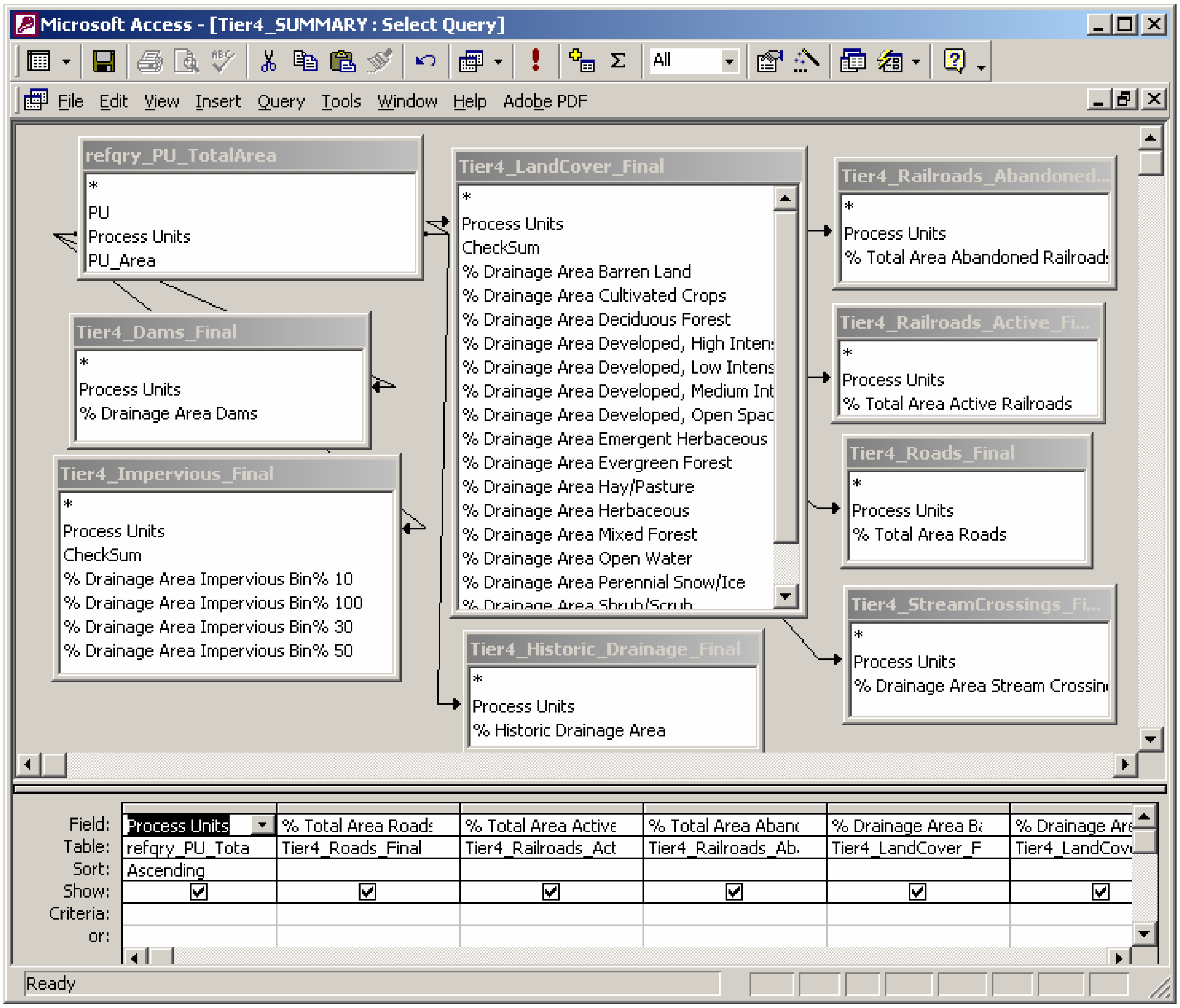
```
SELECT "CurrSF" AS [Time], fd_shoreform_change.SPU1 AS PU, lutSF.Sort_Order, lutSF.SF_Type,
Sum(fd_shoreform_change.C_LenGSU) AS SFLength
FROM fd_shoreform_change INNER JOIN lutSF ON fd_shoreform_change.C_Type = lutSF.SF_Type
GROUP BY "CurrSF", fd_shoreform_change.SPU1, lutSF.Sort_Order, lutSF.SF_Type
HAVING (((fd_shoreform_change.SPU1) Is Not Null))
UNION
SELECT "CurrSF" AS [Time], fd_shoreform_change.SPU1 AS PU, lutSF.Sort_Order, lutSF.SF_Type,
Sum(fd_shoreform_change.C_LenEmbGSU) AS SFLength
FROM fd_shoreform_change INNER JOIN lutSF ON fd_shoreform_change.C_TypeEmb =
lutSF.SF_Type
GROUP BY "CurrSF", fd_shoreform_change.SPU1, lutSF.Sort_Order, lutSF.SF_Type
HAVING (((fd_shoreform_change.SPU1) Is Not Null))
```

The second shoreform query is a cross-tabular (cross-tab) query that sorts the data by process unit, sort order, and shoreform, and then lists the summed total lengths from the first query. The third then calculates the percent change value for the current and historic lengths, based on the desired method of calculation for Change Analysis. In this formula, percent change is calculated as ([current length]-[historic length])/[historic length]) and rounded to four decimal places, with some exceptions. The value is reported as 0 if the historic length is 0; -1 (-100%) if the current length is 0; and the value is limited to 100% if the percent change value exceeds that number:

```
PctChange: IIf(IIf([HistSF]=0,IIf([CurrSF]=0,0,0),Round((([CurrSF]-
[HistSF])/[HistSF],4))>1,1,IIf([HistSF]=0,IIf([CurrSF]=0,0,0),Round((([CurrSF]-[HistSF])/[HistSF],4)))
```

Most of the Tier 2-4 queries include a “Header” column that creates the header used for each metric. Tier 2 queries have headers that show normalization of the Tier 2 stressors by the (reference query) total current shoreline length. Similarly, Tiers 3 and 4 queries create headers within the query that normalizes by zone area (Tier 3) and drainage area (Tier 4), respectively.

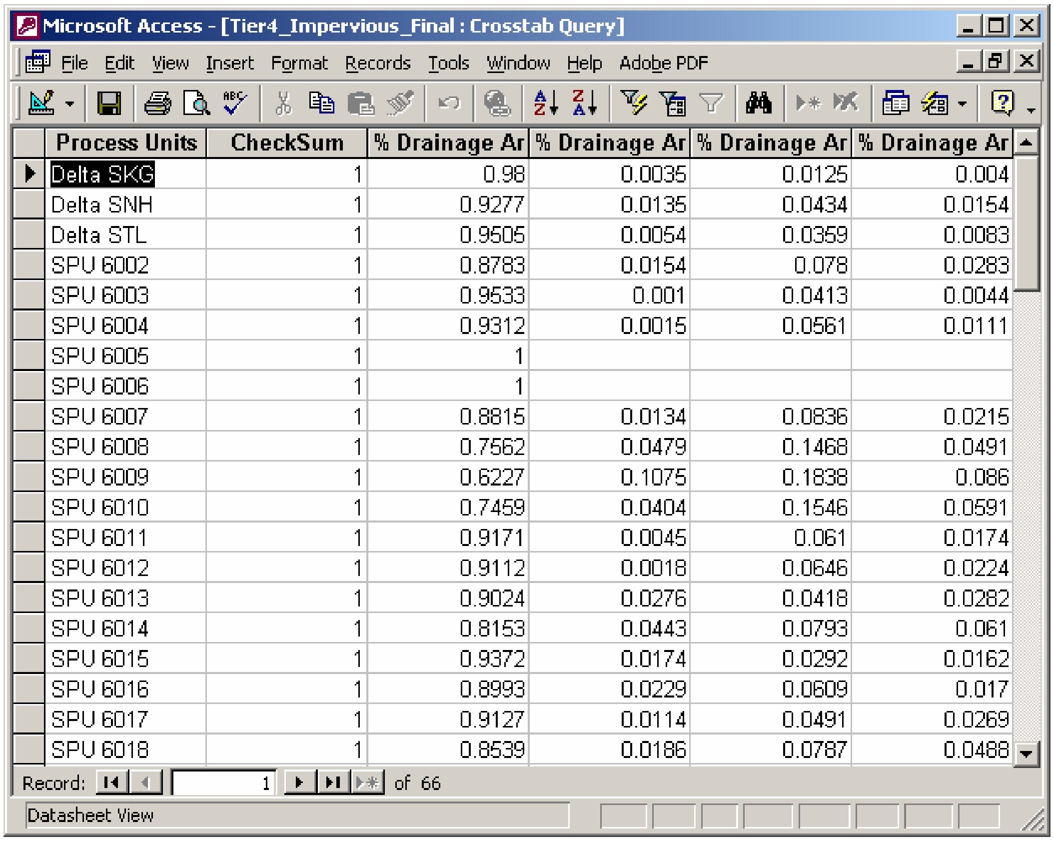
The final output for the spreadsheets are created through the use of a master query that links all of the other queries together for the separate Tiers (Figure 5-3).



Field:	Process Units	% Total Area Road:	% Total Area Active	% Total Area Abanc	% Drainage Area Ba	% Drainage Are
Table:	refqry_PU_Tota	Tier4_Roads_Final	Tier4_Railroads_Act	Tier4_Railroads_Ab.	Tier4_LandCover_F	Tier4_LandCov
Sort:	Ascending					
Show:	☑	☑	☑	☑	☑	☑
Criteria:						
or:						

Figure 5-3. Summary query for Tier 4 metrics that link all of Tier 4 queries for generation of multivariate Change Analysis spreadsheets.

As shown on Figure 5-3, the datasets that have been categorized (land cover and impervious surface) include a cross-tab query so that each category, with a standard header, shows up as column headings. These queries also include a QA step, which includes the total of each category as a column so that the analyst can check to make sure the totals add up to 100% (Figure 5-4).



Process Units	CheckSum	% Drainage Ar	% Drainage Ar	% Drainage Ar	% Drainage Ar
Delta SKG	1	0.98	0.0035	0.0125	0.004
Delta SNH	1	0.9277	0.0135	0.0434	0.0154
Delta STL	1	0.9505	0.0054	0.0359	0.0083
SPU 6002	1	0.8783	0.0154	0.078	0.0283
SPU 6003	1	0.9533	0.001	0.0413	0.0044
SPU 6004	1	0.9312	0.0015	0.0561	0.0111
SPU 6005	1	1			
SPU 6006	1	1			
SPU 6007	1	0.8815	0.0134	0.0836	0.0215
SPU 6008	1	0.7562	0.0479	0.1468	0.0491
SPU 6009	1	0.6227	0.1075	0.1838	0.086
SPU 6010	1	0.7459	0.0404	0.1546	0.0591
SPU 6011	1	0.9171	0.0045	0.061	0.0174
SPU 6012	1	0.9112	0.0018	0.0646	0.0224
SPU 6013	1	0.9024	0.0276	0.0418	0.0282
SPU 6014	1	0.8153	0.0443	0.0793	0.061
SPU 6015	1	0.9372	0.0174	0.0292	0.0162
SPU 6016	1	0.8993	0.0229	0.0609	0.017
SPU 6017	1	0.9127	0.0114	0.0491	0.0269
SPU 6018	1	0.8539	0.0186	0.0787	0.0488

Record: 1 of 66

Figure 5-4. Tier 4 impervious surface query showing the field "CheckSum" that verifies 100% sum.

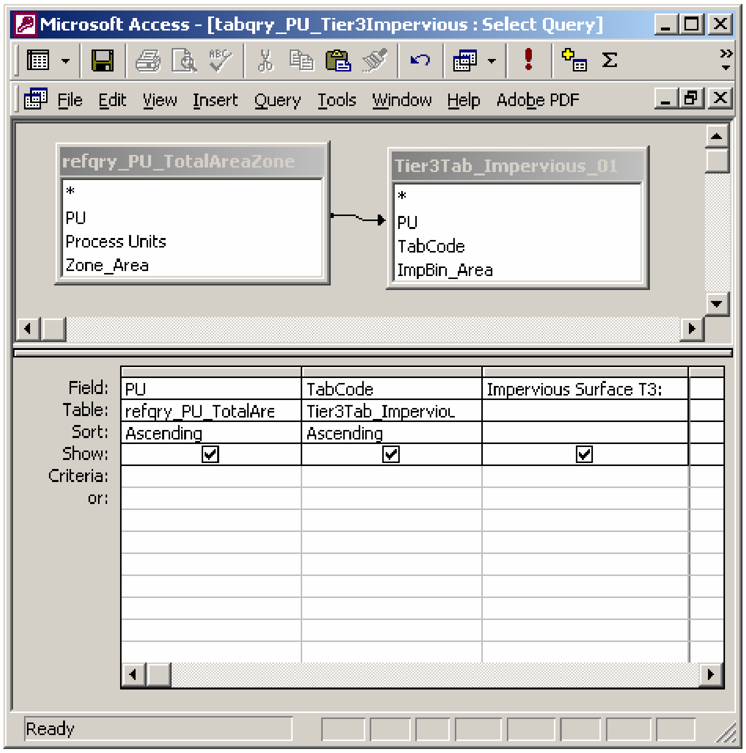
Also note that some of the cross-tab queries result in null values that are filled with zeros in the final spreadsheets using a VBA macro.

5.2 TABULATION QUERIES

The tabulation databases are a separate series of databases that include code to generate tabulations, and will be documented separately. There are some calculations and therefore queries and support tables unique to the tabulations that are useful to discuss here.

The raster datasets (impervious surface and land cover) have lookup tables for grouping and sorting data for the tabulations (Table 4-1). So, for example, rather than a descriptive header as created for the Change Analysis queries, the Tabulation query will use the tabulation code as the header in the output (e.g., "Developed" and "Natural" for land cover, Table 1-1). The other difference is that the output is reported as a percent rather than a fraction, without the limitations of maximizing the output to 100%, here normalized for Tier 3 to the zone area, rounded to one decimal place:

Impervious Surface T3:
*Round(([Tier3Tab_Impervious_01].[ImpBin_Area])/([refqry_PU_TotalAreaZone].[Zone_Area])*100,1)*



Field:	PU	TabCode	Impervious Surface T3:
Table:	refqry_PU_TotalAre	Tier3Tab_Imperviou	
Sort:	Ascending	Ascending	
Show:	☑	☑	☑
Criteria:			
or:			

Figure 5-5. Tier 3 impervious surface tabulation query that uses the 'TabCode' field as the cross-tab header.

The tabulations required creation of a report called a 'Transition Matrix' which showed the number of shoreforms that transformed from one kind of shoreform to another between historic and current. As with the Change Analysis query, this calculation requires extracting the shoreforms present in both the on-line and off-line areas, then comparing the current and historic using the unique identifier SF_Change_ID. In the statement below, the current and historic embayment shoreform type (C_TypeEmb and H_TypeEmb) are selected for each SPU1 and SF_Change_ID. If they are different, then a 1 is stored, if not, a 0 is stored.

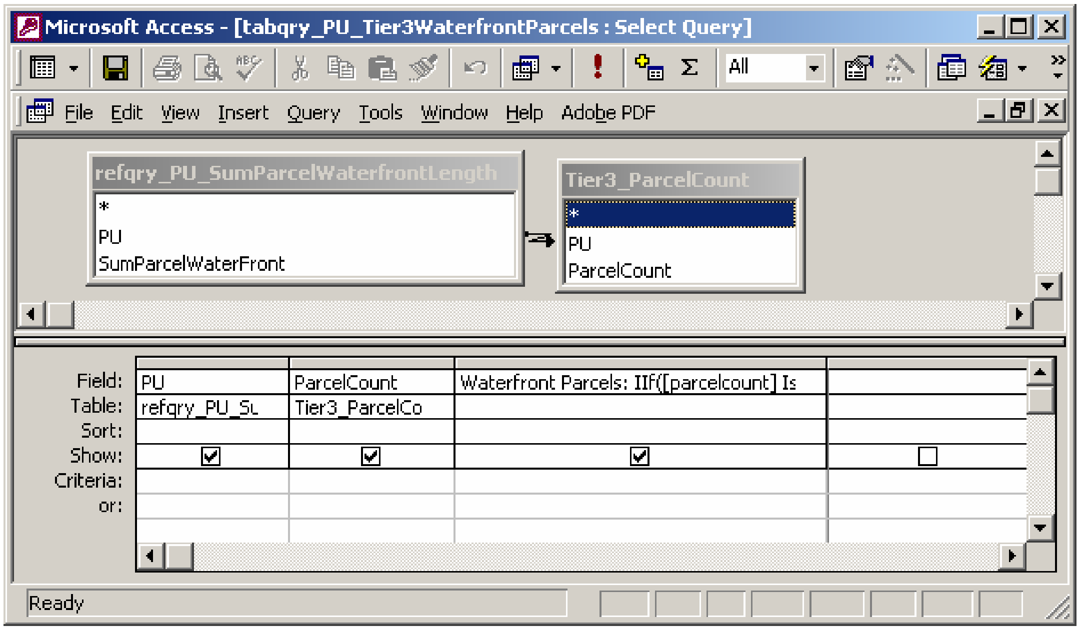
```
SELECT fd_shoreform_change.SPU1 AS PU,
fd_shoreform_change.SF_Change_ID,
fd_shoreform_change.C_TypeEmb,
fd_shoreform_change.H_TypeEmb,
IIf([C_TypeEmb]=[H_TypeEmb],0,1) AS Change
FROM fd_shoreform_change
GROUP BY fd_shoreform_change.SPU1,
fd_shoreform_change.SF_Change_ID,
fd_shoreform_change.C_TypeEmb,
fd_shoreform_change.H_TypeEmb,
IIf([C_TypeEmb]=[H_TypeEmb],0,1)
HAVING (((fd_shoreform_change.SPU1) Is Not Null))
ORDER BY fd_shoreform_change.H_TypeEmb
```

Figure 5-6. SQL to classify change between current and historic shoreforms.

By creating this query for each process unit and shoreform type, a total number of changes can be calculated and a cross-tab query is used to create the final transition matrix.

One metric calculated for tabulations is a waterfront parcel metric, reported as the number of waterfront parcels per 10,000 meters of waterfront parcel length (Figure 5-7). This calculation requires counting the unique parcels, calculating the waterfront parcel metric as;

IIf([parcelcount] Is Null,0,round([Tier3_ParcelCount.ParcelCount]/([sumparcelwaterfront]/10000),1))



Field:	PU	ParcelCount	Waterfront Parcels: IIf([parcelcount] Is	
Table:	refqry_PU_Su	Tier3_ParcelCo		
Sort:				
Show:	☑	☑	☑	☐
Criteria:				
or:				

Figure 5-7. Calculation of waterfront parcel metric using a reference query that summarizes waterfront length and the parcel count.

6 References

Anchor Environmental Consultant Team. In prep. Geospatial Methodology used in the PSNERP Comprehensive Change Analysis of Puget Sound. Prepared for the U.S. Army Corps of Engineers, Seattle District. Prepared in support of the Puget Sound Nearshore Partnership. Prepared by Anchor Environmental, Sound GIS, and Exa Data & Mapping.

Anchor Environmental Consultant Team. 2008. Data Discovery Summary Report. Prepared for the U.S. Army Corps of Engineers, Seattle District. Prepared in support of the Puget Sound Nearshore Partnership. Prepared by Anchor Environmental, LeeSaa Consulting, and Sound GIS. September 2008.

Coastal Geologic Services (CGS). 2008. Net Shore-drift QA/QC Methods for Puget Sound and Northwest Straits. Prepared for the U.S. Army Corps of Engineers, Seattle District. Prepared in support of the Puget Sound Nearshore Partnership. Under Contract to Anchor Environmental. March 27, 2008.

Federal Geographic Data Committee (FGDC) 1998. FGDC-STD-001-1998. Content standard for digital geospatial metadata (revised June 1998). Federal Geographic Data Committee. Washington, D.C.

APPENDIX C

CHANGE ANALYSIS GEODATABASE DATA PREPARATION AND QUALITY CONTROL DOCUMENTATION

APPENDIX C

CHANGE ANALYSIS GEODATABASE DATA PREPARATION AND QUALITY CONTROL DOCUMENTATION

Prepared for

U.S. Army Corps of Engineers, Seattle District
4735 East Marginal Way South
Seattle, Washington 98124

Prepared In Support of

PUGET SOUND
NEARSHORE
PARTNERSHIP

RESTORING OUR
ECOSYSTEM HEALTH

Prepared by

Anchor QEA, LLC
1423 Third Avenue, Suite 300
Seattle, Washington 98101

May 2009

Table of Contents

1 GEOGRAPHIC SCALE UNITS

Feature Name	fd_GSUs
Feature Geometry Type	polygon
Tier(s)	All
Data Source(s) Used	USGS, 10-meter resolution DEM Natural Resources Canada DEM, variable resolution (15-m by 23-m pixels in region of interest). Ecology, Net Shore-Drift in Washington State, Updated by Corps/Coastal Geologic Services University of Washington, Finlayson bathymetry, 2000 and 2005 University of Washington, Puget Sound River History Project Geodatabase WDNR, Hydrography Data U.S. Department of Agriculture, National Aerial Imagery Program (NAIP) color orthophotos, 2006 Ecology, Oblique Aerial Photographs, 2005-2006 WDNR, ShoreZone Inventory

1.1 Entity/Attribute Definitions for Geographic Scale Units

Attribute Name	Attribute Type	Description	Allowed Values
SUBBASIN	Text, 5	Two-letter Sub-basin code	HC = Hood Canal JF = Juan de Fuca NC = North Central Puget Sound SC = South Central Puget Sound SJ = San Juans SP = South Puget Sound WH = Whidbey AA|BB = Combined sub-basin codes separated by a pipe character (e.g., "HC|NC") means these areas are shared between two adjacent sub-basins. The first two-letter code refers to an entire sub-basin; the second two-letter code refers to the fraction of the adjacent sub-basin that shares areas with the first one.
GSU_ID	Text, 20	Unique value for each feature.	Concatenation of DU + “-“ + DAU + “-“ + ZU
DU	Long Integer	Drainage Unit identifier	5-digit integer value. Unique across subbasins.
SAU	Long Integer	Shoreline Accounting Unit identifier	4-digit integer value. Unique across subbasins.
SPU1	Long Integer	First Shoreline Process Unit identifier	4-digit integer value. Unique across subbasins.
SPU2	Long Integer	Second Shoreline Process Unit identifier	4-digit integer value. Unique across subbasins.
DPU1	Text, 3	First Delta Process Unit identifier	DOS, DUC, HAM, QUL, SKO, DUN, ELW, DUW, PUY, NKS, SAM, DES, NSQ, SKG, SNH
DPU2	Text, 3	Second Delta Process Unit	STL

Attribute Name	Attribute Type	Description	Allowed Values
		identifier	
DAU	Text, 2	Delta Accounting Unit	BA = Basin LO = Local TF = Tidal freshwater OT = Oligohaline transition EM = Estuarine mixing EU = Euryhaline unvegetated SH = Shoreline (outside of delta)
ZU	Long Integer	Zone Unit code	0 = uplands outside of zone 1 = 200-meters landward from shoreline or historic wetlands 2 = waterward from shoreline or historic wetlands to 10-meters depth
CELL_TYPE	Text, 4	Drift cell component type	LtoR = left-to-right transport RtoL = right-to-left transport CZ = Convergence zone DZ = Divergence zone NAD = No Appreciable Drift

1.2 Data Preparation

For GSU development methods, please see Section 4.1 in *Geospatial Methodology used in the PSNERP Comprehensive Change Analysis of Puget Sound*.

1.3 Quality Control

1.3.1 Spatial QC Process

Note: Spatial review needs to be done with a version that is single part. After spatial QC is done, dissolve on all columns to complete tabular QC process.

(1) Drainage Units (DU) Spatial Rules

☑ Drainage Units do not have gaps or overlap.

QC Approach:
Use ArcGIS topology tools to identify gaps and/or overlaps and remove them.

☑ Drainage Units follow the terrain.
☑ Drainage Unit boundaries do not contain more than one drift cell component.
☑ Waterward boundaries of drainage units are generally perpendicular to shore.
☑ Waterward boundaries of drainage units that feed small embayments contain the embayment area only, and do not necessarily extend out to 10-meter depth boundary.

QC Approach:
Visually review Drainage Units (DUs) labeled by DU using a semi-transparent shade with hillshade displayed underneath. Drift cells are also dispayed. This allows QC of DU delineation with respect to the terrain and the drift cells.

☑ Outside of Delta Process Units (DPU), a unique DU identifier is assigned to a contiguous section of upland and waterward area.

☑ Outside of DPUs, the DU should not have a tiny polygon area.

QC Approach:
Dissolve GSUs on DU and do not allow multipart features.
Query – *DU_discontinuous*, *DU_discontinuous_DPU*
Review any duplicates visually and correct.
Sort on Shape_Area field and visually review any small polygons.

<u>(2) Shoreline Accounting Units (SAU) Spatial Rules</u>

☑ A Shoreline Accounting Unit (SAU) consists of a group of contiguous DUs that encompass a single drift cell component (NAD, LtoR, RtoL, DZ, CZ).

☑ The drift cell component code for the SAU is assigned to the CELL_TYPE attribute of all DUs in that SAU.

QC Approach:
Display GSUs and drift cells by CELL_TYPE using same color scheme. This will easily highlight GSUs that do not have the correct drift cell type assigned.

