Quality Assurance Project Plan

Feeder Bluff Mapping of Puget Sound

Personal Services Agreement #C1200221

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1.0 Title Page

Quality Assurance Project Plan

Puget Sound Feeder Bluff Mapping Project

July 31, 2012

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2.0 Abstract

Effective implementation of policies to protect beaches and nearshore habitats on Puget Sound requires maps showing the location and extent of sensitive areas such as feeder bluffs. This allows local governments to identify potential concerns during planning efforts, to develop appropriate policies for these areas, to effectively permit development applications, and to defend against subsequent appeals. Unfortunately, although many jurisdictions have policies related to feeder bluffs, only about half of Puget Sound's shoreline has been mapped for feeder bluffs. In addition, sources of data on which to base new mapping are often of inadequate resolution, inappropriate for identifying potential sediment sources, and/or require geological expertise to interpret correctly. The overall goal of this project is to complete the necessary mapping tasks including an assessment of currently available data and the completion of a Puget Sound-wide dataset that is relatively consistent with existing mapping information. By completing this dataset and providing it to local governments and the public, guidance for better shoreline management may be applied to coastal restoration and appropriate protection measures of Puget Sound shorelines.

3.0 Background

Puget Sound has almost 2,500 miles of shoreline east of Cape Flattery and south of the Canadian border, half of which consists of sand and gravel beaches and forested coastal bluffs. These beaches and bluffs are part of a dynamic geomorphic system, in which sediment derived from bluff erosion and streams builds spits, forms back-barrier tidal wetlands, creates substrate for spawning forage fish, and maintains beaches in the face of storms, long-term erosion, and sea level rise. The construction of seawalls and bulkheads to prevent the erosion of coastal bluffs prevents sediment from reaching the beach and the local littoral cell. Over time, armoring of these sediment sources can reduce the width of the high tide beach, change sediment size distributions, increase erosion on down-drift beaches, and adversely impact ecological functions.

The term feeder bluff is used on Puget Sound to describe bluffs that provide a significant volume of sediment to the beach. Beaches, sustained by the on-going supply of sand and gravel from feeder bluffs, are a key element in the Puget Sound nearshore ecosystem.

CGS developed methods to efficiently map feeder bluffs, which have been applied to approximately 1,183 miles of greater Puget Sound shoreline to-date (Johannessen 2010). This mapping cumulatively represents the majority of feeder bluff mapping in the region. CGS mapping was conducted as many different mapping projects with mapping areas ranging in length from 20-200 miles. Others have applied similar mapping of nearshore sediment sources, but with different methods, which often did not entail field work. Qwg Applied Geology (Qwg) recently completed remote mapping of Kitsap County sediment source areas. Herrera Environmental Consultants mapped landslides in Thurston County and Amec mapped feeder bluffs in portions of Skagit County.

Feeder bluffs are the focus of intense development pressure due to their beauty and productivity. Property owners understandably seek to reduce erosion along their shorelines, inadvertently upsetting the balance between beaches and their sediment supply.

Much of the challenge for local governments currently updating their Shoreline Master Programs is the need to balance this increasing development with requirements to maintain ecological functions. Many local jurisdictions have policies that discourage armoring on feeder bluffs, but implementation has been difficult without maps. Some jurisdictions have mapped feeder bluffs, but no Puget Sound-wide coverage is available.

The Feeder Bluff Mapping Project was developed specifically to address issues in the Puget Sound Partnership's 2008 Action Agenda, which emphasizes:

- Technical support to local governments updating their Shoreline Master Programs
- Improved protection of feeder bluffs through regulatory measures
- Better management of shoreline armoring
- Restoration of Puget Sound nearshore ecosystems
- Collaboration among groups to protect and restore Puget Sound
- Improved integration of science and management needs

This project ties in closely with other initiatives as well. The Feeder Bluff Mapping Project directly supports local governments in implementing their Shoreline Master Programs. Improved information on sediment sources complements existing restoration planning work by the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP). This will aid the Estuarine and Salmon Restoration Program (ESRP) in prioritizing and evaluating proposed beach restoration and protection projects. Feeder bluff maps will also help the USGS in developing models of future beach conditions based on sediment supply and coastal armoring.

Finally, Ecology, as a member of the Aquatic Habitat Guidelines (AHG) Program, will ensure feeder bluff information is available to and incorporated in future AHG documents, which provide technical assistance to shoreline property owners, local governments, and others.

4.0 Project Description

This project will entail compilation of existing feeder bluff data with new mapping to complete a Puget Sound-wide Feeder Bluff mapping data set. The study area includes all marine shoreline east from Cape Flattery; north to the Canadian border, and south to the southernmost shores of the Salish Sea. Mapping will be focused within net shore-drift cells and not within areas mapped as having no appreciable drift (NAD). The project approach consists of two major tasks; the first of which is exclusively focused on compiling and assessing the relative quality and coverage of existing mapping. Existing mapping that is of acceptable quality will be compiled into an interim data set, which will also include the remaining areas upon which the forthcoming task will be focused. New mapping will primarily be conducted in the field by applying the same mapping criteria that have been used in previous CGS feeder bluff mapping efforts (see Section 8.0). Some areas will be mapped remotely, if they meet the remote mapping standard. New mapping will be digitized and merged with the interim geodatabase to create a contemporary, comprehensive Sound-wide feeder bluff mapping data set. Descriptions of project goals, objectives, and potential (appropriate) uses for the data are included in the following section.

Project Goals

The goals of this project are to deliver a compilation map and database of feeder bluffs and related coastal landforms for all of Puget Sound.

Project Objectives

The project objectives are to produce a comprehensive mapping coverage of Puget Sound feeder bluffs that is suitable for guidance of better shoreline management. To do this, we plan to:

- compile existing information and amend it with new data to fill geographic gaps,
- maintain appropriate spatial resolution, and
- improve overall data quality and documentation.

This mapping project is intended to provide local governments with information about the relative potential for bluffs to contribute sediment to adjacent beaches. The final map and associated feeder bluff inventory database will:

- support the development of appropriate shoreline designations and policies
- help planners identify eroding bluffs important to the long-term maintenance of critical beach habitat, or that are particularly sensitive to human activities such as armoring and upland development
- improve the implementation of Shoreline Master Programs
- allow regional planners to assess progress towards improving the health of Puget Sound (e.g. the Puget Sound Partnership has established a target of reducing new armoring on feeder bluffs)
- assist restoration groups in characterizing the status of key ecological processes
- Prioritize restoration needs (e.g. PSNERP has analyzed sediment degradation on beaches throughout Puget Sound, but this work would be much improved with higher resolution data)

The mapping will not identify geologic hazard areas nor will it be used to make final site-specific management decisions in the absence of additional field investigations. The data will probably have limited value as a baseline for regular monitoring, since the scale of the project area will not allow for that and the project is not designed with that in mind. Additionally, the resolution of the mapping outputs will be are larger than measured changes in the Puget Sound, in which shoreline change occur episodically with little cumulative change as compared to higher energy shores.

5.0 Organization and Schedule

The project team assembled by Coastal Geologic Services, Inc. (CGS) is comprised of experienced professionals in the disciplines and specialties required to accomplish Puget Sound-wide feeder bluff mapping. The project team includes all staff from CGS and the principals of Qwg Applied Geology (Qwg) and Sound GIS, Wendy Gerstel and Allison Bailey, respectively. Leadership roles have been identified for team members based on areas of expertise. Leadership roles of the project team are outlined in Table 1, as well as smaller, task-oriented working groups (Table 2, Figure 1) that have been established to ensure strong communication and cooperation in producing the major elements of this large project.

Key Individuals and Responsibilities

Table 1. Project team and responsibilities.

Jim Johannessen, MS & LEG	Coastal Geologic Services
Project Manager & Principal	

Jim began working on Puget Sound coastal geomorphology and geology analysis in the late 1980s. Jim specializes in mapping and assessment of coastal features, coastal processes, coastal restoration and alternative coastal erosion control design. Jim started CGS in 1993 and has worked exclusively on these issues in the Puget Sound region. He has a deep understanding of the region's coastal processes and management issues based on his experience working directly with local jurisdictions, tribes, and residential landowners in every Puget Sound county.

Jim has mapped net shore-drift cells along more than 500 miles of Puget Sound shore and has worked to collect and compile regional data sets for groups such as PSNERP and US Army Corps of Engineers. Jim has field-mapped feeder bluffs along a cumulative Puget Sound shore length of approximately 500 miles.

