British Columbia Estuary Mapping System

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Preface

This report is submitted to the Resources Inventory Committee (RIC) by the Coastal Task Force. The Resources Inventory Committee members are resource specialists from a number of professional disciplines and represent Provincial, Federal, First Nation and private sector agencies and other resource interests. RIC's objective is to develop a common set of standards and procedures for provincial resource inventories.

The Coastal Task Force has identified a number of projects to develop a common set of inventory mapping standards for the coast of British Columbia. This manual provides documentation of the British Columbia Estuary Mapping System. It is one of several mapping standards developed by the Coastal Task Force since the early 1990's.

RIC funding for this work has been provided by the Corporate Resource Inventory Initiative (CRII) and by Forest Renewal BC (FRBC). Funding from these sources does not imply acceptance or approval of any statements or information contained herein by the Provincial Government or FRBC. This document is not official policy of either the government or FRBC.

Abstract

This manual provides a mapping and database system and methodology for large scale (typically 1:5,000) mapping of estuaries. This standard provides an overview of the mapping system, and describes the methodology, database structure and mapping procedures of the system.
The system builds upon an estuarine classification developed by the Ministry of Environment in 1983 (Hunter et al 1983) and integrates components from the following RIC standards:

- British Columbia Physical Shore-Zone Mapping System (Howes et al., 1994),
- British Columbia Biological Shore-zone Mapping System (Searing and Frith, 1995),
- Wetland and Riparian Ecosystem Classification (MacKenzie & Banner, in preparation) and
- Standards for Terrestrial Ecosystem Mapping for British Columbia (Resource Inventory Committee, 1998).
- Terrain Classification System (Howes and Kenk, 1997)

This standard is composed of seven databases that separate biotic from abiotic attributes and point from polygon attributes. The design of this system permits the comparison of estuaries throughout the province, and can easily be updated to incorporate changes in any of the existing standards this work is based upon. It has been developed and structured in a manner that facilitates the incorporation of data from this standard into a GIS. Lastly, this standard is applicable for research or scientific applications, as data collection methods are rigorous and the database and mapping structure has been designed with research needs in mind.

Acknowledgments

Funding of the Resource Inventory Committee work, including the preparation of this document, is provided by the Corporate Resource Inventory Initiative (CRII) and by Forest Renewal BC (FRBC). Preliminary work of the Resources Inventory Committee was funded by the Canada-British Columbia Partnership Agreement of Forest Resource Development FRDA II.

The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nation peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report ‘The Future of our Forests”.

For further information about the Resources Inventory Committee and its various Task Forces, please refer to the RIC website at: http://www.for.gov.bc.ca/ric

Coastal Task Force, Resource Inventory Committee

This document has been prepared by Don Howes, Mary Morris and Mark Zacharias. Trevor Davis, John Harper, and Carol Ogborne also contributed to this standard. The estuary mapping system was developed for the Coastal Task Force of the British Columbia Resource Inventory Committee. The idea for developing an estuary mapping system originated with the scientific authority, Mr. Don Howes, who provided administrative, technical and financial support.

An early draft paper on estuary classifications and techniques was prepared by Trevor Davis and John Harper for discussion in a one-day workshop prior to the development of this classification. We would like acknowledge the collective contribution of workshop participants: Helen Berry, Washington State Department of Ecology; Carmen Cadrin, Resources Inventory Branch, Ministry of Environment, Lands and Parks; Trevor Davis, Department of Geography, University of British Columbia; Patricia Halpern, Oregon State University; John Harper, Coastal & Ocean Resources Inc.; Don Howes, Land-Use Coordination Office; Colin Levings, Habitat Group, Fisheries and Oceans Canada; Will McKenzie, Ministry of Forests; Mike McPhee, Quadra Planning Consultants; Ken Morgan, Canadian Wildlife Service; Sarah North, Habitat Group, Fisheries and Oceans Canada; Rob Russell, Habitat and Enhancement Branch, Fisheries and Oceans Canada; Joe Truscott, Ministry of Agriculture, Fisheries and Food; Ken Warheit, Washington Department of Fish and Wildlife; Maureen Wayne, Habitat Conservation Trust Fund, Ministry of Environment, Lands and Parks, Will McKenzie, Carmen Cadrin and Ted Lea assisted in coordinating this standard with the newest revisions to the Terrestrial Ecosystem Mapping and new Wetland Classifications from the terrestrial group. They also provided valuable input on various versions of this standard.

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1.0 Introduction

1.1 Purpose

The purpose of this manual is to describe a Resources Inventory Committee (RIC) standard for mapping the biophysical character of British Columbia's estuaries. The mapping system is intended to facilitate the collection and organization of biophysical information with the objective of designing a flexible system that meets the requirements of a broad spectrum of potential uses. The system is compatible with existing standards (including TEM) developed by the Coastal Task Force and RIC. The manual details the conceptual framework used to develop the mapping system, mapping procedures and an estuary mapping database (and data dictionary).

The mapping system is descriptive in approach, and provides a framework for describing the physical and biological character of an estuary. It has been designed for detailed, large-scale mapping. A scale of 1:5,000 or larger is suggested, as this scale permits a level of inventory appropriate for detailed studies and analyses. The mapping system allows for the ability to combine biophysical attributes within a flexible framework for various planning and scientific applications. A comprehensive, linked database has been developed that allows the mapper to record information related to the estuary or units within the estuary (e.g. physical and biological units).

This manual provides an update on an earlier Estuarine Habitat Mapping and Classification System developed by Hunter *et al.*, (1983). The system represents an integration of features and components from the British Columbia Biophysical Shore-zone Mapping Systems (Howes *et al.*, 1994, Searing and Frith, 1995), the Wetland and Riparian Ecosystem Classification (MacKenzie & Banner, in preparation), and the Standards for Terrestrial Ecosystem Mapping in BC (Resource Inventory Committee, 1998).

1.2 Background

The estuarine ecosystem includes components of marine, aquatic and terrestrial systems as well as the interactions between these realms. As a result, there are a number of RIC mapping/inventory standards in British Columbia that record various aspects or features of estuaries. They include:

- British Columbia Physical Shore-zone Mapping System (Howes *et al.*, 1994),
- British Columbia Biological Shore-zone Mapping System (Searing & Frith, 1995),
- Wetland and Riparian Ecosystem Classification (WREC MacKenzie & Banner - in preparation)
- Terrain Classification System (Howes & Kenk, 1997)
- Standards for Terrestrial Ecosystem Mapping in BC (Resource Inventory Committee 1998)

These RIC standards have been reviewed to identify where these different mapping systems overlap and to ensure that this estuary mapping system is consistent with them. The following is a brief summary of each program.

British Columbia Physical Shore-Zone Mapping System

The BC Physical Shore-Zone Mapping System (Howes *et al.*, 1994) is a descriptive mapping system for recording the physical character of the shoreline at a variety of map scales. It involves the subdivision of the shore-zone into along-shore *units*. Units are portrayed as line segments or polygons depending on the level of survey and the scale of the base map used for presentation. These segments are subdivided into across-shore *zones* according to relative across-shore elevation and across-shore *components* within each zone.
Unit components are described according to their form, material, slope and width. *Form* refers to the morphological character or surface expression; material is a description of the surficial material. In most instances, the primary form of this mapping system includes a description of geomorphic processes such as marine, coastal and fluvial (e.g. beach – coastal).

Most of the physical shoreline mapping in British Columbia has been conducted as part of a regional inventory program. The spatial information is usually presented on 1:40,000 to 1:50,000 scale maps. At these scales, most shoreline units including estuaries are depicted as linear segments and are accompanied with an across-shore description of their form and material. Larger estuaries however, are mapped and subdivided into units. Each unit is accompanied with attributes that characterize the unit. The Cowichan Estuary in the Strait of Georgia is an example of an estuary mapped as discrete units during a regional inventory project. The system has been designed for multiple mapping scales and has been used for detailed physical shore-zone mapping of the Saanich Peninsula.

Each along-shore unit is also classified into a *coastal class* that provides a general description of the unit's geomorphology. Estuaries are one of 34 coastal classes identified and are defined as being: "characterized by a highly variable distribution in texture [of sediments] although muds and organics are common. Wetland grasses frequently rim the estuary at the high water mark. Brackish water conditions are common due to freshwater input to the estuary from stream runoff. Exclusively confined to low wave-exposure environments."

The British Columbia Biological Shore Zone Mapping System

The BC Biological Shore-Zone Mapping System (Searing & Frith, 1995) is a descriptive mapping system for recording the biological character of the shoreline at a variety of map scales. The purpose of the system is to standardize the methodology for recording and mapping biological characteristics of the marine shoreline and provide a clear and concise database structure. Data related to community and species are collected from a combination of aerial and ground surveys that attempt to relate species composition of observable elevational "bands" on aerial video with observed community structure from *in situ* sampling.

The biotic mapping system has been integrated with the BC Physical Shore-Zone Mapping System. The physical shoreline structure of units, zones and components are used to define the boundaries for describing the distribution and abundance of species. Components are divided across the shoreline into bands of common biotic assemblages. These bands are visible in aerial video and slide imagery. Species information is collected from site sampling. The biotic information can be combined with physical data to predict the probable biological community present in the area. As a result, information from the British Columbia Physical and Biological Shore-zone Systems can be combined to model shoreline habitat types.

BC Wetland & Riparian Ecosystem Classification (WREC)

The objective of the Wetland and Riparian Ecosystem Classification (WREC) is to systematically classify all wetlands (such as bogs and fens as well as coastal marine estuaries) within a framework of biological and physical characteristics. The WREC framework categorizes wetlands into two components. These are an *ecosystem* component (the biological state and associated biological community) and the *hydrogeomorphic* component (the hydrological processes and geomorphic forms). Subdivisions within each of the components are hierarchical. The biological and physical components are integrated to create repeatable patterns of ecosystem complexes, called a *landscape association.*

WREC defines estuaries within the highest level of the ecosystem components as the *realm* which "occurs at the junction of all primary realms (terrestrial, freshwater and marine)". Estuaries are intertidal ecosystems that receive inputs of freshwater from rivers and saltwater from marine sources. They are defined by the presence of vascular plant species and benthic invertebrates tolerant of waterlogged soils, variable ambient salinity and inundation by tides (Mackenzie & Banner, in prep.).

In the physical component of WREC, an estuary *system* is the highest level of the classification. The system is defined as "intertidal habitats where ocean water is at least occasionally diluted by freshwater runoff from the land…and extends from those areas where salinity is high and freshwater inputs are minimal, to upstream sites with minimal saltwater influence but regular tidal flooding" (Mackenzie & Banner, In prep.). The finest category of the physical component is the *feature* that is equivalent to the *terrain form* used in the BC Terrain Classification (Howes & Kenk, 1998).

Three estuarine *classes* are currently defined in WREC; each class is characterized by similar vegetation physiognomy (or species guild), hydrology, and water quality. The classes are salt marsh, salt meadow and salt swamp and represent subdivisions within the vegetated part of the estuary. Within each class, *site series* (distinct species assemblages) have been identified.

The WREC is an excellent framework of relating estuaries to other wetlands. However, within an 'estuary' as defined in WREC, areas ***that are primarily in marine-process dominated and not vegetated with vascular, terrestrial vegetation, are not included because they do not meet the 'wetland' criteria of having soil development and rooted vascular vegetation***. WREC does not include codes for algal plant assemblages nor for detailed marine-dominated processes. Thus, the WREC only provides classification units for the upper portion of the estuary.

Terrain Classification System for British Columbia

The Terrain Classification System is a descriptive mapping system designed for mapping geologic processes, landforms and surficial materials (Howes & Kenk, 1997). Terrain mapping involves the identification and delineation of terrain units. Each unit is described in terms of their surficial material (origin), texture, surface expression (form) and geological process. The effective level of mapping is about 1:20,000 scale although it has been used for larger and smaller scale mapping projects.

Some large estuary areas have been mapped using the Terrain Classification System although the major focus of terrain mapping has been in the terrestrial environment above the higher, high water line or log line. Large estuaries are usually mapped as a single unit; occasionally they may be subdivided into a few units due to changes in the origin of their surficial material.

Several aspects of the Terrain Classification System are common to the BC Physical Shore-zone Mapping System as a result of the Physical Shore-zone System being partially based on the Terrain Classification System model. Aspects that are common to the two mapping systems include similar texture classifications for clastic sediments. In addition, the surface expression component in the Terrain Classification System is similar to the *form* of the BC Physical Shore-Zone Mapping System. However, the latter provides more variation and detail than the former. The most significant difference between the two systems is that there is no surficial material component (origin of material) in the Physical Shore-zone Mapping System. Forms in the BC Physical Shore-zone Mapping System however, often provide an indication of origin of a material (e.g. the beach form term implies origin by wave action).

1.3 Estuary Definitions and Background

There are numerous definitions of an estuary, of which perhaps the simplest is "a semi-enclosed body of sea water where salinity is measurably diluted by freshwater." Estuaries are often characterized as having low salinities, shallow depths, high turbidities, excess nutrients, high productivity and low species diversity.

The two main characteristics of estuaries in British Columbia are that they are geologically young, as sea levels did not reach their present state until 5000 years before present, and they are ephemeral, meaning they are depositional environments with life spans of hundreds to thousands of years (Dawes 1998). The primary abiotic processes that influence estuarine ecology include seasonal variation in temperature, wave energy, type and rates of sedimentation, and the nature and amount of freshwater inputs. While low species diversity is a characteristic of all estuaries, these regions provide important spawning, nursery, rearing, staging, and holding areas for numerous species. Estuaries are unique environments, where factors which may be limiting elsewhere in the marine environment (e.g. nutrients) are not limiting in the estuarine realm.

Estuaries have historically been classified using abiotic factors such as geomorphic type, salinity stratification, and tidal currents. Geomorphic types include drowned river valleys, bars across the mouth of a river, fjords and different deltaic types. Classifications based on salinity stratification include well-mixed estuaries that have abundant oxygen for benthic areas versus weakly stratified estuaries with an undiluted layer of sea water near the bottom. Strongly stratified estuaries exhibit a landward transport of sea water and the seaward transport of freshwater. Classification of estuaries by tidal currents yields estuaries with standing wave tides, where tidal amplitude is similar throughout the basin. Progressive wave tides are characterized by a delay as the tide travels up the basin. Between the standing wave tides and progressive wave tides are estuaries with mixed tidal waves, which show characteristics of both types (Dawes, 1998; Day *et al.* 1989).

Many definitions include a combination of geomorphic, hydrologic, and biological elements. A definition incorporating these considerations, and the one used for this standard is "an intertidal, brackish shore-zone linked through ecological processes to surrounding environs (marine, terrestrial and aquatic), generally low energy and characterized by brackish water biotic communities. It is an area of river, tidal and wave process interaction."

1.4 Estuary Definition for this Mapping System

The definition of an estuary for this mapping standard includes the area from the marine limit to –20 metres in the nearshore subtidal relative to the "zero tide" or chart datum.

For practical purposes, indicators of the marine limit include the storm log line or the upper extent of salt tolerant vegetation (e.g. the tree line). River channels below the tree line are included in this system, whereas channels above the tree line are excluded. The lateral boundary of the subtidal portion of the estuary from the low water line to the 20 metre depth is often difficult to establish, particularly if there is insufficient subtidal information related to geomorphology. The lateral boundary of estuaries that occur on open, linear coastlines may be defined by extending a line seaward from where the shoreline changes from estuary to non-estuary morphology (refer to Figure 1). In narrow or constricted inlets, the lateral boundary of the subtidal portion of the estuary may be defined by extending the –20 metre shoreline directly to the shoreline as outlined in Figure 2. These guidelines are presented to assist mappers in establishing estuary boundaries. Prior to establishing these boundaries, each estuary should be assessed using the best information including field observations.

Note that the higher high water and lower low water have slightly different definitions for Canada and the United States. Canadian marine charts show the chart datum at the "lowest normal tide," where the US defines chart datum at "mean lower low water". As a result, the US chart datum is slightly higher in elevation than the Canadian chart datum (Thomson, 1981).