Dissolve GSUs on SAU and do not allow multipart features.
Query – *SAU_duplicates*
Review any duplicates visually and correct.

Pay special attention to DUs at the edge of the subbasin to determine if the SAU crosses the subbasin boundary. If the DUs on the boundary contain part of a single, contiguous drift component (RtoL, LtoR), assign a 4-digit SAU identifier starting with 8.

<u>(3) Shoreline Process Units (SPU) Spatial Rules</u>

☑ A Shoreline Process Unit (SPU) consists of a group of contiguous DUs (or SAUs) that encompass an entire drift cell (one or more continuous drift cell components).

QC Approach:
Dissolve GSUs on SPU1 and do not allow multipart features.
Dissolve GSUs on SPU2 and do not allow multipart features.

Querys – *SPU1_duplicates, SPU2_duplicates*

Display SPU1 and SPU2 individually with drift cells to confirm that each SPU is a contiguous area that contains a single drift cell.

Pay special attention to DUs at the edge of the subbasin to determine if the SPU crosses the subbasin boundary. If the DUs on a subbasin boundary are shared by two SPUs (CZ, DZ, or NAD), get the second SPU id from the adjacent subbasin GSUs. If the DUs on the boundary contain part of a single, contiguous drift component (RtoL, LtoR), assign a 4-digit SPU identifier starting with 8.

☑ DUs that are shared by two SPUs will have a DZ, CZ, or NAD drift cell component.

QC Approach:
Query for DUs with two SPU ids and a unidirectional drift component. Visually review any selected DUs.
ArcMap Query: [*SPU1] is not null AND [SPU2] is not null and ([CELL_TYPE] = 'LtoR' or [CELL_TYPE] = 'RtoL')*

☑ DUs with DZ, CZ, or NAD, (outside of DPUs), will generally be shared by two SPUs. Exceptions occur, (such as NAD sections within larger segments of unidirectional drift), and need to be reviewed visually.

QC Approach:
Query for DUs that are not in the DPUs, have a drift component of CZ, DZ, or NAD, and are not shared by two SPUs. Visually review any results.
ArcMap Query: *([CELL_TYPE] = 'NAD' or [CELL_TYPE] = 'CZ' or [CELL_TYPE] = 'DZ') and ([SPU1] is null or [SPU2] is null) and ([DPU1] is null and[DPU2] is null)*

(4) Zone Units (ZU) Spatial Rules for SPUs

☑ Zone Unit = 2 is the area waterward of the ShoreZone shoreline
☑ Zone Unit = 1 is the area within 200 meters landward of the ShoreZone shoreline
☑ Zone Unit = 0 is the upland area beyond 200 meters landward of ShoreZone shoreline.

QC Approach:
Display the Zone Units with a unique color and visually review these areas to confirm that they are assigned correctly.

(5) Delta Process Units (DPU) Spatial Rules

☑ A Delta Process Unit (DPU) consists of a group of contiguous DUs that encompass a large river's drainage, delta mouth, and associated wetlands (historic and current).
☑ The extent of the DPU is determined by the extent of shoreline at the river mouth with No Appreciable Drift (NAD) as well as the historic extent of broad unvegetated tidal flats.

QC Approach:
Display the DPUs with the drift cells and historic wetlands data to review for correct delineation.

☑ DUs in a DPU that have No Appreciable Drift (NAD) are generally not shared by an adjacent SPU. Exceptions are small embayments that are within sections of drift in the DPU.
☑ DUs in a DPU are also shared by an SPU where there is drift (RtoL, LtoR, CZ, or DZ) within the DPU.

☑ The exception to this rule is in the Straits of Juan de Fuca and Hood Canal where there are deltas that have no sections or minimal sections of NAD (Elwha, Dungeness, Dosewallips, Duckabush). In these cases, in spite of the presence of drift, none of the DUs in the DPU are shared by an SPU.

QC Approach:
Display DUs (shaded) that have both an SPU and a DPU identifier and visually review for correct attribute assignment. Display shared DPU and SPU areas with drift cells.

ArcMap query statement: *not ([DPU1] is null and [DPU2] is null) and [SAU] is not null*
Review the CELL_TYPE from this query to confirm that there are no NAD values.

ArcMap query statement: *not ([DPU1] is null and [DPU2] is null) and [SAU] is null and [CELL_TYPE] <> 'NAD'*

☑ DUs within a DPU are assigned to a Delta Accounting Unit (DAU) according to the following scheme:

- Basin (BA): the DU that drains to the main stem of the river. There is only one Basin DAU within each delta. The Basin DAU must be contiguous with the uppermost extent of the historic wetland boundaries
- Local (LO): the DU(s) that drain to the wetlands, rather than the main stem of the river.
- Tidal Freshwater (TF): Specific historic wetland types that have been grouped into the tidal freshwater class
- Oligohaline Transition (OT): Specific historic wetland types that have been grouped into the oligohaline class
- Estuarine Emergent (EM): Specific historic wetland types that have been grouped into the estuarine emergent class
- Euryhaline Unvegetated (EU): Specific historic wetland types that have been grouped into the euryhaline unvegetated class

☑ DUs outside a DPU are assigned a Delta Accounting Unit (DAU) type of Shoreline (SH)

QC Approach:
Display shaded, partially transparent DAUs with historic wetland classes, drift cells and DPU outer boundaries and review for correct attribute assignment.

☑ All historic wetlands that are within the DPU, but not shared by an SPU, are assigned a single DU identifier. Areas that are not historic wetlands should not have this DU id.

QC Approach:
Display shaded, partially transparent DUs with historic wetland classes, drift cells and DPU outer boundaries and review for correct attribute assignment.
Query the DUs for the DPU wetlands DU identifier and make sure it does not include areas that are not wetlands.

☑ A Delta shoreform cannot fall within an SPU

QC Approach:
Do an overlay (IDENTITY) of GSUs with shoreforms and confirm that there are no delta shoreforms within an SPU area.

1.3.2 Tabular QC Process

Create a multi-part version of the spatially QC'ed GSUs in the QC geodatabase for tabular QC. Then run the following attribute queries in MS Access:

General Rules:

- ☐ The GSU table should be unique based on the fields DU+DAU+ZU. (*Find duplicates for fd_GSUs*)
- ☐ The DU field is required, and should be a five-digit number following the sub-basin numbering convention. (*NullDUs, DU-MinMax*)
- ☐ The DU has one and only one drift cell component. (*DU_DriftCell2*)
- ☐ The DU is spatially discrete and cannot be split between a DPU and SPU. (*Find duplicates for DU-SPU-DPUCheck*).
- ☐ ZU should be 0, 1, or 2 (*ZUCheck*)
- ☐ If SPU1 and SPU2 is null, then there must be a DPU1 or DPU2. (*SPU-DPUCheck1*)
- ☐ If an SAU is null, then there must be a DPU. (*SPU-DPUCheck2*)

Shoreline Rules:

- ☐ The DU is spatially discrete and entirely encompassed within an SAU (in other words, a DU cannot be split between two SAUs). (*DU_SAU2*)
- ☐ The SAU should be related to only one drift cell component. (*SAU-DriftCell2*)
- ☐ The SAU should be a four-digit number following the sub-basin numbering convention. *(SAU_MinMax)*
- ☐ The SAU is spatially discrete and entirely encompassed within an SPU. Note that an SAU CAN be shared between an SPU1 and SPU2 (by definition). (*SAU-SPU(FINAL)*).
- ☐ Every SPU must have an SAU. (*SPU-SAUCheck*)
- ☐ There should be no duplicate SPU numbers that are reported in both SPU1 and SPU2. (*SPUCheck(Final)*)
- ☐ Shoreline data should be unique on DU+ZU (excluding DPU records). (*Find duplicates for Shore-Unique*)
- ☐ The ZU should be entirely encompassed within a shoreline DU (where SAU <> 0), such that the shoreline DU has a 1:1 parent-child relationship with the ZU. A DU should have all three ZU (0,1, 2) or, if they are small, may have only two (1, 2). They should not have only one ZU, or have the combination of ZU = 0 and ZU = 1. (*Shore-DU-ZU2*).

Delta Rules:

- ☐ The DU is spatially discrete and entirely encompassed within a DPU, it cannot be split between DPUs. (*Find duplicates for DU-SPU-DPUCheck*)
- ☐ The DAU is a required field, and must consist of one of the 7 codes for DAU. (*DAUCheck1*)
- ☐ If DPU1 and DPU2 are null, then DAU should be 'SH'. (*DAU-SHCheck*)
- ☐ The DPU1 value cannot equal the value in DPU2. *(DPUCheck(UNION))*.

- ☐ The Basin DAU has a 1:1 parent-child relationship with the basin-type DU. (*DU-BasinCheck*)
- ☐ The Local DAU has a 1:many parent-child relationship with DU type Local. (*DU-DAUCheck2*) (Or run *Find duplicates for DU-DAUCheck1* to see what DUs have multiple DAU types.)
- ☐ In a DPU that is not shared with an SPU, the wetland DAUs are grouped into a single DU. (*Wetland-NADCheck*)
- ☐ If DAU is EU, EM, OT or TF, ZU must be 2. Local or Basin DAUs can have a ZU of 0,1,or 2. (*Wetland-ZUCheck*)

2 SHORELINE CURRENT

Feature Name	fd_shoreline_current
Feature Geometry Type	Line
Tier(s)	Tabulations
Metric(s)	Drift component length/Shoreline length
Data Source(s) Used	WDNR ShoreZone, GSUs
Geometric Intersection	Yes

2.1 Entity/Attribute Definitions for Shoreline Current

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--

2.2 Data Preparation

Dissolve fd_shoreform_change on all GSU fields

2.3 Quality Control

2.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

2.3.2 Phase 2

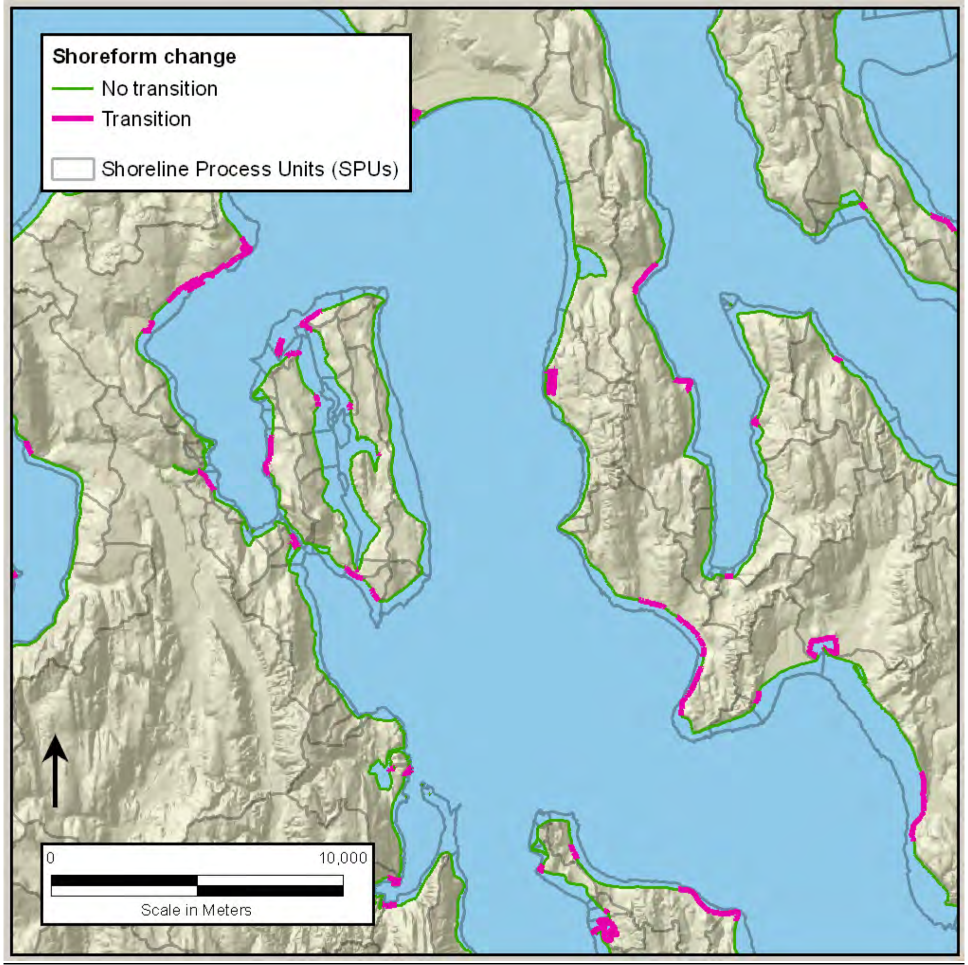
Run Check Geometry and repair any errors

Run topology check for overlap issues (should be none).

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

3 SHOREFORM CHANGE

Feature Name	fd_shoreform_change
Feature Geometry Type	line
Tier(s)	1
Metric(s)	Length shoreform/Length shoreline Shoreform transition matrices (historic to current) Count of shoreforms (historic and current)
Data Source(s) Used	Shoreform change analysis (Anchor Environmental and Sound GIS), historic shoreform (Anchor Environmental and Sound GIS), current shoreform (SSHIAP)
Geometric Intersection	Yes



3.1 Entity/Attribute Definitions for Shoreform Change

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
SF_Change_ID	Long Integer	Unique ID assigned to line segments to be used in SF spatial joins with other metric feature classes	

Attribute Name	Attribute Type	Description	Allowed Values
C_ID	Long Integer	ID assigned to the corresponding segment of the SSHIAP current shoreform typology	
C_Type	Text, 8	Current shoreform type	PL = Plunging Rocky shoreline RP = Rocky Ramp/Platform PB = Pocket Beach BLB = Bluff-backed Beach BAB = Barrier Beach BE = Barrier Estuary BL = Barrier Lagoon CLM = Closed Lagoon or Marsh OCI = Open Coastal Inlet D = Delta ART = Artificial
C_LenFull	Double	Equal to Shape_Length PRIOR TO intersection with GSUs	
C_LenGSU	Double	Equal to Shape_Length AFTER intersection with GSUs	
C_TypeEmb	Text, 8	Off-line current embayment type	BE = Barrier Estuary BL = Barrier Lagoon CLM = Closed Lagoon or Marsh None
C_LenEmb	Double	Embayment line length transferred from other feature class	
C_LenEmbGSU	Double	Proportional length inside GSU (calculated as C_LenEmb*C_LenGSU/C_LenFull)	
H_ID	Long Integer	ID assigned to the corresponding segment of the Anchor historic shoreform typology	
H_Type	Text, 8	Historic shoreform type	PL = Plunging Rocky shoreline RP = Rocky Ramp/Platform PB = Pocket Beach BLB = Bluff-backed Beach BAB = Barrier Beach BE = Barrier Estuary BL = Barrier Lagoon CLM = Closed Lagoon or Marsh OCI = Open Coastal Inlet D = Delta ART = Artificial None

Attribute Name	Attribute Type	Description	Allowed Values
H_LenFull	Double	Full line length (Shape_Length) transferred as an attributed from the historic shoreform typology	
H_LenGSU	Double	Proportional length inside GSU (calculated as H_LenFull*C_LenGSU/C_LenFull)	
H_EmbID	Long Integer	ID assigned to the corresponding off-line segment of the Anchor historic shoreform typology	
H_TypeEmb	Text, 8	Off-line historic embayment type	BE = Barrier Estuary BL = Barrier Lagoon CLM = Closed Lagoon or Marsh None
H_LenEmb	Double	Embayment line length transferred from historic typology feature dataset	
H_LenEmbGSU	Double	Proportional length inside GSU (calculated as H_LenEmb*C_LenGSU/C_LenFull)	
Chg_OnLine	Short Integer	Integer value indicating a change in on-line shoreform	0 or 1
Chg_Embay	Short Integer	Integer value indicating a change in off-line shoreform	0 or 1
Chg_PropLen_OnLine	Double	Percent change in length of on-line features (calculated as [C_LenFull]-[H_LenFull]/[H_LenFull], lines with no historic length will remain Null)	
Chg_PropLen_OffLine	Double	Percent change in length of on-line features (calculated as [C_LenEmb]-[H_LenEmb]/[H_LenEmb], lines with no historic length will remain Null)	
C_ContigID	Long Integer	ID representing continuous, sequential current shoreforms; to be used both in shoreform counts and to facilitate adjacency queries; because of complex linework, this ID cannot be used to count delta (‘D’) shoreforms	
H_ContigID	Long Integer	ID representing continuous, sequential historic shoreforms; to be used both in shoreform counts and to facilitate adjacency queries; because of complex linework, this ID cannot be used to count delta (‘D’) shoreforms	
Transition	Short Integer	Integer value representing line segments that have one or more transitions;	0, 1, or 2

Attribute Name	Attribute Type	Description	Allowed Values
		Chg_OnLine + Chg_Embay	
NST_Review	Text, 1	"Y" = Work reviewed by NST during fly-by	"Y" or <BLANK>
Review_Notes	Text, 255	Notes from fly-by, Areas of Interest, Geomorph Review	

3.2 Data Preparation

Perform the historic-to-current shoreform attribute transfer (see Section 4.4 in *Geospatial Methodology used in the PSNERP Comprehensive Change Analysis of Puget Sound*).

Calculate C_LenFull = Shape_Length

Add field SF_Change_ID, Long Integer

Calculate SF_Change_ID = (10000*SUBBASINID)+OBJECTID (e.g. 40000+OBJECTID for HC)

Dissolve fd_shoreform change_Preintersect on C_Type, Dissolve fd_shoreform change_Preintersect on H_Type, and Dissolve fd_shoreform_change_Preintersect on no fields.

Use ET GeoWizards to generate midpoints for the dissolved C_Type and H_Type features.

Create a Route on the fully dissolved fd_shoreform_change. Locate the C_Type and H_Type midpoints on that Route.

Sort (ascending) the C_Type points and the H_Type points by the MEAS field, and export the attribute tables to Excel spreadsheets.

Add C_ContigID and H_ContigID fields to the spreadsheets, and calculate sequential numbers in them to correspond with the sorted MEAS values (1:n+1::low:high). Paste those ContigID fields from the Excel spreadsheet back into the tables in the Access database.

Spatial Join the points to the original dissolved C_Type and H_Type lines.

Intersect those C_Type and H_Type features with each other.

Intersect that feature with fd_shoreform_change_Preintersect.

Intersect fd_shoreform_change_PreIntersect with GSUs

Intersection with the GSUs creates topology errors (duplicated lines on top of each other) in any dataset that follows ShoreZone, because ShoreZone was used to create one of the GSU boundaries. Calculate ZU = 1 and GSU_ID = DU & “-“ & DAU & “-“ & ZU. Dissolve on all fields.

Calculate C_LenGSU = Shape_Length (post-intersection)

Calculate C_LenEmbGSU = C_LenEmb * (C_LenGSU / C_LenFull)

Calculate H_LenGSU = H_LenFull * (C_LenGSU / C_LenFull)
Calculate H_LenEmbGSU = H_LenEmb * (C_LenGSU / C_LenFull)
(Run query *UpdateProportionLengths*.)

Calculate Chg_PropLen_OffLine = ([C_LenEmb]-[H_LenEmb])/[H_LenEmb]
Calculate Chg_PropLen_OnLine = ([C_LenEmb]-[H_LenEmb])/[H_LenEmb]
(Run queries *Update_OnLine_Proportions* and *Update_OffLine_Proportions*.)

3.3 Quality Control

3.3.1 Phase 1

Visually inspect dataset at sub-basin level against original wetland polygon datasets to ensure complete coverage for final sub-basin extent

All shoreforms (H_Type, C_Type, H_TypeEmb, C_TypeEmb, QC_Shoreform) must have valid shoreform type. Valid types are in lutSF. DEL and NULL values will not be in final deliverable. (Run queries *Distinct_Type_C, Distinct_Type_H, Distinct_Type_QCShoreform, Distinct_TypeEmb_C, Distinct_TypeEmb_H*. Look for NULL values or DEL.)

Shoreforms of type "None" should have a value of zero in the associated length field. (Run query *SF_None_ZeroLength.*)

Historic shoreforms of type "None" should have a null in the associated ID field. (Run query *SF_None_NullIDs*.)

Verify historic lengths accurately transferred to current shoreline. Sum H_LenFull & H_LenEmb, grouped once by historic shoreform and once by H_ID. Should equal length sums from fd_shoreform_historic with the same groupings by shoreform and H_ID. (Run queries *LengthByID_Compare_Historic_PreIntersect* and *LengthBySF_Compare_Historic_PreIntersect*.)

No duplicate IDs in C_ID or H_ID in both historic shoreform and shoreform change feature classes. (Run queries *DupIDs_Current, DupIDs_Historic, DupIDs_HistoricInCurrent*.)

3.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Lines must not overlap, must be covered by GSUs.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

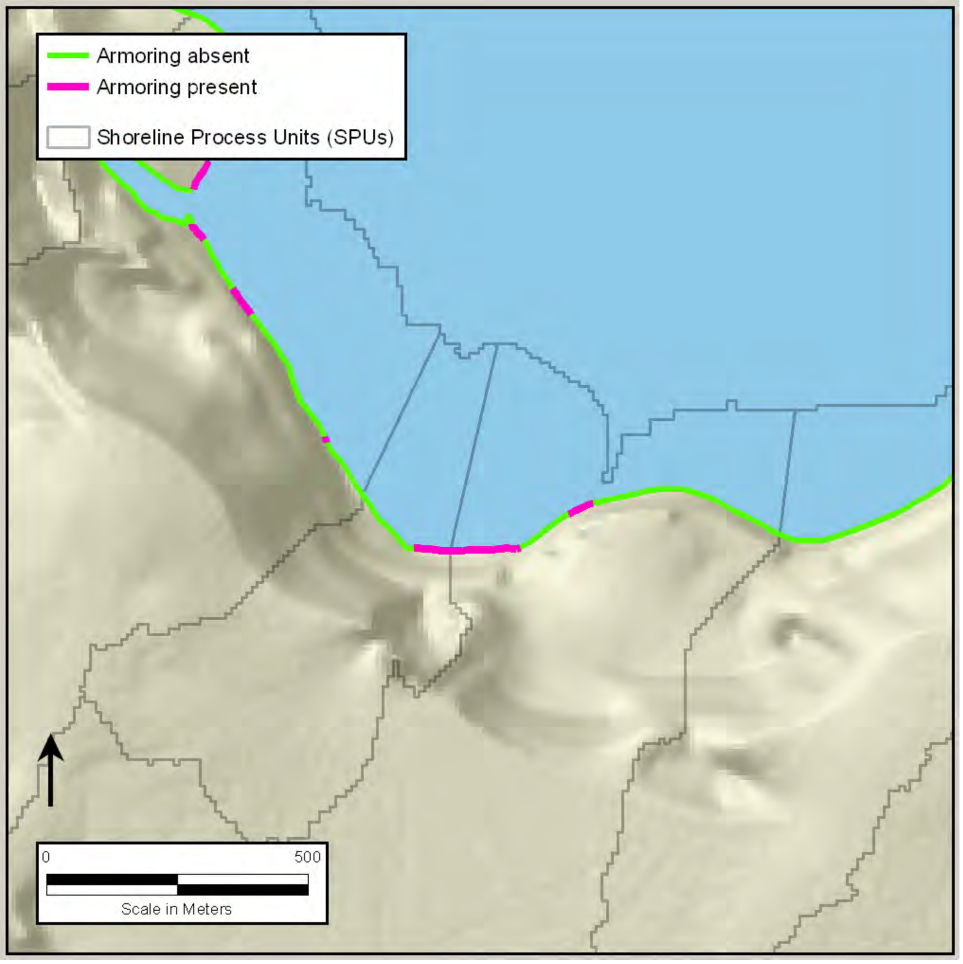
Verify proportional lengths within the GSU add up correctly. Sum H_LenGSU and H_LenEmbGSU both by shoreform and by H_ID should equal pre-intersection sums of length. (Run queries *LengthByID_Compare_Historic_GSU* and *LengthBySF_Compare_Historic_GSU*.)

3.3.3 Phase 3

Confirm row and column totals are equal; check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

4 SHORELINE ARMORING

Feature Name	fd_armoring
Feature Geometry Type	line
Tier(s)	2
Metric(s)	Armoring length/Shoreline length Armoring length/Shoreform length
Data Source(s) Used	Local efforts (Point No Point Treaty Council) and WDNR ShoreZone, supplemented by aerial photo analysis
Geometric Intersection	Yes



4.1 Entity/Attribute Definitions for Shoreline Armoring

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Armor_YN	Text, 1	Indicator of presence or absence of armoring	Y, N
Cont_Length	Double	Full length (meters) of contiguous armored and unarmored segments, prior to overlay with GSUs	

Attribute Name	Attribute Type	Description	Allowed Values
SF_Change_ID	Long Integer	Unique identifier for contiguous shoreform segments in fd_shoreform_change	

4.2 Data Preparation

Dissolve ShoreZone on field SM_TOT_PCT. Dissolve other available datasets (county data, field results) on applicable armoring fields.

Add field Armor_YN, Text, 1

Add field Cont_Length, Double

Snap county, and field armoring lines to ShoreZone line (ET GeoWizards, insert vertices, vertices and edges matching)

Intersect shoreform, ShoreZone, county, and field armoring lines, creating a single line feature class with overlapping lines that follow the shoreform.

If county or field data are available, use their armoring attributes. Where no county or field data exist, use ShoreZone SM_TOT_PCT = 100 as armored areas.