Jim serves as senior project manger and senior technical lead. Jim will lead the field mapping working group which will focus on refinement of field mapping methods, field work planning, and data consistency. Jim will be responsible for the overall quality and consistency of the field mapping and will serve as one of the two field team leads, with a focus on North Puget Sound and the Hood Canal regions. Jim is a collaborating member of the QAPP working group and will contribute to the development and planning for the project. Jim is also a member of the remote mapping working group, where he will assist with development and refinement of remote mapping methods, determine where remote mapping is suitable, and check data for consistency. Jim will provide senior technical oversight of the final report and final mapping products.

Andrea MacLennan, MS **Coastal Geologic Services**

Deputy Project Manager

Andrea's educational and professional background is exclusively focused on coastal geomorphologic and ecologic processes. She has worked at CGS since 2003 and in Puget Sound since 1999, over which time she has conducted mapping projects and assessments in every county in the Puget Sound region from Budd Inlet to Point Roberts. She specializes in using GIS tools and metrics to inform restoration planning and coastal management. Andrea was the only private sector professional to work on each of the major efforts of the Puget Sound Nearshore Ecosystem Restoration Project. She has lead hundreds of miles of field-based feeder bluff mapping, revised net shore-drift mapping Puget Sound-wide, aided in the development and application of an historic sediment supply mapping approach and recently developed an approach to identify nearshore habitats vulnerable to implications of sea level rise. Andrea has also worked on characterizing and highlighting the importance of feeder bluffs in numerous Shoreline Master Program updates including: the cities of Steilacoom, University Place, Coupeville, Gig Harbor, and Whatcom, Jefferson, Island, Pierce, Mason, and Clallam Counties.

Andrea is the lead for the GIS working group and is a collaborating member of the QAPP, Field Mapping, and QA/QC working groups. She is also a field team lead, with a focus on south Puget Sound. Andrea is deputy project manager and will oversee day-to-day task management, QAPP implementation, communication within the team, and client communication.

Wendy Gerstel, MS, LEG & LHG **Qwg Applied Geology**

Senior Geologist

Wendy is principal and owner of Qwg Applied Geology and a licensed geologist, engineering geologist, and hydrogeologist in Washington. She has over 30 years of experience in geologic mapping and engineering geology investigations throughout the U.S., with the past 20 years in Washington. Wendy works with local, state, federal, and tribal governments; non-profits; and private landowners throughout the Pacific Northwest to advise on land use and risk management relating to geologic hazards, Wendy is an expert in coastal geology and slope stability assessment. She has mapped glacial deposits in Puget Sound and the Olympic

Peninsula, and provides technical input to shoreline managers, planners, engineers and other scientists on permitting, restoration, landslide mitigation, and responsible development.

Wendy is the lead for the remote mapping working group and is a contributing member to the QAPP working group. She will lead the development of landslide mapping methods; particularly those based on LiDAR analysis, as well as provide added objectivity in the assessment of existing feeder bluff data. Her input will focus on mapping coastal and adjacent upland geology and slope processes, and assure smooth merging of newly-collected data.

Allison Bailey, MS **Sound GIS**

Senior GIS Analyst

Allison is the principal of Sound GIS and has over 15 years experience using GIS and remote sensing for natural resource management, specializing on Pacific Northwest coastal areas. She is trained as a biologist and has applied this expertise and analytical skill to numerous projects. A defining characteristic of her approach to GIS is to use appropriate and scientifically valid tools and techniques for each problem, and to avoid allowing the tools to dictate or limit the questions of the project. Allison is an expert with GIS and spatial analysis and specializes in customizing databases for technical teams.

Allison is the lead for the QA/QC working group and a collaborating member of the GIS working group. Allison will develop QA/QC procedures for evaluating spatial and attribute quality of existing feeder bluff mapping. She will also develop QA/QC procedures to assess spatial and attribute quality of new feeder bluff mapping, for both field and remote mapping methods. For the GIS working group, Allison will provide guidance and hands-on support on geodatabase design, data synthesis, GIS workflow approaches and efficiencies, automation, spatial analysis, QA/QC, and documentation.

Jonathan Waggoner, BS **Coastal Geologic Services**

CAD/GIS Analyst

Jonathan has participated in a wide range of coastal monitoring and restoration projects in the Puget Sound over his six years at CGS. His experience includes data collection (as survey manager), feeder bluff mapping, advanced GIS analysis, collaborating on design, overseeing implementation, and quantitative beach and bluff monitoring. As an experienced computer programmer, Jonathan brings a wealth of technical expertise to CAD and GIS projects.

Jonathan is a collaborative member of the GIS working group and a contributing member of the QAPP working group. As a GIS technical analyst, he will play a major role in gathering and evaluating previous feeder bluff mapping data. He'll also have a supporting role during field data collection and processing.

Stephanie Williams, BA/BS **Coastal Geologic Services**

Associate Geologist/GIS Analyst

Stephanie has an educational background in both geology and ecology, and has eight years of experience working for state and local governments, as well as NGOs. At CGS, Stephanie conducts feeder bluff and geomorphic shoretype mapping, shore change analysis, research in support of Shoreline Management Plan (SMP) updates and shoreline restoration assessments,

beach monitoring surveys, residential field assessments, various GIS applications, and education outreach and workshop coordination. To date, Stephanie has experience mapping, compiling and producing GIS data for six feeder bluff mapping projects at CGS.

Stephanie is the lead for the QAPP working group and is a contributing member to the GIS, remote mapping, and field mapping working groups. By providing support to several working groups Stephanie will act as a go-between for smooth communication and project efficiency. For the GIS working group Stephanie will prepare usable existing data for compiling and digitize GPS data from field mapping. She will be conducting field mapping with both field team leads. Stephanie will also work with Wendy Gerstel to map areas remotely, acting as another set of eyes and quality control measures, as Stephanie is very familiar with the different shore types mapped along the Puget Sound shore. Throughout the duration of the project Stephanie will play a supporting role, dispensing information to team members as needed.

Alexis Blue, PE and MS **Coastal Geologic Services**

Coastal Engineer, GIS Technician

Alexis has 10 years of experience in coastal construction, numerical modeling, coastal enhancement design, and dredging projects. She is an experienced project manager having worked for the U.S. Army Corps of Engineers (USACE) and private consulting firms (RETEC/AECOM). At CGS, Alexis applies her skills to coastal mapping, restoration and enhancement including: physical modeling of coastal systems, GIS mapping, and CADD analysis and design.

Alexis is a contributing member to the QAPP working group. Alexis' role for this project is to provide GIS, field, and Quality Control support as needed.

Table 2. List of working groups and respective leads and members.

Group	Lead	Members
QAPP	Stephanie Williams	All team members
GIS	Andrea MacLennan	Allison, Jonathan, Stephanie
Remote Mapping	Wendy Gerstel	Jim, Stephanie
Field Mapping	Jim Johannessen	Andrea, Stephanie
QA/QC	Allison Bailey	Andrea, Jonathan

Project Organizational Chart

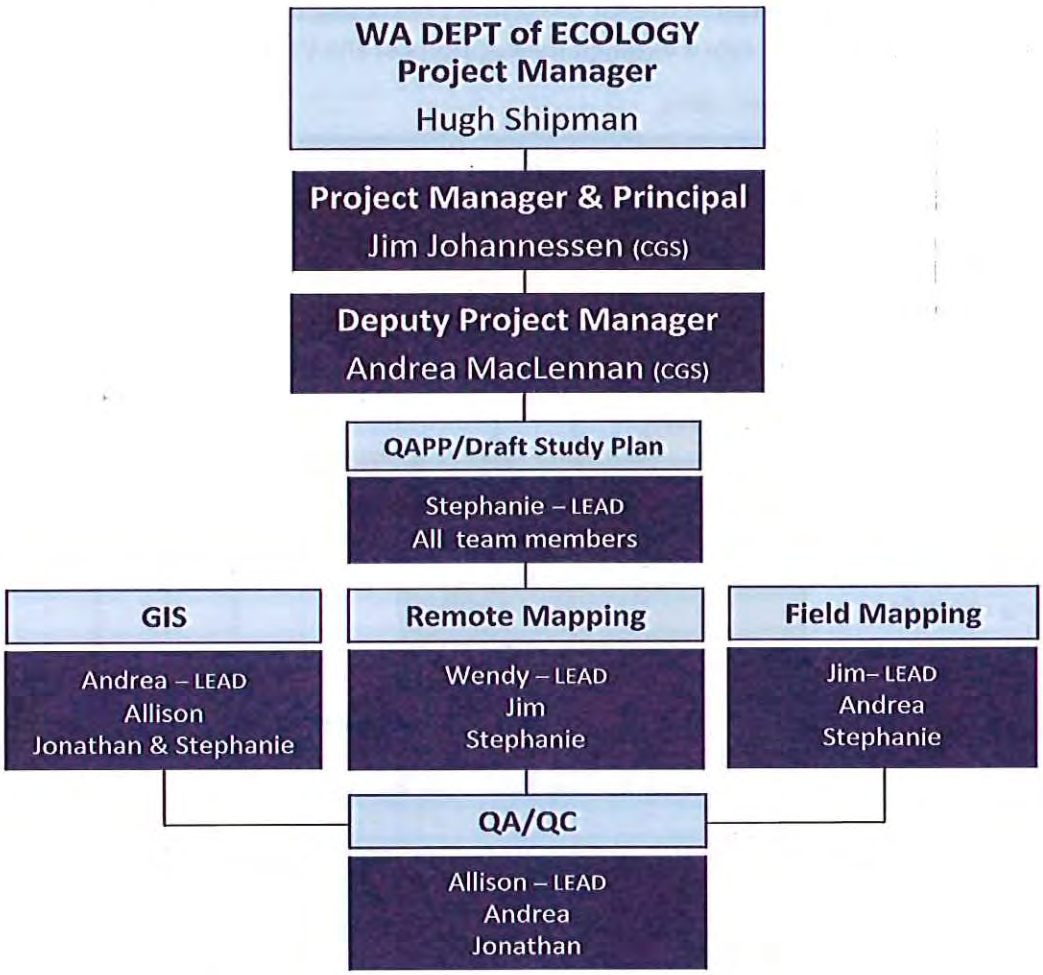

Figure 1. Project organizational chart.