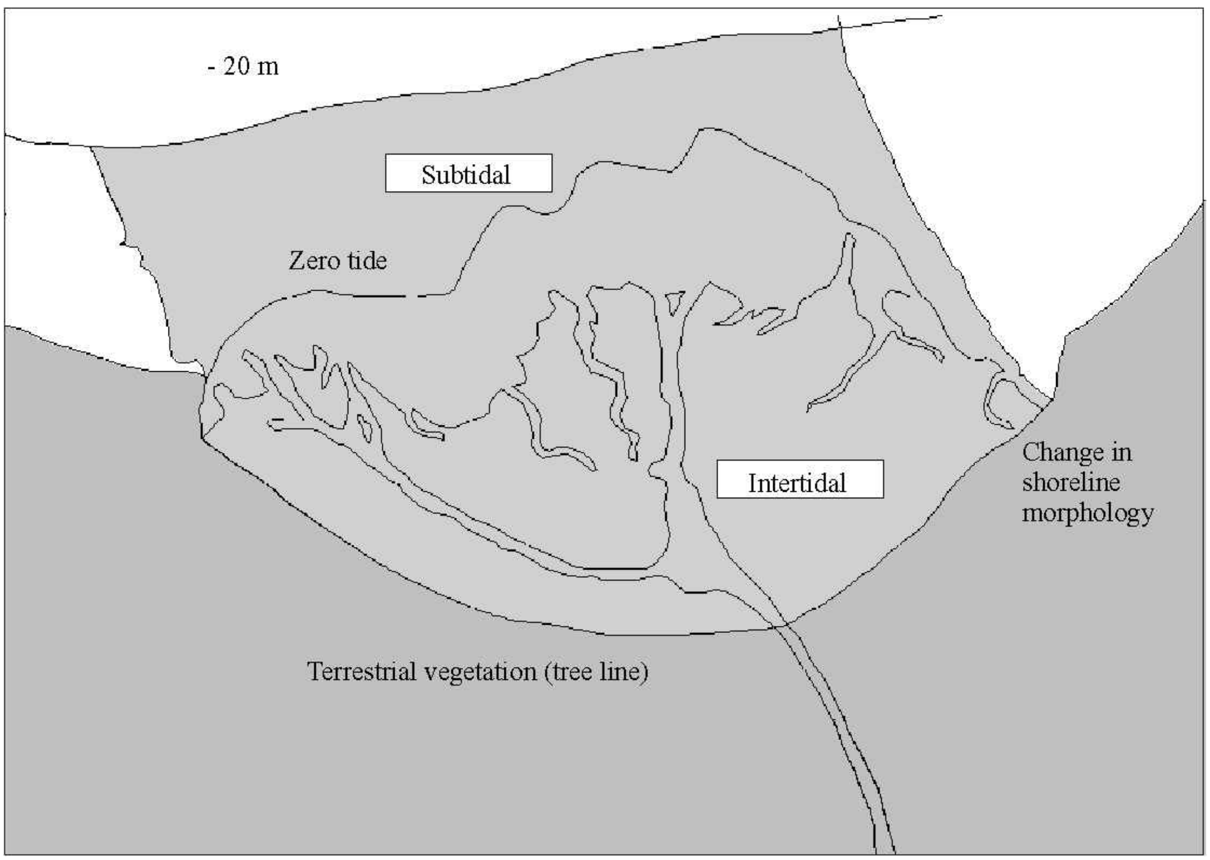


Figure 1 - Planimetric diagram of an estuary on an open coastline.

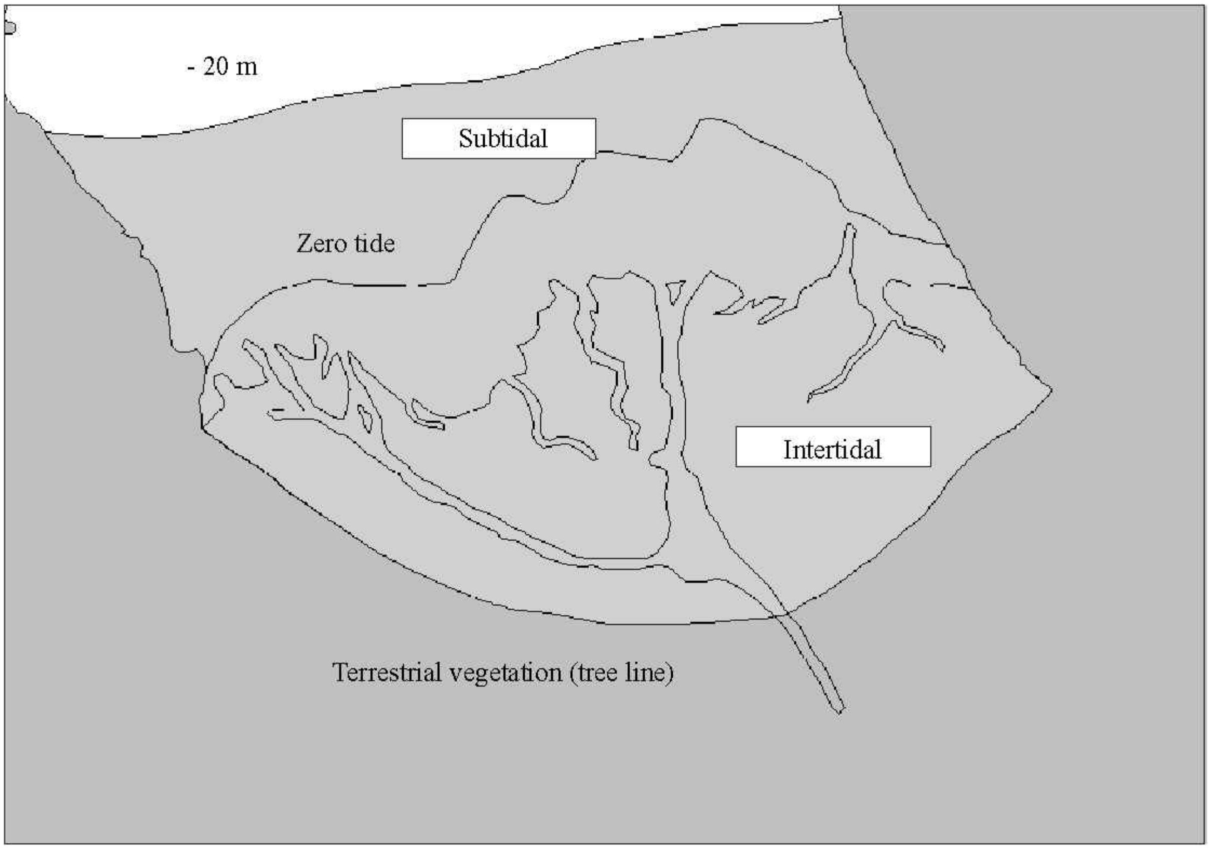


Figure 2 - Planimetric diagram of an estuary in narrow, constricted inlets.

2.0 Philosophy and Approach

The estuary mapping approach presented in this manual is a descriptive system designed for detailed mapping of estuaries at scales of 1:5000 or larger. Design of the mapping system is similar to that previously developed for the biophysical shoreline mapping systems. These RIC mapping systems use a framework of along-shore units, across-shore zones, and other components to independently map the physical and biological character of the shoreline (refer to Background 1.2). The biophysical character is described by a number of descriptive attributes and stored in databases that are flexible in their ability to manipulate data for multiple planning and scientific applications. Both systems are independent of scale and can be applied to different levels of survey. Most of this basic approach has been adhered to in the development of this estuary mapping system. The benefit is a flexible system for the collection and use of biophysical estuary information for practical applications.
The Physical and Biological Shore-zone Mapping Systems were considered to be the appropriate systems to form the basis and structure of the estuary mapping system when they were compared to the WREC and Terrain Classification System. The WREC definition of an ‘estuary’ does not apply to mid and lower elevations of the intertidal zone nor to the subtidal environment. These zones of estuaries (as defined by WREC) are primarily in marine-process dominated zones, and do not meet the criteria for ‘wetland’ of having soil development and rooted vascular vegetation. WREC also does not include codes for algal plant assemblages.

Although some large estuaries have been mapped by the Terrain Classification System (usually as a single terrain unit), this classification was designed primarily for terrestrial mapping, particularly at scales of 1:20,000, 1:50,000 and smaller, although some smaller 1:5,000 and 1:10,000 scales studies have been completed. It was not intended for detailed intertidal and subtidal mapping, whereas both the Physical and Biological Shore-zone Mapping Systems meet this objective

As a result of this review, this estuary mapping system was based on the Physical and Biological Shore-zone Mapping Systems with some minor modifications incorporated from both WREC and the Terrain Classification System. The benefit of this approach is that it will promote integration of the estuary information with the British Columbia Biophysical Shore-Zone Mapping Systems as well as maintaining consistency with other RIC standards. Key features of the estuary mapping system include:

1. The physical character of the estuary is mapped using a modified version of the Physical Shore-zone Mapping System. Modifications include:

- Units are mapped according to their form and material only. There are no across-shore components and across – shore zones based on elevation are mapped separately.
- The primary form “Delta” has been excluded; the primary form “River Channel” has been expanded to include bars and other associated fluvial deposits.
- The primary material descriptor “Ice” has been excluded.
- The organic textures from the Terrain Classification System have been included as secondary material descriptors for organic materials.

2. The biological character of the estuary is mapped according to a modified version of Biological Shore-zone Mapping System. Modifications include:

- Aspects of WREC have been incorporated into the biological descriptions (e.g. description of vascular plant assemblages) to describe the upper intertidal and estuary/terrestrial interface. The classes incorporated are salt swamp, salt meadow, salt marsh, estuarine shallow water, and estuarine tidal flat.
- The species list has been expanded to include species that occur in the upper intertidal and estuary/terrestrial interface.
- The middle and lower intertidal, and the nearshore subtidal, where marine processes dominate, the biota will be mapped using the BC Biological Shore-zone Mapping System species and 'bio-bands' to describe the vegetation and fauna.

Due to the level of detail required for mapping the estuarine features, the preferred inventory base is the use of high resolution, low tide aerial photos (Zoltai & Vitt, 1995). Ground truthing is required to determine vegetation types and other textural parameters. A map scale of approximately 1:5,000 is recommended for the data acquisition and presentation for the estuary mapping system. It is also recommend that estuary mapping be conducted using a team approach (geomorphologist/geologist and biologist). This will help to promote better integration between the physical and biological mapping as well as reducing survey costs.

3.0 General Mapping Procedures

General mapping procedures for detailed estuary mapping are outlined below and follow similar approaches to other RIC standards. The estuary mapping methodology includes the following tasks:

1. Assemble the resource material and other sources of information.
2. Determine estuary overview information.
3. Pre-type the imagery independently mapping the physical and biological units (polygons) and record the attributes in the appropriate database.
4. Using field inspections, verify the pre-typing boundaries and associated information; this includes undertaking sampling plots and visual inspections of the various units.
5. Revise map units and attribute information based on the field verification program to complete final maps.

3.1 Resource Materials and Other Sources of Information

This mapping system is flexible in its use of applicable and available data sources depending on estuary size, composition, and location. The materials required to implement this standard are discussed below.

Imagery

The preferred inventory base for estuary mapping are high resolution colour aerial photos collected during low tide (Zoltai & Vitt, 1995). Low tide colour aerial photos are considered the best data source for mapping estuarine physical and biological units. The air photographs should be georeferenced and produced in a digital format. Scales of 1:5,000 to 1:10,000 are preferred. Alternatively, black and white high resolution, vertical low tide photos can be used. There is some loss of resolution with these photographs, although they are less expensive to obtain.

Base Maps

A base map is required for initial boundary delineation, providing control points for aerial photos, and providing geodetic control for ground surveys. As a general guideline, mappers should seek out the most accurate base map available for a site. Some alternatives include hydrographic charts, the Watershed Atlas, or TRIM maps. The BC Watershed Atlas provides a ‘true’ shoreline at a 1:50,000 scale. TRIM data provides considerable topographic and planimetric control, however it should be noted that TRIM data are designed for use at 1:20,000 and were gathered from 1:63,000 aerial photos. TRIM 2 aerial photos, however are acquired at 1:40,000 scale. Digital coastline data are also available from the Canadian Hydrographic Service (CHS), although they often omit landward features required for aerial photo control. In addition, there is not a consistent systematic coverage at appropriate scales for estuary mapping.

In most instances, mappers may be forced to combine elements from these different map systems to create a base map. The accuracy of the base map is less of an issue when differential GPS is utilized for ground survey. However, ground control is still required for proper air photo pre-typing of the biophysical properties.

Other Data Sources

An overview of larger estuaries may be provided by satellite imagery. Classification of satellite data can be used as a coarse filter for vegetation types. Satellite data has been commonly used for broad scale change detection (regarding in-filling rather than vegetation change) in estuaries in the U.S.

Airborne multi-spectral scanners have only recently been applied to typing coastal vegetation. They have been found to be useful for broad vegetation typing, and can be of use in pre-typing broad vegetation classes and change detection. Spectrographic resolution of finer distinctions in vegetation is primarily limited by variance due to the presence of old vegetation (Aitken & Borstad, 1995; Zacharias *et al.* 1992). However, the fine spatial resolution of such sensors (e.g. 0.8 m) is one of their key attributes in fine scale estuary mapping. At present, these new technologies are generally prohibitively expensive.

Historical air photos, reports and other existing inventory data for the study area permit an assessment of the relative stability of the features. This procedure also facilitates investigation of the influence of anthropogenic impacts on the estuary and may assist in explaining conditions that are difficult to interpret in the field. The original B.C. Estuary Series Maps, using the classification system of Hunter *et al.* (1983) are comparable with the present system.

Other types of data, including ground or air 35 mm photography, aerial video imagery, and any other existing relevant sources may be useful. While georeferencing is not possible from these media, they can provide invaluable typing assistance, especially in recognizing features more apparent from a profile rather than a vertical image.

3.2 Determine Estuary Overview Information

The estuary overview database is designed to provide general information on the overall character of the estuary. Examples of overview information include total area of the watershed, watershed name, and measures of discharge. This overview information allows a regional comparison between estuaries, which can then be integrated with more detailed biotic and physical information collected at much large scales.

3.3 Unit Pre-typing Mapping Procedures

Pre-typing can be completed using digital enlargements of air photos or on transparent overlays on aerial photos. Study area boundaries and biotic and physical units can be identified and mapped from aerial photos. Preferably, a digitizing tablet may be used to enter pre-typed boundaries directly into a GIS. Whether manual or digital, each of the required layers (tidal elevation, biological unit, and physical unit) should be pre-typed on a separate sheet/layer. Boundaries that coincide should be *copied* from the relevant layer rather than redigitized.

A minimum polygon size of 0.5 cm^2 is recommended, following the TEM guidelines (RIC, 1998). This corresponds to an area of 0.125 ha at a scale of 1:5,000, and 0.5 ha at 1:10,000. Items smaller than the minimum polygon size may be included as point or line features (e.g. plot locations or man-made features).

Field Verification and Sampling

Estuary field work involves a combination of marine and terrestrial sampling strategies. The objectives of the field survey are to confirm polygon boundaries and designations, to collect further biophysical data, and to refine the classification of the mapped units.

The field survey intensity of biological resources can be based on the guidelines outlined in the Standards for Terrestrial Ecosystem Mapping (TEM) (RIC, 1998) and should be based on a 'minimum sampling density', where the number of ground sites depends on the overall study area. For estuaries of 20 to 500ha, and map scales of 1:5,000, a survey intensity of approximately one plot per hectare is recommended. Based on an average polygon size of 3 to 4 cm^2, this level of ground inspection means that most polygons will be checked. The TEM methodology further recommends a ratio of full plots to ground inspections to visual checks at a ratio of 2:15:83.

TEM presents these survey intensity guidelines to assist in the design of the field program. The survey intensity selected for the specific estuary project will be dependent on the project objectives and the level of confidence required in the final mapping. Increased reliability is achieved through higher survey intensity and larger scale mapping (RIC, 1998).

Field work should be conducted during the lowest tides of the summer months. Ideally, sampling should take place as close as possible to the dates of the source material (air photos or airborne scanner data), but late enough in the growing season for the grasses to have flowered. Pre-typed data should be fully available to field staff.