Dissolve on Armor_YN, Cont_Length.

Calculate Cont_Length = [Shape_Length]

Intersect with fd_shoreform_change feature class that HAS been attributed with GSUs. Delete all shoreform fields except SF_Change_ID.

4.3 Quality Control

4.3.1 Phase 1

Visually inspect dataset at sub-basin level against original wetland polygon datasets to ensure complete coverage for final sub-basin extent

Visually inspect shoreline at 1:4000 scale against original armoring datasets to ensure complete and correct transfer of armored areas onto ShoreZone

4.3.2 Phase 2

Run Check Geometry and repair any errors

Join attribute table to fd_shoreform_change using SF_Change_ID, keeping matching records only Display armoring using C_Type. Display fd_ shoreform using C_Type. Compare against shoreform datasets to ensure appropriate shoreform association at 1:4000 scale.

Review possibly odd combinations of armoring and shoreform (e.g. artificial and armored, rocky and armored)

Verify removal of topology errors. Lines must not overlap, must not self-overlap, must not self-intersect, must not have dangles, must not have pseudos, and must be covered by boundary of GSUs.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

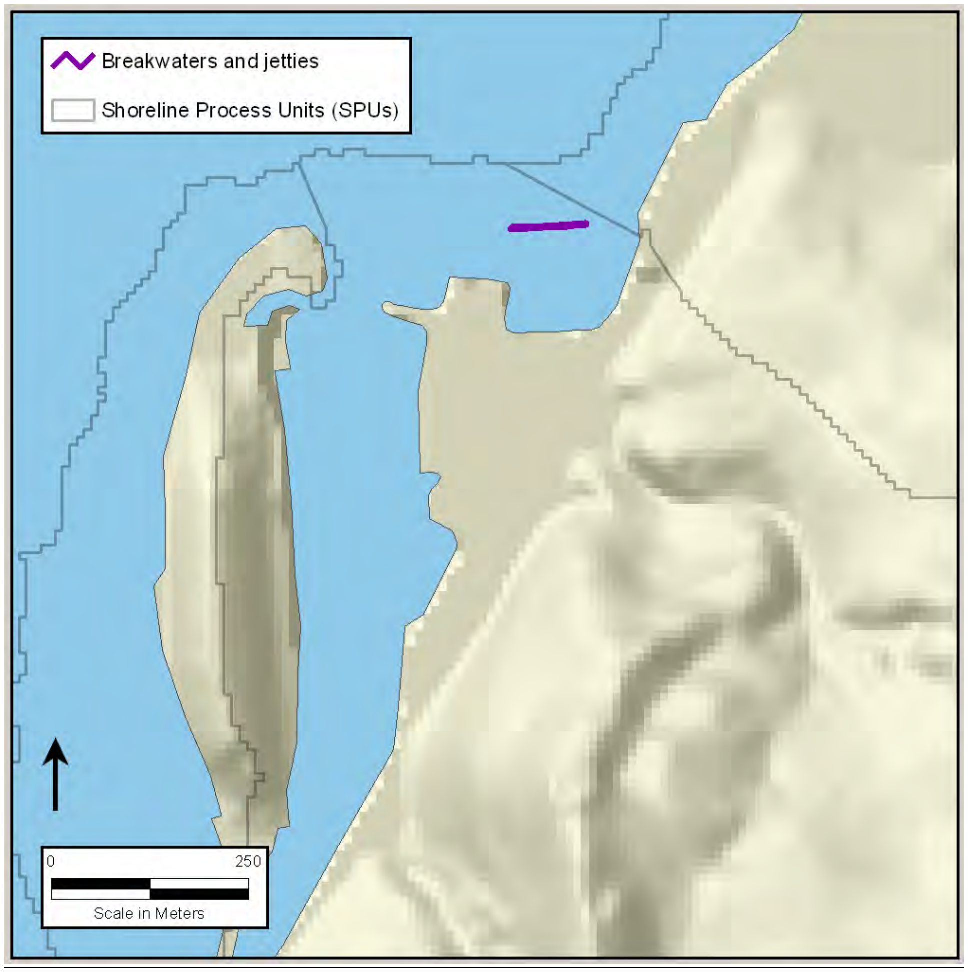
4.3.3 Phase 3

Run query for ratio of process unit armored length to process unit shoreline length. Verify all ratios are less than 1.

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

5 BREAKWATERS/JETTIES

Feature Name	fd_breakwaters_jetties
Feature Geometry Type	line
Tier(s)	2
Metric(s)	Structure length/Shoreline length Count of structures per shoreform
Data Source(s) Used	WDNR Overwater Structures data (extensively edited by Anchor Environmental and Hamer Environmental using aerial photo interpretation)
Geometric Intersection	No



5.1 Entity/Attribute Definitions for Breakwaters/Jetties

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Structure_Length	Double	Approximate centerline length of structure. Set to the Shape_Perimeter * 0.5 PRIOR to intersection with GSUs	

Attribute Name	Attribute Type	Description	Allowed Values
Waterward_Distance	Double	Average distance from shoreline to the 10-m waterward depth boundary for the DU	
SF_Change_ID	Long Integer	Unique identifier for contiguous shoreform segments in fd_shoreform_change	

5.2 Data Preparation

Convert breakwater/jetties features to line

Merge and explode all line features

Add field called Unique_ID, Long Integer

Calculate Unique_ID based on SUBBASIN ID*100 + ObjectID (e.g. for Whidbey use 600+ObjectID)

Add field Structure Length, Double

Calculate Structure_Length = 0.5 * Shape_Length

Intersect breakwaters with GSUs

Spatial select those GSUs that intersect the breakwaters/jetties features.*

Export selected GSUs to new feature class.

Convert selected GSUs to lines.

Edit GSU lines retaining only those that represent the most waterward edge of the GSUs. For breakwaters that fall only in DPUs and not in SPUs, the edge retained will be the waterward-most edge of the DPU. For those breakwaters in or partly in SPUs, retain the waterward-most edge of the DU.

Create a Euclidian distance raster from the edited GSU lines. Use a 10m cell size, zoom the display to the selected GSUs (polygons, not lines), and set the analysis environment to the display window.

Spatially join breakwater/jetty line features with fd_shoreform_change dataset. Assign breakwater/jetty line features the attributes of the shoreform line closest to them. Use settings: Keep All Target Features, Join One to One, Match Option: Intersects, and Search Radius = -1. Manually transfer SF_Change_IDs to lines that fail to work in the Spatial Join tool. Some breakwaters/jetties will not spatially join and will have to be manually attributed with SF_Change_ID.

Spatial select features from fd_shoreform_change that intersect the desired GSUs.

Dissolve those features from fd_shoreform_change on DU, SPU, and DPU.

Run Zonal Statistics as Table on this subset of fd_shoreline_current using DU as the zone field.

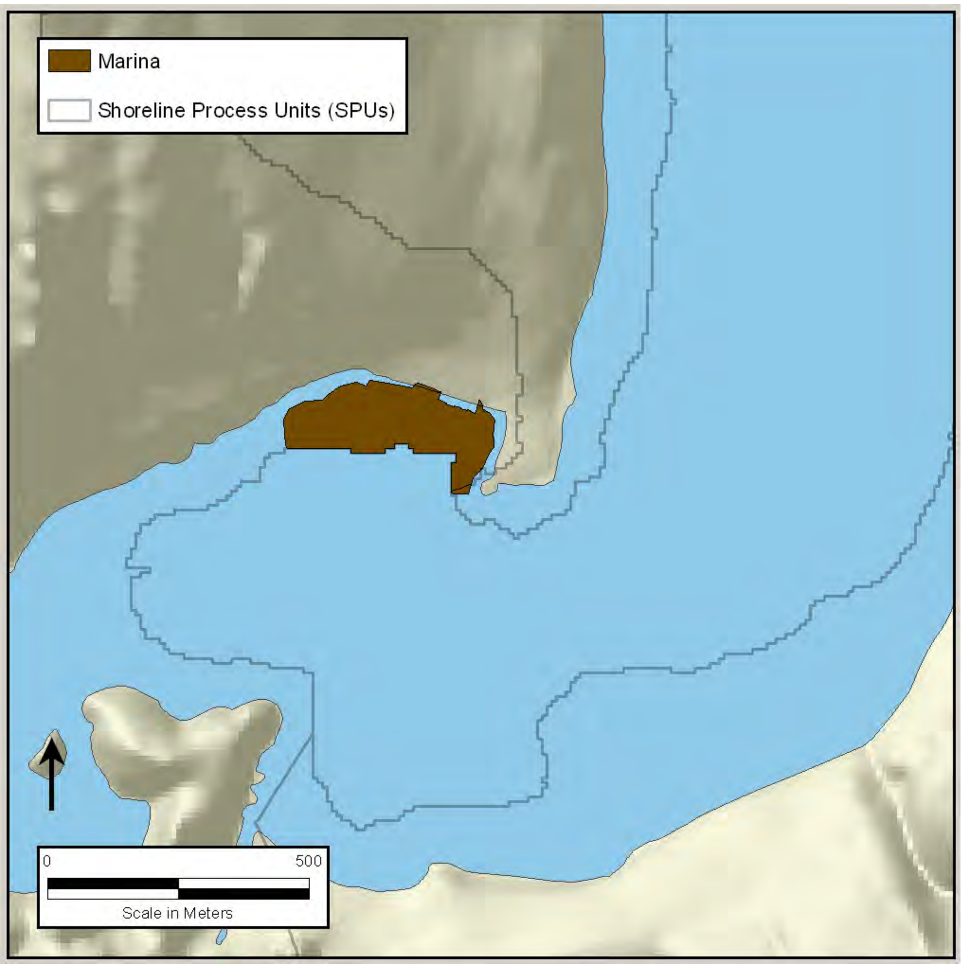
Join the attributes of the resulting table by DU for the Zonal Stats results. Use the MEAN field to populate the Avg_Waterward_Dist. Then rejoin by DPU and perform the same calculation on those segments that fall only in the DPUs with no shoreline component.

Remove join.

*Note – the post-GSU-intersect steps (Euclidean distance, Zonal Statistics, etc) result in an Average Waterward Distance value that is not used in the simpler metric of "Structure length as a percent of shoreline length."

6 MARINAS

Feature Name	fd_marinas
Feature Geometry Type	polygon
Tier(s)	2
Metric(s)	Marina area/Aquatic area Count of marinas per shoreform
Data Source(s) Used	WDNR Overwater Structures data (extensively edited by Anchor Environmental and Hamer Environmental using aerial photo interpretation)
Geometric Intersection	No



6.1 Entity/Attribute Definitions for Marinas

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Unique_ID	Long Integer	Unique ID associated with each marina footprint	
Footprint_Area	Double	Area of entire marina footprint prior to intersection with GSUs	

Attribute Name	Attribute Type	Description	Allowed Values
SF_Change_ID	Long Integer	Unique identifier for nearest contiguous shoreform segment in fd_shoreform_change	

6.2 Data Preparation

Select marinas from OWS dataset. Select by attributes where [Structure_Type] LIKE 'Marina*'

Dissolve marina polygons completely (no selected attribute fields), no multipart polygons

Add field called Unique_ID, Long Integer

Calculate Unique_ID based on SUBBASIN ID*100 + ObjectID (e.g. for Whidbey use 600+ObjectID

Add field called Footprint_Area, Double

Calculate Footprint_Area = Shape_Area

Spatially join marina polygons with fd_shoreform_change dataset. Assign polygons the attributes of the shoreform line closest to them.

Intersect with GSUs.

Move GSU attribute fields to front of data table (field reordering can be done in MS Access)

Delete shoreform fields gained from spatial join so that attribute table contains only SF_Change_ID from fd_shoreform_change.

6.3 Quality Control

6.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

Visit each marina and verify appropriate footprint area has been captured.

6.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Polygons must not overlap, must be covered by GSUs.

Join attribute table to fd_shoreform_change using SF_Change_ID, keeping matching records only. Display marinas using C_Type. Display fd_ shoreform_change using C_Type. Compare against shoreform datasets to ensure appropriate shoreform association at 1:4000 scale.

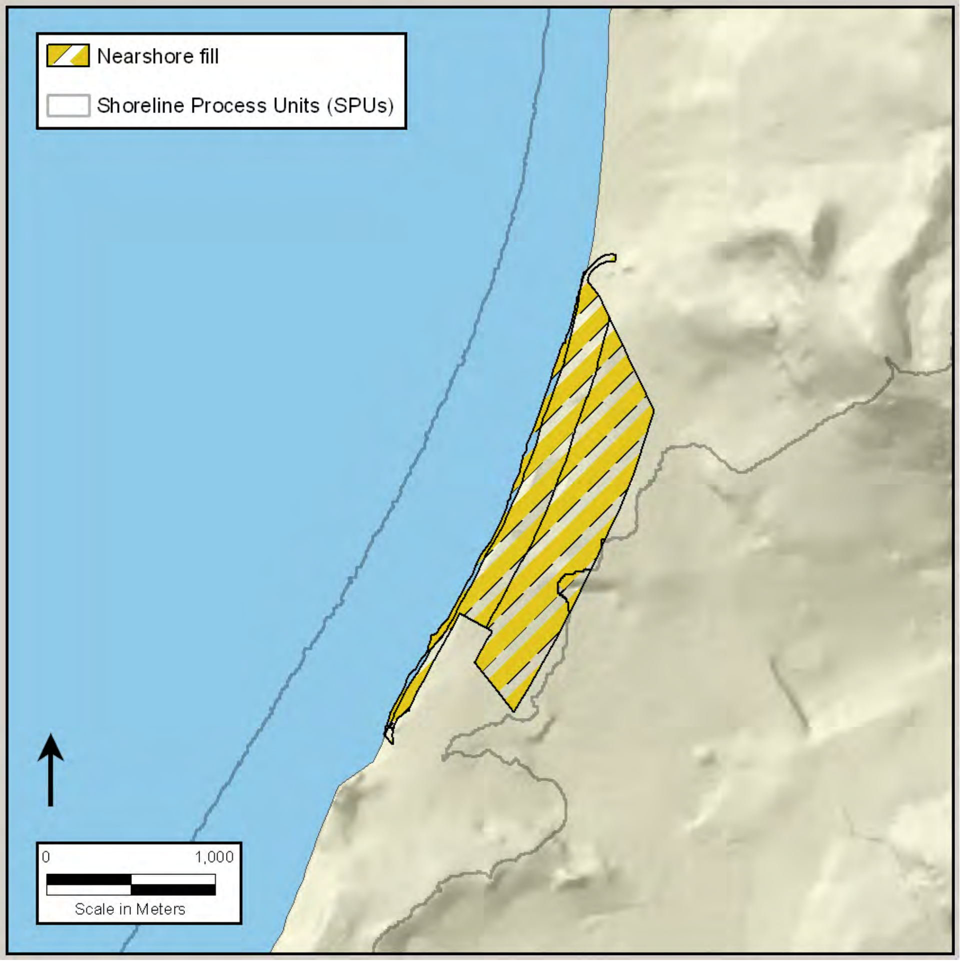
Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

6.3.3 Phase 3

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

7 NEARSHORE FILL

Feature Name	fd_nearshore_fill
Feature Geometry Type	polygon
Tier(s)	2
Metric(s)	Fill area/Aquatic area
Data Source(s) Used	Coastal Zone Atlas artificial fill dataset (geo-referenced and digitized by ICF Jones and Stokes under contract to Anchor)
Geometric Intersection	Yes



7.1 Entity/Attribute Definitions for Nearshore Fill

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--

7.2 Data Preparation

Intersect with GSUs

7.3 Quality Control

7.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent.

7.3.2 Phase 2

Run Check Geometry and repair any errors.

Run topology check. Polygons must not overlap, must be covered by GSUs.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

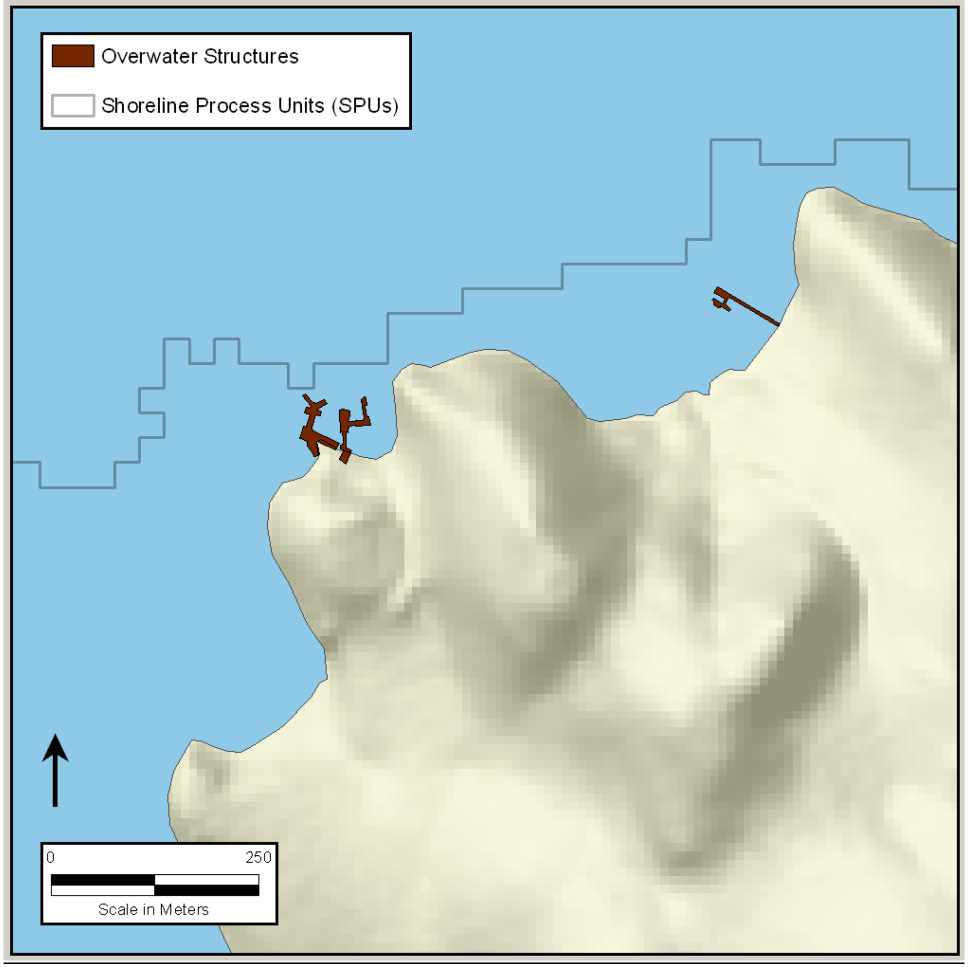
7.3.3 Phase 3

Calculate sum of area of nearshore fill. Include upland (ZU=0) in sum of nearshore fill area. Normalize by reference query that summarizes aquatic area, report as fraction.

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

8 OVERWATER STRUCTURES

Feature Name	fd_OWS
Feature Geometry Type	polygon
Tier(s)	2, Tabulations
Metric(s)	OWS Area/Aquatic area Count of structures per shoreform
Data Source(s) Used	WDNR Overwater Structures data (extensively edited by Anchor Environmental and Hamer Environmental using aerial photo interpretation)
Geometric Intersection	No



8.1 Entity/Attribute Definitions for Overwater Structures

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Unique_ID	Long Integer	Unique ID associated with each overwater structure	

Attribute Name	Attribute Type	Description	Allowed Values
Structure_Type	Text, 50	Type of overwater structure	Bridge, Buoy/Float, Dock/Pier, Ferry Terminal, Marina, Other
Footprint_Area	Double	Area of structure prior to intersection with GSUs	
SF_Change_ID	Long Integer	Unique identifier for nearest contiguous shoreform segment in fd_shoreform_change	

8.2 Data Preparation

Dissolve OWS polygons on Structure_Type, no multipart polygons

Add field called Footprint_Area, Double

Calculate Footprint_Area = Shape_Area

Intersect with GSUs

Spatially join OWS polygons with fd_shoreform_change dataset. Assign polygons the attributes of the shoreform line closest to them.

Delete shoreform fields gained from spatial join so that attribute table contains only SF_Change_ID from fd_shoreform_change.

8.3 Quality Control

8.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

8.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Polygons must not overlap, must be covered by GSUs. This is key given the topology errors inherent in the original source data.

Join OWS attribute table to fd_shoreform_change using SF_Change_ID, keeping matching records only. Display OWS using C_Type. Join shoreform attribute table to OWS using SF_Change_ID, keeping matching records only. Display fd_ shoreform using C_Type. Compare against shoreform datasets to ensure appropriate shoreform association.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

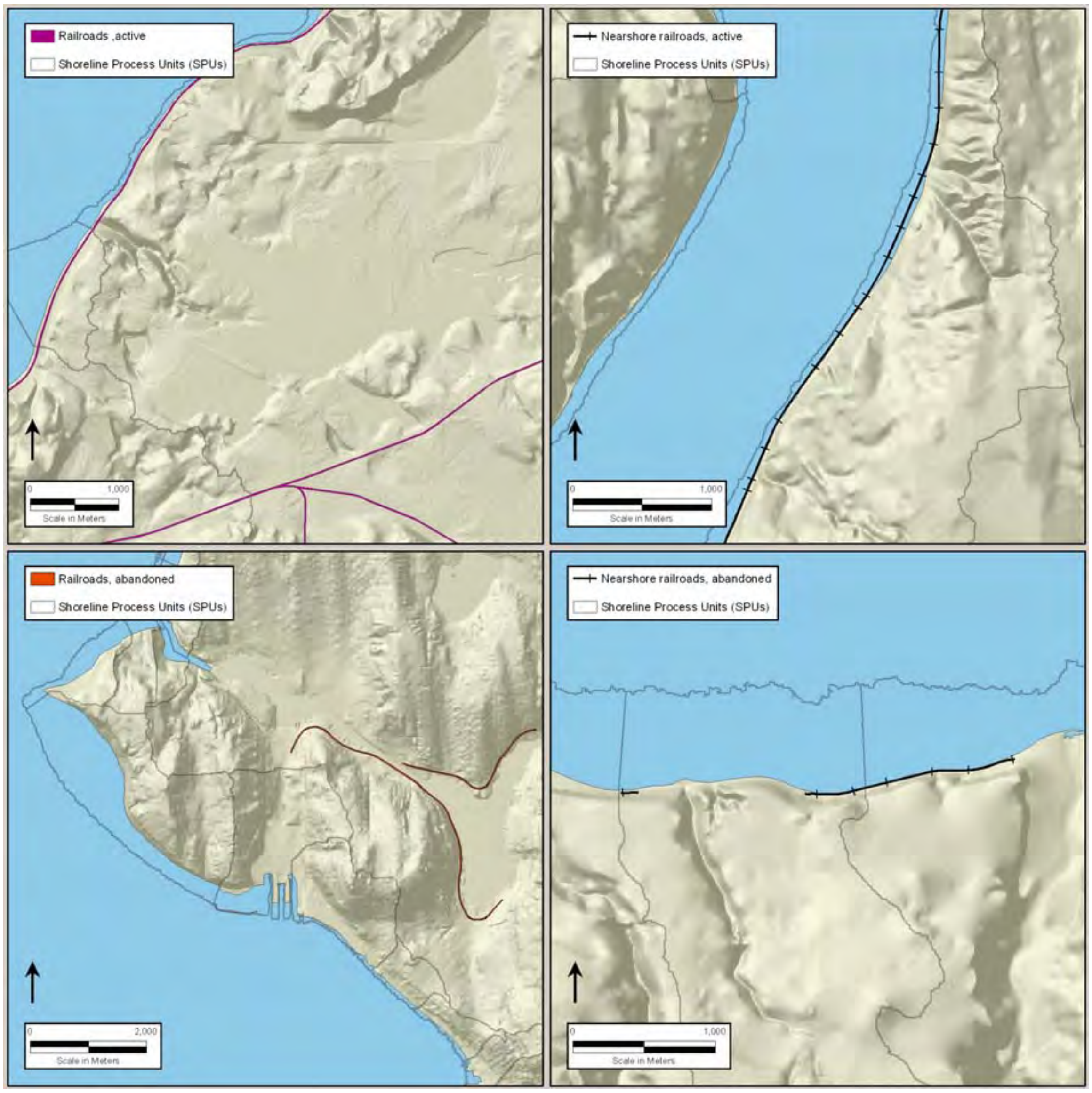
8.3.3 Phase 3

Calculate total aquatic area for each spatial unit of interest (ZU = 2); normalize OWS for each spatial unit by aquatic area and report as fraction.

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

9 RAILROADS (ACTIVE AND ABANDONED) (NEARSHORE ONLY AND WATERSHED WIDE)

Feature Name	fd_railroads_active_nearshore fd_railroads_abandoned_nearshore fd_railroads_active fd_railroads_abandoned
Feature Geometry Type	line, line, polygon, polygon
Tier(s)	2, 3, 4
Metric(s)	Railroad length/shoreline length Railroad area/Upland nearshore zone area Railroad area/Upland drainage area (all metrics for both active and abandoned)
Data Source(s) Used	WSDOT Railroads Active in Washington State and Railroads Abandoned in Washington State datasets
Geometric Intersection	Yes



9.1 Entity/Attribute Definitions for Active and Abandoned Railroads, and for Active and Abandoned Railroads in the Nearshore

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--

9.2 Data Preparation

9.2.1 Length

Maintain separate line datasets for active and abandoned railroads

Buffer ShoreZone shoreline by 25 meters, "FULL" side type, "ROUND" end types, dissolve all. Dissolve resulting polygon data with "water" polygon based on ShoreZone. The area of coverage thus expands as far as necessary in a waterward direction so as to capture any railroads that fall further than 25m waterward from ShoreZone (due to spatial inconsistencies between ShoreZone and the roads datasets). The coverage still only extends 25m inland from ShoreZone, however.