Project Schedule

The overall project schedule is provided in the list of contract tasks and deliverables that follow in Table 3. Please see Section 7.0 for more detailed descriptions of the Project Tasks.

Table 3. Project timeline with sub-task delivery dates.

Task	Deliverables	2012							2013			
		June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	**Develop Project Plan & Study Design**											
1.1	Draft study design	6/14										
1.2	Final study design		7/27									
2	**Assess & Compile Existing Feeder Bluff Information**											
2.1	Existing Data report-draft				9/27							
2.2	Existing Data report-final					10/11						
2.3	GIS Coverage					10/11						
3	**Complete Mapping of Puget Sound Feeder Bluffs**											
3.1	Interim data and status updates					10/24	11/20			2/6		
3.2	Draft report										3/15	
3.3	Final report											4/30
3.4	Sound-wide GIS coverage											4/30

Limitations on Schedule

Factors that could cause delays or otherwise affect the project schedule are shown in the bulleted list below. All measures will be taken to avoid delays in the project schedule.

- Delayed QAPP approval
- Personnel availability
- Equipment availability
- Foul weather and small craft advisories

Budget and Funding

Budget and funding for this project is listed below by task (Table 4.)

Table 4. Budget per task and sub-task.

TASK/DELIVERABLE	COST
1 – Project Plan and QAPP/Study Design	**$36,904**
1.1 - Project management, coordination, planning, and draft development	
1.2 - Finalize QAPP/Study Design	
2 – Assess and Compile Existing Feeder Bluff Mapping	**$57,316**
2.1 - Inventory previous mapping, assess quality and criteria for usability, form recommendations and methods, draft assessment report	
2.2 - Final assessment report	
2.3 - Compile usable existing data into single GIS coverage	
3 – Complete New Feeder Bluff Mapping	**$205, 780**
3.1a (Remote mapping) - LiDAR interpretation, ground truth, digitizing, QC, data corrections	
3.1a (Field mapping)- Form field plan, schedule, routes, QC, data corrections	
3.1b - Summarize and analyze data, finalize digital data	
3.2 - Prepare draft report	
3.3 - Finalize report	
3.4 - Prepare and deliver final maps	
TOTAL	**$300,000**

6.0 Quality Objectives

Data quality objectives for this project are focused on repeatability and consistency in interpretation, sensitivity (scale and resolution), as well as comprehensiveness. Feeder bluff mapping is an interpretative process, as opposed to a statistically based sampling design, that uses expert-level assessment and a clearly described mapping criteria, to describe and delineate features that are part of a continuum. Therefore, it is difficult to determine the absolute accuracy of the interpretation from an objective standard. Rather, our quality objectives aim to systematically produce a high-quality, comprehensive geospatial data set with a landform classification that is consistent across regions and shoretype attribute interpretations that are repeatable by other experts.

Spatially, it is most important that the shoretypes are delineated on a single, consistent shoreline that is commonly used by state, federal, and local entities, so that these data can be

used with other existing data sets for planning and analysis. Because of this consideration, it is of less importance to evaluate the absolute accuracy and precision of the shoretype locations. The final geospatial shoretype data set will meet quality objectives for attribute and spatial consistency, repeatability, comprehensiveness, and to a lesser degree, positional accuracy (see Table 5).

Measurement Quality Objectives

Data quality objectives were developed for data collection that will occur during the major elements of this project (Table 5).

Table 5. Quality criteria set for the final geospatial shoretype data set.

TARGET	CRITERIA
Attribute Consistency	All shoreforms, for both existing and new data, will be classified according to the classification system described in Table 8. All interpretation will be conducted by a trained coastal geomorphologist/geologist with a minimum 10 years of experience delineating shoreforms in the study area. New mapping and shoreform interpretation will be conducted by a small team of experts across the entire study area.
Spatial Consistency	All shoreforms will be delineated on the Washington Department of Natural Resources' ShoreZone shoreline
Repeatability	Comparison of two independent shoretype classifications for a minimum of 30 randomly selected sites (remote and field mapping) will show a 75% (or greater) level of agreement
Comprehensiveness	All segments of shoreline in the study area will be assigned a shoreform type. There will be no null values for shoretype.
Positional Accuracy	The final geospatial data will meet the same positional accuracy as the ShoreZone shoreline (+/- 12-m)

Existing data sets will be assessed for potential inclusion into the final product based on the quality criteria for the final product. For example, the classification system must be compatible, and able to be translated to the final classification system, see Section 8.0, Figure 2.

To systematically limit bias, error in shoretype characterization and measurement (within an acceptable degree), the project includes several built-in cross checks of data collection that will ensure a high degree of quality and consistent map coverage of feeder bluffs and related coastal landforms throughout the entire Puget Sound (see Section 9.0).

Existing Data Screening Criteria

Compilation and adequacy of all existing data will be conducted independently by team members. Existing mapping data compilation is underway, however assessment will not be initiated until QAPP approval occurs. Reports and studies that may be suitable to use as

existing data are recorded in a table that includes evaluation of the quality, resolution and other factors contributing to adequacy and ultimate usability of that data for this project (see Appendix 1, still under development). Further discussion of existing data usability can be found in Section 8 and Figure 2.

New Feeder Bluff Mapping

Areas within the Puget Sound not previously mapped, or mapped but found inadequate for use as existing data, will either be mapped remotely or mapped in the field. Criteria for determining areas appropriate for remote mapping or field mapping were developed by the technical leads for this project and are outlined in the following two sections.

7.0 Sampling Process Design

The project is essentially a geomorphic mapping effort carried out using rules-based field mapping techniques (mapping criteria), augmented by remote mapping in relatively easily assessed areas, with data products developed in GIS. Therefore it is not technically a sampling effort in the traditional sense, but instead follows mapping criteria and protocol similar to most geomorphic/geologic mapping. The term sampling will be used here for consistency with other QAPP documents.

The sampling process follows mapping criteria established in early feeder bluff mapping projects in Puget Sound with minor revisions to boost efficiency and improve accuracy. The earlier sampling processes were designed by CGS with technical input from regional experts (Johannessen and Chase 2005). The revised sampling process for this project was designed by CGS in collaboration with Qwg and Sound GIS to complete comprehensive mapping coverage of feeder bluffs and related coastal landforms of Puget Sound. The elements of this project design are described in the task list below. In addition to developing the project design (Task 1), this study design is essentially comprised of two separate tasks; assessing and compiling all existing feeder bluff data (Task 2) and completing feeder bluff mapping and integrating Task 2 data with new mapping into a single Puget Sound-wide coverage (Task 3). Each major task is comprised of different elements some of which require specific methods, that have been described in previous sections of this document (Tables 5 and 6, Section 8), while others will be described in greater detail in Section 8. A general description of each task is provided below.

Assess & Compile Existing Feeder Bluff Information (Task 2)

The objective of this task is to compile and assess the relative quality of existing feeder bluff mapping data sets to screen appropriate data sets for inclusion into a larger Puget Sound-wide data coverage. The data quality assessment will evaluate all known feeder bluff data sources, to determine if they are appropriate for inclusion as-is, with minor adjustments, or insufficient. Criteria have been developed for this assessment, which is detailed in Section 8. The assessment report will identify opportunities to improve existing mapping where inadequate, inconsistent, or of lower quality, within the constraints of the project.