New Boundaries

While in the field, special attention should be paid to the location of vegetative, surficial geology and 'form' boundaries not evident in aerial photography. New polygon boundaries should be generated and the sampling strategy altered accordingly. A new boundary is generated on the appropriate layer whenever there is a significant change in the appropriate factor. Generating new polygon edges may be accomplished using a series of GPS waypoints, or through taking a GPS fix at the center of the new polygon and delineating edges using standard survey techniques.

3.4 Finalize Mapping and Associated Attributes

The final stage of the mapping project involves the completion of photo-typing and the finalizing of polygon boundaries and labels for each of the data layers. Before beginning, all relevant information should be available including pretyped air photos and digital files, field data, and other existing data for the area.

3.5 Quality Assurance

The most important part of quality control is attention to detail and standardization at all stages of the mapping project. Reviews and reports at each stage of the project provide a method of evaluating and tracking progress.

Quantitative Assessment: A sample of the map polygons should be assessed in the field by the mapping project supervisor or designate. The objective of this assessment is to provide statistics on the accuracy of the polygon designations and to "audit" the mapping project. The process utilized may vary, but the following is recommended:

1. Identify attributes to be assessed at each sample point and determine the allowable variation from the measured value.
2. Randomly select sample polygons. This can be done as an overall percentage, or a specific number within each class.
3. Sample within each polygon chosen along transects or using random sample sites (10-20 per). In estuarine areas the sample methods chosen may depend more upon accessibility.
4. Assess each sample site using the ground truthing methods described in this document, focusing on the attributes chosen above.

3.6 Mapper Qualifications

Estuarine systems represent a complex interweaving of geomorphic and vegetation influenced forms, modified by salinity, flow, anthropogenic factors and others. As such, application of this classification system requires professional interpretation and a commitment to integration of biological and physical information. It is recommended that mapping be conducted in a team approach to ensure integration of the different types of information and to reduce field costs. A minimum level of professional experience is suggested for mappers in order to ensure a consistency and professional treatment of estuarine mapping as outlined in this manual. These requirements should be applied to all persons responsible for conducting, coordinating, directing or reporting on estuarine mapping projects. Requirements include:

Geomorphology and Physical:

Registered Professional Geoscientist and/or Master of Science degree in geology or physical geography, with a specialty relating to geomorphology. Alternately, a Bachelor of Science with an equivalent combination of training and experience. Demonstrated knowledge and experience related to:

- mapping procedures and techniques
- designing and conducting biophysical mapping projects
- coastal / fluvial geomorphology and processes

Marine Biology:

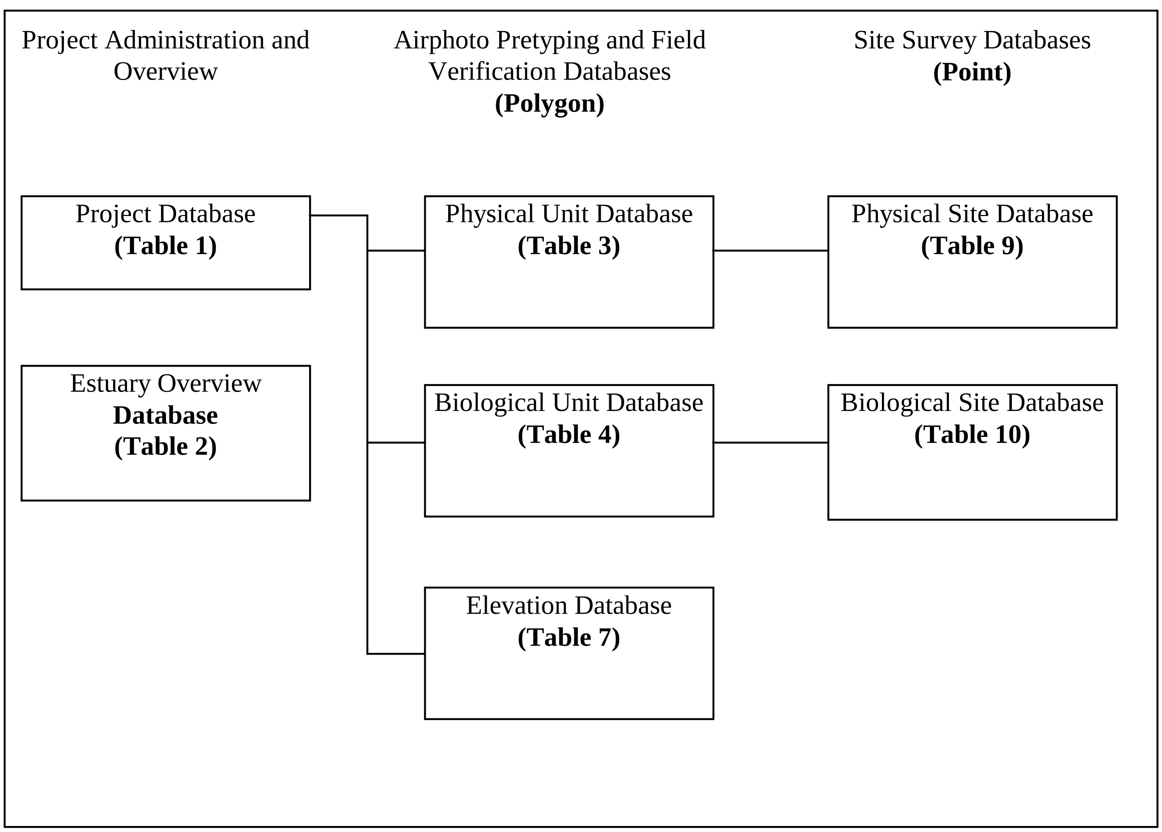
Master of Science in biology, with a specialty in marine biology. Alternately, a Bachelor of Science with an equivalent combination of training and experience. Demonstrated knowledge and experience related to:

- mapping procedures and techniques
- designing and conducting biophysical mapping projects
- marine / fluvial biology

4.0 Overall Mapping and Database Structure

This mapping system is composed of seven individual databases / digital coverages that are inter-linked and designed to separate administrative from mapping data, biological from physical data, polygon from point data, and small scale data from large scale data (Figure 3). The **project database** contains high level administrative information on the project that can be easily accessed for those interested in the project details. The **estuary overview database** stores information related to the overall character of the estuary and adjacent terrestrial and marine areas, including – for example - basin size and wave exposure. The estuary overview database captures small scale (large area) information that are common to the points and polygons of the other more large scale databases. The **physical unit database** stores polygon information acquired from airphoto interpretation and field survey, using codes and definitions primarily from the BC Physical Shore Zone Mapping System, and to a lesser extent from the Terrain Classification System. The information in the physical unit database is also attached to an ARC/INFO coverage. The **biological unit database** stores polygon information pertaining to the WREC class/site series and BC Biological Shore Zone Mapping System bio-bands. The information in the biological unit database is acquired by a combination of airphoto interpretation in conjunction with field survey, and is incorporated into an ARC/INFO coverage. It is important to note that the physical unit and biological unit databases (including mapped databases) are kept separate in this standard. The **elevation zone database** maps similar elevation zones from the marine limit to the 20 metre isobath relative to the chart datum (zero tide) in an ARC/INFO coverage. The **biological site database** is a point database that captures information from detailed field plots used to verify the site series/bio-bands. The **physical site database** is a point database used to capture forms and materials from detailed survey plots.

Figure 3 - A Schematic diagram of the seven databases used in the British Columbia Estuary Mapping System.



4.1 Project and Estuary Overview Data and Database Structure

The project database contains high level administrative information on the project. The estuary overview database stores general information on the estuary and its surroundings. Field names, types, widths and descriptions are outlined in Table 1. **Note the EstuaryID is the field used to link all the estuary databases, and is common to all databases.**

Table 1 - Description of the Project Database.

Field Name	Type	Width of Field	Description
Estuary	Alpha	50	Name of Estuary
EstuaryID	Alphanumeric	14	Unique identifier for Estuary (eg. SEYMWSD0001890x). Determined from Watershed Atlas
Date	Date	10	Day/month/year (eg. 02/12/1999)
Agency	Alpha	50	Name of Government Agency responsible for project
Scale	Numeric	7	Scale of mapping (eg. 10,000)
Mapsheet	Alphanumeric	6	NTS / TRIM Sheet number (eg. 93H3)
Chart	Numeric	8	CHS chart number
Pdata_src	Alphanumeric	50	Data source (eg. NTS sheet, CHS chart, aerial photo)
Notes	Alpha	255	Notes on data source

The estuary overview database is designed for comparisons between estuaries, and contains items that are related to the estuary as a single unit (e.g. area, drainage basin size, etc.) Field names, types, widths and descriptions are supplied in Table 2.

Table 2 - Description of the Estuary Overview database.

Field Name	Type	Width of Field	Description
EstuaryID	Alphanumeric	14	Unique identifier for Estuary (eg. SEYMWSD0001890x)
Estarea	Numeric	10	Total area of the Estuary in square meters
Interarea	Numeric	10	Total area of the Intertidal in square meters
Subarea	Numeric	10	Total area of the Subtidal in square meters
DomIN	Alpha	2	Dominant material in the Intertidal (g - gravel s - sands)
Subslope	Numeric	3	Slope of the subtidal zone (degrees)
Intslope	Numeric	3	Slope of the intertidal zone (degrees)
Watershed	Alpha	50	Watershed name (from FISS)
Shedarea	Numeric	10	Total area of the Watershed in square meters
Dispeak	Numeric	10	Peak monthly discharge in cubic meters per second
Dispmon	Alpha	3	Month of peak discharge
Dispan	Numeric	10	Annual peak discharge in cubic meters per second
Dismin	Numeric	10	Monthly minimum discharge in cubic meters per second
Dismmon	Alpha	10	Month of minimum discharge
Dismann	Numeric	10	Annual minimum discharge in cubic meters per second
Dis_src	Alpha	255	Source of discharge
Exposure	Alpha	2	Wave exposure code (eg. P – Protected SE - Semi-exposed) (refer to Appendix A)
Orientation	Numeric	3	Orientation of estuary in degrees (aspect)
Marsection	Alpha	25	Ecosection from the BC Marine Ecological Classification
Marunit	Alpha	7	Ecounit from the BC Marine Ecological Classification
Ecosection	Alpha	25	Terrestrial ecosection
Beclabel	Alphanumeric	9	Biogeoclimatic zone identifier
Phy_ident	Alpha	13	Physical shoreline identifier (if available) from BC Physical Shore-zone Mapping System (eg. 03/04/0056/00)
Mapper	Alpha	25	Name of mapper (last name, first name)

Most of the items in the estuary overview database can be calculated using a GIS, or from basemaps (e.g. TRIM or hydrographic charts). Discharge rates can be obtained from the BC Ministry of Fisheries. Wave exposure can be obtained from the BC Physical Shore Zone Mapping System, or through the wave exposure calculation provided in Appendix A (Howes *et al.* 1994).

4.2 Physical Unit Data and Database Structure

The definitions and descriptions for the codes of the physical unit database have been derived for the most part from the BC Physical Shore-zone Mapping Manual (Howes *et al*, 1994). A few terms have been added to the organic form and material secondary descriptors from the Terrain Classification System (Howes & Kenk, 1997). Field names, item types and widths as well as item descriptions are outlined in Table 3, and explanations of the codes are listed in Section 4.2.2.

Table 3 - Description of the Physical Unit Database.

Field Name	Type	Width of Field	Description
EstuaryID	Alphanumeric	14	Unique identifier for Estuary (eg. SEYMWSD0001890x)
Phy_ident	Alpha	13	Physical unit from BC Shorezone System if available
PhyunitID	Numeric	2	Unique identifier of estuary physical polygon
Order	Alpha	2	Degree of importance of subunit (D – dominant, S - subordinate)
AreaP	Numeric	10	Area of estuary physical polygon in square meters
Slope	Numeric	2	Slope of estuary physical polygon in degrees
Level	Numeric	1	Used only when a veneer of sediment overlies a subsurface
Primform_1st	Alpha	2	Primary Form Descriptor 1
Primform_2nd	Alpha	2	Primary Form Descriptor 2
Secform_1st	Alpha	2	Secondary Form Descriptor 1
Secform_2nd	Alpha	2	Secondary Form Descriptor 2
Secform_3rd	Alpha	2	Secondary Form Descriptor 3
Strata_1st	Numeric	1	Strata layer 1 (where 1 is the topmost)
Strata_2nd	Numeric	1	Strata layer 2
Depth	Numeric	6	Depth of each strata in meters (eg. .5 = 50cm)
Primmat_1st	Alpha	2	Primary material descriptor
Secmat_1st	Alpha	2	Secondary material descriptor
Percent_1st	Numeric	2	Percent cover of 1st material descriptor
Primmat_2nd	Alpha	2	Primary material descriptor
Secmat_2nd	Alpha	2	Secondary material descriptor
Percent_2nd	Numeric	2	Percent cover of 2nd material descriptor
Primmat_3rd	Alpha	2	Primary material descriptor
Secmat_3rd	Alpha	2	Secondary material descriptor
Percent_3rd	Numeric	2	Percent cover of 3rd material descriptor
Mapper	Alpha	25	Mapper name(s) (Last name, first name)
Date	Alpha	8	Date dd/mm/year

Explanation of the physical unit database

EstuaryID: Refers to the estuary identification number from the estuary project and overview database

Phy_ident: Physical unit from BC Physical Shore-zone Mapping System (if available)

PhyunitID: Refers to the unique identification number assigned to the estuary physical unit from airphoto pretyping.

Order: each unit may consist of up to two components or subunits. Order is used when it not possible to map these subunits into discrete units. It indicates the degree of importance of the subunits when two have been identified and occur within a unit.

Code	**Term**	**Definition**
D	Dominant	Occupies >50% of the unit area
S	Subordinate	**OCCUPIES <50% OF THE UNIT AREA**

AreaP: Area of the unit in square metres; generated by GIS.

Slope: Slope of the unit is measured in degrees; slope can be recorded as an unique value (e.g. 8 degrees) or as a range (e.g. 3 –6 degrees).

Level: Only used when a veneer of sediment (<1 metre in thickness) or blanket (> 1 metre in thickness) overlies sediment or bedrock whose surface determines the form or shape of the overlying surface. An example where the level would be coded or used is when a beach veneer of sediment overlies a bedrock platform. The upper level is coded as 1 (in this example: the beach veneer) and the underlying layer is coded as 2 (in this example: the rock platform).

Primary and Secondary Form Descriptors

Descriptors of the morphological character (form) or surface expression of a unit are described by the combination of primary and secondary form descriptors. Secondary descriptors provide additional information on the primary form types. Definitions of Primary and Secondary form descriptors are listed below.

Application of Form Terms

The primary form of each unit (or subunit as indicate by the order code) is described by a primary form descriptor (eg. A,B,S). Usually, only one primary form descriptor term is used to describe the primary form of a unit (or subunit). The only exception is when a veneer or blanket of sediment overlies sediment or bedrock whose surface determines the form or shape of the overlying surface. In this instance, two primary form descriptors are used to describe the unit (or subunit) however only one primary form descriptor can be applied to each the upper and underlying layer.

Additional information related to form can be indicated through the use of **secondary form modifiers** (eg. Ap, Bfxbu, S). Up to 3 secondary form modifiers may be used with each primary form descriptor. Their order has no significance.

