Developing a Guidance Document for Puget Sound Marine Shorelines

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Introduction

Shoreline armoring—the construction of bulkheads and seawalls—has become a significant environmental issue on Puget Sound. Armoring influences beaches on the shoreline, alters coastal ecology, and reduces the resilience of the coast to rising sea level (Williams and Thom, 2001). The Aquatic Habitat Guidelines (AHG, a consortium of federal, state, and local stakeholder groups) document "Protecting Nearshore Habitat and Functions in Puget Sound" (Environ Vision and others, 2007) states that planners should enforce or encourage the use of alternative design methods in nearshore development projects to avoid and minimize environmental impacts. Currently, there is no comprehensive document to provide a technical foundation for the design of alternatives to rock and concrete bulkheads and the myriad of other projects, including restoration, that are proposed for our shorelines. The audience for this document would be the restoration, regulatory, and marine shoreline community who are looking for help to protect nearshore resources while permitting development. A proposed Marine Shoreline Design Guideline (MSDG) would build on the scientific background developed at the Shoreline Armoring Impacts Workshop. This guideline would integrate assessment, risk analysis, mitigation, and site requirements into the design processes, similar to the approach taken in AHG's Integrated Streambank Protection Guidelines (Cramer, Bates and others, 2002).

Aquatic Habitat Guidelines

The Aquatic Habitat Guidelines program is a group of agencies and stakeholders whose mission includes the promotion, protection, and restoration of fully functioning marine, freshwater, and riparian habitat through comprehensive and effective management of activities affecting Washington's aquatic and riparian ecosystems. Project participants include the Washington Departments of Fish and Wildlife, Ecology, Transportation, and Natural Resources; the Interagency Committee for Outdoor Recreation; the United States Army Corps of Engineers; and the United States Fish and Wildlife Service. Recently the Washington State Association of County Engineers and the Washington Forest Protection Association were added to the list of contributing agencies. This broad group produces guidance that has become essential in the design and permitting of aquatic projects. The composition of workgroups changes with the task, and participation in the MSDG development might include only a portion of the mentioned groups.

AHG has produced a number of successful guidance documents. Most relevant in this context is the Integrated Streambank Protection Guidelines (ISPG). The floods of 1996-97 caused catastrophic bank failures along many Washington rivers. The response of landowners was to use traditional rip rap countermeasures, resulting in serious environmental consequences. Natural resource agencies found themselves without viable alternatives to rip rap and without a rational mitigation strategy to compensate for the impacts. At the same time, certain salmon species were listed under the Endangered Species Act. This required a coordinated and consistent approach to the regulation of development that affected these fish.

AHG documents begin with a set of guiding principles to focus and direct them. There are AHG General Guiding Principles for Project Planning and Implementation that cover all the guidelines. These include using the best available science; recognizing and maintaining geomorphic processes; encouraging responsible land use practices that maintain natural processes and avoid adverse cumulative effects; providing compensatory mitigation to restore historical ecological functions; considering the project impacts over time and across the landscape; and recognizing that monitoring and adaptive management are critical components of restoration, mitigation, and management activities (Cramer, Bates and others, 2002). Without guidance documents, the designers do not have these principles in front of them to guide their decisions, and the permit writers or planners do not have a rationale for stewardship.

For example, a landowner's riverbank is washed away in a flood and part of his yard is gone. Before ISPG was published, the landowner might hire an engineer who refers to a time-honored U.S. Army Corps of Engineers (Corps) bank stabilization manual and designs a fractured rock revetment composed of rock of a certain size, laid at a certain thickness and slope, all determined from quantitative design methods and criteria. The landowner and designer feel confident that they have followed reliable advice. To a regulator charged with preserving and protecting natural resources, it is obvious that this is the worst possible alternative, but there is no comprehensive method to evaluate it and no alternatives to suggest that might mitigate impacts. ISPG provides those methods and alternatives, and this document has become

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a respected resource and the industry standard for environmental design of bank protection.

Present-day conditions along Washington's marine nearshore are similar to those in the late 1990s on Washington's rivers, and the need for a Marine Shoreline Design Guidance is nearly identical to the one that brought about ISPG. Thirty percent of the Puget Sound shoreline is already armored, and every year approximately 1.5 mi of new bulkheads are built and about 2.5 mi are replaced (R. Carman, Washington Dept. of Fish and Wildlife, oral communication concerning the number of Hydraulic Project Approvals written in Washington State for bulkheads on Puget Sound, May 2010). There are alternative techniques but no comprehensive monitoring to document their success, or standard of care for their proper design. MSDG will develop the science and design methodology for integrated shoreline protection.