Following data screening, areas will be identified where feeder bluff data gaps exist. This may be due to previous mapping being if insufficient scale, quality, or consistency, or because it was never mapped in the first place. Currently 721 miles of Puget Sound shoreline appear to

require mapping, however, that number may be reduced. The data screening will also include recommendations regarding methods for mapping remaining areas (which will be carried out in Task 3), including where remote or field mapping would be the most appropriate mapping method. It will also include additional interpretation of areas in which mapping is not required, referred to as areas of no appreciable-drift (NAD). These shores will be further described to better explain the absence of littoral drift.

This task concludes with the delivery of an interim GIS geodatabase of feeder bluffs and closely associated landforms for all of Puget Sound, based on previous mapping work. Areas will be clearly outlined where new data should be collected, both remotely or in the field, and where mapping is not necessary due to the absence of littoral drift. This preliminary data set provides multiple functions, as it clearly spells out where new mapping will occur (in Task 3), provides an interim product for potential users of the data, and an initial dataset that Ecology can work out protocols for deploying the final data set on its GIS servers.

In addition to the GIS deliverables, an assessment report will summarize the availability and character of existing data and identify areas where adequate mapping is not available. Methods used in mapping data sets will be summarized and important differences and inconsistencies in data collection, resolution and accuracy will be reported. The report will describe the overall results of the data assessment and the ensuing recommended approach to complete feeder bluff mapping Puget Sound-wide.

Complete Mapping of Puget Sound Feeder Bluffs (Task 3)

A combination of field work and office methods will be used to complete mapping of feeder bluffs and related shoretypes on all remaining Puget Sound shorelines, as identified in Task 2. Mapping will include both remote and field-based methods, with field mapping occurring at the majority of the Puget Sound shores. Field mapping is primarily driven by on-the-ground observations and application of a well-defined mapping criteria (Table 7). Field-based classifications are reviewed in the office while assembling the data in to GIS.

Field mapping and remote mapping will adhere to the criteria and methods outlined in Section 8 (*Sampling Procedures*), along with any additional recommendations made in Task 2. The minimum mapping unit size will be 20 ft in length (alongshore). During mapping the shoreline will be delineated into shoreform types using GPS waypoints that note shoreform breaks. This method is consistent with many other CGS feeder bluff mapping methods, and will provide added consistency across the larger Puget Sound study area. The date of mapping, mapping approach, and additional supporting information such as drift cell name and direction will be noted in the attribute table (Appendix 3). A photographic record (referenced to a GPS point) will be maintained to illustrate representative and anomalous shoretypes, mapping criteria, and problem issues and areas. New mapping will be compiled with existing mapping continually as it is collected. Preliminary mapping data will be submitted to Ecology in installments by county or other agreed upon geographic areas.

The final GIS geodatabase delivered to Ecology will cover the entire shoreline of Puget Sound, including both the existing data compiled in Task 2, the new Task 3 mapping, and all NAD shorelines. All geographic data will meet Ecology and EPA/WDFW grant requirements and metadata will comply with Federal Geographic Data Committee (FGDC) standards (http://www.fgdc.gov/metadata/geospatial-metadata-standards/). The final mapping products

will be produced at a 1:24,000 scale, which has an accuracy standard of better than 67 ft for 90% of known points (United States National Map Accuracy Standards http://nationalmap.gov/standards/nmas.html).

The Task 3 report will include, at a minimum, an executive summary, brief background, a detailed description of methods, a summary of mapping results with breakdowns by geographic area, and a discussion of major findings. The report will also include recommendations for future work, identification of data needs important (scientific) uncertainties related to sediment source mapping on Puget Sound. Figures and photographs will be included where appropriate. The report will include maps covering the entire Puget Sound shoreline at a printed scale of no less than 1:100,000. A final map portfolio will be developed that includes comprehensive coverage of the entire Puget Sound region at 1:24,000 scale. .

8.0 Sampling Procedures

Sampling procedures for the Feeder Bluff Mapping project is interpreted to be the specific methods in which existing data will be assessed and new mapping will be conducted both in the field and remotely. The methods are described in detail below.

Incorporating Existing Mapping

All existing feeder bluff mapping data will be carefully and objectively evaluated for methods, mapping unit definitions (e.g. minimum mapping units, fundamental definitions), and accuracy. Twenty-two mapping data sets have been compiled thus far. Data fields have not yet been populated with assessment data, however the blank assessment matrix is found in Appendix 1. The fields used to assess the relative quality of data sets include: date, methods, resolution, coverage, consistency, format, availability, and the degree to which adaptations are required to incorporate the data into the project geodatabase. The Appendix 1 table will be populated as Task 2 commences (following QAPP approval). Once the table is complete, each feeder bluff mapping data set will be systematically evaluated for inclusion or rejection using the criteria shown in Figure 2.

Some existing mapping data sets will be incorporated with minor revision/adaptations to meet the objectives of this project, while others may be included in an ancillary capacity only to inform remote mapping decisions. An example of minor adjustments to datasets would be where older feeder bluff mapping used slightly different terminology for the two types of feeder bluffs mapped. Mapping data from this area is anticipated to be "cross walked" with some additional interpretation to produce mapping using the current typology. This process is outlined in Figure 2. A few datasets may be unsuitable for the objectives of this project due to a lack of field verification and sole use of data sets that are now out-dated (such as shoreline oblique images from the 1990s).

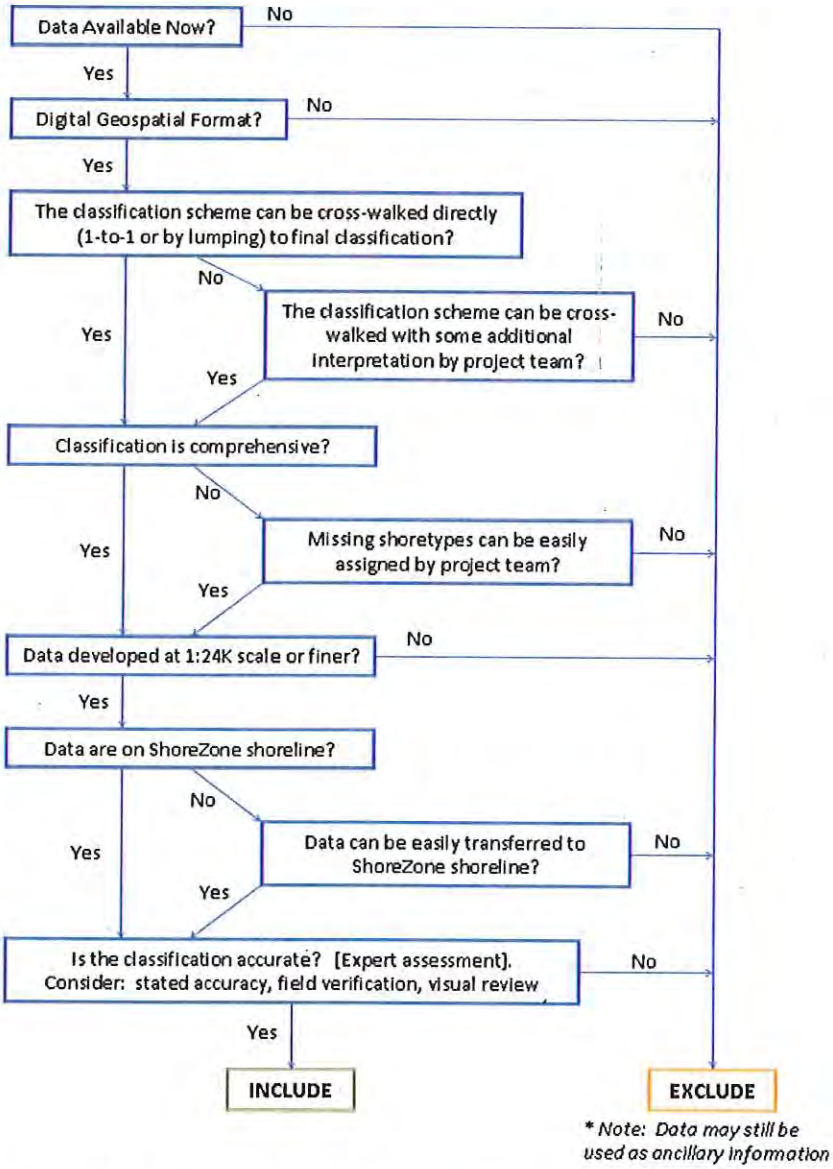

Figure 2. Flow chart showing the inclusion or exclusion criteria for existing mapping projects for incorporation into the Puget Sound-wide data-set.