PRIMARY FORM DESCRIPTORS

Code	**Term**	**Code**	**Term**
A	**ANTHROPOGENIC**	L	Lagoon
B	Beach	M	Organic
C	Cliff	O	Offshore Island
E	Dune	P	Platform
F	Reef	R	River (Fluvial)
		T	Tidal Flat

Primary Form Descriptors: Definition Of Terms and Codes

Code	Term	Definition
A	**Anthropogenic:**	Man-made or man-modified features; includes those constructed by man for purposes of moorage (e.g. docks, marinas) or for protected anchorage (e.g. breakwater) or commercial activities, and features in which material is deposited for backshore protection (e.g. seawalls) or shore land extension (e.g. fill) or excavated, commonly by dredging (e.g. gravel extraction sites).
B	**Beach:**	An accumulation of unconsolidated material formed by waves and wave-induced currents in the zone that extends landward from the lower low water line for large (spring) tides to a place where there is a marked change in material or physiographic form usually the effective limit of storm waves. The character of materials and forms associated with beaches is variable. Beach materials may consist of any combination of sand, gravel and angular fragments. Common beach forms include beach faces, low-tide-terraces, bars and troughs.
C	**Cliff:**	A sloping face that is steeper than 20^{o} usually formed by erosional processes and composed of either bedrock or unconsolidated materials (or both). Also includes material deposited at the base of cliffs as talus or fans by mass movement processes (e.g., rockfall, mud flows, slumping).
E	**Dune:**	A mound or ridge formed by the transportation and deposition of wind-blown material (sand and occasionally silt) common dune forms include crescentic, transverse, longitudinal, parabolic attached and irregular.
F	**Reef:**	A rock outcrop, detached from the shore, with maximum elevations below the high-water line (outcrops with areas above the higher-high water line are classified as "Offshore Islands").
L	**Lagoon:**	Usually a shallow depression within the shore zone continuously occupied by salt or brackish water lying roughly parallel to the shoreline separated from the open sea by a barrier or barriers such as a spit. The barrier provides protection from wave action although overwash may occur during storms. Lagoons may be open, that is connected to the open sea by an inlet or closed (no surface connection to the sea). Sediments in lagoons are commonly fine textured, usually mud or muddy sand except near inlets where sand tends to dominate.
M	**Organic:**	A coastal wetland area which is periodically inundated by tidal brackish or salt water and which supports significant (>15% cover) non-woody vascular vegetation (e.g. grasses, rushes, sedges) for at least part of the year). Organic forms are characterized by a surface accumulation of organic matter deposited in water but the substratum normally is dominated by mineral material. Tidal channels and/or ponds may be present.
O	**Offshore Islands:**	A piece of land made up of either rock or unconsolidated material or both, that projects above and is completely surrounded by water at higher high water during a large (spring) tide. Islands vary in shape from narrow, steep-sided pillar forms (sea stacks) to smooth, elongate hillocks in the general shape of the back of a whale.
P	**Platform:**	A relatively level or inclined surface with a slope of 20^{o} or less formed by erosional processes. Platforms are usually composed of bedrock but may be made up of unconsolidated materials. Their surface topography is variable; they may be smooth, irregular, or step-like, and pitted with tidepools.
R	**River (Fluvial):**	Includes river channels and associated fluvial landforms such as islands and bars.
T	**Tidal Flat:**	A level or gently sloping (less than 5°) constructional surface exposed at low tide, usually consisting primarily of sand or mud with or without organic detritus, and resulting from tidal processes.

Secondary Form Modifiers: Definition of Terms and Codes

Additional information can be provided for these primary forms. The following is a list of the additional codes and terms that can be used with each of the primary forms.

ANTHROPOGENIC (A): SECONDARY FORM DESCRIPTORS

Code	Term	Code	Term
A	dolphin	m	marina
B	breakwater	n	ferry terminal
C	**LOG DUMP**	p	port facility
F	float	s	seawall, bulkhead, revetment
H	shell midden	**W**	wharf
I	jetty	x	outfall
K	dyke	y	intake

A DOLPHIN**: A PILING OR GROUP OF PILINGS USUALLY USED FOR MOORING LOG BOOMS, BARGES OR SHIPS.**

b **breakwater:** A structure extending into the sea for any of the following uses: (1) to direct and channelize stream or tidal flows; (2) to prevent channel shoaling by longshore drift; (3) to trap littoral drift or retard shore and; (4) to provide protection for a harbour, anchorage or basin.

c **log dump**: Log handling structure(s) and/or terrain modified for the purposes of log handling or storage; includes log dumps and haulout areas.

f **float**: A float platform, often associated with a wharf; several linked floats that are primarily used for berthage are classified as "Marinas".

h **shell midden**: Accumulations of waste shells and shell fragments; includes refuse heaps and shell middens.

j **jetty**: A structure used to provide protection from wave exposure for a port or harbour.

k **dyke**: A wall or mound built around a low-lying area to prevent flooding by the sea; the surfaces of some dykes may be used as a road.

m **marina**: A series of docks, usually in a protected location that provides secure moorings for motorboats and yachts, as well as offering supplies, repairs and other facilities.

n **ferry terminal**: A landing facility for ferries, usually consisting of a complex of bulkheads, dolphins and ramps.

p **port facility:** A terminal and related structures extending from the backshore to subtidal waters for loading/unloading cargo and/or passengers from large ships; includes docks, storage yards, parking lots; includes ferry terminals.

s **seawall, bulkhead**: A wall, embankment, or facing of stone, bulkheads, concrete etc. revetment bulkheads, constructed parallel to the shoreline to protect revetments, scarps or shore structures against erosion by wave action or currents or to prevent sliding of land.

w **wharf**: A structure used for the mooring or tying of vessels while loading or discharging cargo and/or passengers; includes wharves, quays and piers.

x **outfall**: Structures in which water and effluent is discharged into the sea.

y **intake**: Structures in which water is captured from the sea.

Beach (B): Secondary Form Descriptors

Code	Term	Code	Term
b	berm	r	single ridge/bar
c	washover channel	s	storm ridge
f	**FACE**	t	low tide terrace
M	multiple bars and troughs	w	washover fan
n	relic ridges	v	veneer

b **berm**: A horizontal or landward sloping bench of a beach, formed of material deposited by receding storm waves; some beaches have no berms, others have one or several.

c **washover**: A channel formed by storm waves through the berm or dunes.

f **face**: The sloping section of a beach, below the beach berm, normally exposed to the action of wave uprush.

m **multiple bars**: Elongate embankments or ridges that usually trends parallel to the and troughs shoreline in the intertidal and/or subtidal zones. Rough separated by troughs characterized by gently to moderately sloping sides.

n **relic ridges**: Multiple beach ridges in the backshore marking the former location of active foredune ridges.

r **single ridge/bar**: An elongate embankment or ridge that usually trends parallel to the shoreline in the intertidal and/or subtidal zones.

s **storm ridge**: A backshore ridge formed by storm waves.

t **low tide terrace**: A horizontal to gently sloping surface, less than 3° slope, that extends from the lower low water line for spring tides to the break in slope marked by the beach face.

w **washover fan**: A fan-shaped accumulation of sediment that can be likened to a segment of a low-angled cone deposited on the landward side of an overwash channel by storm waves.

v **veneer**: A very thin (<1 metre thick) veneer of unconsolidated sediment that overlies bedrock or other sediments and takes on the form of the underlying material.

Cliff (C): Secondary Form Descriptors

Code	Term	Code	Term
a	eroding	i	inclined (20-35^0)
p	passive (inactive)	s	steep (>35^0)
c	cave	l	low (<5m)
f	fan, apron	m	moderate (5-10m)
t	terraced	h	high (>10m)

a **eroding**: A cliff showing evidence of active erosion such as slumping, lack of vegetation, talus cones at base, etc.

p **passive (inactive)**: A cliff which shows no signs of active erosion or mass-wasting such as indicated by a vegetated cliff face.

c **cave**: A cleft or cavity in a cliff formed by the action of waves or weathering; caves may occur at present sea level or at higher elevations in the cliff.

f **fan, apron**: An accumulation of unconsolidated materials (sand, gravel, rubble, blocks) along the base of the cliff that is fan-shaped surface or has an unidirectional (planar) surface; the sediments are formed by mass movement processes operating on the cliff face above.

t **terraced**: An inclined or steep cliff that is characterized by alternating horizontal or gently sloping surfaces and scarps.

Slope

i **inclined (20-35^o)**: A cliff with a slope between 20 and 35 degrees.

s **steep (>35^o)**: A cliff with a slope greater than 35 degrees.

Height

l **low (<5m)**: A cliff with a vertical rise of less than 5 metres.

m **moderate (5-10m)**: A cliff with a vertical rise between 5 and 10 metres.

h **high (>10m)**: A cliff with a vertical rise greater than 10 metres.

Dune (E): Secondary Form Descriptors

Code	Term	Code	Term
b	blowouts	r	ridge/swale
i	irregular	p	parabolic/ crescentic
n	relic	v	veneer
o	ponds		

b **blowouts**: A saucer- or trough-shaped depression formed by wind erosion on a pre-existing dune.

i **irregular**: A dune with multi-directional slopes that in plan has a chaotic form.

n **relic**: A dune which is no longer actively aggrading or degrading; usually indicated by heavy vegetation.

o **ponds**: A natural body of permanent standing fresh water usually less than 2 hectares in surface area.

r **ridge/swale**: An asymmetrical sand dune elongated perpendicular to the direction of the prevailing winds or a long, narrow sand dune, usually symmetrical in cross profile, orientated parallel with the direction of the prevailing wind (longitudinal dune).

p **parabolic**: A crescent-shaped dune lying transverse to the direction of the crescenticprevailing wind with the horns of the crescent pointing downwind (syn. with barchan) or a dune with long, scooped-shaped form, convex in the downwind direction so that its horns point upwind.

v **veneer**: A very thin (<1 metre thick) veneer of unconsolidated sediment that overlies bedrock or other sediments and takes on the form of the underlying material.

Reef (F): Secondary Form Descriptors

Code	Term	Code	Term
f	horizonal	r	ramp
i	irregular	s	smooth

f **horizonal**: A horizontal or gently sloping surface less than 5^o.

i **irregular**: A horizontal or ramped platform that is characterized by undulating or hummocky surface topography; local relief is greater than 1 metre.

r **ramp**: An inclined surface with a slope between 5^o and 20^o.

s **smooth**: A horizontal or ramped platform that is characterized by an even surface topography; local relief is less than 1 metre.

Lagoon (L): Secondary Form Descriptors

Code	Term	Code	Term
o	**OPEN**	c	closed

o **open**: A lagoon connected to the open sea by an inlet.

c **closed**: A lagoon in which there is no visible connection to the open sea.

Organic (M): Secondary Form Descriptors

Code	Term	Code	Term
b	blanket	o	pond
c	tidal creek	v	veneer
e	levee		

b **blanket**: A very thin (<1 metre thick) veneer of organic material that overlies bedrock or other sediments and takes on the form of the underlying material.

c **tidal creek:** A creek with a definite bed and banks that is formed and maintained by fluvial processes.

e **levee**: A slightly elevated area usually elongate and parallel to a creek bank.

o **pond**: A natural body of permanent standing fresh water usually less than 2 hectares in surface area.

v **veneer**: A very thin (<1 metre thick) veneer of organic material that overlies bedrock or other sediments and takes on the form of the underlying material.

Offshore Island (O): Secondary Form Descriptors

Code	Term	Code	Term
b	barrier	w	whaleback
c	chain of islets	l	low (<5m)
t	table-shaped	m	moderate (5-10m)
p	pillar/stack	h	high (>10m)

b **barrier**: An island made up of unconsolidated materials that usually trends parallel to the shore and 'protects' other features, such as lagoons and marshes, from direct wave attack of the open ocean.

c **chain of islets**: A chain of offshore islands, often linear in distribution and sub-parallel to shore.

t **table-shaped**: An island with a horizontal or irregular surface bounded by a cliff, in cross-sectional profile the shape of a table.

p **pillar/stack**: An isolated, pinnacle-shaped island that is characterized by steep to vertical sides; also referred to as sea stacks, chimney rocks.

w **whaleback**: A smooth, elongate island having the shape of a whale's back.

Elevation

l **low (<5m)**: Indicates that the surface elevation of the island is less than 5m above the higher high water line for large spring tide.

m **moderate (5-10m)**: Indicates that the surface elevation of the island is between 5 to 10m above the higher high water line for large spring tide.

h **high (>10m)**: Indicates that the surface elevation of the island is greater than 2m above higher high water line for large spring tide.

Platform (P) Secondary Form Descriptors

Code	Term	Code	Term
f	horizontal	t	terraced
i	irregular	s	smooth
r	ramp	p	tidepool

f **horizontal**: A horizontal or gently sloping surface less than 5^{o}.

i **irregular**: A flat or ramped platform that is characterized by undulating or hummocky surface topography; local relief is greater than 1 metre.

r **ramp**: An inclined surface with a slope between 5^o and 20^o.

t **terraced:** Stepped or bench-like topography; a flat or ramped platform that is characterized by alternating horizontal or gently sloping surfaces and scarps.

s **smooth**: A horizontal or ramped platform that is characterized by an even surface topography; local relief is less than 1 metre.

p **tidepool**: A closed, more or less circular depression filled with sea water when the sea is standing at the lower low water line for large (spring) tide.

River (R) Secondary Form Descriptors

Code	Term	Code	Term
a	perennial channel	m	multiple channels
b	bar, island	s	single channel
f	flat	t	intermittent channel

a **perennial**: A stream that flows continuously throughout the year.

b **bar, island**: A channel bar or island formed by fluvial processes that has a gently sloping unidirectional surface up to 5 degrees.

i **intermittent**: A stream that only flows at certain times of the year.

m **multiple channels**: The channel zone that is characterized by many diverging and converging channels separated by bars; vegetation is either absent or limited on bars; many channels are dry at low flow.

s **single channel**: The channel zone characterized by a single channel.

t **flat**: Flat or gently sloping unidirectional surface with gradients up to 3 degrees; local irregularies of the surface generally have a relief of less than 1 metre.

Tidal Flats (F) Secondary Form Descriptors

Code	Term	Code	Term
b	bar, ridge	l	levee
c	tidal channel	s	multiple tidal channels
e	ebb-tidal delta	t	flats
f	flood-tidal delta	p	tidepool

b **bar, ridge**: An elongate embankment that usually trends parallel to the shoreline.

c **tidal channel**: A channel that dissects the tidal flat surface that is formed and maintained by tidal current.

e **ebb-tidal delta**: An delta created by ebb-tidal currents, usually associated with an inlet to a lagoon or harbour.

f **flood-tidal delta**: An delta created by ebb-tidal currents, usually associated with an inlet to a lagoon or harbour.

l **levee**: A bank of unconsolidated sediment formed adjacent to a tidal channel that is elevated above the general level of the tidal flat surface.

s **multiple tidal**: Tidal flat surface dissected by several channels that are formed and channels maintained by tidal currents.

t **flats**: A unidirectional, horizontal or gently sloping surface less than 5°.

p **tidepool**: A closed, more or less circular depression filled with sea water when the sea is standing at the lower low water line for large (spring) tide.

Material Descriptor - Codes and Definitions

The physical materials (e.g. sediments or bedrock) of a primary form are described by primary and secondary material descriptors. Different layers of sediment that occur in a form are indicated by a strata code.

Strata: Different layers or strata within a form are indicated by a number; the upper or topmost layer is indicated by the number 1 and the remainder of the underlying strata are numbered sequentially in decreasing order downwards.

Depth: The depth of each stata is recorded in metres; if the base of a strata is not observed the depth of the strata should be preceded the > symbol (e.g. .5 indicates the strata depth as 50 cm; >1.0 indicates the depth of the strata is greater than 1 metre and the base was not observed).

Primary and Secondary Material Descriptors – each strata is described by a number of primary and secondary material descriptors. The application of these various codes is detailed below.

Primary Descriptors

Code	**Term**	**Code**	**Term**
A	Anthropgenic	C	Clastic
B	Biogenic	R	Bedrock

<u>Code</u> <u>Term</u> <u>Definition</u>

A **Anthropogenic**: Materials made or modified by man; includes concrete, metal and wood.

B **Biogenic**: Materials produced by living organisms excluding man.

C **Clastic**: Materials made up of fragments of rock; these can be any size and shape; texture of clastic sediments is the size, roundness and sorting of particles. The size of a clast greater than 2mm is determined by the b axis.

R **Rock**: Bedrock aggregates of mineral grains, sometimes a simple mineral but more often of several minerals, that are coherent under ordinary conditions.

Secondary Form Modifiers

Additional information can be provided for these primary forms. The following is a list of the additional codes and terms that can be used with each of these primary material types.