Intersect railroads dataset (lines) with this buffer, which will grab all nearshore railroads

Dissolve railroads completely (no selected attribute fields), no multipart lines

Intersect with GSUs

9.2.2 Area

Maintain separate polygon datasets for active and abandoned railroads

Buffer active and inactive railroads by one-half the average right-of-way distance, “FULL” side type, “ROUND” end types, dissolve “ALL”

Intersect with GSUs

9.3 Quality Control

9.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

9.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Lines must not overlap, must not self-overlap, must be covered by boundary of GSUs. Polygons must not overlap, must be covered by GSUs.

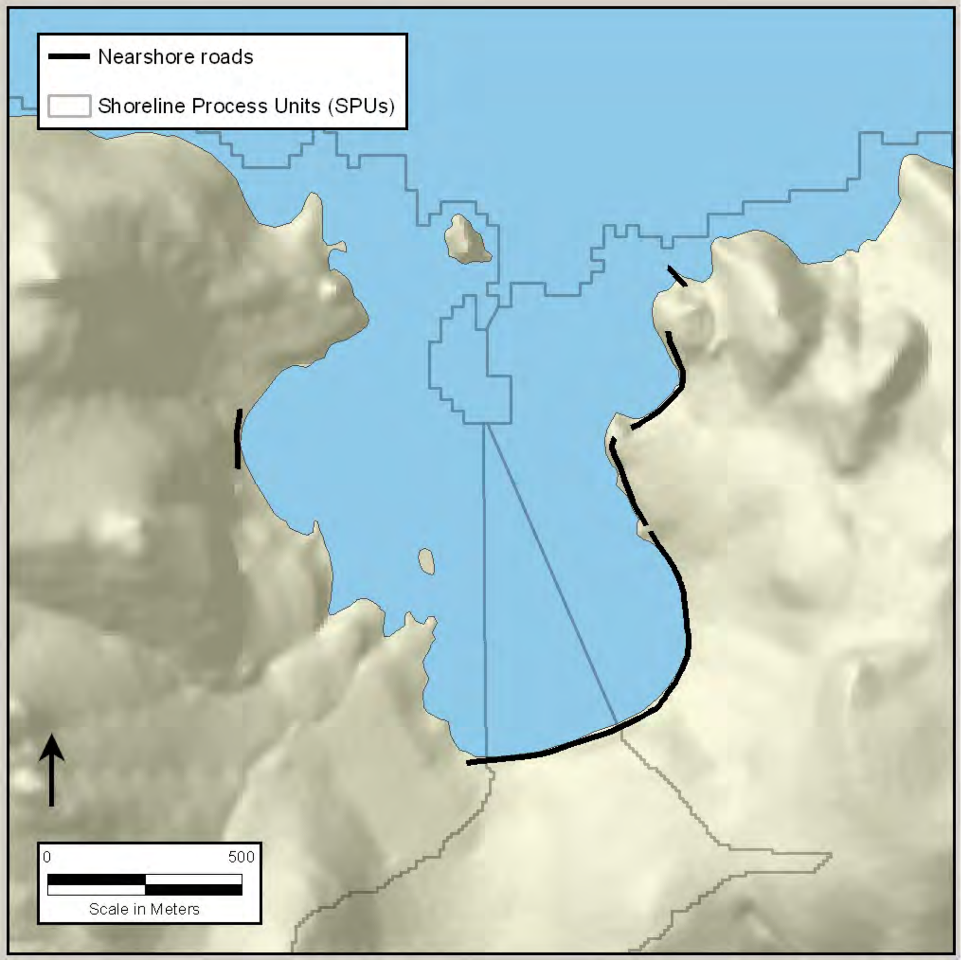
Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

9.3.3 Phase 3

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

10 ROADS (NEARSHORE ONLY AND WATERSHED WIDE)

Feature Name	fd_roads_nearshore, fd_roads
Feature Geometry Type	line, polygon
Tier(s)	2, 3, 4
Metric(s)	Road length/shoreline length Road area/Upland nearshore zone area Road area/Upland drainage area
Data Source(s) Used	WDNR Transportation Dataset
Geometric Intersection	Yes



10.1 Entity/Attribute Definitions for Roads in the Nearshore Zone

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Road_Class	Text, 2	Road type classification from source data	1 = Primary highway 2 = Secondary highway 3 = Light-duty road 4 = Unimproved road 9 = Unknown

10.2 Entity/Attribute Definitions for Roads

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--

10.3 Data Preparation

10.3.1 Length

Buffer ShoreZone shoreline by 25 meters, "FULL" side type, "ROUND" end types, dissolve all. Dissolve resulting polygon data with "water" polygon based on ShoreZone. The area of coverage thus expands as far as necessary in a waterward direction so as to capture any railroads that fall further than 25m waterward from ShoreZone (due to spatial inconsistencies between ShoreZone and the roads datasets). The coverage still only extends 25m inland from ShoreZone, however.

Intersect roads dataset (lines) with this buffer, which will grab all nearshore roads

Dissolve roads on Road_Class, no multipart lines

Intersect with GSUs

10.3.2 Area

Perform a spatial selection of roads that intersect the sub-basin GSUs, buffered out 500m from GSU boundaries to ensure complete coverage for the entire sub-basin

Use road class to differentiate road widths – code the width in a fixed field

Buffer the road lines out based on the road width field (using ½ road width), “FULL” side type, “ROUND” end types

Dissolve all polygons to remove overlap (no selected attribute fields), no multipart features

Intersect with GSUs

10.4 Quality Control

10.4.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

10.4.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Lines must not overlap, must not self-overlap, must be covered by boundary of GSUs. Polygons must not overlap, must be covered by GSUs.

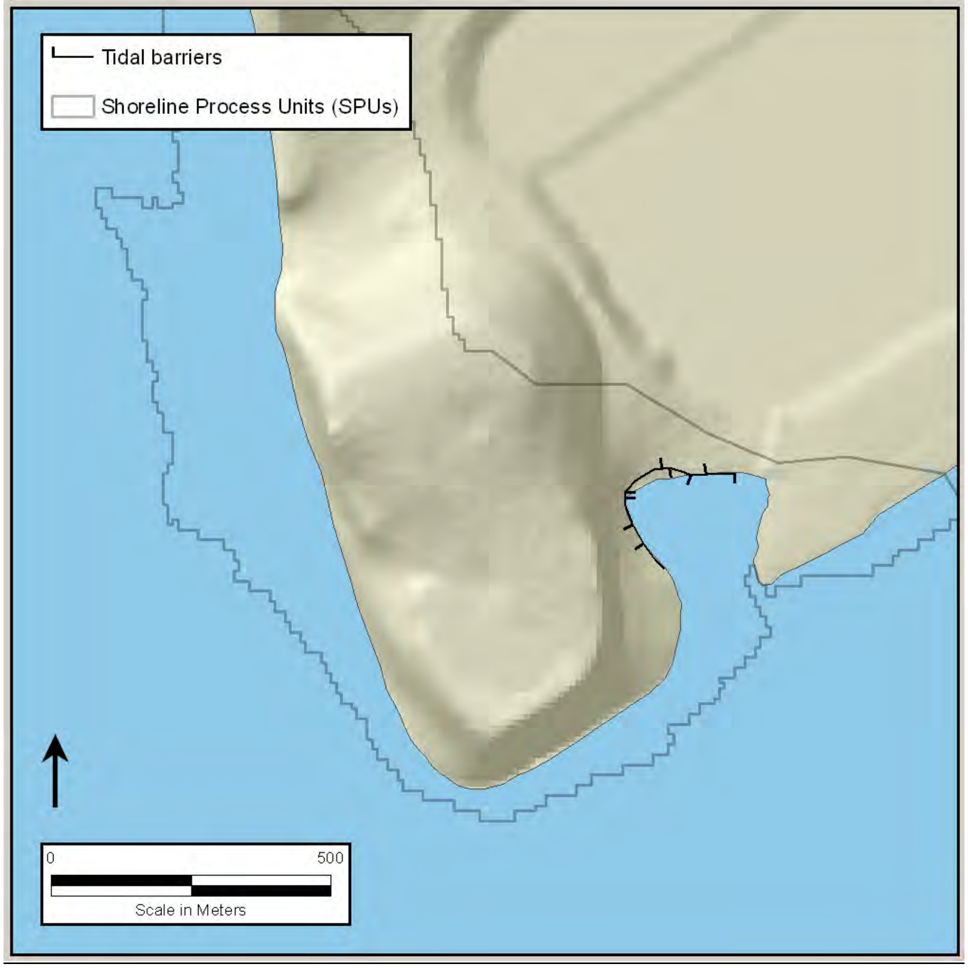
Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

10.4.3 Phase 3

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

11 TIDAL BARRIERS

Feature Name	fd_tidal_barriers
Feature Geometry Type	line
Tier(s)	2
Metric(s)	Barrier length/Shoreline length
Data Source(s) Used	SSHIAP “Tidal barrier line”
Geometric Intersection	Yes



11.1 Entity/Attribute Definitions for Tidal Barriers

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Barrier_type	Text, 10	Describes extent of tidal hydrology impediment associated with tidal barrier structure	Complete, Partial, Other
LiDAR_presence	Short Integer	Indicates whether tidal barrier structure is clearly evident in LIDAR	0 = not evident 1 = evident

Attribute Name	Attribute Type	Description	Allowed Values
Ortho_presence	Short Integer	Indicates whether tidal barrier structure is clearly evident in orthophoto	0 = not evident 1 = evident
Roads_presence	Short Integer	Indicates whether tidal barrier structure is clearly evident in roads data	0 = not evident 1 = evident
Railroads_presence	Short Integer	Indicates whether tidal barrier structure is clearly evident in railroads data	0 = not evident 1 = evident
Existing_levee_presence	Short Integer	Indicates whether tidal barrier structure is clearly evident in existing levees data	0 = not evident 1 = evident
Confidence	Short Integer	Indicates level of confidence in identification of tidal barrier structure	1 = Low (not clearly evident in either LIDAR or ortho but some evidence from other sources exist) 2 = Medium (clearly evident in either LIDAR or ortho but not both sources) 3 = High (clearly evident in both LIDAR and ortho)
Notes	Text, 50	Additional information associated with tidal barrier structure or wetlands	Additional information associated with tidal barrier structure or wetlands
Barrier_type_cd	Short Integer	Numeric code corresponding to Barrier_type text	1 = Complete 2 = Partial 3 = Other
Oblique_presence	Short Integer	Indicates whether tidal barrier structure is clearly evident in oblique photos	0 = not evident 1 = evident

11.2 Data Preparation

Intersect with GSUs

11.3 Quality Control

11.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

11.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Lines must not overlap, must not self-overlap, must be covered by boundary of GSUs.

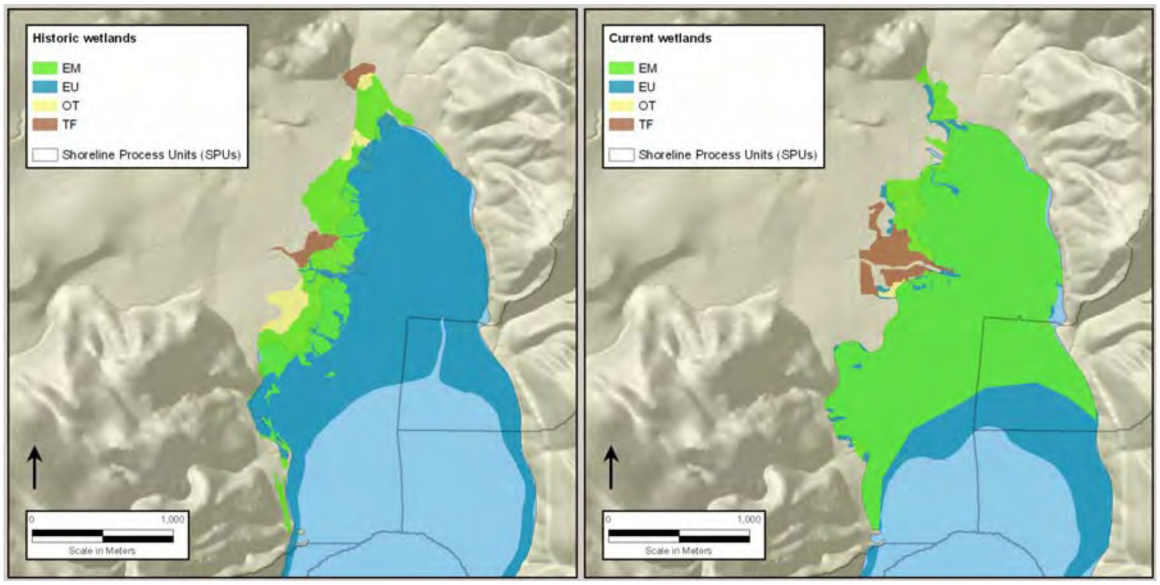
Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

11.3.3 Phase 3

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

12 WETLANDS – CURRENT AND HISTORIC

Feature Name	fd_wetlands_current, fd_wetlands_historic
Feature Geometry Type	polygon
Tier(s)	2
Metric(s)	(Historic wetland area – current wetland area)/historic wetland area (calculated for each wetland class separately)
Data Source(s) Used	University of Washington Puget Sound River History Project
Geometric Intersection	Yes



12.1 Entity/Attribute Definitions for Historic Wetlands

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Wetland_Class	Text, 2	Type of wetland (along a tidal gradient)	TF = Tidal Freshwater OT = Oligohaline Transition EM = Estuarine mixing EU = Euryhaline Unvegetated
VDatum_Conf	Text, 50	Confidence level in vertical datum of historic "low water" lines; data source notes.	Low, Medium, High; data source (T-sheet or H-sheet)

12.2 Entity/Attribute Definitions for Current Wetlands

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Wetland_Class	Text, 2	Type of wetland (along a tidal gradient)	TF = Tidal Freshwater OT = Oligohaline Transition EM = Estuarine mixing EU = Euryhaline Unvegetated

12.3 Data Preparation

Classify historic* and current RHP polygons according to wetland classes (Oligohaline transition, Estuarine mixing, Tidal freshwater, Euryhaline unvegetated).

Select polygons where the class is one of the 4 wetland classes (Oligohaline transition, Estuarine mixing, Tidal freshwater, Euryhaline unvegetated)

Dissolve on wetland class, no multipart polygons, retaining only those polygons in those classes (no Mixed, Upland, Anthropogenic or NULL)

Add field Wetland_Class, Text, 2 for current and historic wetland polygons

Calculate each of the new wetland classes to be two-letter code for each of the 4 wetland classes (OT, EM, TF, or EU)

Intersect with GSUs

Add VDatum_Conf field to fd_wetlands_historic. Populate with "Medium" for EU areas derived from T-sheets and H-sheets; note which areas are derived from T- or H-sheets. Refer user to Data Quality section for further detail.

Note:

*Geo-referenced Hydrographic sheets (H-sheets) from the same era as the T-sheets were used to provide a "low-water" line in deltas where the T-sheets and the River History Project data did not have one. Below are notes from this process:

H-Sheet H01815 ("Padilla Bay," 1887 – Samish Delta) says it is based on "the mean of the lowest low waters" with a note saying "to reduce to mean lower low water add 1.1 ft." H-sheet H01815s (1887) is a supplement to H01815. It says nothing but presumably the same terms apply. Their shorelines very closely match the overlapping T-Sheets, T1746 (1886), T1747 (1886), T1794 (1887), and T1795 (1887), which all say they are based on "mean tide."

H-sheet H01728 ("Possession Sound," 1886 – Snohomish Delta) says it is based on "the mean of the lower low waters" with a note saying "which is 2ft. below M.L.L. Water." Its shorelines very closely match the overlapping T-Sheets, T1682 (1885), T1681 (1884-5), and T1552a (1884), and they say nothing about their vertical datums.

H-sheet H02050 ("Skagit Bay," 1890 – Skagit Delta) says it is based on "the mean of the lower low waters" and has no other notes. Its shorelines mostly match those of T2108 (1892), which says it is really a "Topography and Hydrography" map, and which says its soundings are "reduced to the mean of the lowest low tides observed." The "zero" line derived from H02050 matches closely the "zero" line on T2108. Its shorelines very closely match those of T2156 (1889), which says nothing about vertical datums.

H-sheet H01730 ("Port Susan," 1886 – Stillaguamish Delta) says it is based on "mean low water" with a note saying "Add 2ft to reduce to mean lower low water." Its shorelines very closely match the overlapping T-Sheets, T1682 (1885) and T1755 (1886), and they say nothing about their vertical datums.

Pertinent text from ***Shore and Sea Boundaries*** (1964) by Aaron L. Shalowitz and Michael W. Reed, volume 2:

Pages 185-186 (from Chapter 4, ***Analysis and Interpretation of Topographic Surveys***) (emphasis added):

> It may therefore be inferred that whether expressed in the instructions or not, the intention was for the topographer to locate the low-water line as far as it was feasible for him to do so.[45] This conclusion is important in a consideration of the plane of reference used for the low-water line on the Pacific Coast (*see* 4462).
>
> ***4462. Planes of Reference***
>
> ...on the Pacific coast, where the diurnal inequality in the low waters is quite pronounced, questions have arisen regarding the plane of reference for the low-water line on topographic surveys, that is, whether it approximates mean low water or mean lower low water.
>
> Based on a detailed study of many topographic surveys, together with the contemporary hydrographic surveys, along the coasts of California, Oregon, Washington, and Alaska, and covering the period from 1850 to 1920***, the conclusion was reached that the low-water line delineated on topographic surveys represents the topographer's estimate of the mean lower-low-water line rather than the mean low-water line.*** This necessarily results from the fact that in the determination of the low-water line delineated on the nautical chart the compiler selected portions of the low-water line from both the hydrographic and topographic surveys whenever necessary (see 4461).[46] It would have been a contradiction for the topographer to delineate the *mean low-water line* when it was to be used on a chart where the plane of reference was *mean lower low water.* A comparison of topographic surveys with hydrographic surveys in lower San Francisco Bay bears this out.[47] The low-water line on the hydrographic surveys is well controlled by sounding lines that terminate at the shore so that minus soundings are available from which a mean low-water line can be plotted.[48] ***While the topographic low-water line is sometimes inshore and sometimes offshore of the hydrographic line, it does not approximate the mean low-water line and shows conclusively that the topographer was attempting to delineate a mean lower-low-water line. This is also borne out in Puget Sound.*** A comparison of the topographic survey with the contemporary hydrographic survey shows the topographic low-water line to correspond generally to the mean lower-low-water line on the hydrographic survey. It definitely does not correspond to the mean low-water line.[49] And on the 1913 topographic survey of Olympia Harbor (Register No. T-3379), there is a note "L.L.W. (Sketched)" which negatives any inference of a mean low-water line.
>
> [45] An examination of many of the early topographic surveys shows a failure to locate the low-water line on many portions of the survey. The 1949 instructions for photogrammetric surveys state that "Features seaward from the high-water line, including the low-water line ... are the mutual responsibility of both the photogrammetric survey and the hydrographic survey." SWANSON (1949), *op. cit supra* note 25, at 507, 524.
>
> [46] On some hydrographic surveys, such as Register No. H-564 (1856) in San Diego Bay, where portions of the low-water line were not so well controlled by soundings, the line was transferred from the topographic survey. This is also true of Register No. H-1256 (1875) in Newport bay.
>
> [47] *See* Register No. T-664 (1857), Register No. H-628 (1857-58), Register No. H-629 (1857-58).
>
> [48] The hydrographic surveys show only zero soundings above the plane of reference, but by replotting some of the lines from the original records, soundings ranging from zero to minus 5 feet were available from which the mean low-water line could be ascertained.
>
> [49] See Register No. T-1682 (1885) and Register No. H-1728 (1886). The plane of reference for the hydrographic survey was based on the mean of the lower low waters of a few days. This was later found to correspond to a plane 2 feet below mean lower low water. Allowance for this was made in the comparison.

Page 256 (from Chapter 5, ***Analysis and Interpretation of Hydrographic Surveys***):

> ***5643. Puget Sound, Washington***
>
> Puget Sound, Wash., has had a rather varied history insofar as planes of reference for soundings are concerned, and has gone through almost a complete cycle. It began with the use of mean low water for the period between 1849 and 1853. In 1854, the plane used was the mean of the lowest low water of each 24 hours (*see* Annual Report , U.S. Coast Survey (Sketches 52, 53)) (1854)), which is considered to be the same as mean lower low water. Some time during the late 1870's, the plane was changed to the mean of selected lowest low waters (Register No. H-1426b (1878-1879)). For the area of this survey, the plane was 3.2 feet below the plane of mean lower low water (*see* note on smooth sheet). In 1897, this was changed to the harmonic or Indian tide plane (Register no. H-2483 (1900)).[67] In 1902, the plane of reference was changed to 2 feet below the plane of mean lower low water, which plane was in use in 1911.[68] For Puget Sound this plane closely approximates the harmonic tide plane.[69] The plane of mean lower low water was again adopted with the publication of the General Instructions for Field Work in 1921, and this is the plane in use today (*see* 5363).[70]
>
> [67] The Indian tide plane or the harmonic tide plane, as it is sometimes called, has been used for a number of ports in India. It is also called the plane of Indian spring low water and corresponds approximately to tropic spring lower low water and is usually somewhat lower than low water ordinary springs. It is best derived from harmonic analysis. MARMER, TIDAL DATUM PLANES 129, 130, SPECIAL PUBLICATION No. 135, U.S. Coast and Geodetic Survey (1951). On Register No. H-2483 (1900) this plane is 2 feet lower than the plane of mean lower low water (*see* note on smooth sheet).
>
> [68] Letter (1911), *supra* note 64. One survey during this period was noted as being on the plane of mean lower low water (Register No. H-2985 (1909)), but this is noted in the accompanying Descriptive Report as an inadvertence and the soundings should have been reduced to the plane of 2 feet below mean lower low water, the plane adopted for the area. Register No. H-3423 (1913) showed the plane as 2 feet below the plane of mean lower low water.
>
> [69] Based on the computations for seven stations in Puget Sound, the mean difference between the harmonic plane and the plane of 2 feet below mean lower low water was found to be -0.03 foot. Letter of May 15, 1902, from Chief of Tidal Division to Assistant in Charge of Office.
>
> [70] It should be pointed out that the date of the published instructions does not necessarily represent the exact line of cleavage for the change from one plane to another. In some cases, surveys were already based on a new plane (probably as a result of specific written instructions to a chief of party) before the use of the plane was actually codified in the published instructions. In Puget Sound, for example, the first mention of a return tot the plane of mean lower low water was in the 1921 instructions but the plane was already in use in 1917 (Register No. H-3999).

Full text of the Shalowitz volumes may be had here as PDFs of scanned page images:
http://www.nauticalcharts.noaa.gov/hsd/shalowitz.html

12.4 Quality Control

12.4.1 Phase 1

Visually inspect dataset at sub-basin level against original wetland polygon datasets to ensure complete coverage for final sub-basin extent

Visually inspect dataset at 1:24,000 scale to ensure both wetland class is correct and appropriate polygons are retained

12.4.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Polygons must not overlap, must be covered by GSUs

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

12.4.3 Phase 3

Create reference query with total current and historic wetlands in spatial unit of interest; calculate percent change between historic and current as (historic area – current area)/historic area; report final value as absolute value of loss or gain (fraction), rounded to 1 for values > 1.

Count sum of gain/loss – should be = 0 (check); verify count of historic/current wetlands are accounted for; check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

12.5 Quality Control

12.5.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

Visit each breakwater manually. Using the measurement tool, check the accuracy of the distance to the 10m bathymetric contour and the length of the breakwater.

Check for consistency of units of structure length and average distance.

12.5.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Lines must not overlap, must be covered by GSUs.