All CGS feeder bluff mapping results from this project are expected to be usable for the purposes intended because they will be prepared with appropriate resolution and largely following the same consistent mapping criteria. Several elements of early CGS feeder bluff mapping projects will require some revision and adaptation. For example, CGS mapping in eastern Jefferson and eastern Mason County are not currently on the WDNR Shorezone shoreline so this mapping will need to be slightly adjusted for incorporation into the feeder bluff mapping geodatabase. Some other small inconsistencies occur across the various data sets (for example the addition to the typology of "feeder bluff exceptional", as mentioned above). Each of these issues will be documented and evaluated as part of this task.

Mapping Methods

Mapping methods are based on those developed over 13 years of CGS feeder bluff mapping with slight adaptations to fit the needs of this larger Puget Sound-wide mapping project. The

earlier applications of the methods can be found in such documents as *Island County Feeder Bluff and Accretion Shoreform Mapping* (Johannessen and Chase 2005), *Inventory and Assessment of Current and Historic Beach Feeding Sources/Erosion and Accretion Areas for the Marine Shorelines of Water Resource Inventory Areas 8 & 9* (Johannessen et al. 2005), *Assessing Littoral Sediment Supply (Feeder Bluffs) and Beach Conditions in King and Southern Snohomish Counties, Puget Sound, WA* (Johannessen 2010). Methods for this project are further described herein.

The large majority of the remaining portions of the study area (on the order of 575 miles) will be mapped using the field-based approach. Remote mapping will likely occur along approximately 20-25% of the remaining Puget Sound shoreline to be mapped. The same general methods apply to remote mapping, which can be efficiently and effectively completed along appropriately selected shores. Shores appropriate for remote mapping should meet the criteria shown in Table 6 and include: more exposed portions of the eastern Strait of Juan de Fuca and Central Puget Sound Basin, among other locations.

Table 6. Criteria for determining remote and field mapping locations.

REMOTE MAPPING	FIELD MAPPING
High wave energy shores, not in major embayments	Bays and inlets
Relatively linear shorelines	Shores with moderate to high complexity
Bedrock shores	Areas where mapping needs revisiting or field truthing
Digital visibility: No or low shading of landform	Low digital visibility: shaded or north-facing shores

All feeder bluff mapping (field and remote mapping) will adhere to a specific set of mapping rules that were developed for identifying geomorphic shoretypes, as outlined in Table 7 and Figure 3. Field mapping is conducted by interpreting field mapping characteristics and criteria while traversing the shoreline in a small boat at mid to high tides, close to shore. Continuous mapping units are delineated by placing a waypoint, using a hand-held GPS. Waypoint numbers are recorded on a field form along with other observations such as landmarks,, and field photo numbers. The field mapping forms are included in Appendix 2. The detailed methods associated with GPS field data collection and GIS data processing are described in detail in Appendix 3 *GPS Standard Operating Procedures* and Appendix 4 *GIS Data Processing and Specifications*, respectively. Remote mapping will similarly place GIS points to delineate shoreform types while traversing the shoreline; see the following section for additional explanation.

The standard CSG feeder bluff mapping criteria entails delineating the shoreline into one of 9 different alongshore segments, or shoretypes including: feeder bluff exceptional, feeder bluff, feeder bluff-talus, transport zone, accretion shoreform, no appreciable-drift - bedrock, no appreciable-drift - low energy, no appreciable-drift - delta, and modified. All shoretypes can be found in net shore-drift cells, except for areas with no appreciable-drift (NAD), which by

definition are found outside of shorelines where net shore-drift occurs. Toe erosion and landslides will also be mapped as ancillary data within/across the shoretypes as they occur.

Table 7. Criteria to define feeder bluffs and related coastal landforms for remote and field mapping. Note criteria are listed in order of priority within each category.

Presence:	Absence of:
Feeder Bluff Exceptional (FBE, Figure 3a)	
1. Steep bluff/ bank 2. Recent landslide scarps 3. Bluff toe erosion 4. Abundant sand/gravel in bluff 5. Colluvium/ slide debris 6. Primarily unvegetated or vegetated slumps 7. Trees across beach 8. Boulder/ cobble lag	1. Shore protection/fill 2. Backshore 3. Old/ rotten logs 4. Coniferous bluff vegetation 5. Bulkhead
Feeder Bluff (FB, Figure 3b)	
1. Steep bluff/ bank 2. Past landslide scarps 3. Intermittent toe erosion 4. Moderate amount sand/gravel in bluff 5. Intermittent colluvium 6. Minimal vegetation 7. Trees across beach 8. Boulder/ cobble lag	1. Shore protection/fill 2. Backshore 3. Old/rotten logs 4. Coniferous bluff vegetation 5. Bulkhead
Feeder Bluff - Talus (FB-T, Figure 3c)	
1. Steep bluff/ bank 2. Past landslide scarps, mapped landslides 3. Bedrock lithology, bedding or jointing conducive to breaking 4. Intermittent toe erosion 5. Intermittent colluvium 6. Minimal vegetation on bluff face 7. Trees across beach 8. Boulder/ cobble lag	1. Shore protection/fill 2. Backshore 3. Old/rotten logs 4. Basalt, or other moderate-high strength rock 5. Bulkhead
Transport Zone (TZ, Figure 3d)	
1. Coniferous bluff vegetation 2. Apparent relative bluff stability 3. Gentle slope bluff (relative alongshore) 4. No bulkhead at transport zone adjacent	1. Visible landslide scarps 2. Toe erosion 3. Backshore & backshore vegetation 4. Old/rotten logs 5. Colluvium 6. Trees across beach 7. Shore protection/fill
Accretion Shoreform (AS, Figure 3e)	
1. Backshore & backshore vegetation 2. Lagoon/wetland/marsh behind berm 3. Backshore "platform" 4. Old/rotten logs 5. Fine, well-sorted sediment (relative alongshore)	1. Bluff/bank in backshore 2. Toe erosion at bank 3. Landslide scarps 4. Boulders on beachface 5. Shore protection/fill

Table 7 Con't. This table identifies criteria to define feeder bluffs and related coastal landforms for remote and field mapping. Note criteria are listed in order of priority within each category.

Modified (MOD, Figure 3f)	
1. Shore armor/seawall, revetment/bulkhead	1. Toe erosion at bank

2. Boat ramp, groin, rubble, 3. Large quantity of debris/fill	2. Landslide scarps
NAD-B (No Appreciable-drift – bedrock, Figure 3g)	
1. PSNERP mapping: bedrock ramp, plunging rocky or pocket beach 2. Bedrock in intertidal and backshore (WDNR) 3. Bedrock in shallow subtidal	1. Sand/gravel in bank 2 Continuous, active beach
NAD-LE (No Appreciable-drift - low energy, Figure 3h)	
1. Salt marsh vegetation 2. Silt/fine sand in intertidal	1. Continuous, active beach 2. Toe erosion at bank 3. Landslide scarps
NAD-D (No Appreciable-drift – delta, Figure 3i)	
1. PSNERP mapping: delta 2. Sand flats/ marsh 3. Distributary channels	1. Continuous, active beach 2. Bank or bluff

a) Feeder bluff exceptional - Double Bluff, Island Co

b) Feeder bluff - Normandy Park, King County

c) Feeder bluff-talus - East of Salt Creek, Clallam Co

d) Transport zone - North Fidalgo Island, Skagit Co

Figure 3. Photos of representative geomorphic shoretypes from CGS feeder bluff mapping projects.

e) Accretion shoreform - Indian Cove, Shaw Island

f) Modified - Puget Sound, Bainbridge Island

g) No appreciable-drift - bedrock

h) No appreciable-drift - low energy

i) No appreciable-drift - delta

Figure 3 Continued. Photos of representative geomorphic shoretypes from CGS feeder bluff mapping projects.

Remote Mapping

Several different methods have been applied for remotely mapping feeder bluffs and related landforms in Puget Sound. Remote mapping offers the advantages of:

1. Covering more area in a shorter amount of time than field-based mapping (thereby resulting in cost savings to meet the project budget and needs of the client where conditions allow for results of acceptable resolution),
2. Facilitating the identification of larger landforms (such as deep-seated landslides) that can be difficult to distinguish on the ground,
3. Helping to guide the prioritization of ground-based observations, and
4. Being useful in mapping where steep, unstable, and often dangerous slopes preclude ground access.

Remote mapping will follow the same mapping criteria and typology as field based (detailed above), but will be carried out using the data sets outlined below. The rationale for the selection of where to conduct remote mapping is discussed above and summarized in Table 6, above. Within remotely mapped reaches, a select portion will be cross-checked with field-observations (see Section 9.0 for additional detail).