Anthropogenic (A) Secondary Material Descriptors

Code	Term	Code	Term
a	metal	r	rubble
d	debris	t	logs
c	concrete	w	wood

a **metal:** Any class of substance that is typically fusible and opaque, good conductors of electricity and have a peculiar metallic lustre.

d **debris**: A man-made mixture of refuse such as old building materials, concrete and metal; may include some unconsolidated materials (gravel, earth).

c **concrete**: Building material made up of mineral aggregate (sand, gravel) and a cementing agent.

r **rubble**: Angular-shaped blocks of rock, greater than 64mm, produced by blasting or ripping bedrock.

t **logs**: A length of tree trunk sawed by man; usually logs from log booms.

w **wood**: Structural lumber, such as boards and pilings.

Biogenic (B) Material Secondary Descriptors

Code	Term	Code	Term
c	coarse shell	l	trees
e	fibric	o	organic litter
f	fine shell hash	u	mesic
h	humic		

c **coarse shell**: Shell material greater than 4mm in size; also includes shell material modified by man such as middens and shell heaps.

e **fibric**: The least decomposed of all organic materials. It contains amounts of well-preserved fibre (40% or more) that can be identified as to botanical origin upon rubbing.

f **fine shell hash**: Shell material less than 4mm in size; also includes shell material modified by man such as middens and shell heaps.

h **humic**: Organic material at an advanced stage of decomposition; it has the lowest amount of fibre, the highest bulk density and the lowest saturated water-holding capacity of the organic materials; fibres that remain after rubbing constitute less than 10% of the volume of the material.

l **trees**: Applies to trees that are no longer living and accumulate along the shoreline by natural processes; for example, mass movements or wave action.

o **organic litter**: Vegetative matter, excluding trees; includes wood debris (bark) and kelp accumulations.

u **mesic**: Organic material that is at a stage of decomposition intermediate between fibric and humic.

Clastic (C) Material Secondary Descriptors

Code	**Term**	**Code**	**Term**
a	blocks	k	clay
b	boulders	p	pebbles
c	cobbles	r	rubble
d	diamicton	s	sand
f	fines	$	silt
g	gravel	x	angular

a **blocks**: Angular particles >256 mm.

b **boulders**: Rounded and subrounded particles >256 mm.

c **cobbles**: Rounded and subrounded particles between 64- 256 mm.

d **diamicton**: A non-sorted to poorly sorted mixture of sand and larger rounded and angular particles in a matrix of silt and clay.

f **fines**: A mixture of silt and clay; may include a minor (mud) fraction of sand.

g **gravel**: A mixture of pebble, cobble and boulders (>2 mm); may include some interstitial sand.

k **clay**: Particles less than .0195 mm.

p **pebbles**: Rounded and subrounded particles between 2 - 64 mm.

r **rubble**: Angular particles with a size range of 2 - 256 mm.

s **sand**: Particles with a size range of .0625 - 2 mm.

$ **silt**: Particles with a size range of .0195 - .0625 mm.

x **angular**: A mixture of blocks and rubble; may include some fragments of interstitial sand.

Bedrock (R) Material Secondary Descriptors

Code	**Term**	**Code**	**Term**
i	igneous, intrusive	v	volcanic
m	metamorphic	1	jointing
s	sedimentary	2	massive

i **igneous, intrusive**: Rock formed below the surface of the earth by the crystallization of magma.

m **metamorphic**: Rocks that have been modified from its original nature (texture or composition) by heat, pressure or chemical action.

s **sedimentary**: A rock resulting from the consolidation of loose sediment and formed at or near the surface of the earth.

v **volcanic**: Rocks of volcanic origin, usually extrusive, and including: andesites, trachytes, rhyolites, dacites, basalts, agglomerates, breccias and tuffs.

Bedrock Structure

1 **jointing**: A fracture or parting in rock without displacement; the surface is usually plane and often occurs with parallel joints to form part of a joint set.

2 **massive**: Bedrock that has a homogeneous structure; no bedding or joints present.

Application of Material Codes

Each strata can be described by a maximum of 3 primary material descriptors and accompanying secondary material descriptors. They are entered in order of decreasing importance. Each primary material descriptor is followed by a secondary material modifier and the percentage estimate of the material type. Only one secondary material descriptor can be used with each primary material descriptor except for Bedrock (R) were up to 3 modifiers can be used.

If the percentage can not be estimated (not entered) and only one primary material descriptor is used, that material type comprises approximately >75% of the volume of the strata (e.g. Cs); if two material descriptors are used, the first comprises 50-75% and the second 25-50% (e.g. Cs Bc); if three material descriptors are used, each covers 25% or more (e.g. Cs Bc An).

Percentage: An estimate of the percent that the material texture makes up of the strata; usually made by a visual inspection.

Mapper: Name of the mapper.

Date: Date of the mapping.

4.3 Biological Unit Data and Database Structure

Biotic mapping in the estuary uses a combination of the WREC system for the upper estuary where rooted, vascular vegetation dominates, and the BC Biological Shore-zone Mapping System for the marine-dominated areas. Often the lower limit of the shrubs, grasses and halophytes like *Salicornia* of the upper estuary will be present as a distinct line between the meadows and the tidal flats in the lower estuary (Day *et al.*, 1989, Adam, 1993.).

Depending on the objectives and scale of the estuary mapping, two options are suggested for mapping the biota of the upper estuary. If site series information is not available or if the survey is a general overview, then the WREC *class* is used for the mapping. In a more detailed survey, the *site series* is mapped. An overview of the WREC classification is described in Section 1.2.3 and further background about the system is described in MacKenzie and Banner (in preparation). The codes and definitions for each of the classes and site series for upper elevations of estuaries are discussed below.

Mapping for the marine-dominated lower estuary is based on the groups of species called *'bio-bands'*. The *bio-band* descriptors were developed as a way to summarize aerial video observations and are approximately equivalent to *site series*, in that a number of dominant species are used to identify an assemblage of species at certain physical habitats (see overview in Section 1.2 and

Searing & Frith (1995) for more detail). The species which comprise the band are determined from field verification.

Biotic polygons in the estuary will be mapped based on the visible macrobiota. Each of the biotic polygons identified will be coded to include a number of attributes (Table 4). These attributes are determined in pre-typing of the study area, based on aerial photos or other remotely-sensed imagery and then are verified during the field survey. Polygon boundaries may be adjusted based on the field verification of the biota present.

Field plots are an important component of the mapping of the biotic polygons. Details of the field plots are recorded in the Biological Site Form Database discussed in Section 4.5.

Table 4 - Description of the Biological Unit Database.

Field Name	Type	Width of Field	Description
EstuaryID	Alphanumeric	14	Unique identifier for Estuary (eg. SEYMWSD0001890x) from BC Watershed Atlas.
Bio_ident	Alphanumeric	13	Biological unit identifier from BC Biological Shorezone Mapping System (if available).
BiounitID	Numeric	2	Unique identifier of estuary biological polygon.
WREC	Alpha	3	Only applies in the upper intertidal where rooted shrubs, graminoids, forbs, ferns, bryophytes, aquatics may occur. The *class* is a summary of physiognamy of groups of the *site series*. There is no equivalent for the marine-dominated biota mapped in the mid- to lower intertidal. See Table 5.
Sseries	Alpha	225	In the upper intertidal, use the WREC *site series* (if available) which is a species assemblage, identified by one, two or three dominant species. Site series for estuaries are currently under development by MacKenzie et al. In the mid- to lower intertidal, use the *bio-band* which describes a species assemblage of the dominant species of sessile macrobiota (both vegetation and fauna). See Tables 6 - 7.
Dom1	Alpha	7	Species name of the species with the highest cover in the polygon. If species identification is not possible, the three species name fields may be left blank and only the general summary of biota (class, site series or bio-band) coded for the polygon. Dominant species (1, 2 and/or 3) can then be verified during field survey.
Cover1	Numeric	2	% cover value of species 1 (estimated in pre-typing if possible, verified in field survey)
Dom2	Alpha	7	Species name of the species with the next highest cover in the polygon (verified during field survey)
Cover2	Numeric	2	% cover value of species 2 (estimated in pre-typing if possible, verified in field survey)
Dom3	Alpha	7	Species name of the species with the next highest cover in the polygon (verified during field survey)
Cover3	Numeric	2	% cover value of species 3 (estimated in pre-typing if possible, verified in field survey)
Mapper	Alpha	25	Mapper name(s) (last name, first name)
Date	Alpha	8	Date dd/mm/year
Notes	Alpha	255	Other information

Codes and Definitions for the Biological Unit Database

WREC class (from MacKenzie & Banner, in preparation):

Es: **Salt swamp**: Salt swamps are treed or shrubby mineral ecosystems that occur in brackish lagoon, channel and estuary edges with occasional tidal flooding and waterlogged, slightly saline soils. Thickets of tall shrubs and trees tolerant of wet, slightly saline soils are typical. Soils are usually mineral though some sites may have a significant well-humified organic horizon.

Ed **Salt meadow:** Salt meadows are ecosystems dominated by tall forbs and graminoids that develop in the high intertidal and supratidal zones of estuaries where tidal flooding is less frequent than daily. These sites are flooded during higher high tides, storm events or during river flood. Soils are often waterlogged during portions of the growing season and are oligo- to eusaline mineral soils.

Em **Salt marsh:** A salt marsh is an intertidal ecosystem dominated by salt-tolerant emergent graminoids and succulents. They occur in the middle to upper tidal zones of estuaries where fresh water and salt water mix. Sites are alternately flooded and exposed daily. Elevationally banded surface patterns that reflect degree of tidal inundation are common.

Ew **Estuarine shallow water:**

Et **Estuarine tidal flat**:

Site Series (from MacKenzie & Banner, in preparation)

Site series are named by the common name of the dominant species (Table 5). More site series are presently being described and defined for coastal BC (MacKenzie, pers.comm.) and the codes for Site series units are not yet compiled to be included in this table. The groupings of the Site series into the more-general WREC class is included in Table 6.

Table 5 - Estuary Site Series Units. These are treated as equivalent to the species assemblages described in the marine - process - dominated Bio-band Units (Table 6).

WREC Class (code in parenthesis)	Site Association Name	Scientific name
ESTUARINE SWAMP (Es)		
	Pacific crabapple – False lily-of-the-valley	*Malus fusca – Maianthemum dilatatum*
	Myrica gale – Bluejoint	*Myrica gale – Calamagrostis canadensis*
	Sitka willow – False lily-of-the-valley	*Salix sitchensis – Maianthemum dilatatum*
	Sitka spruce – Slough sedge	*Picea sitchensis – Carex obnupta*
	Sitka spruce – Pacific crabapple	*Picea sitchensis – Malus fusca*
ESTUARINE MEADOW (Ed)		
	Nootka reedgrass	*Calamagrostis nutkaensis*
	Tufted hairgrass	*Deschampsia cespitosa*
	Tufted hairgrass – Douglas' aster	*Deschampsia cespitosa – Aster subspicatus*
	Cow parsnip – Silverweed	*Heracleum lanatum – Potentilla anserina*
	Dunegrass – Pacific hemlock-parsley	*Leymus mollis – Conioselinum pacificum*
ESTUARINE MARSHES(Em)		
	Common orache	*Atriplex patula*
	Pond water-starwort – Flowering quillwort	*Callitriche stagnalis – Lilaea scilloides*
	Lyngby's sedge	*Carex lyngbyei*
	Seashore saltgrass - American glasswort	*Distichlis spicata – Salicornia virginica*
	Common spike-rush	*Eleocharis palustris*
	Sea milk-wort mudflat	*Glaux maritima*
	Arctic rush	*Juncus arcticus*
	Seaside plantain – Dwarf alkaligrass	*Plantago maritima – Puccinellia pumila*
	American glasswort	*Salicornia virginica mudflat*
	Seacoast bulrush	*Scirpus maritimum*
	American bulrush – Soft-stemmed bulrush	*Scirpus americanus – Scirpus validus*
	Canadian sand-spurry – Blue-green algae	*Spergularia canadensis – Cyanophyta spp.*
ESTUARINE SHALLOW WATER (Ew)	Widgeon-grass	*Ruppia maritima*
ESTUARINE TIDAL FLAT (Et)	None currently described. Bio-bands are currently used.	

Bio-bands (after Searing & Frith, 1995):

Most of the bio-bands found in estuaries are equivalent for the banding described for other low wave exposure shorelines or estuaries throughout BC (Searing & Frith, 1995). However, a band has been added for the estuarine mapping to describe polygons which are bare of sessile macrobiota – the BRE, bare band. Because the estuary mapping is always verified by ground survey, the detail required to map biota which may not be visible from remote-sensed photos or video can be included. In the BRE (bare) band, observations on the ground may detect low cover of sessile biota or infauna in these bare-looking polygons. Species lists for all the observed biota and an associated percent cover estimate for each species, would appear in the plot data for field verification (see the Site Form and data attributes In Section 4.6).

Table 6 - Estuary Bio-band codes and description for marine-process-dominated elevations in the estuary. These are summary species assemblage codes are treated as equivalent to the Site Series Units (Table 5).

Bio-band Code	Colour Band Name	Colour	Description
VER	'Verrucaria'	Black or bare rock	Splash zone: marked by black encrusting lichen & blue-green algae. Generally only occurs on bedrock shoreline.
FUC	'Fucus'	Golden brown	Dominated by *Fucus*, includes *B. glandula*. upper intertidal.
BAR	Upper barnacle	Grey-white	Continuous band of *B. glandula*, upper intertidal.
BRE	Bare substrate	Bare substrate	No visible attached macrobiota. In-fauna (i.e. clams & worms) or holes of burrowing shrimp may be observed during ground verification.
OYS	Oyster	White	Abundance of *Crassostrea*. Only found in warm water areas Strait of Georgia, none north of Campbell R/ Desolation Sound.
BMU	Blue mussel	Dark blue-black	Dense beds of *Mytilus trossulus* (blue mussel).
ULV	'Ulva'	Bright green	*Ulva/'Ulvaria'* blade greens and *Enteromorpha*-type filamentous greens. May appear as thick patches or as green haze of small plants.
SBR	Soft browns	Brown	*Sargassum*, and large bladed *Laminaria spp.* - the unstalked blade browns, which are seen in the lower intertidal and nearshore subtidal.
ZOS	'Zostera'	Dark green	Eelgrass, (*Zostera marina* and introduced spp. *Z. japonica*) fine sediment, may extend slightly upslope into intertidal. Often heavily encrusted with epiphytic blade red.

4.4 Tidal Zone Information and Database

The across-shore elevations of estuaries can be identified and mapped. The three broadest divisions are the upper *supratidal*, the *intertidal* , and the lower elevations of the nearshore *subtidal*. Tidal variations and variations in morphology of estuaries and their adjacent coastlines will change the absolute measure of the elevation associated with each of these boundaries. Therefore, the definition of tidal zones will usually be somewhat subjective (Howes *et al.,* 1994).

In BC, the *marine limit* is equal to the *storm log line* and marks the boundary between the terrestrial upland and the *supratidal* splash zone. The *higher high water line,* usually described as the previous large tide's higher high water swash mark, follows the approximate elevation of the boundary between the supratidal and the *intertidal*. The lower boundary of the intertidal is the *chart datum,* defined in BC as the level of the "lowest normal tide" (Thomson, 1981) and commonly referred to as "zero tide". Note that the higher high water and lower low water have slightly different definitions for Canada and the United States. Canadian marine charts show chart datum at the "lowest normal tide" where the US defines chart datum at "mean lower low water". As a result, the US chart datum is slightly higher elevation than the Canadian chart datum (Thomson, 1981).

The Tidal Zone database summarizes features relative to different elevation zones of an estuary. The three major zones are schematically illustrated in Figure 4 and are:

Supratidal (may also referred to as the **Backshore**): The zone that extends inland from the *higher high water line* (HHW) of the mean tides. The upper boundary of this zone is equivalent to the landward line of marine processes (i.e. the *storm surge limit* or *storm log line* that is the lower limit of strictly terrestrial vegetation such as mosses). These areas may be inundated as a result of exceptionally high tides, tidal damming and/or freshet conditions. The supratidal zone corresponds to the 'A' zone of the Physical Shore-zone Mapping system (Howes *et al.,* 1994).