Join attribute table to fd_shoreform_change using SF_Change_ID, keeping matching records only Display armoring using C_Type. Display fd_ shoreform using C_Type. Then compare against shoreform datasets to ensure appropriate shoreform association at 1:4000 scale.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

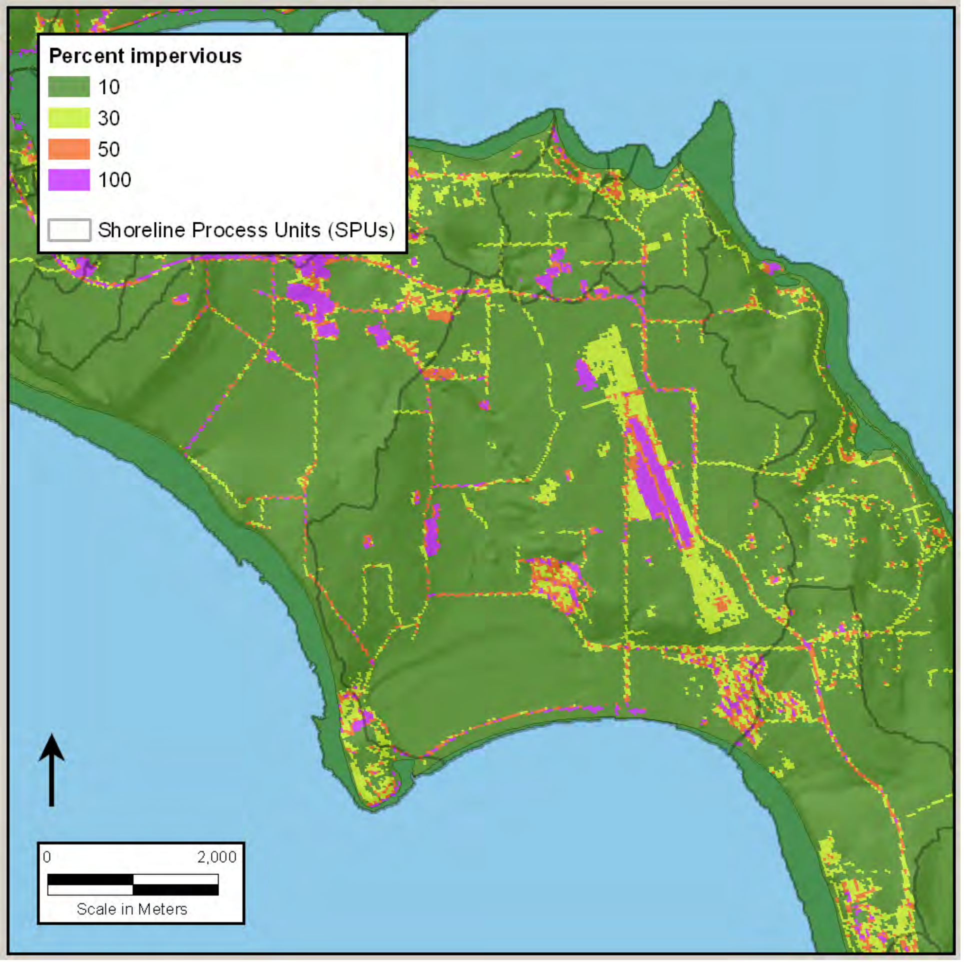
12.5.3 Phase 3

Sum Structure_Length and Avg_Waterward_Dist for each unique drainage unit; normalize structure length by average distance, and sum over spatial unit of interest.

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

13 IMPERVIOUS SURFACES

Feature Name	fd_impervious
Feature Geometry Type	polygon
Tier(s)	3, 4
Metric(s)	Impervious class area/Upland nearshore zone area Impervious class area/Upland drainage area
Data Source(s) Used	Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Data (MRLC NLCD)
Geometric Intersection	Yes



13.1 Entity/Attribute Definitions for Impervious Surfaces

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Imperv_Code	Double	Numeric code for grouped imperviousness ranges. (code is the maximum value of that range)	10 = 0-10% 30 = 10-30% 50 = 30-50% 100 = 50-100%

13.2 Data Preparation

Reclassify impervious raster based on the following bins: 0-10, 10-30, 30-50, 50-100

Convert reclassified impervious land cover raster to feature dataset

Reproject feature dataset to NAD83 UTM Zone 10N, meters

Add field Imperv_Code, Double

Calculate Imperv_Code as gridcode from initial raster

Group the polygons into the bins above.

Intersect with GSUs

13.3 Quality Control

13.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

Verify that Imperv_Code is not Null or equal to 0. Must be 10, 30, 50, or 100.

13.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Imperviousness polygons must not overlap; polygons must be covered by GSUs.

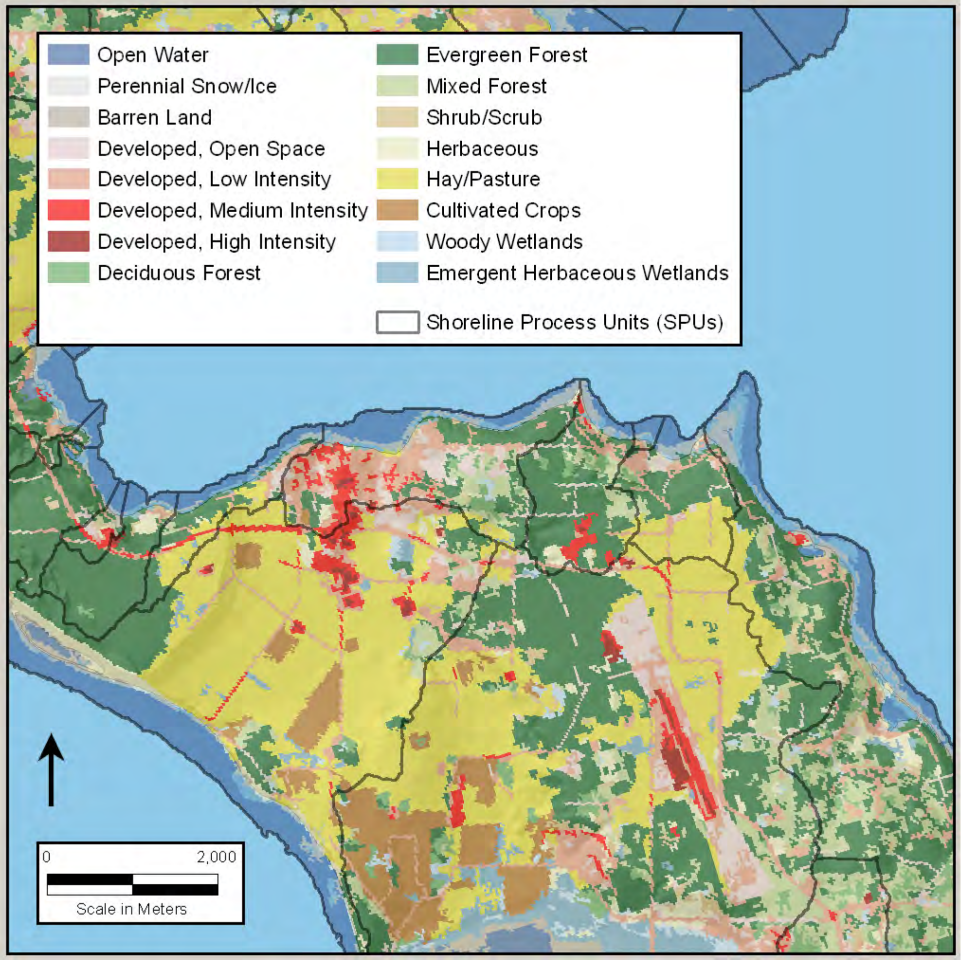
Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

13.3.3 Phase 3

Calculate metrics for Tiers 3 and 4. For a given PU, all impervious ratios should sum to 1.

14 LAND COVER

Feature Name	fd_landcover
Feature Geometry Type	polygon
Tier(s)	3, 4
Metric(s)	Land cover class area/Upland nearshore zone area Land cover class area/Upland drainage area
Data Source(s) Used	Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Data (MRLC NLCD)
Geometric Intersection	Yes



14.1 Entity/Attribute Definitions for Land Cover

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--

Attribute Name	Attribute Type	Description	Allowed Values
LC_Class	Double	Land cover class from MLRC	Developed, High Intensity Developed, Medium Intensity Developed, Low Intensity Developed, Open Space Emergent Herbaceous Wetlands Woody Wetlands Herbaceous Evergreen Forest Deciduous Forest Mixed Forest Scrub/Shrub Open Water Perennial Snow/Ice Cultivated Crops Hay/Pasture Barren Land

14.2 Data Preparation

Export landcover raster extent sufficient to cover entire sub-basin plus 500m around the buffer

Convert exported land cover raster to feature dataset

Reproject feature dataset to NAD83 UTM Zone 10N, meters

Add field LC_Class, Text, 35

Calculate LC_Class = Landcover

Remove all fields in feature dataset except LC_Class

Intersect with GSUs

14.3 Quality Control

14.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

Verify no LC_Class values are Null.

14.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Polygons and GSUs must cover each other.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

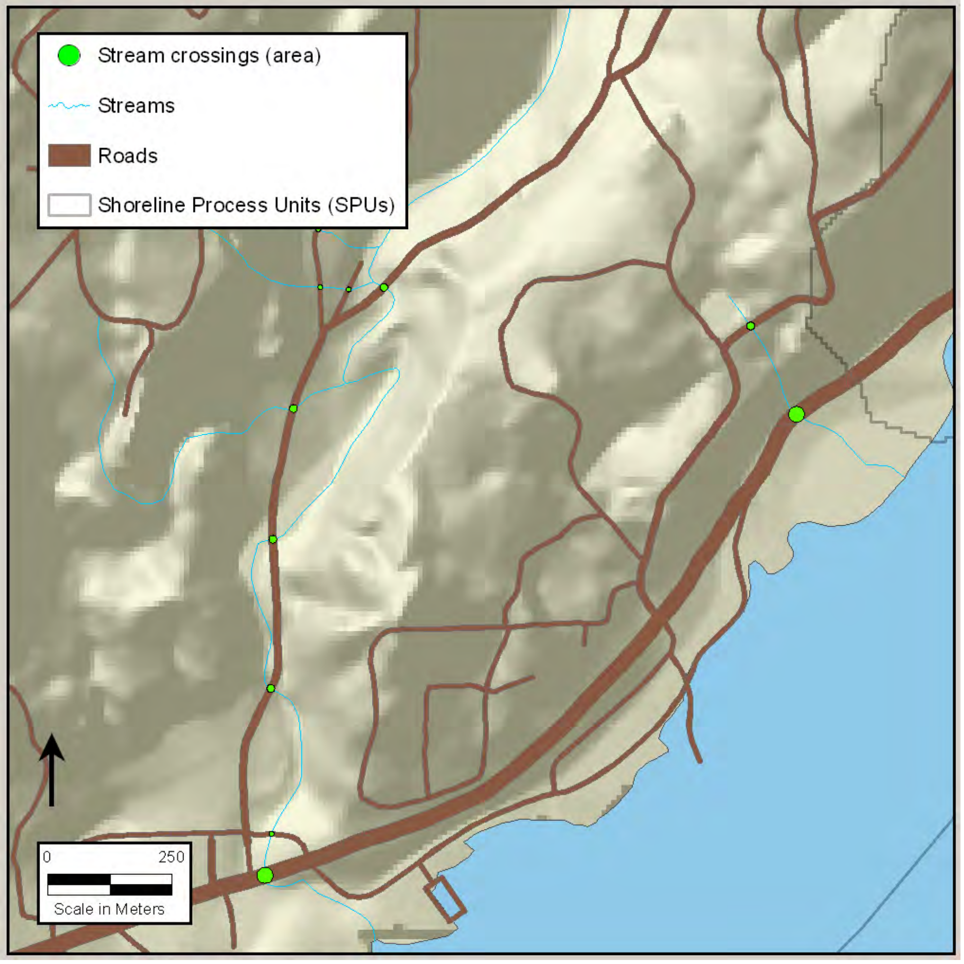
14.3.3 Phase 3

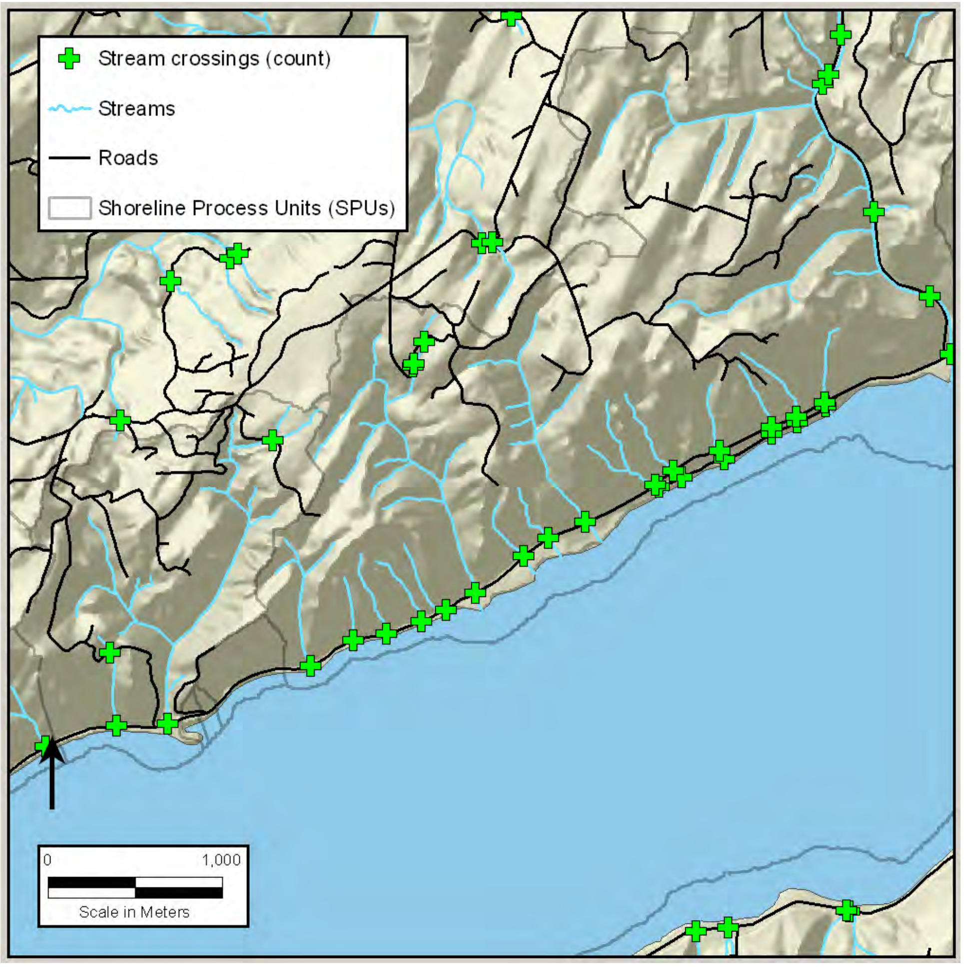
Calculate metrics for Tiers 3 and 4. For a given PU, all land cover class ratios should sum to 1.

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

15 STREAM CROSSINGS

Feature Name	fd_stream_crossings, fd_stream_crossing_pts
Feature Geometry Type	Polygon, point
Tier(s)	3,4, Tabulations
Metric(s)	Stream crossing area/Upland nearshore zone area Stream crossing area/Upland drainage area Count of stream crossings per PU
Data Source(s) Used	WDNR Transportation dataset, WDNR hydrography dataset
Geometric Intersection	Yes





15.1 Entity/Attribute Definitions for Stream Crossings

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--

15.2 Data Preparation

Intersect streams with roads with an output type of POINT

Buffer points based on one half of the road width

Dissolve on no fields, no multipart polygons

Intersect points, polygons with GSUs

15.3 Quality Control

15.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent.

Zoom in and verify at appropriate scales that streams are buffered by one half road class width.

15.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Polygons must be covered by GSUs.

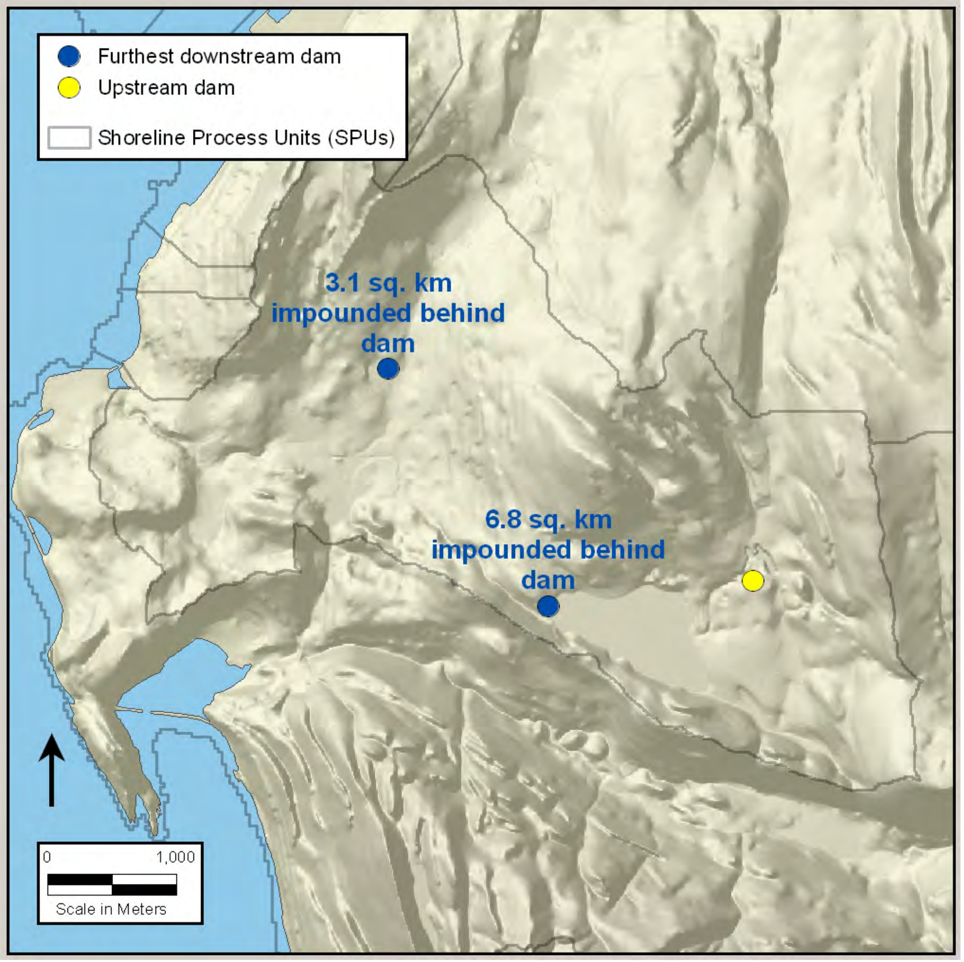
Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

15.3.3 Phase 3

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

16 DAMS (IMPOUNDMENT)

Feature Name	fd_dams
Feature Geometry Type	point
Tier(s)	4, Tabulations
Metric(s)	Dam impoundment area/Upland drainage area
Data Source(s) Used	WDOE Washington State Dams dataset
Geometric Intersection	Yes



16.1 Entity/Attribute Definitions for Dams

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
FED_NR	Text, 11	Official Federal National Inventory of Dams identification number	
DRAIN_NR	Double	Drainage area above dam in square miles. (Hard-coded from source data)	
Drain_Area	Double	Drainage area above dam in square meters	

Attribute Name	Attribute Type	Description	Allowed Values
Downstream	Text, 1	Identifies the dam that is furthest downstream on a particular stream fork	Y, N

16.2 Data Preparation

Scroll through WDOE dams points file to remove points that are duplicates (overlap, or multiple parts of the same dam complex) Remove those clearly in the wrong place, judging from available LIDAR, aerial imagery, or other information. Document those removed from points dataset.

Add field DOWNSTREAM, Text, 1.

Dams furthest downstream get a DOWNSTREAM value of “Y”. Others will be assigned a value of "N".

Remove those where DRAIN_NR = 0.

Retain FED_NR and DRAIN_NR from original dataset

Add field Drain_Area, Double

Calculate Drain_Area in square meters, or DRAIN_NR * 2,589,988 m^2/mi^2

Intersect with GSUs

16.3 Quality Control

16.3.1 Phase 1

Visually inspect the dams to make sure only those furthest down any particular stream fork are attributed with DOWNSTREAM = “Y”

Visually inspect dataset to ensure complete coverage for final sub-basin extent. All dams must be retained in the feature class so they can be counted in the tabulations, but only those furthest downstream will be used for impoundment area calculations.

Sort by DRAIN_NR and look for duplicated impoundment areas or 0s. Duplicated impoundment areas can indicate duplicated points for the same dam complex.

16.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Points must be covered by GSUs.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

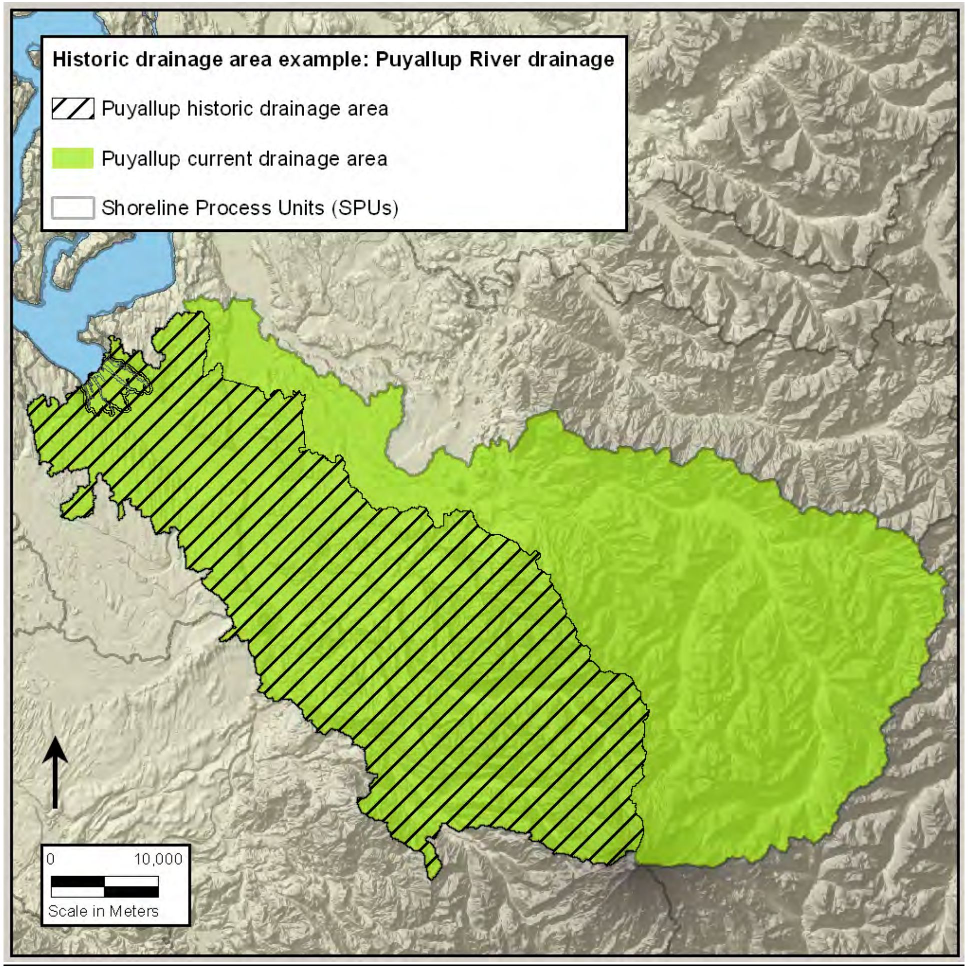
16.3.3 Phase 3

Calculate the metric where and visually verify that the ratio of impoundment area to PU area is appropriate. The sum of all the impoundment areas in a PU cannot be greater than the total PU area. Impoundment areas should be taken from points where DOWNSTREAM = 1.

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

17 HISTORIC DRAINAGES

Feature Name	fd_historic_drainage_area
Feature Geometry Type	polygons
Tier(s)	4
Metric(s)	Current DPU area/Historic drainage area (excludes aquatic area where ZU=2)
Data Source(s) Used	USGS 10-meter DEM, review of various documents related to White/Cedar/ Duwamish/Green Rivers (WRIA 9 Habitat Limiting Factors and Reconnaissance Assessment Report) and Skokomish River (Skokomish River Chinook Salmon Rcovery Plan)
Geometric Intersection	None



17.1 Entity/Attribute Definitions for Historic Drainage Area

Attribute Name	Attribute Type	Description	Allowed Values
DPU1	Text, 3	First Drainage Process Unit identifier	3-letter code for one of 16 DPUs
DPU2	Text, 3	Second Drainage Process Unit identifier for overlapping DPUs	3-letter code. (STL is the only DPU2 in Puget Sound.)
ZU	Long Integer	Zone Unit code	0 = uplands outside of zone 1 = 200-meters landward from shoreline or historic wetlands 2 = waterward from shoreline or historic wetlands to 10-meters depth
SUBBASIN	Text, 5	Two-letter Sub-basin code	HC = Hood Canal JF = Juan de Fuca NC = North Central Puget Sound SC = South Central Puget Sound SJ = San Juans SP = South Puget Sound WH = Whidbey AA|BB = Combined sub-basin codes separated by a pipe character (e.g., "HC|NC") means these areas are shared between two adjacent sub-basins. The first two-letter code refers to an entire sub-basin; the second two-letter code refers to the fraction of the adjacent sub-basin that shares areas with the first one.