Previous remote feeder bluff mapping efforts have included work by CGS in portions of Clallam and Whatcom Counties. Most recently, Qwg has completed remote mapping of sediment

sources in Kitsap County. We will employ the mapping methods similarly to those CGS has applied in the past, with the addition of LiDAR analyses. The relative accuracy of each of these approaches has not yet been fully explored or compared, but will be evaluated as part of Task 2. For this method oblique shoreline photos, LiDAR imagery, and geologic mapping (at 1:24,000 and 1:100,000 scale) will be interpreted and analyzed using an interactive GIS virtual "fly-over" technique to view the shoreline and adjacent uplands. The "fly-over" technique entails systematically reviewing data sets while virtually moving along shore while delineating shoretype start and end points, similar to field mapping. For the higher energy and more linear shores selected for remote mapping, the distinguishing features of the different shoretypes (Table 7) can typically be clearly seen in oblique shoreline photos. Other data sets that will be accessed during remote mapping include net shore-drift mapping (Schwartz et al. 1991, Johannessen 1992), and the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) landform typology (Simenstad et al. 2011).

The remote mapping is anticipated to be done jointly and simultaneously by two team members; one a senior level coastal geomorphologist/geologist with extensive experience mapping geology in Puget Sound, the other a GIS specialist with a background in geology and familiar with established Puget Sound feeder bluff mapping protocol. This will make seamless the transfer of data from remote visual mapping tools into GIS framework. Furthermore, the two sets of eyes making observations during the "fly-over" will provide quality control through virtual "on-site" discussion (similar to the dialog that might occur at an outcrop.)

In addition to feeder bluff mapping, net shore-drift mapping will also be reviewed and revised as needed, particularly in areas currently mapped as having No Appreciable Drift (NAD). Many areas mapped as NAD represent bedrock shores, and therefore do not have adequate sediment supply for littoral drift to occur. These areas will be identified using surface geology and PSNERP shoreform mapping and re-mapped as NAD-B (bedrock). NAD shores are also found at the mouth of major river deltas, which are dominated by fluvial deposition, rather than wave processes. These NAD shores will be further defined as NAD-D (delta). Other NAD shores have little sediment transport due to an absence of wave energy such as at the head of embayments or the inner shores of a lagoon. These areas will be further identified as NAD-LE (low energy).

9.0 Quality Assurance and Quality Control

Quality assurance and control (QA/QC) protocols were developed to meet our quality objectives. The focus of the QA/QC protocols is to produce a high quality shoreform data set with repeatable methods that are consistent across Puget Sound.

A number of procedures and best practices will be followed during field and remote mapping in order to promote development of a high quality data product. Many of these QA/QC measures will be documented in the Task 2 and 3 Logs (Appendices 5 and 6, respectively), which is further discussed in Section 11.0 *Audits and Reports*. The overall QA/QC procedures include the following:

- Expert Mappers – all field mapping team leads have a minimum of 10 years of experience identifying and mapping shoreforms in Puget Sound.

- Group Training – At the beginning of the mapping program field mappers will conduct group mapping sessions in the north and south regions of the Puget Sound that include a variety of shoretypes. This exercise will create a shared understanding of mapping protocols, field mapping operations, and classification methods (Section 8, Table 7, and Figure 3) and will promote consistency in field mapping once teams are working independently. Group trainings will be documented on the field sheets and also noted on the Feeder Bluff Mapping QA/QC Measures Table (Appendix 6).
- Team-Based Mapping – All mapping will be conducted by teams of two (or more) and include a lead expert geologist or geomorphologist. In addition to practical and safety considerations, team-based mapping provides an opportunity to interactively check on mapping decisions and criteria during the mapping process.
- GIS Data Development by Field Team – Transfer of data from field mapping data sheets and GPS files to final GIS format is conducted by field team members. This process provides an additional quality check on the source field data, as well as minimizing errors in data transcription that can be caused by a lack of domain knowledge.
- Field Verification of Remote Mapping Sites – Some field verification of the sites chosen for remote mapping will be conducted to ensure that the remote mapping methods are accurate. Areas verified by field mapping will be noted in Appendix 6.
- All shoretype start and end locations will be transferred to the ShoreZone shoreline in order to retain the positional accuracy of the source shoreline.
- Task 2 and Task 3 Logs will be used to document the mapping process, track task progress, and review QA/QC protocol application. These logs are currently under development but will be completed before work for Task 2 or 3 is started.

Shoretype Classification Assessment

As stated in the Data Quality Objectives (Section 6.0), it is difficult to assign an absolute accuracy value to an interpretive process. However, we will conduct independent assessments, or cross-checks, of a sampling of mapped shoretype segments, to provide an estimate of the level of repeatability in assigning shoretypes.

- Remote mapping cross-check: 1-2% of the linear extent of mapping will be classified by two teams independently. Results will be recorded with an error matrix (Table 8). If total agreement of shoretypes is less than 75% more training sessions will be issued until the total agreement is greater than 75%.
- Field mapping cross-check: 1-2% of the linear extent of mapping will be visited by both field teams independently. The second field team will assign a shoretype to the site and compare this to the shoretype assigned by the first team. Results will be recorded with an error matrix (Table 8). If total agreement of shoretypes is less than 75% more training sessions will be issued until the total agreement is greater than 75%.

Validation and assessment of shoretype classification will be conducted as a regular component of data processing and development. This will allow the team to catch potential errors and inconsistencies earlier in the mapping process and develop approaches to increase consistency

and repeatability in the classification. Extra effort will be spent on assessment of shoretypes that are the most difficult to distinguish, specifically feeder bluffs and transport zones.

Table 8. Error matrix example.

		Team 1									
	Shoretype	FBE	FB	FB-T	TZ	AS	NAD-B	NAD-LE	NAD-D	Mod	Total
Team 2	FBE	25	3	0	0	0	0	0	0	0	28
	FB	4	26	0	2	0	0	0	0	0	32
	FB-T	1	1	30	0	0	0	0	0	0	32
	TZ	0	0	0	28	2	0	0	0	0	30
	AS	0	0	0	0	28	0	0	0	0	28
	NAD-B	0	0	0	0	0	29	0	0	0	29
	NAD-LE	0	0	0	0	0	1	30	0	0	31
	NAD-D	0	0	0	0	0	0	0	30	0	30
	MOD	0	0	0	0	0	0	0	0	30	30
	Total	30	30	30	30	30	30	30	30	30	270
	% Agree	83%	87%	100%	93%	80%	97%	100%	100%	100%	

Total Agreement: 95%

10.0 Data Management Procedures

Multiple sources and types of data will be collected as part of this mapping project. Data management procedures include a list of existing mapping that is deemed adequate for use integration into the Puget Sound-wide GIS formatted data set, new remote mapping data conducted for portions of Puget Sound (to be determined in Task 2, see Table 6 for criteria) and new field mapping data which includes GPS points processed in GIS with associated data including completed field forms and field photos. The way in which data will be managed for each of the three mapped/mapping products is described below.

Data Compiling

Existing Data

A number of existing mapping products are already available to team members for use in this project (Appendix 1). Other data under consideration for use in this project will be obtained from the various agencies, jurisdictions, or companies who hold this data. It is anticipated that groups who hold existing data will be cooperative in releasing it for screening and potential inclusion into the Puget Sound-wide feeder bluff mapping data set. However, if we are unable to obtain existing data for screening we will map the data either remotely or in the field based on the criteria outlined in Section 8.0.

Existing data will likely include text documents, PDF documents and maps, and GIS shapefile data. GIS shapefile data is the preferred data format and will be stored in a geodatabase on the CGS network server that undergoes daily incremental back up with off site archive. All team members will have full access to data files most of which can be emailed or transferred via the online Dropbox which is currently being utilized to collectively draft this QAPP document.

Existing data that passes the initial screening test, based on the criteria outlined in Figure 2, will be compiled into a single shapefile for working towards the final GIS deliverable. The GIS final

deliverable, as well as attribute data and metadata, is detailed in Appendix 4 GIS Data Processing and Specifications.

Data Recording

Remote Mapping

A tested and efficient method of remote data collection will be used to capture and record shoretypes and larger landscape features into the GIS framework. This will be done jointly by two team members; one a senior coastal geomorphologist/geologist with extensive mapping experience in Puget Sound, the other a GIS specialist with a background in geology and familiar with established Puget Sound feeder bluff mapping protocol. The shoretype interpretation of the remote mapping areas will be primarily input directly into GIS by way of delineating shoretypes by splitting the Shorezone shoreline at shoretype start and end-points. By inputting remote mapping interpretations directly into GIS while working side by side, the potential to introduce errors in data or information transfer that could result from intermediate products, such as additional maps or photo/LiDAR overlays, is eliminated. A brief log will record information including team members, areas mapped, data sources used to inform shoretype interpretation, and questions that come up upon completion of each working day. A printed version of the remote mapping will be used for QC protocols by the team members and a reviewed during the *Data Verification* process (see Section 12.0).

Remotely mapped GIS data with completed attribute tables will be merged with the existing compiled data and data collected in the field to produce the final map and database products.