Intertidal: The area of tidal influence occurring between *chart datum* (defined by Canadian Hydrographic Service as the plane below which the tide will seldom fall (Thomson, 1981) and *higher high water line* (HHW) of the mean tides. Higher high water can often be recognized as the recent high tide swash line. The intertidal zone is often subjectively divided into 'upper', 'middle' and 'lower', and corresponds to the 'B' zone of the across-shore description in Howes *et al.,* (1994).

Subtidal: The area below zero *chart datum* and usually covered by brackish or marine water in an estuary. The 20m isobath dividing shallow, nearshore waters from deeper subtidal environments may be considered the practical limit of the estuarine study area. The subtidal zone corresponds to the 'C' and 'D' zones of Howes *et al.,* (1994).

Elevation is known to provide an important control on biota in estuaries from both submergence times and from the relative effect of salinity that is related to submergence. In general, biota, especially vegetation, follow well-defined zonation patterns (see Gray and Scott 1987 for an excellent example) based on elevation and related submergence time and there has been considerable discussion in the literature as to whether there are any "critical elevation" controls to zonation; Raffaelli and Hawkins (1996) conclude that there are no definitive breaks for elevation control of species zonation – slope, substrate, elevation, tidal regime, wave exposure and freshwater influence are all factors that contribute significantly to zonation.

In a comparison of different estuaries, elevation becomes an important consideration as the relative elevations of various biological communities in relation to known elevations (zero tide, log line etc.), can be used to infer estuarine processes (wave energy, desiccation, etc.).

Provided in this Section is a description of how elevation can be mapped and incorporated into the elevation zone database supplied in Table 7. This methodology is separated into three components discussed below.

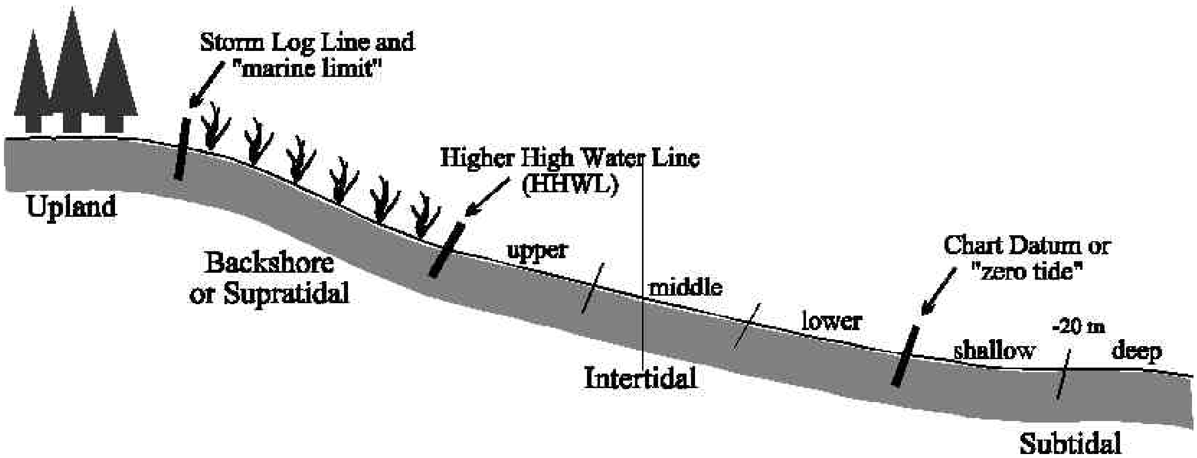


Figure 4 - Schematic representation of across-shore elevations and definitions for elevation zones.

Table 7 - Description of the elevation zone database.

Field Name	Type	Width of Field	Description
EstuaryID	Alphanumeric	14	Unique identifier for Estuary (eg. SEYMWSD0001890x)
PolygonID	Alpha	13	Unique identifier for elevation polygon
Zone	Alpha	15	Name of the elevation zone (e.g. intertidal etc.)
AreaP	Numeric	50	Area of subunit in square meters
Slope	Numeric	2	Slope of subunit in degrees
Upper_elev	Numeric	4	Elevation in metres above/below chart datum
Lower_elev	Numeric	4	Elevation in metres above/below chart datum

Calculating Tidal Zone Elevation

Elevations within the estuary may be difficult to measure. A methodology for computing elevation from tidal curves is outlined below and worked examples are provided in Table 8.

Step 1: Airphoto pretyping

When planning an estuary elevation survey, locate one or more across-shore sampling transects from the airphoto. Transects should be selected to include a range of vegetation and substrate types, as well as including channels.

Step 2: Compute Elevations

In certain instances, transect surveys will not be feasible in the larger estuaries, therefore elevation data will have to be interpolated. This step provides a methodology to compute elevations using the Canadian Hydrographic Service Tidal Tables (CHS 1998).

Estimations of tidal elevations between the marine limit and the zero datum can be obtained for individual estuaries by consulting tide tables of the nearest reference port. Table 8 provides a method and examples of determining intermediate tidal elevations using the Canadian tide tables. The position of those elevations within the estuary can then be determined by observation of the position of the water line at a known tide level (e.g. using tide prediction tables, find the time at which the water level will be at the prescribed elevation and shoot a picture(s) of the estuary at that time). Alternatively, the waterline can be walked with a recording GPS to fix different elevations within the estuary.

Definition of general elevations of across-shore zonation in an estuary are included as qualitative descriptions of general locations within the estuary. When available, an elevation survey, with height in decimeters above zero datum should be included in the mapping. Surveys may be confounded by the differences in the datum used for land-based survey and that of the chart datum. Care must be taken to ensure that estuary elevations are tied to marine chart datum.

Table 8 - Methodology for computing for tidal zone elevations.

Methodology	Example 1	Example 2	Submergence (%)
Select closest CHS reference port	Fulford Harbour	Prince Rupert	
Determine marine limit from CHS reference tables	4.4 m	8.0 m	0%
Determine High High Water, Mean Tides (HHWMT) of closest reference point	3.2 m	6.1 m	5%
Determine sub-zone height (HHWL÷3)	1.07 m	2.03 m	
Determine marine limit to HHWMT to identify supratidal zone	marine limit to 3.2 m	marine limit to 6.1 m	0 – 5%
Determine upper intertidal zone HHWMT to (HHWMT – [HHWMT÷3])	3.2 m to 2.15 m	6.1 m to 4.07 m	5 – 50%
Determine Middle Intertidal (HHWMT – [HHWMT÷3]) to (HHWMT÷3)	2.15 m to 1.07	4.07 m to 2.03 m	50 – 90%
Determine Lower Intertidal (HHWMT÷3) to zero (chart datum)	1.07 m to 0.0 m	2.03 m to 0.0 m	90 - 100%

The *Supratidal* Z*one* is the zone from the “marine limit” or break in terrestrial vegetation, which will correspond to the elevation of measured extreme tides, to the elevation of Higher High Water, Mean Tides (HHWMT). This elevation corresponds approximately to submergence of ~5% of the time.

The remaining zones, the upper, middle and lower intertidal zones, are less likely to consistently correspond to vegetation or faunal breaks due to exposure, substrate, aspect and runoff effects. These intertidal zones are easily calculated and useful for generally characterizing different portions of the estuary.

The calculated elevations should be plotted on the airphotos and later digitized into polygons. If the estuary is suitable for transect surveys, then elevations from the transects should be used to verify the computed elevations prior to digitizing.

Step 3: Field Survey

Where possible, at least one across shore transect running from the log line to the zero tide should be surveyed. Elevation measurements should be made in metres, and the elevation of each change in substrate or biological community type noted on the elevation zone field sheets. Using a combination of the computed elevations in conjunction with field surveys, the elevation zone database should be updated.

4.5 Physical and Biological Site Form Databases

The field sampling program is an integral part of the estuarine mapping system. The spatial variability of the materials and biota within an estuary, and the detailed level of mapping make ground surveys necessary to verify mapped boundaries and polygon attributes. Clear objectives and pre-planning of the field program is required to ensure efficient field survey and coordination between physical and biological mappers. Objectives may include: sampling of homogeneous areas for descriptive purpose, checking polygon boundaries or confirming the distribution of materials (including subsurface) and species compositions of areas to be used for description of new site series definitions.

Field Sampling Procedures

The field sampling of the physical and biological character of an estuary can be conducted together or independently although the former is recommended. The Physical and Biological Site Form Databases are outlined in Tables 9 and 10. Codes and definitions explaining codes and definitions of each form follow each site form. The field survey physical and biological site forms are supplied in Figure 5.

As a general rule most physical and biological map units should be surveyed or visited during the field sampling because of the detailed level of mapping. The level of survey can range from a visual overview to subsurface sampling (physical) or full plot (biological). While minimal site survey would include a *visual inspection* at each mapped polygon, full geological and biological plots should be conducted as often as possible. Several full biological plots should be undertaken in areas where new site series are being developed (as in TEM, 1998). A minimum of 3 to 5 full plots is recommended for defining new site series.

A detailed site sample for physical mapping will include documentation of subsurface materials and a description of their character (e.g. texture, bedrock type, etc.). Field sampling procedures for biological mapping are based on the protocols described in detail in Field Manual for Describing Ecosystems in the Field (RIC 1998), the Terrestrial Ecosystem Mapping manual (RIC, 1998) and the BC Biotic Shore-zone Mapping System (Searing and Frith, 1995).

Detailed site selection for geological sampling or biological plots depends on:

- the size of the estuary
- existing data about the estuary and other field sampling results
- knowledge of local site series or species assemblages being sampled
- questions or concerns developed during pre-typing

Location of the plots in the estuary may be subjective or placed at intervals along a transect which has been laid out to cover the greatest variety of polygon types. In biological sampling, areas of transition between types should be avoided and plots should be representative of a homogenous example of the species present in the site series or bio-band. Recommended plot sizes are smaller than those used to sample vegetation in forested lands. Full plots or visual plots may be circular with radius of as small as 1.8m (10m^2 plot) up to 4m radius (50m^2 plot). Plot shapes may be adapted to best sample the sometimes narrow extent of biotic community present.

4.6 Site form and associated databases

BC ESTUARY MAPPING, BIOPHYSICAL PLOT SITE FORM SITE DATA
Date:___Time start: ______ end: _______
EstuaryID:______Project ident:___________
Location:______________________
Plot GPS latitude:________Plot GPS longitude:_____________
Photo Number(s):______________________ Elevation:____________________________

PHYSICAL DATA

Surveyor Name(s):______________________ Phy_ident:______________PhyunitID:_____
Primary form:___________________________ Secondary form:________________________

MATERIAL

Strata	**Depth**	**First**			**Second**			**Third**		
		P_1	**S_1**	**%**	**P_1**	**S_1**	**%**	**P_1**	**S_1**	%

PROFILE DESCRIPTION AND SKETCH

____

____

____

____

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____

____

SAMPLE ID:_________(CHECK IF SAMPLE COLLECTED)

BIOLOGICAL DATA
Plot ident number:__________ Bio_ident:___________________ BiounitID:_________
Date:_______________________________________Time start: ________ end: _____________
Biotic Unit polygon Ident:____
Surveyors:____
Survey type: Full plot___________Visual inspection plot: _________________Plot area:_____________
Site series/Bio-band of plot:____
Wetland class if applicable:____________________Aspect_________________Slope:________________

Layer*	% Cover
A – total tree	
B – total shrub	
C – herbaceous	
D – mosses and lichens	

*For plots in the upper estuary, areas described by WREC methodology:

Order of dominance	Species name*	% Cover
1		
2		
3		

*Dominant species in the plot to verify polygon mapping in pre-typing:

Photo ident (roll & frame #)	**PHOTO DESCRIPTION**	Photo ident (roll & frame #)	Photo description

SPECIES OBSERVED

Species name *	**Species abbreviation**	**% cover**

* Include all biota observed at the plot: vascular and non-vascular flora and invertebrate fauna, both sessile and infauna if possible.

Table 9 - Description of the Physical Site Form Database.

Field Name	Type	Field Width	Description
EstuaryID	Alphanumeric	14	Estuary identifier, unique code, links to other databases
Plot_ident	Alphanumeric	12	Unique identifier for each plot, links to polygons in the physical unit database
Phy_ident	Alphanumeric	13	Physical unit identifier from BC Physical Shore-zone Mapping System (if available).
Date	Alpha	10	Date dd/mm/yr
Time_start	Alpha	4	Start time of the plot survey. Time of day is important for knowing the level of the tide.
Time_end	Alpha	4	End time
Location	Alpha	50	General location of plot in estuary
PhyunitID	Alpha	2	Unique ident code of the mapped polygon in which the plot is placed, determine from the pre-typing and field survey pre-plan
Surveyors	Alpha	30	Surveyor names
Latitude	Numeric	8	GPS latitude (decimal degrees)
Longitude	Numeric	8	GPS longitude (decimal degrees)
PhotoID	Alphanumeric	8	Project number, roll number and frame numbers of photos taken at the plot. Only the unique photo ident code is recorded in the plot database. The description of the photos is retained on the datasheets for further information about the estuary and the plot sites
Elevation	Numeric	3	Elevation above chart datum (zero tide)
Primform_1st	Alpha	2	Primary Form 1
Primform_2nd	Alpha	2	Primary Form 2
Secform_1st	Alpha	6	Secondary Form 1
Secform_2nd	Alpha	6	Secondary Form 2
Secform_3rd	Alpha	6	Secondary Form 3
Strata_1st	Numeric	1	Strata layer 1 (where 1 is the topmost)
Strata_2nd	Numeric	1	Strata layer 2
Depth	Numeric	6	Depth of each strata in meters (eg. .5 = 50cm)
Primmat_1st	Alpha	1	Primary material descriptor
Secmat_1st	Alpha	1	Secondary material descriptor
Percent_1st	Numeric	2	Percent cover of 1st material descriptor
Primmat_2nd	Alpha	1	Primary material descriptor
Secmat_2nd	Alpha	1	Secondary material descriptor
Percent_2nd	Numeric	2	Percent cover of 2nd material descriptor
Primmat_3rd	Alpha	1	Primary material descriptor
Secmat_3rd	Alpha	1	Secondary material descriptor
Percent_3rd	Numeric	2	Percent cover of 3rd material descriptor
Notes	Alpha	255	Other information
Slope	Numeric	2	Slope of subunit in degrees
Level	Numeric	1	Used only when a veneer of sediment overlies a subsurface

Table 10 - Description of the Biological Site Form Database.

Field Name	Type	Width of Field	Description
EstuaryID	Alphanumeric	14	Estuary identifier, unique code, links to other databases.
Plot_ident	Alphanumeric	12	Unique identifier for each plot, links to polygons in the biological unit database.
Bio_ident	Alphanumeric	13	Biological unit identifier from BC Biological Shore-zone Mapping System (if available).
Date	Alpha	10	Date dd/mm/year
Time_start	Alpha	4	Start time of the plot survey. Time of day is important for knowing the level of the tide.
Time_end	Alpha	4	End time.
Location	Alpha	50	General location of plot in estuary.
BiounitID	Alphanumeric	15	Unique ident code of the mapped polygon in which the plot is placed, determine from the pre-typing and field survey pre-plan.
Surveyors	Alpha	30	Surveyor names.
Latitude	Numeric	8	GPS latitude (decimal degrees).
Longitude	Numeric	8	GPS longitude (decimal degrees).
Survey_type	Alpha	6	Full plot or Visual Inspection.
AreaP	Numeric	10	The area of the plot in square metres.
Sseries	Alpha	225	WREC site series or BC Shore-zone Mapping System bio band (see Tables 5 – 6).
WREC	Alpha	3	WREC Class if applicable to the plot (i.e., in the upper elevations of the estuary) WREC class (see Table 5).
Aspect	Numeric	3	Aspect of the plot in degrees magnetic, measured from the plot as if it was a point along the across-shore profile, the perpendicular from HHW to the low tide line.
Slope	Numeric	3	Measured slope of the plot in degrees.
Layer_A	Numeric	2	estimated % cover of Total Tree layer (A).
Layer_B	Numeric	2	estimated % cover of Total Shrub layer (B).
Layer_C	Numeric	2	estimated % cover of Total Herb layer (C).
Layer_D	Numeric	2	estimated % cover of Total Moss layer (D).
Dom1	Alpha	7	Species name of the first most dominant species in plot.
Dom1_per	Numeric	2	% cover of the most dominant species.
Dom2	Alpha	7	Species name of the second most dominant species in the plot (if applicable).
Dom2_per	Numeric	2	% cover of the second most dominant species.
Dom3	Alpha	7	Species name of the third most dominant species in the plot (if applicable).
Dom3_per	Numeric	2	% cover of the third most dominant species.
PhotoID	Alphanumeric	8	Project number, roll number and frame numbers of photos taken at the plot. Only the unique photo ident code is recorded in the plot database. The description of the photos is retained on the datasheets for further information about the estuary and the plot sites.
Notes	Alpha	255	Any other brief notes about the plot.
Species1	Alpha	7	Species name of biota observed in the plot
Species1_per	Numeric	2	% cover observed for species 1.
Speciesn	Alpha	7	All species observed in the plot.
Speciesn_per	Numeric	2	% cover observed for each species recorded in the plot.
SampleID	Alphanumeric	8	Used if sample(s) collected in the field.