17.2 Data Preparation

Where the historic drainage was equal or less than the current drainage area, dissolve on DPU1 and DPU2 (All rivers except Duwamish, Puyallup)

Where the historic drainage was greater than the current drainage area, keep the created historical drainage polygon and attribute with DPU1 or DPU2 accordingly to facilitate attribute joins with GSUs (applies to Duwamish and Puyallup only)

Intersect with GSUs that have been dissolved on ZU

17.3 Quality Control

17.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

17.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Polygons must be covered by GSUs.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

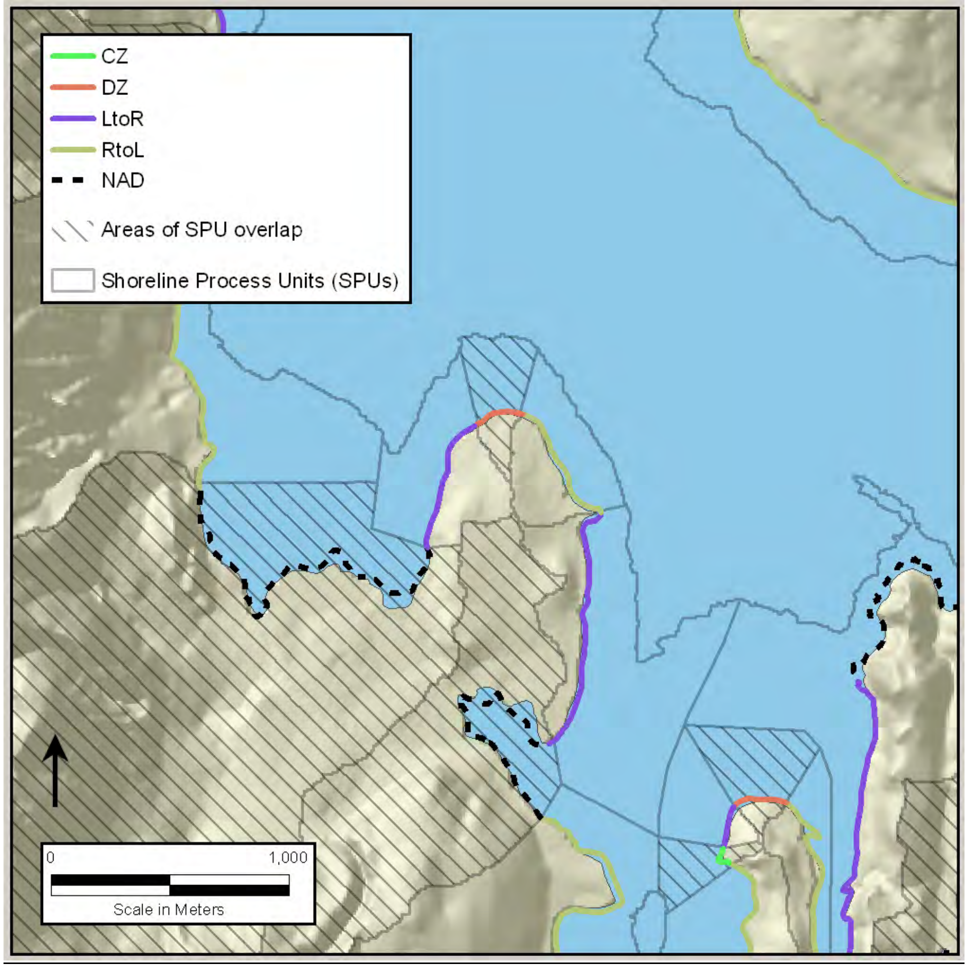
17.3.3 Phase 3

Calculate metric. Should not be greater than 1.

Check 10% of the process units, including at least one example of each type of spatial unit (e.g., SPU and DPU) to ensure that the queries are retrieving data correctly.

18 DRIFT CELLS

Feature Name	fd_drift_cells
Feature Geometry Type	polyline
Tier(s)	Tabulations
Metric(s)	None (for reference only); see Shoreline Current (Section 2) for "Drift component length/Shoreline length" metric
Data Source(s) Used	Shorelands and Environmental Assistance Program (SEA) and WDOE's "Net Shore-Drift in Washington State," edited by Coastal Geologic Services under contract to Anchor Environmental
Geometric Intersection	Yes



18.1 Entity/Attribute Definitions for Drift Cells

Attribute Name	Attribute Type	Description	Allowed Values
SUBBASIN	Text, 5	Two-letter Sub-basin code	HC = Hood Canal JF = Juan de Fuca NC = North Central Puget Sound SC = South Central Puget Sound SJ = San Juans SP = South Puget Sound WH = Whidbey AA|BB = Combined sub-basin codes separated by a pipe character (e.g., "HC|NC") means these areas are shared between two adjacent sub-basins. The first two-letter code refers to an entire sub-basin; the second two-letter code refers to the fraction of the adjacent sub-basin that shares areas with the first one.
DCELL_NR	Text, 20	Drift cell component ID from source data	Unique alpha-numeric values
CELL_TYP	Text, 4	Drift cell component type	LtoR, RtoL, DZ, CZ, NAD

18.2 Data Preparation

Ensure sufficient coverage of drift cells to cover entire sub-basin

Identity with GSUs and delete lines outside GSUs and look inside GSUs for scrap pieces that didn't get attributes at all.

18.3 Quality Control

18.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

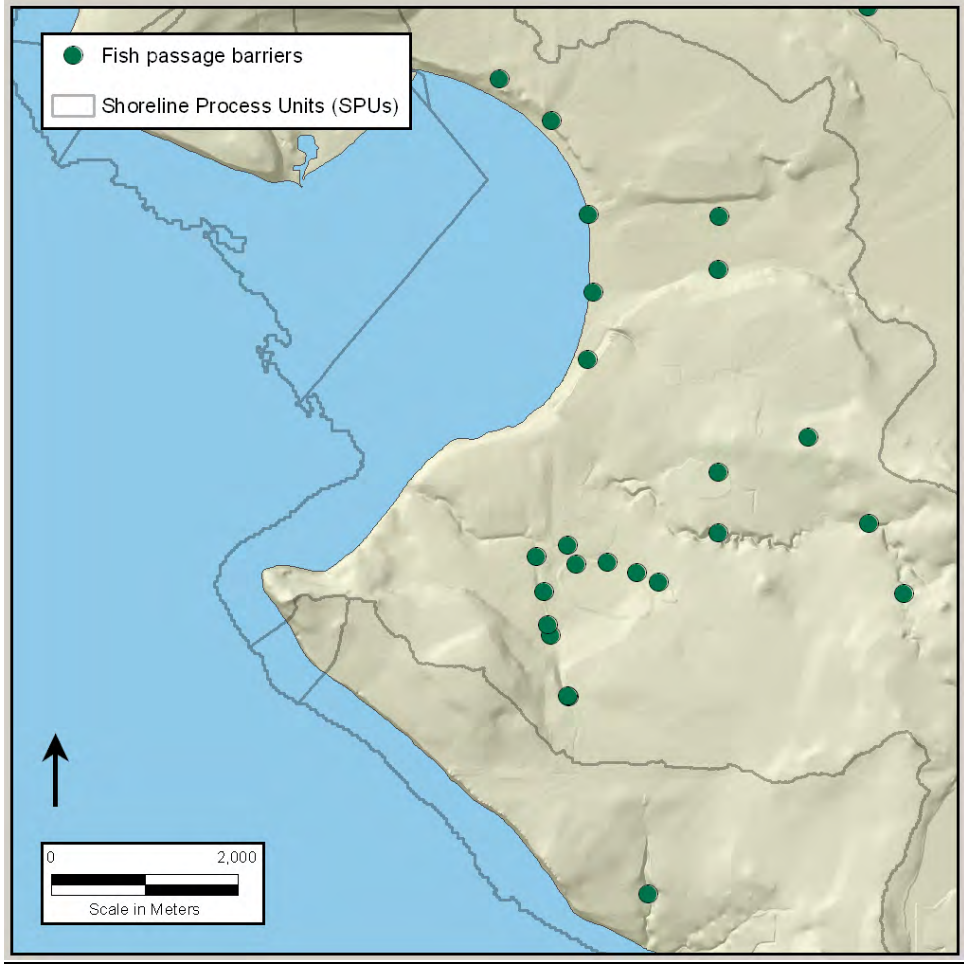
18.3.2 Phase 2

Run Check Geometry and repair any errors

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

19 FISH PASSAGE BARRIERS

Feature Name	fd_fish_passage_barriers
Feature Geometry Type	point
Tier(s)	Tabulations
Metric(s)	Count of fish passage barriers
Data Source(s) Used	Washington Department of Fish and Wildlife's (WDFW) Fish Passage and Diversion Screening Inventory (FPDSI) database
Geometric Intersection	Yes



19.1 Entity/Attribute Definitions for Fish Passage Barriers

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Barrier_Desc	Text, 25	Type of structure (from source data)	Culvert, Bridge, Ford, Fill/Puncheon, Abandoned, Washout, Undefined, Flume, Roughened Channel, Dike/Levee, Streambed Control, Hatchery, Tide/Flood Gate, Artificial Waterfall, Stormwater, Erosion Control, Fill/Debris, Lake Screen, Pipeline Crossing, Trash Rack, Flash Board Riser, Misc Obstruction
Barrier_Status	Text, 20	Status of fish barrier	Yes, Unknown

19.2 Data Preparation

Merge fish passage barrier inventory points (Dams, Misc_Barriers, Road_Crossings) into single dataset.

Retain field “BARRIER_ST” and “BARR_DEHC”

Rename to fields to Barrier_Status and Barrier_Desc.

Select those where BARRIER_ST IN (“Yes”,”Unknown”)

Intersect selection with GSUs

19.3 Quality Control

19.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

Visually inspect dataset against original points to ensure complete coverage.

19.3.2 Phase 2

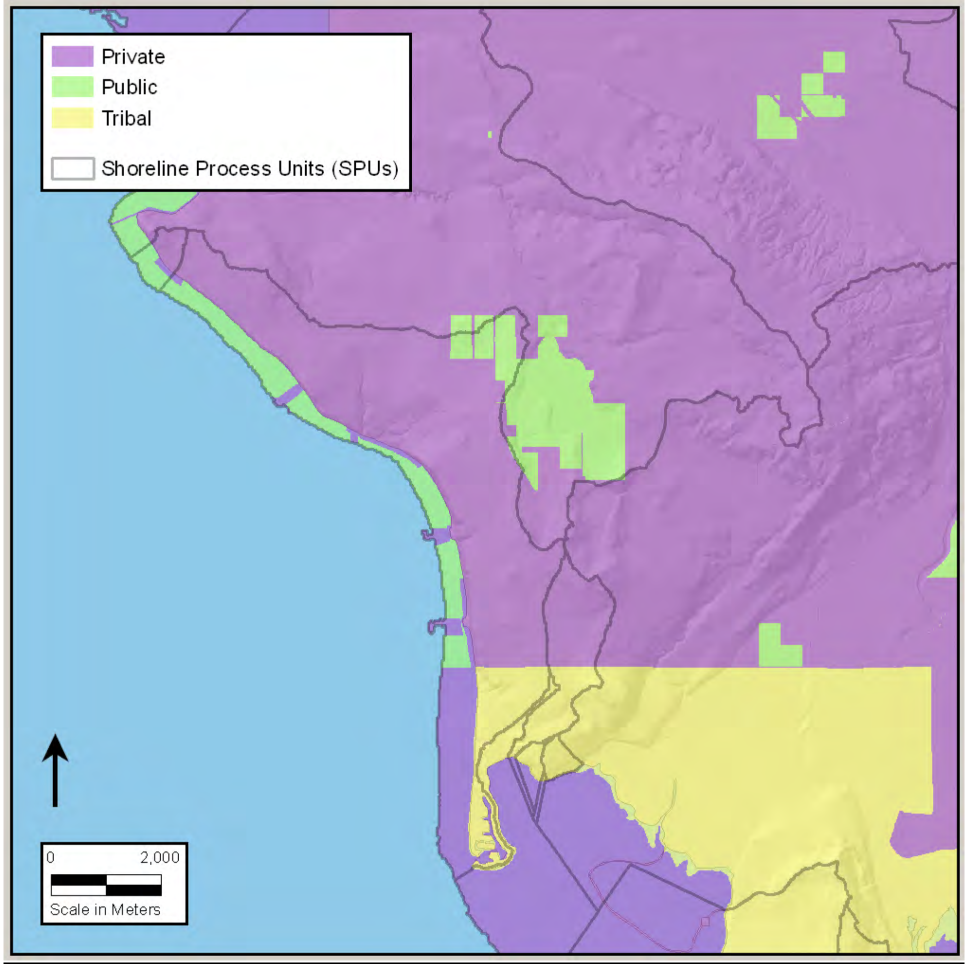
Run Check Geometry and repair any errors

Run topology check. Points must be covered by GSUs.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

20 LAND OWNERSHIP (PUBLIC/PRIVATE/TRIBAL LANDS)

Feature Name	fd_ownership
Feature Geometry Type	Polygon
Tier(s)	Tabulations
Metric(s)	Area of ownership class / drainage area
Data Source(s) Used	TNC Ecoregional Status Measures Version 1.0: Framework and Technical Guidance To Estimate Effective Conservation
Geometric Intersection	Yes



20.1 Entity/Attribute Definitions for Land Ownership

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Owner_Class	Text, 20	Type of land owner	Public, Private, Tribal

20.2 Data Preparation

Dissolve polygons on Owner_Class (Public, Private, or Tribal)

Remove areas where Owner_Class is null, and where Owner_Class is unknown because of topology errors in original data.

Intersect with GSUs

20.3 Quality Control

20.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

20.3.2 Phase 2

Run Check Geometry and repair any errors

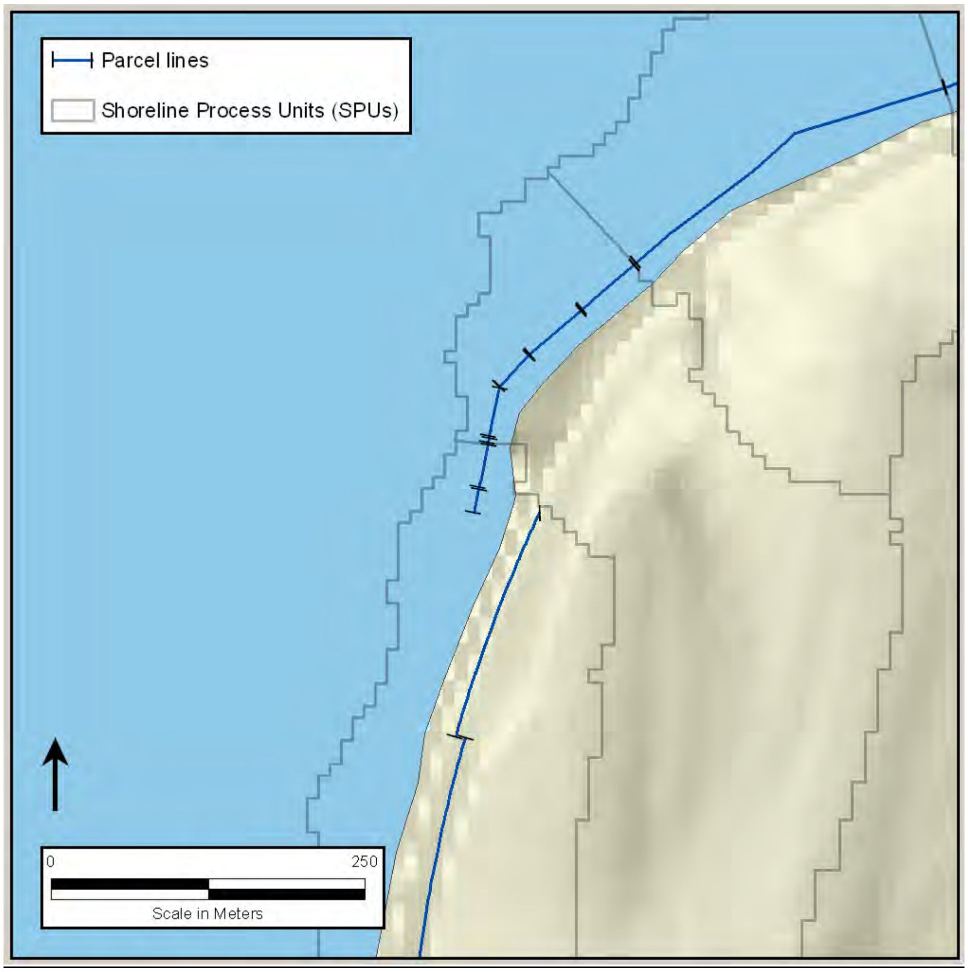
Run topology check. Polygons must be covered by GSUs.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

Verify complete coverage for ownership – infer private ownership where no data exists.

21 PARCELS

Feature Name	fd_parcel_lines
Feature Geometry Type	line
Tier(s)	Tabulations
Metric(s)	Count of waterfront parcels per 10,000m of total parcel waterfront length
Data Source(s) Used	Clallam, Island, Jefferson, King, Kitsap, Mason, Pierce, SanJuan, Skagit, and Snohomish counties parcels data
Geometric Intersection	No



21.1 Entity/Attribute Definitions for Parcels

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Front_Length	Double	Length of entire original parcel line length, prior to intersection with GSUs	
Unique_ID	Long Integer	Unique identifier for original parcel, to facilitate parcel count	

21.2 Data Preparation

Select parcels within 100m of ShoreZone shoreline

Convert selected parcels from polygon to line

Planarize lines

Manually moving along shoreline, remove parcels that are entirely aquatic. Use available fields in parcels datasets if available to exclude these parcels when performing that first selection, or, if the parcel attributes do not specify aquatic parcels, use aerial imagery to identify parcels found entirely in aquatic areas.

Retain the lines corresponding to the waterfront edge of the parcel. Generally, this will approximately parallel ShoreZone. In areas where it does not parallel ShoreZone, make a best professional guess as to the line that represents the parcel boundary most likely to be subject to tidal erosion, and will therefore be more likely to be armored.

Digitize any gaps between parcels as parcel fronts (e.g. parcels separated by roads)

In DPUs, remove entirely the agricultural parcels that were created through tidal barriers (levees, dikes). To identify agriculture, use aerial imagery, the land cover raster values of "Hay/Pasture" or "Cultivated Crops", or use any zoning or land use fields in the parcels themselves that might identify agricultural use. Also use tidal barrier delineation datasets from SSHIAP, and compare against historic t-sheet polygons.

Remove all attribute fields.

Add field Unique_ID, Long Integer

Add field Front_Length, Double

Calculate Unique_ID = ObjectID

Calculate Front_Length = Shape_Length

Intersect with GSUs

Intersection with the GSUs creates topology errors (duplicated lines on top of each other) in any dataset that follows ShoreZone, because ShoreZone was used to create one of the GSU boundaries. Calculate ZU = 1, GSU_ID = DU & "-" & DAU & "-" & ZU. Dissolve on all fields except Object_ID and Shape_Length.

21.3 Quality Control

21.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

Visually inspect dataset at 1:24,000 scale to ensure only appropriate parcels were included, and that the waterfront line captured is correct.

Inspect attribute table: sort by Shape_Area and look for unintentional tiny segments (review those under 10m)

21.3.2 Phase 2

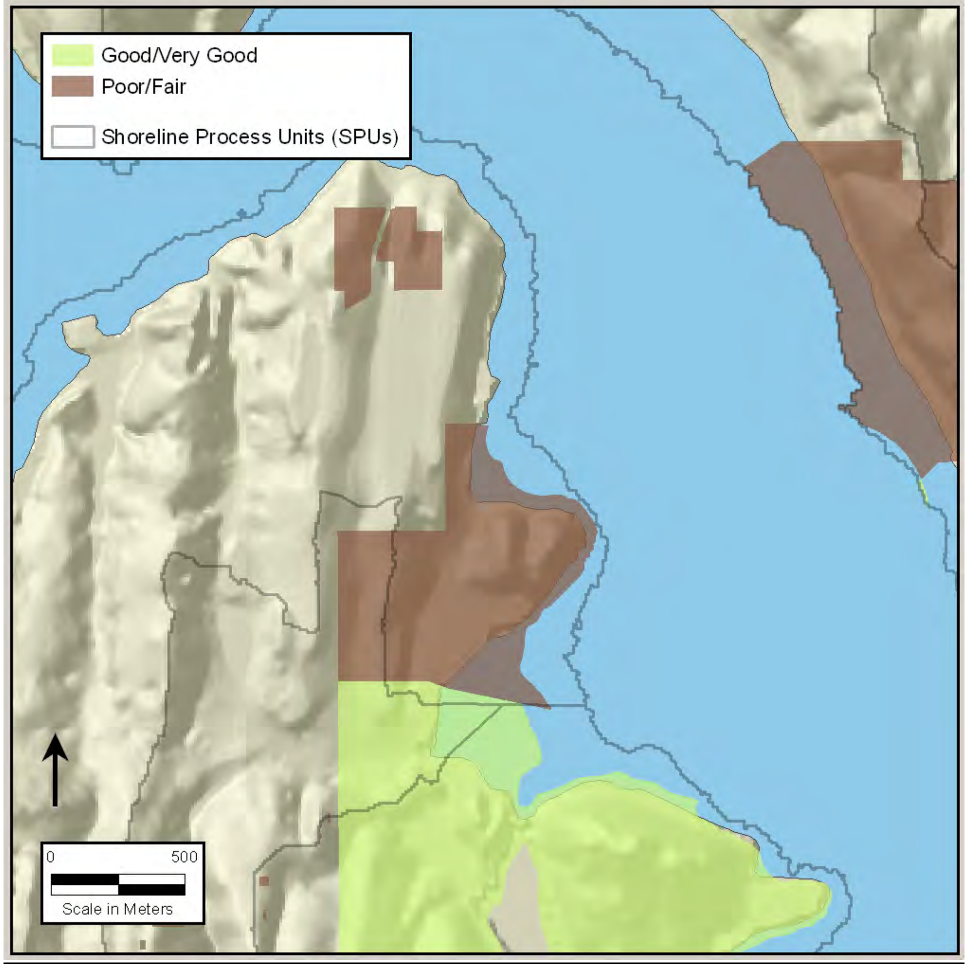
Run Check Geometry and repair any errors

Run topology check. Lines must be covered by GSUs.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

22 PROTECTED LAND

Feature Name	fd_protected_lands
Feature Geometry Type	Polygon
Tier(s)	Tabulations
Metric(s)	Area of protected lands/nearshore zone area Area of protected lands/drainage area
Data Source(s) Used	TNC Ecoregional Status Measures Version 1.0: Framework and Technical Guidance To Estimate Effective Conservation
Geometric Intersection	Yes



22.1 Entity/Attribute Definitions for Protected Lands

Attribute Name	Attribute Type	Description	Allowed Values
All fields from fd_GSUs	--	--	--
Conserve_Stat	Text, 15	Level of protection as determined by TNC	Poor/Fair, Good/Very Good

22.2 Data Preparation

Dissolve polygons on Conserve_Stat (fair/poor or good/very good)

Remove areas where Conserve_Stat is null, and where Conserve_Stat is unknown because of topology errors in original.

Intersect with GSUs

22.3 Quality Control

22.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

22.3.2 Phase 2

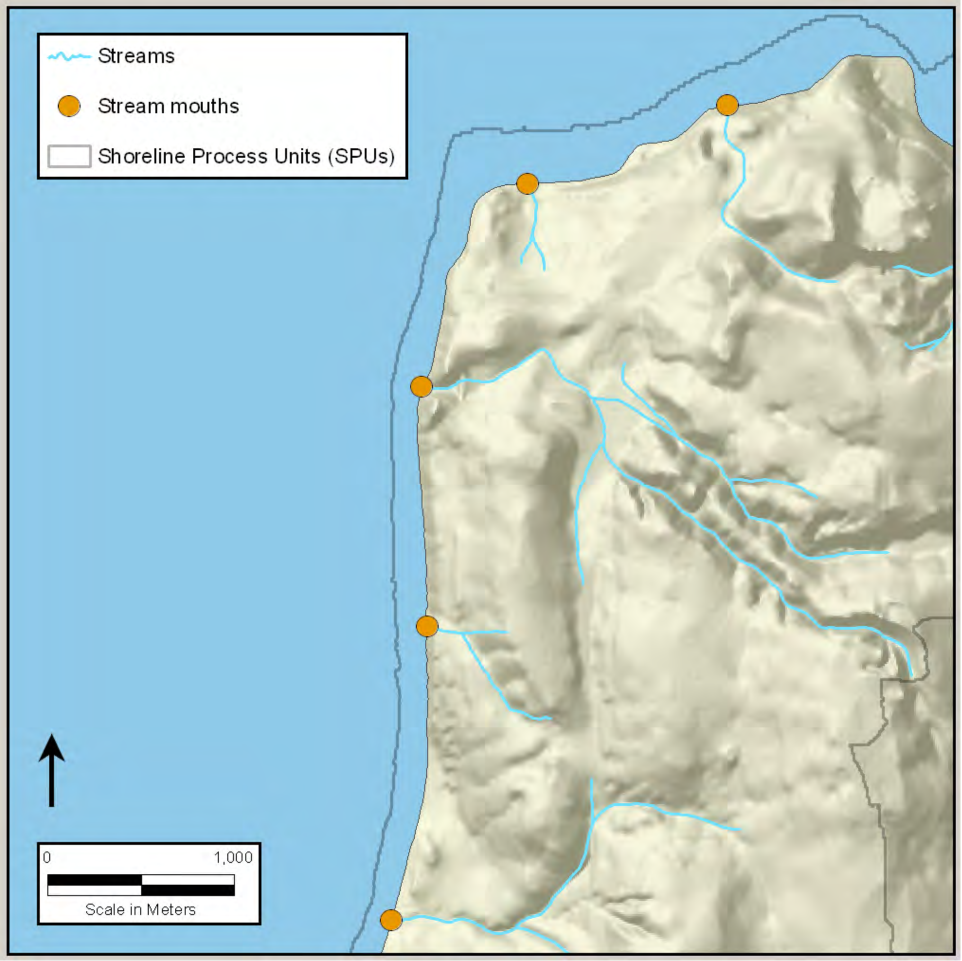
Run Check Geometry and repair any errors

Run topology check. Polygons must be covered by GSUs.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

23 STREAM MOUTHS

Feature Name	fd_stream_mouths
Feature Geometry Type	point
Tier(s)	Tabulations
Metric(s)	Count of stream mouths Count of stream mouths per shoreform
Data Source(s) Used	WDNR hydrography dataset, WDNR ShoreZone
Geometric Intersection	Yes



23.1 Entity/Attribute Definitions for Stream Mouths

Attribute Name	Attribute Type	Description	Allowed Values
SF_Change_ID	Long Integer	Unique ID assigned to line segments to be used in SF spatial joins with other metric feature classes	--
All fields from GSUs	--	--	--

23.2 Data Preparation

Intersect streams with ShoreZone shoreline. Retain the points where they cross.