Field Mapping

Field mapping will be compiled from GPS data points in conjunction with field form notation as described in detail in Appendix 3. After each day of field mapping all field data will be transferred and backed up to a laptop computer. This will include GPS points, field photographs, and photographs of the field data sheets. Field mapping in remote areas of the Puget Sound will require several days of mapping in a row. When the field team returns to the office the GPS points will be transferred into Arc GIS and shoretypes will be processed in accordance with methods described in Appendix 4.

11.0 Audits and Reports

Audits

Several elements of the project design and QA/QC protocols are built-into the project and will serve as audits throughout the duration of this project. Many of the items listed below are included in Section 9.0 *QA/QC* and 12.0 *Data Verification* in further detail. The results of these built-in audits will be documented in the appropriate log book (see below in next subsection) and corrective actions to conform to QA/QC measures will take place immediately or on the next available working day.

- The evaluation criteria for screening existing data for adequacy will serve as an audit of data quality of the existing data used in this project (Figure 2). Existing data that passes this screening test for primary or ancillary use in feeder bluff mapping will be stored in the appropriate geodatabase (see Appendix 4 for details). Citations of the existing data

will be included in the final report. Screening the data will be conducted by the QA/QC working group lead and a senior geologist/geomorphologist.

- Remote and field mapping will be cross-checked along 1-2% of the linear extent mapped to ensure that the shoretype interpretations are calibrated accurately among the senior coastal geomorphologists/geologists using the 2 different methods. Results of the remote and field mapping cross-checking will be recorded in an error matrix (Table 8). If considerable error (less than 75% agreement) exists between the 2 mapping methods then more field training will be required. See section 9.0 under Shoretype Classification Assessment.
- Since there will be 2 field mapping teams, a cross-check at a select number locations is planned to see how they compare. The results will be recorded in an error matrix. If considerable error exists between the shoretype interpretations of the field mapping teams then more field training will be required and discussions of how field teams can come to consensus will take place. See section 9.0 under Shoretype Classification Assessment.
- The Ecology project administrator, Hugh Shipman, has expressed interest in participating in at least one day of field mapping. As a regional expert in coastal geology with considerable background understanding of Puget Sound shorelines, Hugh will serve as an objective auditor of shoretype interpretation. This will be conducted early in the field mapping schedule to ensure that all senior coastal geomorphologists/geologists are in agreement with shoretype interpretations.

Reports and Task Logs

Task 2 and Task 3 project deliverables will be completed in accordance with the Project Schedule (Table 3) and summarized for incorporation into the final report. This will serve as the majority of content for the final report, but other supporting information will be included in the final report (as previously described in Section 7; Task 3 description).

The project team will initiate internal logs for each task to document exchange of ideas; changes made to methods; QA/QC measures taken, in need of addressing, or in need of correcting; and/or any other circumstances where record keeping would serve the needs of the project. If an external audit of this project were to occur steps taken in this project could be easily researched based the documentation within the logs. The Task 2 Log and Task 3 Log will be used as a project management tool.

12.0 Data Verification

The final shoretype classification and geospatial data will be verified in the following ways:

- A subset of the final shoretypes will be reviewed and results recorded via an error matrix. The total accuracy (# matching /total) will be compared to the target of 75% level of agreement.
- Shoretype attributes will be queried to ensure that there are no null values, and that all values correspond to the list of shoretype codes in Table 8.

- The net shore-drift shapefile attributes will be queried to ensure that all shoretypes correspond correctly to the presence or absence of littoral drift. For instance a feeder bluff should not be mapped in an area of no appreciable-drift (NAD) and NAD-B (bedrock) should not be mapped in a drift cell.
- Shoretype and drift cell attributes will be cross-referenced to assure that all combinations are logically consistent. The drift cell attribute field used for querying will be CELL_TYP where DZ (divergence zone), RtoL (right to left), and LtoR (left to right) indicate presence of a drift cell and NAD (no appreciable drift) indicates absence of a drift cell. The following table (Table 8) shows which shoretypes should be found within a drift cell and which shoretypes should be found outside of a drift cell or no appreciable-drift.

Table 9. Shoretypes that should be found in presence of absence of drift cells.

Shoretype	**Drift Cell**	**No Appreciable-drift**
FBE	X	
FB	X	
FB-T	X	
TZ	X	
AS	X	
NAD-B		X
NAD-LE		X
NAD-D		X
MOD	X	X

- The geospatial data will be checked to confirm there are no gaps in shoreline segments (dangling nodes) that are not present in the source ShoreZone shoreline.
- Mapping products will be reviewed by a senior geomorphologist to assure consistency in shoretype interpretation. This additional review will result in confirmed interpretation of remote shoretype mapping from 3 geologists/geomorphologists.

13.0 Data Quality (Usability) Assessment

These data are intended for use by local, state and federal shoreline planners, policy makers, and restoration planners to identify, protect and restore critical shoreline types of Puget Sound. If the data meet the criteria identified in Section 6.0 Quality Objectives, they will be acceptable for use by the intended audience. Currently, the available data for these purposes is incomplete and not available in a consistent format. Providing a Puget Sound-wide coverage of shoretypes on a single shoreline will be a vast improvement and will facilitate improvements in regional shoreline planning.

Data will be provided to Department of Ecology as a single, unified geodatabase with comprehensive shoreline coverage throughout Puget Sound. Shoretype data will also be summarized in a series of maps. The Department of Ecology will ultimately distribute the data and prepare accompanying guidance materials for end users.

14.0 References

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Appendix 1 – Existing Data Compilation and Evaluation Table (Task 2)

EXISTING DATA	Citation author, date, report	Available Now	Digital Geospatial Format	Classification scheme 1 to 1 with FINAL	Classification scheme w/ interp for FINAL	Classification is comprehensive	Missing shoretype easily assigned to FINAL	Consistency of data to mapping protocols	Resolution (1:24K preferred)	Data on ShoreZone shoreline	Data easily transfer to ShoreZone shoreline	Classification accurate (a, b, c)	a) Stated accuracy	b) Field verification	c) Visual review	Include for FINAL	Include as ancillary with FINAL	Exclude
Shoreline Rest. Prio.and Feasibility Study																		
Kitsap LiDAR interpreted LS mapping																		
Thurston Co landslides mapping																		
Mason Co DNR landslides mapping																		
Other DNR geologic mapping -1:24K, 1:100K																		
USGS geologic mapping - 1:100K																		
Geology & Landslide Mapping of Tulalip																		
Skagit Co landslide mapping																		
Coastal Zone Atlas of WA mapping																		
Anchor Env Bainbridge Is. mapping																		
USGS mapping (WA CZA??)																		
WDNR Shorezone database																		
PSNERP change analysis mapping																		
East Jefferson Co FB mapping																		
Portions of Mason Co FB mapping																		
Island Co FB mapping																		
WRIA 8 & 9 FB mapping																		
Portions of Whatcom Co FB mapping																		
Portions of Skagit County																		
Kayak Pt (Snohomish Co) FB mapping																		
Bainbridge Island FB mapping																		
Portions of Pierce Co																		
San Juan County																		
Clallam County																		

***FINAL EVALUATION conducted by QA/QC lead and senior geomorphologist**
See also Figure 2.

Appendix 2 – Field Forms

Puget Sound FB Mapping Field Data Collection - Coastal Geologic Services - 2012				
Date:	**Name:**		**Mapping Area:**	
Weather:			**Comments:**	
Start Waypoint	**End Waypoint**	**Feature**	**Photo #**	**Comments**
Shoretypes: FBE, FB, FB-T, TZ, AS, MOD, NAD-B, NAD-LE, NAD-D Ancillary Data: LS, TE				

Appendix 3 – GPS Standard Operating Procedures

Global Positioning System Unit:

Positional waypoint data are recorded using a handheld *Trimble GeoXH 2008* GPS unit in the WGS84 coordinate system. The GPS unit is WAAS (wide area augmentation system) enabled, the range of accuracy is a function of the number of satellites within range, but is typically less than 1 m real time. The GPS automatically calculates and records the dilution of precision for each position, and alerts the user if the value falls below a given threshold, thereby assuring a certain standard of accuracy. The estimated accuracy of these positions is ± 1.5 ft. Base data from the Washington Continually Operating Reference Stations (CORS) will be used to post-process the waypoint locations.

Operating Procedures:

Collecting Field Data

Features are mapped by collecting GPS waypoints based on field observations from a small boat offshore at mid to high tides with good visibility. Field mapping criteria (Table 8) are applied to map individual segments in the field based on observed shoreline features. GPS waypoints are collected and noted at the beginning and end of each field-mapped segment as close inshore to the position of mean high water (MHW) as possible.