Current Marine Shorelines Design Guidance

The structural approach to marine shore protection has been used and studied for generations and reached a highpoint in the Army Corps of Engineers' Shore Protection Manual (U.S. Army Corps of Engineers, 1984), in which engineers were given the tools to design marine shoreline protection. The underlying physical processes were analyzed and the design of seawalls, bulkheads, and revetments explained. The concepts of "protective beaches" and dunes were discussed as alternatives that supplied the aesthetic, recreational and dynamic characteristics lost in the structural approaches, although only in broad terms. This document has been superseded by the Coastal Engineering Manual (U.S. Army Corps of Engineers, 2008). This exhaustive work still contains the hard armoring design methods, but discusses environmental issues in planning and design, some alternative methods such as vegetated revetments, and extensively explores beach fill design (beach nourishment), and the creation or enhancement of berms, dunes, feeder beaches, nearshore berms, dune stabilization, and groins. Beach nourishment, in this context, is the construction of a wider protective beach, and/or a more substantial berm, using materials found in the backbarrier, offshore, or from navigation channel dredging. Largely, this design method is suited for open coast settings utilizing sand-sized sediments. The other alternative methods receive little attention, understandably, considering the generally large scale of Corps projects and the higher energy environments of many coastal developments.

The unique nature of Puget Sound beaches, and the challenges of protecting them, have been recognized for some time (Downing, 1983; Terich, 1987). Puget Sound has a glacial heritage, with beaches that generally are coarse grained, in a fetch-limited environment, and subject to large tidal ranges (Finlayson, 2006). This setting is distinct from the sandy, high energy open coast more common in the rest of the United States.

To adapt to the unique conditions on Puget Sound, some shoreline protection techniques, mostly hard armoring, but also a variety of soft methods, have been employed (table 1). Some variations on these techniques could be used anywhere, but local practice has modified their application in Puget Sound.

Rock and concrete bulkheads are probably the most commonly used techniques for shoreline protection, with new projects often fitting into an already established line of similar structures. Although some sites with high wave energy require aggressive, structural approaches, in many areas of Puget Sound rock bulkheads are really more like retaining walls for landscaping features or toe protection for bluffs than for dissipating wave energy with runup, as we might see them used on the coast. Similarly, vertical concrete bulkheads create an architecturally pleasing line and allow a lawn right up to the edge, rather than serving as a wave barrier. It has been argued that these methods are not essential and do not serve the common

Table 1. Marine shore protection techniques.

[Techniques adapted from Downing, 1983 and Zelo and others, 2000. Ecosystem impacts are the net sum of the advantages and disadvantages to the habitat and natural processes at the site: (-) indicates a negative impact, (+) a positive impact. Erosion control is the ability of the technique to stop upland erosion (+) in a given time frame, or (-) does not actively stop erosion. Fetch length characterizes the relative wave energy at the site from (L) a long fetch with high energy to (S) a short fetch with low energy]

Method of erosion control	Ecosystem impacts	Erosion control	Fetch length
Hard shoreline stabilization			
Sloping rock (rip rap) bulkhead	−	+	L
Vertical concrete or wood bulkhead	−	+	L
Rock groin	−	−	S
Soft shoreline stabilization			
Gravel beach nourishment	+	+	L/S
Berm and hillslope revegetation	+	−	S
Reslope, drift logs, anchored logs	+	+	S
Accommodation and avoidance			
Bulkhead removal, restoration of natural bank	+	−	S
Allow erosion of non-structural improvements	+	−	L
Drainage control	+	−	S
Zoning (SMA/GMA)	+	−	L
Move structure from harm's way	+	−	L

good (Terich, 1987), although the desires of landowners can be a powerful political influence, which, in an extreme case, resulted in the single-family residence exemption to saltwater bulkhead and bank protection rules in Washington State (Chapter 77.55.200, Revised Code of Washington). Washington Administrative Rule 220-110-285). These structural approaches are really the only active ways to protect high energy shorelines, although the success rate can be low depending on the quality of the design and construction. Accommodation and avoidance are the best alternatives in truly challenging high energy situations (Terich, 1987).

Groins are not commonly used on Puget Sound, and cause many problems when they are used. The intended effect is for transported sediment to fill up-drift of a groin over time, deepening the beach and protecting the upland development from wave attack (U.S. Army Corps of Engineers, 2008). Longshore drift on our coarse, fetch limited beaches is low and the effects of groins are reduced (Downing, 1983), as compared to the situation on rapidly moving sandy beaches. Breakwaters (not shown in table 1) are used worldwide to reduce erosion, but on Puget Sound breakwaters are used almost exclusively at marinas to reduce wave height to protect moored boats.

Gravel beach nourishment on Puget Sound is practiced in small scale projects using coarse sediment from upland sources (Shipman, 2002), as opposed to the large beach-fill projects mentioned above. The goal is to use indigenous materials to mimic natural processes, with the expectation that the nourished beach will perform much as a natural one (Johannessen and Chase, 2005), which is different from beach fill that increases the width and height of the existing beach (U.S. Army Corps of Engineers, 2008). Puget Sound beach nourishment probably is a more subtle undertaking than beach fill, which amounts to moving massive quantities of native materials about on the beach; careful planning and design are required for Puget Sound projects. It is now widely accepted that the design community needs more data to refine this technique for more general use (Shipman, 2002). Figures 1 and 2 show two examples of beach nourishment projects on Puget Sound. The Port Peninsula project (fig. 1) replaced a vertical bulkhead with a sloping gravel/cobble beach. It is, more or less, an artificial beach that creates a transition between a subtidal bench and the supratidal fill supporting Port of Olympia development. Figure 2 illustrates a finer grained beach nourishment project at a Superfund site in a protected harbor. The nourishment here is really a cap over contaminated sediments, but functions as a beach.