Delete all attribute fields, retaining simply points with no attributes.

For those streams that do not intersect the ShoreZone shoreline, perform a spatial select of streams within 200m of the ShoreZone shoreline.

Convert both ends of those stream lines to vertices.

Remove all fields, retaining simply points with no attributes

Manually pan along the shoreline, removing vertices that do not need to be retained as stream mouths along the shore. This includes the upstream end points, both ends of forks that are not furthest downstream towards the shore, end points of stream lines that cross ShoreZone, and other possible erroneous vertices remaining. Use DEM or LIDAR and aerial imagery to confirm retention or deletion as necessary.

Snap points to ShoreZone shoreline (ETGeoWizards)

Merge the manually edited point file with the points from first intersection step

Intersect with GSUs

Add fields XYstring (Text, 100), X (Double), and Y (Double), and DUP (Short integer)

Calculate X as the X coordinate, Y as the Y coordinate, and XYstring as [X] & "-" & [Y]

Calculate DUP using the expression \Expressions\Mark_Duplicates_01

Delete points where DUP=1

Delete field XYstring, X, Y, and DUP

Intersect with fd_shoreform_change and capture the SF_Change_ID field and values. Ensure that all points were intersected correctly (a few may be missed) and manually add them if they are missing.

Re-check for duplicates as described above.

23.3 Quality Control

23.3.1 Phase 1

Visually inspect dataset to ensure complete coverage for final sub-basin extent

Visually inspect dataset at 1:4000 scale against streams to ensure no missed stream mouths.

23.3.2 Phase 2

Run Check Geometry and repair any errors

Run topology check. Points must be covered by GSUs.

Check attribute table structure against schema definitions. Verify fields retained, field order, field types, lengths, etc.

Verify stream mouth points are not duplicates stacked on top of each other after intersection with GSUs.

APPENDIX D
NET SHORE-DRIFT QUALITY CONTROL REVISIONS

DRAFT Net Shore-drift QA/QC Methods for Puget Sound and Northwest Straits

Prepared for: USACE a Puget Sound Nearshore Partnership
Under Contract to: Anchor Environmental LLC/ USACE

Prepared by:
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Jim Johannessen, MS and Licensed Engineering Geologist
Coastal Geologic Services Inc.

March 27, 2008

Background and Objective

The US Army Corps of Engineers and partners contracted the Anchor Environmental LLC consultant team to compile regional datasets to be used to in a large-scale shore change analysis of the entire Puget Sound region. Coastal Geologic Services was sub-contracted to correct specific errors known to occur in the digital net shore-drift database for the entire Puget Sound region from Neah Bay through Puget Sound to the Canadian Border.

Approximately ten different geology master's students working with Dr. Maury Schwartz, Emeritus Professor at Western Washington University mapped net shore-drift in Washington State during the period from the late 1970s to the early 1990s (Schwartz et al. 199, Johannessen 1992). Maps were produced at a variety of scales and in a variety of formats. Some of the maps contained little geographic information and some had net shore-drift arrows drawn very roughly at a large distance from the shoreline. The compiled mapping was later digitized as the Department of Ecology's digital net shore-drift data set, by interpreting the paper maps and text descriptions compiled by the mappers. However, the scale and detail problems present in the original paper maps caused the digital dataset to have numerous, widespread errors. Additionally, the drift cell data set was never adequately reviewed for quality of digitization. Other, more limited drift cell mapping was completed using methods that focused only on the upper bench, such as Bauer (1976).

To achieve the objectives of this project Coastal Geologic Services Inc. (CGS) reviewed and revised the Ecology digital net shore-drift data, initially in the Central Puget Sound Basin, followed by the 6 remaining basins in Puget Sound and the Northwest Straits. Original paper maps with the associated text reports along with vertical and oblique aerial photographs were the primary data sets used to guide all revisions. Drift was reinterpreted where there were obvious scale problems or no previous mapping data existed following general methods described in Jacobsen and Schwartz (1981), and detailed methods explained herein.

Problems with Existing Data

The digital data set had several different types of problems that recurred to various extents across the Puget Sound and Straits study area. There were generally four different types of mapping errors that CGS was tasked to correct, these included:

1. Areas mapped as UN "unidentified", where no previous mapping existed
2. Blank areas where there was a complete absence of data
3. Drift mapped throughout regions where no net shore-drift occurs, areas of "no appreciable drift" (NAD)
4. Other general misinterpretations of the original mapping units

It was communicated to CGS that Department of Ecology digitization process did not include a quality check for shore areas that should have been identified as “no appreciable drift” (NAD), which was short for “no appreciable net shore-drift” (NANSD). After years of working with this data set, CGS had become aware that there were numerous areas in which drift was mapped throughout areas where drift does not occur (a NAD area). Common examples of this type of error were corrected within inner lagoon shores (leeward of barrier spits), and within bayheads and stream mouths. Additionally there were a considerable number of places in which NAD was mapped but drift does appear to occur.

The original net shore-drift paper maps also contained numerous areas where no drift cells were mapped. These “unmapped” areas were labeled UN in the digital data set. Many of these areas were actually areas of no appreciable drift, and NAD was the only appropriate designation. Other UN areas were found along highly modified shores, such as the north shore of Fidalgo Island. For these areas drift was interpreted using the available datasets and the methods described further below. As an example that shows the frequency that UN areas occur, there were 270 UN units within unincorporated Pierce County alone, some of which are shown in Figure 1. Other examples of UN areas and the other types of errors are shown from Dyes Inlet in Kitsap County in Figure 2.

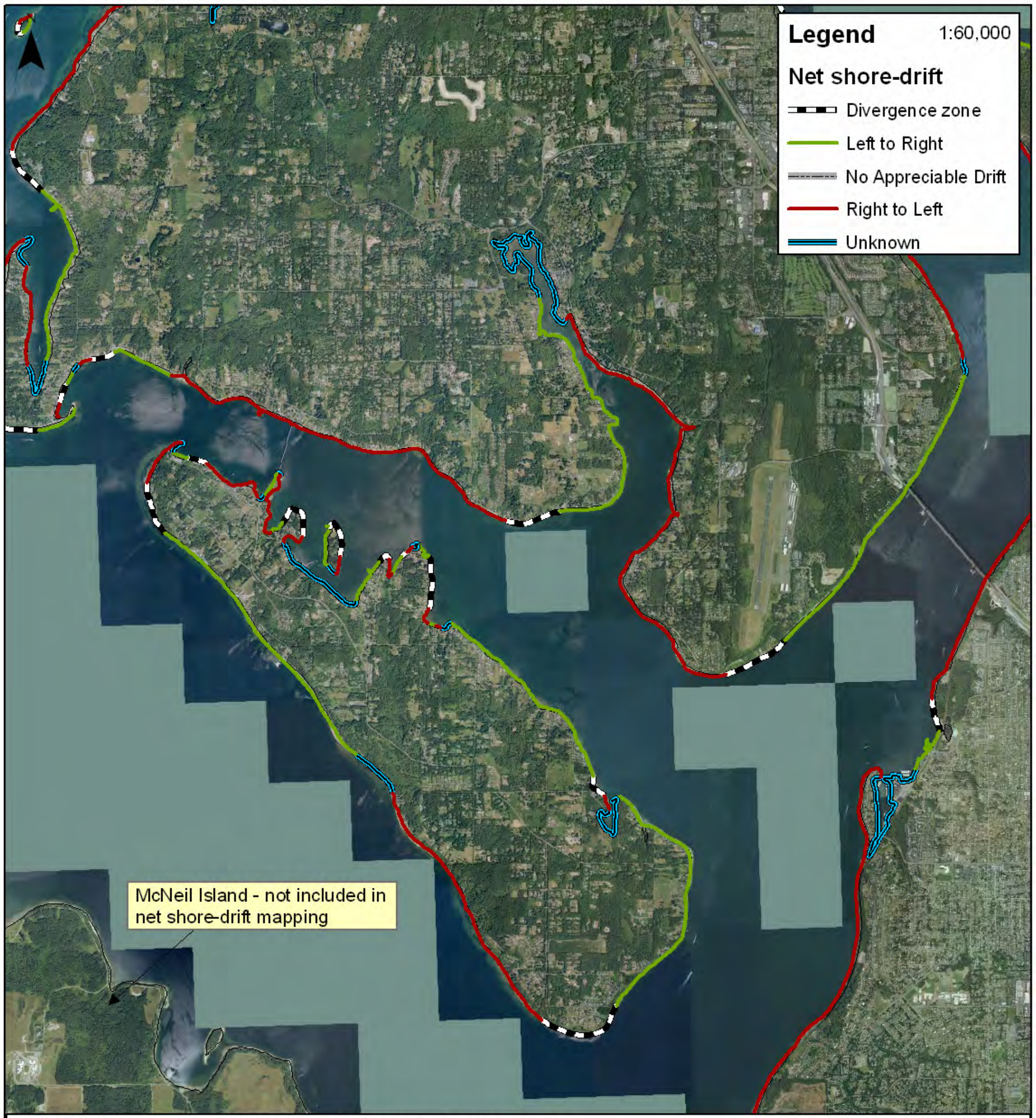
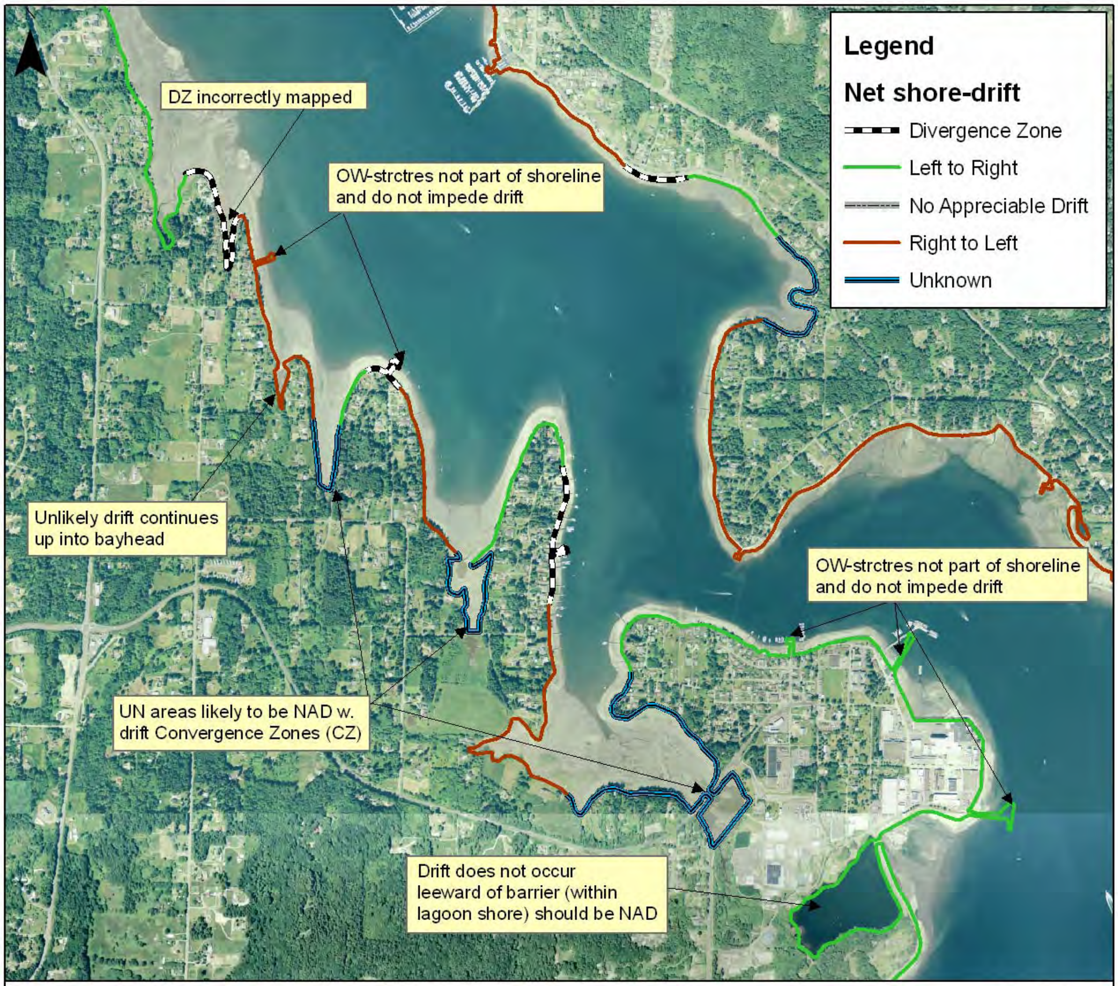


Figure 1. Frequent occurrence of Unknown units in Pierce County.
33 miles of shore unmapped (in unincorporated PC), including 21 miles of UN units and McNeil Island

There were also numerous places where there was a complete absence of original net shore-drift mapping, where either blank/unlabeled units existed or there was no mapping compiled at all. Examples of this type of mapping error includes: McNeil, Squaxin, Pitt, Eagle and Gertrude Islands, all of which are located in the South Puget Sound basin and with an original net shore-drift mapping; and around Guemes Island in northwest Skagit County, where large blank areas were found between mapping units.



DZ incorrectly mapped

OW-strctres not part of shoreline and do not impede drift

Unlikely drift continues up into bayhead

OW-strctres not part of shoreline and do not impede drift

UN areas likely to be NAD w. drift Convergence Zones (CZ)

Drift does not occur leeward of barrier (within lagoon shore) should be NAD

Figure 2. Examples of various net shore-drift mapping errors from Dyes Inlet

Methods

General

Dataset corrections were completed one sub basin at a time. The first step in revising the digital net shore-drift data set was to clip the data down to the appropriate basin boundaries. Units that extended beyond the basin boundaries were included with the basin being edited (in their entirety) and were not truncated to avoid creating additional erroneous unit breaks that could lead to later misinterpretation. However drift was then corrected only within the subject basin boundaries. The clipped basin shapefile was then reprojected from NAD 27 State Plain North to NAD 83 UTM Zone 10 North - HARN (feet), the preferred coordinate system for the client. The Shorezone shoreline, which is the best available science shoreline for the state (WDNR 2001), was then added to the GIS project file to provide a reference to evaluate recent alterations to the shorescape.

This revised net shore-drift mapping was intended to reflect net shore-drift conditions in the region prior to the anthropogenic alteration of the shoreline or "historic net shore-drift". The entire shore was reviewed for errors and to determine if shoreline modifications have lead to changes in littoral drift patterns since pre-development conditions. Areas where historic drift was considerably different from current conditions were bookmarked for further analysis.

The shoreline that the original net shore-drift mapping was digitized on (Ecology shoreline) is not current or correct, and reflects neither current nor historic conditions. In areas where the shoreline's position was deviated considerably from the current position of the shoreline (misrepresenting drift) the more current Shorezone shoreline was used to guide that effort. In areas where anthropogenic alteration to the shoreline necessitated historic drift mapping, drift was interpreted along the US Coast and Geodetic Survey T-sheet shoreline. However, a comprehensive reconfiguration of the shoreline to its historic position was not part of the scope of this effort, and digitizing all historically occurring shoreforms that were not included in the net shore-drift shoreline also went well beyond the scope of this mapping project.

In areas where changes to the dataset were required, the shapefile was edited and corrected, and the changes were briefly described in an Excel spreadsheet. New cells/units that were created were named using a similar naming convention to adjacent cells. Cells that were segmented as part of a correction or revision, but that remained part of a single net shore-drift cell, were merged to re-create a single attribute record.

Unknowns and Blanks

All "unknown" and blank areas in the dataset were systematically reviewed to define those areas as one or several of the primary mapping units. The large majority of the UN areas were addressed through assigning NAD to these areas (where appropriate). Many other UN areas were individually corrected through mapping of convergence zones, as described below. A number of other UN areas occurred between the tips of two converging drift cell arrows on the paper maps, in cases such as these the UN area was typically bisected and merged with the two adjacent cells. Other blank areas were cleared up very readily, using original net shore-drift maps and the associated text descriptions as the primary guide(s) to determine the intended drift cell termini locations.

For determining the extent of a drift cell when transitioning to an area of No Appreciable Drift (NAD), the point where shore-drift became negligible was determined where one or more of the following criteria were:

1. The upper beach narrowed to a barely visible band
2. Contiguous marsh vegetation occurred and, an extensive mud/sand flat or low tide terrace dominates the intertidal
3. No other shoreforms created by littoral drift were present (e.g. nearshore bars, spits etc).

These NAD areas commonly occurred within barrier fronted embayments and estuaries, where wave energy was no longer the dominant influence on the nearshore.

New Net Shore-drift Mapping – McNeil, Squaxin, Eagle, Pitt and Gertrude Islands

Net shore-drift was conducted by CGS for several previously unmapped islands, all of which were located within the South Puget Sound Basin. These islands included McNeil and Squaxin Islands, and the very small Eagle, Pitt and Gertrude Islands, each of which surround McNeil Island. This mapping effort was carried out using aerial photograph interpretation (vertical and oblique), historic T-sheet interpretation, and indicators of net shore-drift outlined in Jacobson and Schwartz (1981) that were of adequate scale. Indicators of drift direction that were used included spit orientation, changes in marine riparian vegetation and beach width, and the orientation of deflected stream mouths, nearshore bars and deltas. Landscape parameters such as fetch and shore orientation were also factored into the analysis. No fieldwork was carried out wave for this effort, so it should be understood that the level of rigor is considerably less than the original field-based mapping methods.

Historic Net Shore-drift Mapping

Numerous anthropogenic shore alterations have been constructed in the nearshore that alter or impede the longshore sediment transport including:

1. Marinas and associated dredge areas
2. Jetties and breakwaters
3. Dikes and fill for agriculture
4. Large coastal developments such as industrial sites and military bases

Historic net shore-drift was mapped through areas where such structures currently significantly alter the natural net shore-drift regime. The protocol described below was used to systematically address specific reoccurring issues.

The extent of drift was extended to the likely historic limit that wave energy enabled net shore-drift prior to the construction of the shore alteration. Historic and current aerial photographs and historic T-sheets were interpreted for indicators of net shore-drift as outlined in Jacobson and Schwartz (1981). Professional judgment through the interpretation of fetch and (historic) shore orientation relative to the predominant wind direction, guided the historic net shore-drift mapping of heavily altered drift cells. In many cases a single historic drift cell was formed from several bifurcated segments as a result of shore-normal structures such as large fill areas or marinas. In these cases, revising mapping to represent historic conditions entailed re-creating contiguous drift and deleting the additional anthropogenic drift cells.

Historic drift cells were named based on the largest drift cell that was originally mapped along that segment of shore. If additional drift cells were mapped, then new names were developed that were similar to the adjacent cells, such as KS-12 and KS-12b. All areas where historic drift was mapped were documented in a worksheet named “historic drift” in the Excel spreadsheet in which all net shore-drift revisions were recorded.

Convergence Zones

Recently, a team of regional scientists referred to as the Puget Sound Nearshore Partnership (PSNP) Nearshore Science Team, interpreted some of the UN areas in Water Resource Inventory Area (WRIA) 9 to largely be areas where drift cells were converging, and referred to them as “Convergence Zones”. These areas were not mapped as convergence zones in the original drift cell mapping, are not a definitive shoretype, nor did they appear to be mapped using explicit methods. Other drift cell assessment work in WRIA 9 did not include the use of convergence zones (Johannessen et al. (2005). However, one past mapping effort for drift cells was completed by Keuler (1988) for the Port Townsend 1:100,000 scale quadrangle that included mapping of “convergent zones.” These features were never defined in the mapping by Keuler though, and methods were not provided. Convergence zones are of interest and utility to the PSNP Science Team thus CGS was contracted to develop and apply a mapping approach for convergence zones Sound-wide.

Convergence zones were intended to represent shoreforms that function as a sediment sink, where the majority of sediment is deposited permanently and not lost to other sedimentary system outputs such as deep water or an embayment. Areas that fulfill the convergence zone (CZ) definition as “a region encompassing the termini of two converging littoral drift cells where sediment is continually accreting and not lost to a nearshore sediment sink, such as deep water or tide channel”. The following guidelines were used to digitize CZs:

1. At location with 2 net shore-drift cells converging from two directions
2. Presence of a sizable upper beach, or barrier spit and wide backshore area without a distinct spit terminus
3. Finer sediment composition in the upper beach appearing lighter in aerial photographs
4. Relatively broad low tide terrace
5. Absence of tide-channel
6. For cuspate forelands, lack of sharp, angular distal end (tip) of spit and indicators of a transport pathway around the distal end and deposition on one or both limbs of the foreland

A small to moderate number of convergence zones were mapped throughout the Puget Sound region through systematic application of the above methods, but a fair amount of subjective analysis was required as the depositional beaches of the region occur in a wide spectrum of configurations and at different scales. Therefore mapping of CZs may not have the same level of consistency as other aspects of the net shore-drift cells.

Conclusion

The methods outlined in this report were used in the net shore-drift QA/QC revision process for each of the six Puget Sound regional basins. Applying a systematic approach to such a diverse shorescape was challenging, as conditions are far from homogenous, and are the result of numerous interacting variables. In addition, original mapping methods relied primarily on extensive field observations, the resulting quality of which cannot be replicated in a remote mapping effort, such as this. However, regardless these caveats, the resulting corrected dataset is dramatically improved and much more consistent mapping product compared to the previous uncorrected Ecology dataset. The use of this net shore-drift dataset will be central for process-based restoration planning. It may also be a very useful additional step to go through this dataset to create corrected *current* (not historic) net shore-drift mapping coverage for use in restoration planning and also for other groups such as local governments.

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APPENDIX E

DATA COMPLETION REPORT

DRAFT

TASK ORDER #2 DATA COMPLETION REPORT

PUGET SOUND NEARSHORE ECOSYSTEM RESTORATION PROJECT

Prepared for

U.S. Army Corps of Engineers, Seattle District
4735 East Marginal Way South
Seattle, Washington 98124

Prepared In Support of

PUGET SOUND
NEARSHORE
PARTNERSHIP

RESTORING OUR
ECOSYSTEM HEALTH

Prepared by

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October 2008

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1 INTRODUCTION

In support of the Change Analysis that is being completed as part of the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) General Investigation Study and the Puget Sound Nearshore Partnership, available relevant spatial datasets were compiled and evaluated for completeness and suitability for the analysis. The datasets obtained in this data compilation effort are described in the Data Discovery Summary Report prepared by Anchor Environmental, L.L.C. (Anchor), in October 2007 (Anchor 2007a). The data compilation revealed data gaps for several parameters of interest. These parameters include shoreline armoring, breakwaters/jetties and marinas, and nearshore fill. Following the data compilation, a Data Gaps Meeting was convened to identify datasets that are a priority to complete by filling data gaps and to discuss method options for filling the gaps. A Data Gaps Work Plan (Anchor 2008) was prepared to describe method alternatives for filling the data gaps for the priority datasets identified at the Data Gaps Meeting. The Data Gaps Work Plan helped inform decisions about which data gaps to fill and the methods to apply. The U.S. Army Corps of Engineers authorized Anchor to fill datasets for multiple parameters discussed in the Data Gaps Work Plan.

This Data Completion Report documents the parameters and methods used to fill the selected data gaps. The report describes whether filling of the data gap entailed augmentation of an existing dataset or creation of a new dataset.