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Appendix A: Wave Exposure Calculation

Wave processes are the dominant controlling process for shore morphology and sediment redistribution and are probably the dominant control of biota that use the shore zone. Consequently, it is important to have an index of wave exposure for each shoreunit.

Ideally wave exposure estimates would be based on the consideration of wave energy units; however, the calculation of wave energy for a particular shore unit would involve the use of complex wave climate models that use wave fetch characteristics, historical wind climate measurements from shore stations with over-the-water corrections for the area under consideration, wave generation routines, and wave refraction and shoaling routines. The application of these routines would be required for each shore unit.

This method for estimating wave exposure is based on some standard engineering practices for estimating wave heights for a particular wind speed and direction. It was developed for the British Columbia Physical Shore-zone Classification (Howes *et al.* 1994). The method involves the consideration of the wave fetch window; that is, the open-water area offshore from the shoreunit over which waves can be generated by winds **- the larger the fetch window, the greater the wave exposure**.

Estimation of wave exposure involves the consideration of two fetch indices: effective fetch and maximum fetch. The wave exposure estimates provided by this technique represent **a first approximation** of wave exposure. Important controls such as the associated local wind climate and wave refraction are ignored for the sake of simplifying the estimate. As such, the Wave Exposure estimates provide a first-order estimate of wave energy expended within the shoreunit.

Intertidal biotic assemblages have been used as an index of wave exposure categories and have been found to agree reasonably well with the Wave Exposure estimates defined from the "fetch model". Analysis of detailed ground survey stations of intertidal biota showed about 75% agreement with the fetch model and about 85% agreement with video-imagery revisions of the "fetch model". In other words, the Wave Exposure categories defined as part of the fetch model agree with community assemblages observed in the field.

Effective Fetch

Effective fetch calculation involves the measurement of the fetch distance along several directions from a given point from the shore and is a standard engineering measurement for shore protection studies (CERC 1977).

Wave fetch measurement values and exposure calculations

Unit	**Shore Normal Azimuth (°)**	**Shore Normal Fetch (km)**	**Left 45° (km)**	**Right 45° (km)**	**Max. Fetch Azimuth (°)**	**Max. Fetch (km)**	**Effective Fetch (km)**	**Exposure Category**
A	135	15.7	8.2	19.5	131	29	14.6	SP
B	066	19.0	13.0	11.0	073	40	14.9	SP
C	035	13.5	11.5	50	082	75	23.6	SE

To simplify the large number of measurements required for a mapping area (for example there are over 1,800 shore units mapped in the Southern Strait of Georgia), a "modified effective fetch" measurement was developed. The "modified effective fetch" technique involves the measurement of three fetch distances: the shore-normal or perpendicular to the general trend of the shore unit, 45^o to the left of the shore-normal and 45^o to the right of the shore normal.

These three measurements are used to compute a modified effective fetch for the shoreunit based on the fetch equations:

Effective Fetch Calculation (after CERC 1977)

$F_e = \Sigma(\cos\propto_i) \cdot F_i / \Sigma(\cos\propto_i)$

where F_e = effective fetch in kilometres (from CHS chart)

$\propto_i$ = the angle between the shore normal and the direction $_i$

F_i = the fetch distance in kilometres along direction $_i$

Modified Effective Fetch Calculation

$F_m = [\cos(45^o) \cdot F_{45L} + \cos(90^o) \cdot F_{090} + \cos(45^o) \cdot F_{45R}]/[\cos45^o+\cos90^o+\cos45^o]$

$= [(0.707) \cdot F_{45L} + (1.0) \cdot F_{090} + (0.707) \cdot F_{45R}]/[2.414]$

where F_m = modified effective fetch in kilometres

F_{45L} = the fetch distance in kilometres along direction 45^o left of the shore normal

F_{090} = the fetch distance in kilometres along direction the shore normal

F_{45R} = the fetch distance in kilometres along direction 45^o right of the shore normal

Maximum Fetch

The wave climate of a particular point cannot be characterized by effective fetch alone because waves may be generated in an area remote from the shore unit and propagate into the area of the shore unit. These waves are commonly refered to as swell. A good BC example is that of the Juan de Fuca Strait where waves are generated locally (indexed by effective fetch) and are relatively small, but large swell, generated in the open Pacific, can penetrate into the Strait. The maximum fetch of a shoreunit is intended to provide an index of the swell waves and, to a lesser extent, refraction effects.

The Maximum Fetch is the maximum fetch distance in kilometres that can be measured from a centre point of the estuary.

Wave Climate Fields for Calculation of Estuary Wave Exposure

There are several wave climate data fields that need to be calculated to determine the wave exposure of the estuary. These are defined below:

Maximum Fetch Direction - the azimuth (in degrees from true north) of the direction of the maximum fetch.

Maximum Fetch Distance - the distance in kilometres of the maximum fetch as measured along the Maximum Fetch Direction.

Shore Normal Direction - the azimuth (in degrees from true north) of the normal to the general orientation of the shore unit. That is, if the general trend of the shoreline is from northwest to southeast with open water to the east), then the Shore Normal Direction would be 45^o.

Fetch Distances - the distances in kilometres as measured along a line 45° to the left of the Shore Normal, along the Shore Normal and along a line 45° to the right of the Shore Normal.

Modified Effective Fetch - the distance in kilometres as calculated from the Fetch Distance Measurements.

Exposure Category - the exposure category provides a summary indicator of wave exposure for the unit.

The following classes of wave exposure have been utilized and are derived from knowledge of Maximum Fetch and Modified Effective Fetch. These are accompanied with the appropriate code for entry in the wave exposure attribute of the project and overview database, and definition.

VP **Very Protected :** Maximum wave fetch less than one kilometre; usually the location of all-weather anchorages, marinas and harbours.

P **Protected:** Maximum wave fetch less than 10 km; usually areas of provisional anchorages and low wave exposure except in extreme winds.

SP **Semi-protected:** Maximum wave fetch distances in the range of 10 to 50 km. Waves are low most of the time except during high winds.

SE **Semi-exposed :** Maximum wave fetch distances between 50 and 500 km. Swells, generated in areas distant from the shore unit create relatively high wave conditions. During storms, extremely large waves create high wave exposures.

E **Exposed:** Maximum wave fetch distances greater than 500 km. High ambient wave conditions usually prevail within this exposure category, which is typical of open-Pacific type conditions.

Effective and maximum fetch wave exposure Matrix

Modified effective fetch (km)

Maximum fetch (km)	<1	1-10	10 - 50	50 - 500	>500
<10	Very protected	Protected	N/a	N/a	N/a
10 - 50	N/a	Semi-protected	Semi-protected	N/a	N/a
50 - 500	N/a	Semi-exposed	Semi-exposed	Semi-exposed	N/a
>500	N/a	N/a	Semi-exposed	Exposed	Exposed

This procedure, although preliminary and subject to refinement, offers an objective, repeatable basis for estimating wave exposure. Wave exposure, in turn, is of critical importance in determining species distribution, sediment mobility and a variety of other shore processes.

APPENDIX B Marine Species Lists

Species	**Common name/description**
CYANOBACTERIA	BLUE GREEN ALGAE
Various spp	
BACILLARIOPHYTA	**DIATOMS**
Loose skeins on mud	
On rocks, on seaweeds	
CHLOROPHYTA	**GREEN ALGAE**
Acrosiphonia spp	green rope weed
Blidingia spp	
Cladophora spp	branching green filament seaweed
Codium fragile	dark green finger seaweed
Codium setchellii	dark green spongy seaweed
Enteromorpha spp	wrinkled green tube seaweed
Monostroma spp	mono-layer sea lettuce
Prasiola spp	green guano seaweed
Rhizoclonum spp	tangled drk grn filament on mud
Ulva teaniata	sea lettuce
Ulva fenestrata	perforated sea lettuce
Ulva spp	sea lettuce
Various planktonic, pools	
Unbranched filaments	green sea hair
unidentified spp	
PHAEOPHYTA	**BROWN ALGAE**
Var. encrusting	
Agarum spp	solid broad kelp
Alaria marginata	short stipe alaria
Alaria nana	small alaria
Alaria spp	long stipe alarias
Analipus abietina	yellow bottle brush
Coilodesme bulligera	flat sac
Colpomenia spp	globose sac
Costaria costata	multi-ribbed searsucker
Cymothere triplicata	multi-ribbed smooth blade
Desmarestia aculeata	fine branched brown
Desmarestia ligulata	broad branched brown
Egregia menziesii	feather boa
Fucus gardneri	common brown rock weed
Fucus spp	hairy pit rock weed

Haplogloia andersonii	furry soft branch
Hedophyllum sessile	sea cabbage
Laminaria groenlandica	flaccid dissected laminaria
Laminaria saccharina	sugar kelp
Laminaria setchellii	stiff laminaria
Leathesia difformis	convoluted yellow sac
Lessoniopsis littoralis	knarled tough root weed
Macrocystis integrifolia	branching giant kelp
Melanosiphon intestinalis	yellow spagetti weed
Nereocystis luetkeana	bull kelp
Ralfsia spp	yellow-brown thin crust
Sargassum muticum	japanese weed
Scytosiphon lomentaria	mini-sausage links
unidentified spp	
RHODOPHYTA	**RED ALGAE**
Ahnfeltia spp	thick wiry dark weed
Antithamnion spp	red branching fluff
Bangia vermicularis	red sea hair
Bonnemaisonia nootkana	delicate red feather
Bossiella spp	
Calliarthron spp	
Calliarthron/Bossiella spp	broad joint corallines
Callithamnion pikeanum	dark elongate seamoss
Callophyllis, spp	non-veined red leafy
Ceramium spp	micro-cross bands
Corallina vancouveriensis	bushy cylindrical coralline
Corallina pilulifera	
Cumagloia andersoni	gelatinous spiny fat branches
Cryptopleura ruprechtiana	ruffled net vein
Cryptosiphonia woodii	dark branching knob tip
Delessaria decipiens	veinless leaflet edged
Endocladia muricata	thin dark spiny wires
Erythrophyllum delesserioides	tattered veined leaf
Gastroclonium subarticulatum	narrow neck branching cylinders
Gelidium coulteri	
Gelidium purpurescens	blunt-tip candelabra
Gigartina corymbifera	broad turkish towel
Gigartina exasperata	elongate turkish towel
Gigartina spp	
Gloiopeltis furcata	small gelatinous sparse branching
Gracilaria spp	large gelatinous irregular branching

Gymnogongrus leptophyllus	short bifurcated-tip straps
Gymnogongrus linearis	long bifurcated-tip straps
Halosaccion glandiforme	fine spray sea sacs
Hildenbrandia occidentalis	dark red thin crust
Hymenena spp	
Iridaea cordata	purple iridescent broad blades
Iridaea cornucopiae	yellow-brown flaring small blades
Iridaea heterocarpa	brownish iridescent broad blades
Iridaea lineare	purple, rubbery elongate blades
Laurencia spectabilis	flat stiff pinnate branches
Lithothamnion/Lithophyllum, etc	red calcareous crust
Mastocarpus papillatus	small papillate straps
Membranoptera dimorpha	veined leaflet edged
Microcladia borealis	one sided round branches
Microcladia coulteri	alternate sided round branches
Neorhodomela larix	black tufted bottle brush
Nemalion helminthoides	brown spagetti
Nienburgia andersoniana	spiny lateral bladelets
Odonthalia spp	dark dense knob-tip branches
Opuntiella californica	ovoid & lateral bladelets
"Petrocelis" stage	thick tarspots
Phycodrys setchellii	veined blades on stolon
Pikea californica	pointed-tip candelabra
Plocamium cartilagineum	alternate sided outcurved flat branches
Plocamium violaceum	alternate sides incurved flat branches
Polyneura latissima	smooth net vein
Polysiphonia spp	tier-celled fine tufts
Porphyra spp	translucent steel grey/purplish green
Prionitis lanceolata	small lateral blades on lance
Prionitis linearis	wiry spiny tips
Prionitis lyalli	lateral lances on lance
Ptilota spp	serrate edged blades
Rhodochorton purpureum	light red shaded crust
Rhodoglossum affine	short dichotomous twisted branches
Rhodomenia pertusa	perforated red broad blades
Sarcodiotheca gaudichaudii	large one-plane pink branching
Schizymenia pacifica	broad soft slippery blades
Stenogramme interrupta	broad bifurcate straps
unidentified filamentous spp	
unidentified leafy spp	
unidentified red algae spp	

unidentified spp	
FUNGI/LICHENS	
"Verrucaria"	high black crust
unidentified spp	
ANGIOSPERMS	**FLOWERING PLANTS**
Phyllospadix scouleri	surf grass
Salicornia virginica	pickle weed
Zostera marina	common eel grass
unidentified grasses/rushes	
PORIFERA	**SPONGES**
Acarnus erithaceus	thick crimson sponge
Adocia spp	flake top mauve sponge
Aplysilla "glacialis"	pink slippery sponge
Cliona spp	yellow boring sponge
Craniella villosa	spiny tennis ball sponge
Halichondria "bowerbanki"	yellow midtide encrusting sponge
Halichondria panicea	green midtide sponge
"Haliclona permollis"	purple midtide sponge
Halisarca spp	slippery yellow tan sponge
Hymeniacidon spp	yellow in,purple out sponge
Laxosuberites spp	ivory thin nipple sponge
Leucandra spp	small tufted pear sponge
Leucilla nuttingi	stalked vase sponge
Leucosolenia eleanor	white anastomosing sphere sponge
Myxilla incrustans	thick, dull yellow sponge
Ophlitaspongia pennata	red midtide sponge
Reneira sp B	stell blue
"Scypha" spp	unstalked whte vase sponge
Stelletta clarella	thick white prickly sponge
Suberites sp A	thick yellow dense sponge
Tethya aurantium	orange textured ball sponge
Red sponge species	unidentified
Rust brown species	unidentified
Sticky brown soft species	unidentified
Wavy red species	unidentified
unidentified spp	
COELENTERATA - Hydrozoa + HYDROIDS	
Abietinaria spp	regular branched hydroids
Aglaophenia spp	stiff feather hydroids
Eudendrium spp	brown annulated hydroids
Garveia spp	orange hydroids

Obelia spp	plumose hydroids
Plumularia spp	soft feather hydroids
Sertularia	irregular branched yellow hydroids
Sertularella	no/few branched yellow hydroids
Stylantheca petrograpta	red/violet hydrocoral crust
Stylantheca porphyra	purple hydrocoral crust
Tubularia spp	large pink headed hydroids
unidentified hydroid spp	
COELENTERATA - Anthozoa + SEA ANEMONES & ALLIES	
Anthopleura artemisia	drab column tentacled burrowing anenome
Anthopleura elegantissima	small aggregating green anemone
Anthopleura xanthogrammica	large solitary green anemone
Balanophyllia elegans	orange cup coral
Clavularia spp	tan/ivory thin crust soft coral
Epiactis spp	white radial lines on tentacles/oral disc anenome
Epizoanthus scotinus	colonial tan zoanthid
Gersemia rubiformis	sea strawberry soft coral
Haliplanella lineata	small orange striped anemone
Metridium giganteum	solitary giant plumose anemone
Metridium senile	aggregating small plumose anemone
Paracyathus stearnsi	tan cup coral
Peachia quinquecapitata	twelve tentacled burrowing anemone
Urticina lofotenis	red-olive green-variegated anemone
Urticina coriacea	red column blunt tentacled burrowing aenemone
Urticina crassicornis	white tubercle red anemone
unidentified spp	
PLATYHELMINTHES	**flat worms**
Polycladida spp	unidentified spp
NEMERTEA	**ribbon worms**
Amphiporus spp	v-neck ribbon worm
Amphiphorus formidabilis	dirty white ribbon worm
Amphiporus imparispinosus	flesh ribbon worm
Cerebratulus albifrons	brown white tipped flat ribbon worm
Cerebratulus longiceps	narrow neck flat ribbon worm
Cerebratulus marginatus	light margined flat ribbon worm
Paranemertes peregrina	purple top cream bottom ribbon worm
Tublanus sexlineatus	white ringed and white line ribbon worm
unidentified nemertean spp	unidentified spp
MOLLUSCA	
POLYPLACOPHORA	**CHITONS**