Field Form Notation

The waypoints are correlated to shoretype segments that occur between the noted waypoints. For instance, the start of a segment noted as FB starts at waypoint 50 and ends at waypoint 51 as noted on the field form, so the segment between these waypoints is identified as a feeder bluff. Corresponding photographs and notes are recorded on field forms. As well, ancillary data such as landslides, toe erosion, or potential restoration areas may be noted on the field form. See Appendix 2 for field forms and Section 8.0, Table 8 for shoretype abbreviations.

Data Backup

Data collected from each field day will be transferred to a laptop after each working day (if electrical power is available). This includes GPS waypoint data, field photographs, and photographs of each field sheet. Batteries for GPS and camera will be charged each night and an extra battery will

Data Processing

The GPS data are then downloaded for processing using Pathfinder Office (Trimble Corporation), where the data were post-processed using reference station SC02 from Washington State Reference Network (http://www.wsrn.org/). Post-processed data are then exported into ESRI shapefile format. The shapefile is then renamed and assigned the appropriate projection that the data were collected in (Washington State Plain South), and then ready for use in ArcMap 10.0 where the waypoint number will correspond with field data forms.

Appendix 4 – GIS Data Processing and Specifications

GIS Data Deliverables:

- Task 2.2: A single GIS data set of Puget Sound, showing existing feeder bluff mapping where available and adequate, as well as areas needing revision or mapping.
- Task 3.1: Intermediate GIS data products showing new mapping and revisions to date
- Task 3.4: Final GIS data set of Puget Sound shorelines, indicating the extent and location of all feeder bluffs and related landforms.

All data will meet Washington Department of Ecology (Ecology) GIS data standards, http://www.ecy.wa.gov/services/gis/data/standards/standards.htm. Data will be provided with Federal Geographic Data Center (FGDC) compliant metadata, http://www.fgdc.gov/metadata/geospatial-metadata-standards/.

GIS Data Format: All GIS data will be provided in ESRI geodatabase format according to Ecology standards. If the data are small enough (< 1 gigabyte), the personal geodatabase format will be used. Otherwise, the file geodatabase format will be used. It is expected that each data deliverable will be provided as a single geodatabase.

Common Spatial Framework: All final feeder bluff GIS data will be transferred to or directly mapped onto Washington Department of Natural Resources (WDNR) ShoreZone shoreline geography, http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_inventory_projects.aspx. (Note: the ShoreZone attributes will not be retained in the final data set, just the shoreline delineation). The ShoreZone shoreline meets Ecology's specified map accuracy standard of ±40 feet, http://fortress.wa.gov/dnr/app1/dataweb/metadata/dnr_shorezone_metadata.htm.

ArcGIS topology tools will be used to validate that the final GIS products are spatially coincident with the source ShoreZone shoreline.

Spatial Reference System: All GIS data will be provided in Washington State Plane South projection, NAD-83 HARN datum, U.S. survey feet units according to Ecology GIS data standards.

GIS Data Attributes: The following data attributes will be included in the final GIS data, both for existing data sets and new mapping.

Attribute Name	Description	Type	Allowed Values
Shoretype	Code for Final Shoretype	Text (6)	FBE, FB, FB-T, TZ, AS, NAD-B, NAD-LE, NAD-D, MOD
Historic_FB	Flag for presence of historic feeder bluff	Text (25)	Yes, No, Unknown, Not Assessed
Landslide	Flag for presence of landslide	Text (25)	Yes, No, Unknown, Not Assessed
Toe_Erosion	Flag for presence of toe erosion	Text (25)	Yes, No, Unknown, Not Assessed
DCELL_NR	Drift Cell Identifier	Text (20)	From Net-shore drift data set -- alphanumeric identifier
CELL_TYP	Drift Cell direction or type	Text (4)	From Net-shore drift data set -- DZ, CZ, RtoL, LtoR, NAD
HistFB_Method	Method used to determine historic feeder bluff presence	Text (25)	Field, HSSI, Not Applicable

Data_Source	Shortened data source name	Text (40)	Abbreviation for each source, including the year. Full reference will be provided in metadata
Source_Stype	Shoretype from source data	Text (6)	Track this when possible. This will be the basis for the translation from the source classification to the final shoretype
First_Stype	Initially assigned shoretype. Will be compared to the review shoretype. Rules will be developed to assign final shoretype when First_stype and Review_stype disagree and it is not an obvious transcription/data entry error	Text (6)	FBE, FB, FB-T, TZ, AS, NAD-B, NAD-LE, NAD-D, MOD
Review_Stype	The shoretype assigned by the reviewer. For QA/QC comparison with the originally assigned shoretype. This will be the basis of the error matrix	Text (6)	FBE, FB, FB-T, TZ, AS, NAD-B, NAD-LE, NAD-D, MOD
Review_Date	Date that the segment was validated/reviewed	Date	A valid date
Reviewer	Initials of the person who validated/reviewed	Text (2)	WG, JJ, AM, SW, JW
Status	Flag to indicate status of the section of shoreline with regards to completion, need for revision, or need for new mapping	Text (20)	Complete, Needs Revision, To be Mapped

GIS Data Processing Methods:

Existing Feeder Bluff Data Compilation

Once existing shoretype data are determined to meet the criteria for inclusion in the final data compilation (Section 8.0, Figure 2), the GIS data are processed according to the following process:

1. Transfer attributes from the source data set to the ShoreZone shoreline, using automated tool in ET GeoWizards (http://www.ian-ko.com/ET_GeoWizards/UserGuide/Snap_Polyline_Wizard.htm). This has been work through using Mason County data as an example.
2. Edit shoreform end-points to correct location and trace additional sections of ShoreZone shoreline that do were missed during Step 1.
3. Use ArcGIS topology tools to compare newly created shoreline with shoreform attributes to the original ShoreZone shoreline. ArcGIS Topology rule: New Shoretype feature class "Must Be Covered by Feature Class of" ShoreZone. (This means the arcs must be coincident). Fix any errors that remain and repeat this process until they are completely coincident.
4. If necessary, translate shoretype attributes from original data classification to final shoretype classification (Section 8.0, Table 8).
5. Perform data validation/review on the designated subset of features.

After data for each individual source data set are transferred, revised, and validated, they are merged into a single spatial data set.

Field Mapping

The following process is used to develop shoretype maps from field mapping data (GPS and field data sheets):

1. Display GPS points from field mapping (Appendix X and Section 8.0) in ArcMap, along with digital background information, including US Geological Survey (USGS) quadrangles, and the most recent orthorectified images, the ShoreZone shoreline (WDNR 2001), and historic topographic sheets (T-sheets).
2. Split ShoreZone shoreline into shoretypes within ArcMap at a scale no larger than 1:3,000 using GPS points and the field notes while visually interpolating the points shore-normal (perpendicular) to the ShoreZone shoreline.
3. Perform data validation/review on the designated subset of features
4. Use ArcGIS topology tools to confirm that final shoretype data are coincident with ShoreZone shoreline.

Remote Mapping

The GIS data development process for remote mapping is similar to that of the field mapping, in that it uses on-screen digitizing of shoretypes. However, the primary source information for assigning shoretypes consists of ancillary digital data, photos, and maps.

1. Display georeferenced digital imagery and supporting data in ArcMap, such as high resolution orthorectified images, LiDAR, geologic mapping, oblique aerial photos, and the ShoreZone shoreline (WDNR 2001)).
2. Split ShoreZone shoreline into shoretypes within ArcMap using all relevant information.
3. Perform data validation/review on the designated subset of features
4. Use ArcGIS topology tools to confirm that final shoretype data are coincident with ShoreZone shoreline.

Final data from all data sources will be merged into a single, contiguous and comprehensive shoretype data set on the ShoreZone shoreline. GIS data reviews will include final topology validation, as well as checks on the attribute values to confirm that they are consistent with the list of allowed values.

Possible attribute fields for new mapping interim products (copied out of section 10, Appendix referenced, and stored here for consideration.

- Date
- Time
- Unique ID number
- Shoretype
- Length (ft)
- Drift cell
- County
- Puget Sound sub-basin
- Start and end geographic location (of each mapping day)
- Data source(s)
- Modification information of modification made to original (where applicable)
- QA/QC check
- Year of original mapping

Appendix 5 – Task 2 Log

Task 2 Log still under development.

Date	Author/Tech	Subject dataset	Task Summary	Task Status	Entered into Assessment spreadsheet

Appendix 6 – Task 3 Log

Task 3 Log still under development.

Date	Mapping Area	Type of Mapping	Mappers Present	Notes/Issues	Action Required
ex. 9/3/12	S Hood Canal	Field Training			
ex. 9/10/12	N Skagit Co.	Field Training			
ex. 9/10/12	NE Kitsap Co.	Field vs. Remote			
ex. 9/17/12	Whatcom Co.	Field vs. Field			