2 SHORELINE ARMORING

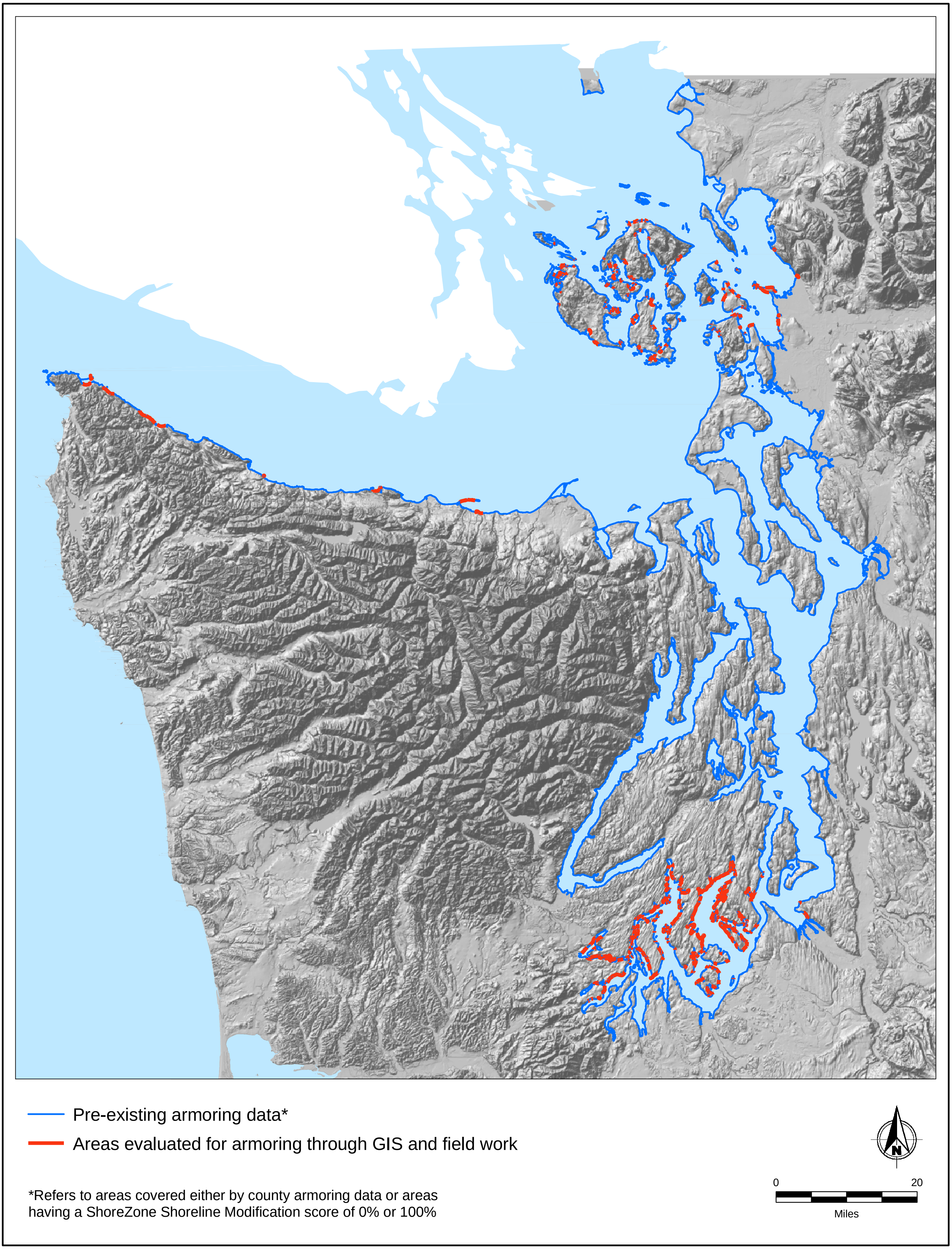
Shoreline armoring data were collected for those shorelines that otherwise had no armoring data on the start and end points of armoring structures. These areas were identified by compiling data from available local efforts around Puget Sound and overlaying it with armoring data from the Washington State ShoreZone Inventory (WDNR 2001) for assessment reaches with 0 or 100 percent armoring. Figure 1 illustrates the extent of data compiled through local efforts and segments of the Washington Department of Natural Resources (WDNR) State ShoreZone Inventory data having 0 or 100 percent armoring versus data gaps filled using photograph interpretation and/or field assessment. Table 1 presents the number of miles of shoreline armoring data gaps filled in each sub-basin.

Table 1
Shoreline Armoring Data by Sub-basin

Sub-basin	Total Miles in Sub-basin	Miles Assessed through Local Efforts or Identified in WDNR State ShoreZone Inventory Data as having 0 or 100 Percent Armoring	Miles of Data Gaps Filled through GIS and Field Work Evaluation
Strait of Juan de Fuca	210	195	15
San Juan Islands/ Georgia Strait	716	672	44
Hood Canal	245	245	0
North Central Puget Sound	128	128	0
Whidbey Basin	349	349	0
South Central Puget Sound	378	373	5
South Puget Sound	445	323	122
Totals	2,471	2,285	186

Shoreline armoring data gaps were filled by interpreting the best available aerial orthogonal and oblique photographs. These datasets included National Agriculture Imagery Program (NAIP) aerial imagery and Washington State Department of Ecology (Ecology) shoreline oblique photographs. A resolution of 30 meters was used during this assessment (i.e., shoreline armoring was only delineated in those areas where it extended along 30 meters or more of the shoreline). During photograph interpretation, the level of confidence in the data was qualitatively characterized as high, medium, or low confidence. In general, photograph interpretation using the best available imagery can be expected to provide high quality data; however, the accuracy of photograph interpretation was limited on north-facing shorelines in which the upper intertidal area was in the shade and in areas with overhanging riparian vegetation. Field verification was conducted at most low and most medium confidence reaches.

The field effort was boat based, and targeted sites were visited to confirm the presence or absence of shoreline armoring. Figure 2 illustrates the field assessment locations.



*Refers to areas covered either by county armoring data or areas having a ShoreZone Shoreline Modification score of 0% or 100%

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Figure 1
Armoring Data Gaps
Data Completion Report

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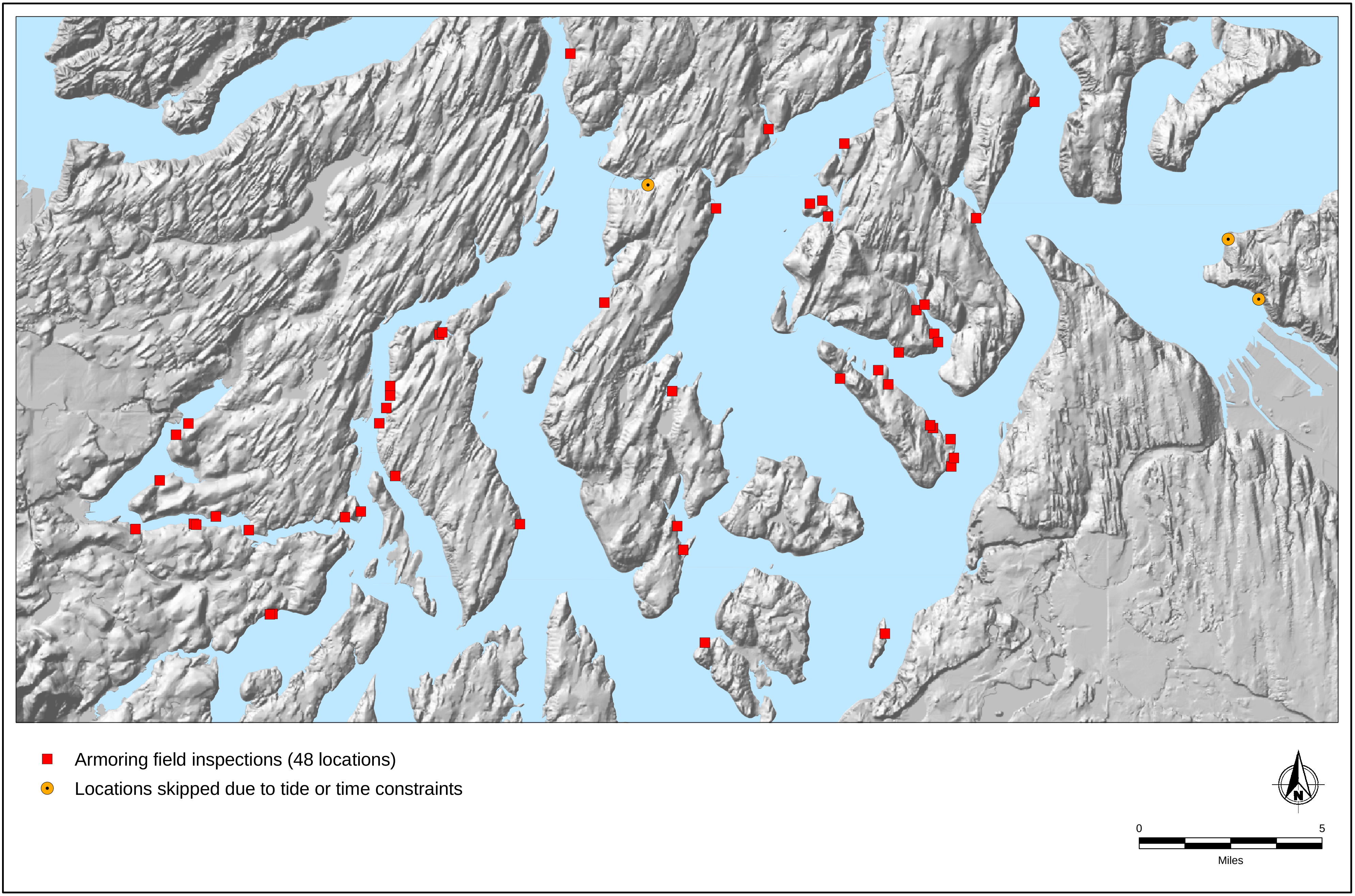

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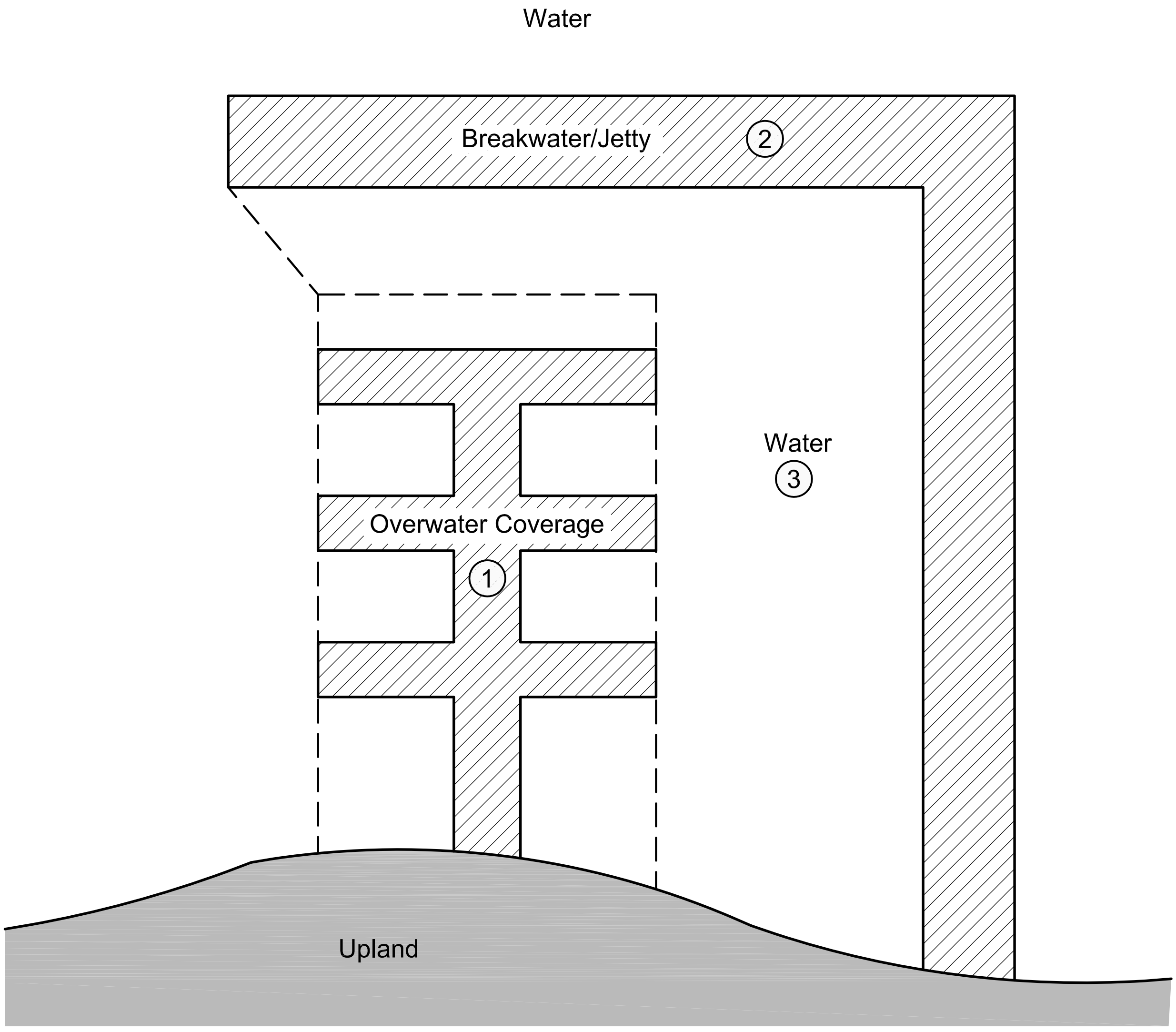
Figure 2
Armoring Field Inspections
Data Completion Report

3 BREAKWATERS/JETTIES AND MARINAS

No satisfactory breakwaters/jetties or marinas datasets were identified during data compilation. Based on the discussion at the Data Gaps Meeting (Anchor 2007b), the desired breakwaters/jetties dataset provides polygons delineating the outline of all breakwaters and jetties and identifies the material (e.g., rock, pier pile, or floating) where possible. Breakwaters and jetties did not need to be differentiated. The desired marina dataset provides polygon delineations for boat moorage areas with 10 or more boat slips. In addition, the desired marina dataset at marinas enclosed by breakwaters/jetties includes separate polygons for 1) aquatic areas with overwater coverage assuming all boat slips are filled, 2) associated breakwaters/jetties, and 3) aquatic unshaded areas (Figure 3). The total marina area could be calculated as the sum of these components. At marinas with no breakwaters/jetties, the dataset is to delineate only the aquatic areas with overwater coverage, assuming all boat slips are occupied.



Legend

— — — — Margins of Delineated Polygons

Note: Breakwater/jetty is not necessary
for site to be considered a marina.

Oct 22, 2008 3:04pm cdavidson K:\Jobs\070202-Puget Sound Nearshore\07020201\07020201-001.dwg FIG 3 NSH-R

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ENVIRONMENTAL, L.L.C.

Figure 3
Marina Delineation
Data Completion Report

To fill the data gap, breakwaters/jetties and marinas were delineated by interpreting the best available aerial orthogonal and oblique photographs. These datasets included NAIP aerial imagery and Ecology shoreline oblique photographs. For both datasets, an initial rapid review of aerial oblique thumbnail images was employed to identify locations to be revisited for polygon delineation.

Breakwaters/jetties and marinas were delineated to provide the desired datasets described above. Table 2 summarizes the number of breakwaters/jetties and marinas delineated in each sub-basin.

Table 2
Breakwaters/Jetties and Marinas Data by Sub-basin

Sub-basin	Number of Breakwaters/Jetties	Number of Marinas
Strait of Juan de Fuca	7	6
San Juan Islands/Georgia Strait	32	40
Hood Canal	7	8
North Central Puget Sound	2	6
Whidbey Basin	49	25
South Central Puget Sound	18	62
South Puget Sound	8	26
Total	123	173

4 NEARSHORE FILL

No available electronic nearshore fill datasets were identified during the data compilation (Anchor 2007a). Based on the discussion at the Data Gaps Meeting (Anchor 2007b), the desired nearshore fill dataset is a collection of polygons outlining each nearshore fill area along the Puget Sound shoreline and in the estuaries of the major rivers.

The 1:24,000 scale geology dataset in the Ecology Coastal Zone Atlas (Ecology 1978 to 1980) includes a nearshore fill designation (af) that was used to describe nearshore fill and will be referred to as nearshore fill in the remainder of this report.

The first step was to identify the Ecology Coastal Zone Atlas 1:24,000 tiles containing one or more nearshore fill polygons other than dikes/levees. Next, the approximately 100 tiles containing nearshore fill were georeferenced to properly position them spatially. The tiles were georeferenced to commercially available, updated U.S. Geological Survey 1:24,000 topographic map Digital Raster Graphics (DRGs) using the methods described in Appendix A. Next, nearshore fill polygons were delineated.

Table 3 provides a summary of the nearshore fill areas delineated in each sub-basin.

Table 3
Nearshore Fill Data by Sub-basin

Sub-basin	**Nearshore Fill Areas (acres)**
Strait of Juan de Fuca	393
San Juan Islands/Georgia Strait	1,876
Hood Canal	177
North Central Puget Sound	332
Whidbey Basin	1,738
South Central Puget Sound	4,266
South Puget Sound	945
Total	9,727

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APPENDIX A

DESCRIPTION OF GEOREFERENCING PROCESS COMPLETED DURING PSNERP NEARSHORE FILL DIGITIZING EFFORT

Description of Georeferencing Process Completed During PSNERP Nearshore Fill Digitizing Effort

Prepared by:
ICF Jones and Stokes

Artificial fill polygons were digitized from the Coastal Zone Atlas of Puget Sound published in 1978 and 1980. The Coast Zone Atlas was published from polygons hand-drawn on 1:24K USGS topo maps. Coastal Zone Atlas pages were scanned to an electronic jpeg format. The Atlas pages contained more information than was necessary for digitizing artificial fill so they were clipped to only the pertinent sections containing artificial fill polygons and transformed to a .gif format in order to reduce file size and increase performance speed. The resulting .gifs were then georeferenced to commercially available, updated USGS 1:24K topo map Digital Raster Graphics (DRGs). The DRG files contain a tag that describes the projection (Universal Transverse Mercator (UTM), NAD27) and the transformation from map image pixels to UTM coordinates. The transformation is redundantly defined by a six-line .tfw file. This .tfw file allows ESRI brand ArcMap software to locate the map image spatially by describing each pixel's coordinate position on the surface of the earth. The georeferencing process began by loading the DRGs and .gif Coastal Atlas pages into ESRI brand ArcMap software. ArcMap placed the DRGs spatially according to their .tfw file but the .gif Coastal Zone Atlas pages had an unknown spatial reference because they were simple .gif images. In order to align the .gif Coastal Zone Atlas pages spatially ArcMap's georeferencing toolbar was used and control points were placed aligning the .gif with the DRG. Control points were placed at easily identifiable, relatively permanent features that were found on both the DRGs and the Coastal Zone Atlas such as maritime markers, street intersections, elevation survey markers, and intersections of latitude and longitude lines on the maps. After several control points had been placed, ArcMap transformed the .gif Coastal Atlas to align the points on the .gif with the points on the DRG. A first order polynomial (affine) transformation was used during this process. When the general formula is derived and applied to the control point, a measure of the error, the residual error—is returned. The error is the difference between where the from-point ended up as opposed to the actual location that was specified—the to-point position. The total error is computed by taking the root mean square (RMS) sum of all the residuals to compute the RMS error. This value describes how consistent the transformation is between the different control points. RMS error is a good assessment of the accuracy of the transformation. Because the 1:24K DRGs had been updated between 1980 when the Coastal Zone Atlas was last published, and 2008 when the DRGs had been last updated, not every Coastal Zone Atlas page lined up perfectly when georeferencing. Differences were not often substantial overall but in some cases shorelines had changed considerably due to erosion and deposition. An attempt was made to keep the RMS error of the control points as close to 0 as possible and always below 5 when georeferencing but in some instances corrections from the 1980 topos to the 2008 topos was dramatic. These situations were usually due to misalignments of portions of the 1980 topos. When these situations were encountered, considerably more control points were used in order to align all portions of the topos accurately. This sometimes led to root mean square errors above 5 but resulted in georeferencing that appeared visually appropriate based on alignment of features between the 1980 topos and the 2008 versions. Once RMS error was as low as possible the .gif's georeferencing was updated and ArcMap attached a .gfw file describing the .gif projection and transformation. In this way each of the Coastal Zone Atlas pages outlining artificial fill were given spatial reference that allowed ArcMap to position them on the surface of the earth.

APPENDIX F

NEARSHORE MODEL CERTIFICATION PLAN CRITERIA TABLE

Appendix F: Nearshore Model Certification Plan Criteria Table

Cover Sheet		
a.	Model Name	Puget Sound Nearshore Marine Ecosystem Restoration Planning Model
b.	Functional Area	Puget Sound and Adjacent Marine Shorelines
c.	Model Proponent	Seattle District, U.S. Army Corps of Engineers
d.	Model Developer	Puget Sound Nearshore Ecosystem Restoration Project Nearshore Science Team with production assistance by Anchor QEA Consultant Team
1. Background		
a.	Purpose of Model	Inventory and attribute Puget Sound nearshore shorelines for ecosystem restoration and protection planning
b.	Model Description and Depiction	***To be prepared by the NST Change Analysis Team***
c.	Contribution to Planning Effort	***To be prepared by the Corps***
d.	Description of Input Data	Input data are the best available data describing nearshore conditions. The details of the data development, data suitability criteria, and QA/QC for input data are described in Sections 4 and 6 of the main report. In overview, the input data include 27 GIS datasets characterizing nearshore conditions. Suitable datasets needed to be consistent throughout the entire project area, readily available, compatible with other datasets, and have adequate method documentation (FGDC metadata preferred). The *Data Discovery Summary Report* provided as Appendix A of the main report describes the assessment of each input dataset. Input data also include a Geographic Scale Unit (GSU) framework for delineating watershed areas. The GSU structure entails delineation of the watershed at multiple nested spatial scales to allow for analysis and a variety of scales. The primary spatial scale in the GSU framework is determined by sediment transport processes, specifically sediment transport sectors (as known as drift cells of net shore-drift).
e.	Description of Output Data	Output data are the quantification of nearshore conditions in the multiple spatial scales of the GSU framework. Output data of multiple parameters in each of the four analysis tiers were prepared using the formulas described in Section 2f of

		this appendix. These outputs were generated per the requirements of the PSNERP Nearshore Science Team and were used in the assessment of similarity among GSU Process Units and Ecological Functions Goods and Services.
f.	Statement on the capabilities and limitations of the model	Conceptual capabilities and limitations ***To be prepared by the NST Change Analysis Team*** The analytical capabilities and limitations of the model hinge upon the quality of the input data. Acceptable data sets covering the entire GI Study Area were identified for an extensive set of natural and manmade features. As described in Section 4 of the main report and in the *Data Discovery Summary Report* provided as Appendix A of the main report, data sets were evaluated for multiple suitability criteria established for the GI Study. The available and created data sets used in the analysis met the criteria for a broad analysis of Puget Sound conditions.
g.	Description of model development process including documentation on testing conducted (Alpha and Beta tests)	Conceptual model development ***To be prepared by the NST Change Analysis Team*** WRIA 9 Pilot Project ***To be prepared by the NST Change Analysis Team***
2. Technical Quality		
a.	Theory	***To be prepared by the NST Change Analysis Team***
b.	Description of system being represented by the model	***To be prepared by the NST Change Analysis Team***
c.	Analytical requirements	***To be prepared by the NST Change Analysis Team***
d.	Assumptions	***To be prepared by the NST Change Analysis Team***
e.	Conformance with Corps policies and procedures	***To be prepared by the Corps***
f.	Identification of formulas used in the model and proof that the computations are appropriate and done correctly	Statement on appropriateness of formulas ***to be prepared by the NST Change Analysis Team*** Formulas were generated per the requirements of the PSNERP Nearshore Science Team with instruction from the GIS Technical Liaison, and are further documented in Section 4 of the main report. Output data from the computations were spatially verified against randomly selected GSU Process Units within each sub-basin and during sound-wide analysis. For quality control, all output data were computed independently by both Anchor QEA and Exa Data & Mapping. Results from these independent

		efforts were then compared against each other and corrections made, resolving any discrepancies. Results were then submitted to the GIS Technical Liaison for final review and approval.
3. System Quality		
a.	Description and rationale for selection of supporting software tool/programming language and hardware platform	***To be prepared by the Corps***
b.	Proof that the programming was done correctly	Programming centered around supporting the calculation of formulas described in Section 4 of the main report through the creation of Structured Query Language (SQL) queries in each geodatabase. The queries were written and run independently by both Anchor QEA and Exa Data & Mapping, with results from each effort compared against each other to resolve discrepancies. Programming results were then submitted to the GIS Technical Liaison for final review and approval.
c.	Availability of software and hardware required by model	***To be prepared by the Corps***
d.	Description of process used to test and validate model	***To be prepared by the NST Change Analysis Team***
e.	Discussion of the ability to import data into other software analysis tools (interoperability issue)	The geodatabase architecture includes ESRI ArcGIS 9.x integrated with a personal geodatabase (Microsoft™ Access). Access is accessible to all users of ArcGIS, and has a client interface for easily writing spatial and non-spatial queries. Data can be exported into any of the other Microsoft Office products, such as Excel, for non-spatial analysis. Spatial data can be utilized in a number of software packages, including AutoCAD and an SDE-Oracle server.
4. Usability		
a.	Availability of input data necessary to support the model	Prior to creation of the model, Anchor performed a data discovery, acquisition, and assessment of necessary input data, including identification of data gaps needing resolution, further discussed in *Data Discovery Summary Report* (Anchor Environmental Consultant Team 2008a), provided as Appendix A of the main report. After this effort, a *Data Gaps Work Plan* (Anchor Environmental Consultant Team 2008b) was prepared to describe possible methods of addressing data gaps, advantages and limits of each

		method, and estimations of level of effort required to fill each data gap. At this time, the remaining data gaps were filled by the Anchor QEA Consultant Team and the Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) of the Northwest Indian Fisheries Commission and Point No Point Treaty Council (NWIFC/PNPTC).
b.	Formatting of output in an understandable manner	Output data was provided in formatted Microsoft Excel spreadsheets in the manner requested by the GIS Technical Liaison. Each spreadsheet contained a worksheet for the results for each analysis tier. A Visual Basic for Applications (VBA) macro formatted each worksheet in each spreadsheet, standardizing column headers, column widths, and fonts in each results deliverable.
c.	Usefulness of results to support project analysis	***To be prepared by the NST Change Analysis Team***
d.	Ability to export results into project reports	Because the database design capitalizes on the interoperability of the Microsoft Office suite of tools, results can be easily added to project reports in Microsoft Word or Excel.
e.	Training availability	***To be prepared by the Corps***
f.	Users documentation availability and whether it is user friendly and complete	***To be prepared by the Corps***
g.	Technical support availability	***To be prepared by the Corps***
h.	Software/hardware platform availability to all or most users	***To be prepared by the Corps***
i.	Accessibility of the model	***To be prepared by the Corps***
j.	Transparency of model and how it allows for easy verification of calculations and outputs	***To be prepared by the Corps***