Cryptochiton stelleri	gumboot chiton
Katharina tunicata	black katy chiton
Lepidozona mertensi	red scaled chiton
Leptochiton rugatus	minute white chiton
Mopalia ciliata	spiny strap haired chiton
Mopalia cirrata	sparse haired chiton
Mopalia lignosa	white spotted hairy chiton
Mopalia muscosa	mossy chiton
Mopalia spp	
Placiphorella velata	carnivorous chiton
Tonicella lineata	wavy lined yellow spot chiton
unidentified chiton spp	
GASTROPODA: PROSOBRANCHIA	**SNAILS & ALLIES**
Acmaea mitra	white capped limpet
Alia carinata	smooth-top, dented aperature snail
Amphissa columbiana	wrinkled dove snail
Astrea gibberosa	red turban snail
Bittium eschrichti	threaded bittium
Calliostoma annulatum	purple ringed top shell
Calliostoma canaliculatum	channeled top shell
Calliostoma ligatum	brown & blue top shell
Ceratostoma foliatum	leafy hornmouth
Crepidula adunca	hooked brown slipper snail
Crepidula perforans	western white slipper snail
Diodora aspera	rough keyhole limpet
Fissurellidae bimaculatus	large key-hole limpet
Fusinus harfordi	red spindle
Fusitriton oregonensis	oregon triton
Haliotis kamtschatkana	northern abalone
Homalopoma lacunatum	open umbilicus dwarf turban
Homalopoma luridum	ridged dwarf turban
Homalopoma subobsoletum	smooth dwarf turban
Lacuna spp	chink shells
Lirularia spp	
Littorina sitkana	sitka periwinkle
Littorina scutulata	checkered periwinkle
Lottia digitalis	ribbed limpet
Lottia pelta	shield limpet
Margarites marginatus	smooth margarite
Margarites pupillus	little margarite
Marsenina spp	pseudoflatworm snail

Nitidiscala indianorum	indian wentletrap
Nucella canaliculata	channeled dogwinkle
Nucella emarginata	emarginate dogwinkle
Nucella lamellosa	frilled dogwinkle
Nucella lima	rough purple dogwinkle
Ocenebra interfossa	
Ocenebra/Trophonopsis spp	rock snails
Olivella biplicata	purple olive
Opalia spp	wentletraps
Polinices lewisi	lewis's moon snail
Lirabuccinum	dire whelk
Tectura persona	mask limpet
Tectura scutum	plate limpet
Tegula pulligo	dusky turban
Trichotropis cancellata	checkered hairy snail
Vermetus compactus	little tube-worm snail
unidentified spp	
GASTROPODA: OPISTHOBRANCHIA	**SEA SLUGS**
Aeolidia papillosa	shag rug nudibranch
Anisodoris nobilis	orange fragrant seaslug
Archidoris montereyensis	monterey dorid
Cadlina luteomarginata	yellow edged cadlina
Diaulula sandiegensis	ring spotted dorid
Dirona albolineata	chalk lined dirona
Haminoea virescens	green bubble snail
Haminoea vescicula	
Hermissenda crassicornis	blue-lined aeolid
Onchidoris bilamellata	barnacle dorid
Rostanga pulchra	red sponge dorid
Tochuina tetraquetra	tochni
Triopha catalinae	sea clown triopha
unidentified spp	
GASTROPODA: PULMONATA	**LUNGED SNAILS**
Onchidella borealis	leather sea-slug
Siphonaria theristes	limpet-like pulmonate
unidentified spp	
BIVALVIA	**bivalves**
Clinocardium nuttalli	basket cockle
Crassadoma gigantea	purple-hinged rock scallop
Glans carpenteri	little heart clam
Glans subquadrata	eccentric ridged clam

Hiatella arctica	nestling saxicave
Kellia suborbicularis	nestling clam
Macoma calcerea	
Macoma nasuta	bent-nose clam
Macoma secta	sand clam
Macoma spp	baltic clam
Modiolus flabellatus	giant horse mussel
Musculus taylori	tiny bearded mussel
Mya arenaria	soft-shell clam
Mya truncata	blunt soft-shell clam
Mytilimeria nuttalli	sea-squirt clam
Mytilus californianus	california mussel
Mytilus edulis	blue mussel
Panope abrupta	geoduck
Pododesmus cepio	jingle shell
Protothaca staminea	native little-neck clam
Saxidomus giganteus	butter clam
Semele rubropicta	red-painted semele
Tellina nuculoides	walking clam
Tresus capax	fat horse clam
unidentified spp	
CEPHALOPODA	**OCTOPODS, SQUIDS**
Octopus dofleini	giant pacific octopus
ANNELIDA	**segmented worms**
POLYCHAETA	**bristle worms**
Arabellidae	red irridescent burrowing worms
Arenicolidae	lug worms
Capitellidae	thread worms
Cirratulidae	filamentous body tentacles
Docecaceria concharum	small black u worm
Dodecaceria fewkesi	large black u worm
Eudistylia spp	giant feather-duster worms
Glyceridae	blood worms
Idanthyrus armatus	cemented tube worm
Maldanidae	bamboo worms
Mesochaetopterus taylori	long parchment tube worm
Myxicola spp	jelly house fan worm
Neanthes brandti	giant nereid worm
Nephtyidae	flat head worms
Nereis vexillosa	green mussel worm
Opheliidae	twitching worms

Orbinidae	bush, pointed snout worms
Owenia collaris	writhing tile worm
Phyllochaetopterus prolifica	colonial parchment tube worm
Phyllodocidae	leafy cirri worms
Pista spp	shaggy tube worm
Polynoidae	scale worms
Sabellaria cementarium	honeycomb worm
Salmacina tribranchiata	tangled white tubes worm
Schizobranchia insignis	feather duster worm
Serpula vermicularis	red calcarious tube worm
Spionidae	palp worms
"Spirorbis" spp	tiny white tube worms
Syllidae	showy cirri worms
Terebellidae	medusa worms
unidentified spp	
SIPUNCULIDA	**PEANUT WORMS**
Phascolosoma agassizi	banded peanut worm
ARACHNIDA	**SPIDERS, MITES, & ALLIES**
Neomolgus littoralis	red shore mite
CRUSTACEA	
COPEPODA	
Tigriopus californicus	red spray pool copepod
CIRRIPEDIA	**barnacles**
Balanus balanoides	false common barnacle
Balanus crenatus	smooth acorn barnacle
Balanus glandula	common pacific acorn barnacle
Balanus nubilus	giant acorn barnacle
Chthamalus dalli	small brown barnacle
Pollicipes polymerus	goose neck barnacle
Semibalanus cariousus	thatch acorn barnacle
unidentified spp	
LEPTOSTRACA	**hooded shrimp**
Nebalia pugettensis	mud flat hooded shrimp
MYSIDACEA	**possum shrimp**
unidentified spp	
ISOPODA	**pill bugs & allies**
Cirolana harfordi	carnivorous grey isopod
Gnorimosphaeroma insulare	estuarine roll-up isopod
Gnorimosphaeroma oregonensis	common roll-up isopod
Idotea aculeata	pink idotea
Idotea montereyensis	monterey idotea

Idotea resecata	concave telson idotea
Idotea spp	unidentified spp
Idotea stenops	fat idotea
Idotea urotoma	no telson point idotea
Idotea wosnesenskii	kidney eye idotea
Limnoria spp	wood boring gribble
Lygia pallasi	speedy shoreline isopod
unidentified spp	
AMPHIPODA - GAMMARIDEA	**side swimmers & allies**
Talitridae	beach hoppers
unidentified gammarids spp	side swimmers
unidentified caprellids spp	skeleton shrimp
DECAPODA	**10-legged crustaceans**
Cancer gracilis	purple legged graceful crab
Cancer magister	dungeness crab
Cancer oregonensis	ovoid nestling crab
Cancer productus	red rock crab
Crangonidae	in-bottom shrimps
Cryptolithodes sitchensis	wide snoot turtle crab
Discorsopagurus schmitti	tube dwelling hermit crab
Hapalogaster mertensi	orange fingered hairy lithode crab
Hemigrapsus nudus	purple shore crab
Hemigrapus oregonensis	drab mud-flat crab
Hyas lyratus	lyre crab
Lophopanopeus bellus	black clawed straight margined crab
Mimulus foliatus	winged shell crab
Neotrypaea californiensis	bay ghost shrimp
Oedignathus inermis	tuberculate nestling lithode crab
Oregonia gracilis	long snoot decorator crab
Pachycheles pubescens	hairy porcelain crab
Pachycheles rudis	knob-on-claw porcelain crab
Pandalus danae	coon striped shrimp
Pagurus armatus	oval eyed long ant. Hermit
Pagurus beringanus	orange banded leg hermit crab
Pagurus granosimanus	blue granular legged hermit crab
Pagurus hemphilli	yellow eye circled hermit crab
Pagurus hirsutiusculus	hairy hermit crab
Pagurus ochotensis	oval eyed short ant. hermit crab
Pagurus samuelis	blue/white banded leg hermit
Pagurus spp	unidentified hermit crab
Petrolisthes cinctipes	red jawed porcelain crab

Petrolisthes eriomerus	blue jawed porcelain crab
Phyllolithodes papillosus	leafy lithode crab
Pugettia gracilis	naked graceful kelp crab
Pugettia producta	naked olive backed kelp crab
Pugettia richii	red decorator kelp crab
Scyra acutifrons	broad sharp nosed decorator crab
Telmessus cheiragonus	yellow horse crab
Upogebia pugettensis	blue mud shrimp
unidentified spp	
BRACHIOPODA	**lamp shells**
Terebratalia transversa	wavy wide lamp shell
PHORONIDA	**lophophore worms**
Phoronopsis harmeri	sand lophophore worm
Phoronis ijimae	colonial rock lophophore worm
unidentified spp	
BRYOZOA	**moss animals**
Alcyonidium spp	gel crust bryozoan
Bowerbankia spp	
Bugula californica	orange spiraled bryozoan
Crisia spp	branched tubes, white joints
Dendrobeania lichenoides	flexible leaf bryozoan
Diaperoecia spp	rough yellow rigid finger bryozoan
Eurystomella bilabiata	orange with red semicircle crust bryozoan
Filicrisia spp	branched tubes, black joints
Flustrellida corniculata	spiny flexible leaf bryozoa
Heteropora magna	smooth yellow rigid finger bryozoan
Hippodiplosia insculpta	rigid orange sinous pallisa bryozoan
Phidolopora labiata	yellow lace bryozoan
Schizoporella unicornis	orange encrusting bryozoan
Scrupocellaria spp	bushy, whip bryozoan
unidentified spp	
ECHINODERMATA	**spiny skinned animals**
HOLOTHUROIDEA	**sea cucumbers**
Cucumaria lubrica	grey scattered tube feet sea cucumber
Cucumaria miniata	orange sea cucumber
Cucumaria piperata	speckled sea cucumber
Cucumaria pseudocurata	grey aligned tube feet sea cucumber
Eupentacta pseudoquinquesemita	white slender feet sea cucumber
Eupentacta quinquesemita	yellow-ivory broad feet sea cucumber
Leptosynapta clarki	papillated pink burrowing sea cucumber
Leptosynapta transgressor	

Parastichopus californicus	red & white spiny sea cucumber
Pseudonchus astigmatus	pale yellow sea cucumber
Psolus squamatus	red sole attached sea cucumber
ECHINOIDEA	**sea urchins**
Dendraster excentricus	excentric sand dollar
Strongylocentrotus droebachiensis	green sea urchin
Strongylocentrotus franciscanus	giant red sea urchin
Strongylocentrotus purpuratus	purple sea urchin
ASTEROIDEA	**sea stars**
Asterina miniata (patiria)	bat star
Crossaster papposus	rose star
Dermasterias imbricata	leather star
Evasterias troscheli	mottled star
Henricia leviuscula	blood star
Leptasterias hexactis	six-armed star
Mediaster aequalis	mediaster aequalis
Pisaster brevispinus	giant pink star
Pisaster ochraceous	purple/ochre star
Pteraster tesselatus	slime star
Orthasterias koehleri	red & white banded star
Pycnopodia helianthoides	sunflower star
Solaster dawsoni	morning sun star
Solaster stimpsoni	purple band sun star
Stylasterias forreri	long armed black star
unidentified spp	
OPHIUROIDEA	**brittle stars**
Amphiodia occidentalis	sand burrowing brittle star
Amphipholis pugetana	tiny banded brittle star
Amphipholis squamata	brooding brittle star
Ophiopholis aculeata	daisy brittle star
TUNICATA:ASCIDACEA	**sea squirts**
Aplidium solidum	translucent orange slab seasquirt
Archidistoma molle	globose white with red dots seasquirt
Archidistoma psammion	leathery sandy slab seasquirt
Archidistoma purpuropunctatum	lavender
Archidistoma ritteri	pale yellow
Ascidia callosa	brown hemisphere solitary seasquirt
Ascidia paratropa	glassy spiny seasquirt
Boltenia villosa	orange stalked hairy seasquirt
Botryllus sp	yellow/orange sunburst array seasquirt
Chelyosoma productum	translucent brown flat-top seasquirt

Clavelina huntsmani	neon lightbulb seasquirt
Cnemidocarpa finmarkiensis	orange solitary hemisphere seasquirt
Corella spp	soft translucent solitary seasquirt
Cystodytes lobatus	spiculated slab seasquirt
Didemnum carnulentum	pink thin seasquirt
Didemnum, Tridemnum	pink/white thin seasquirt
Diplosoma macdonaldi	thin sheet salt & pepper seasquirt
Distaplia occidentalis	variegated colour sponge
Halocynthia aurantium	sea peach
Halocynthia igoboja	large drab spiny seasquirt
Metandrocarpa dura	red-orange crowded social seasquirt
Metandrocarpa taylori	red-orange spaced social seasquirt
Perophora annectens	green mini sea grapes
Pycnoclavela huntsmani	orange tipped elongate sand-covered seasquirt
Pyura haustor	orange siphon wrinkled seasquirt
Ritterella pulchra	orange flat-top lobes
Ritterella rubra	crimson lobed colonial seasquirt
Styela montereyensis	narrow stalked grooved solitary seasquirt
Styela spp	broad stalked solitary seasquirt
Synoicum parfustis	sandy-red zooid, orange tunicate
unidentified compound ascidians	
unidentifed spp	
VERTEBRATA	**backboned animals - fish**
Anoplarchus insignis	slender cockscomb
Anoplacrchus purpurescens	high cockscomb
Apodichtys flavidus	penpoint gunnel
Artedius harringtoni	scalyhead sculpin
Clinocottus globiceps	mosshead sculpin
Gobiesox maeandricus	northern clingfish
Jordania zonope	longfin sculpin
Leptocottus armatus	pacific staghorm sculpin
Myxocephalus polyacanthocephalus	great sculpin
Oligocottus maculosus	tidepool sculpin
Oligocottus rimensis	saddleback sculpin
Pholis laeta	crescent gunnel
Sculpinidae, other	sculpins
Syngnathus griseolineatus	pipefish
Xererpes fucorum	rockweed gunnel
Xiphister atropurpureus	black prickleback
Xiphister mucosus	rock prickleback
unidentified spp	