Considering the low-energy character of most shoreline sites in southern Puget Sound, bank revegetation and resloping should be much more common than they are. These techniques are inexpensive to implement and utilize natural materials and processes to manage unstable areas through site drainage and vegetation management (Myers, 1993). Further design development, with a reference to accepted geotechnical engineering practice and example projects, may be all that is necessary to make these techniques more acceptable to shoreline owners.

Figure 1. Port Peninsula beach nourishment, Budd Inlet, Washington.

Figure 2. Wycoff Superfund site beach nourishment, Eagle Harbor, Washington.

Wood is a plentiful, naturally occurring material in the upper intertidal and supratidal zones of Puget Sound beaches, and has found its way into many alternative shoreline protection projects here. The projects illustrated in figures 2–6 all have a wood component, either as slope stabilization features, to have a groin-like effect, for its habitat value as substrate for organisms, for accumulating finer sediment, or as a nutrient source. Drift logs and anchored logs are used frequently in Puget Sound alternative bank protection techniques to retain sediment and absorb wave energy during storms (Zelo and others, 2000). These logs can have both a stabilizing and destabilizing influence, however, depending on the severity of the storm. They remain stranded at high elevations or partly buried in beach sediments during low water events, but may become mobile at high water, working the upper shore and digging into otherwise stable sediments (Finlayson, 2006). This dual nature of large wood makes the design of bank protection measures complex under sensitive conditions. Anchoring is one alternative, although there are liabilities associated with the anchoring mechanism and uncertainty about the magnitude of wave energy, both of which would be remedied through monitoring and reliable guidance.

As the public and government agency attitudes toward responsible stewardship of natural shorelines improve, the accommodation and avoidance alternatives (table 1) should become more common. It is significant that the conservative Coastal Engineering Manual (U.S. Army Corps of Engineers, 2008) clearly outlined the continuum of response to erosion, flood surge, and sea level rise from do-nothing to rigid seawall, with all the possibilities in between. There are many points at which a landowner and natural resource agency can enter into this continuum, expressed in the range of projects listed in table 1. As landowners come to understand the value and benefits of the natural Puget Sound beach, they are more likely to consider bulkhead removal and restoration to natural conditions. In a given year, three to four bulkheads are removed in Puget Sound This represents only 2 percent of permitted projects, a number that can be increased with proper guidance to designers and landowners.

Figure 3. Turnbull large wood placement, Fox Island, Washington.

Figure 4. Frye Cove County Park, large wood and cobble slope stabilization, Eld Inlet. Washington.

Figure 5. Mercer large wood placement, Key Peninsula, Washington.

Figure 6. Suquamish Tribal Natural Resources large wood and bank resloping, Agate Pass, Washington

Washington's Shoreline Management Act, local Critical Areas Ordinances, and other local zoning laws govern activities on the shore. The effect of these laws varies with the county, although the intention is to limit activities, to reduce impacts, and to mitigate for the loss of natural function and values. The most powerful tool is the construction setback, which keeps development away from the dynamic shoreline environment (Terich, 1987). Finally, when all else fails and costs outweigh any benefits, the landowner must consider moving the structure or the dedicated use out of harm's way—physically moving the structure beyond the reach of expected erosion.

Through time, certain design techniques and construction details provide the basis for an engineering "standard of care." This standard is fairly well established for the traditional approaches, rock and concrete bulkheads. Soft armor techniques mentioned above are relatively new in the Puget Sound area and no standard of care has been established. This especially is true in high bank settings, where very risk-averse geotechnical assessments have recommended "hard" solutions in almost every case. We have for too long been working under the weight of past practices, which have weighed in favor of rigid structures regardless of their short- and long- term habitat impacts. Rip rap and concrete bulkheads have well-established design equations, standard sizes, and established sources of uniform materials. A similar body of knowledge and reliable sources of materials must be developed for alternative shoreline protection techniques (Johannessen and Chase, 2005).

Project design incorporates a factor of safety determined, in part, by the certainty inherent in the design, construction and materials. The other part of this factor concerns risk. The higher the risk, the higher the factor of safety, which influences not only the size and strength of the components, but also the technique used. Often, very high safety factors create heavy, overbuilt, rigid structures, which have corresponding high environmental impacts. Better guidance, more monitoring data, and more experience with multiple projects will lower this factor and improve the performance of alternative marine shoreline protection methods.

New Marine Shorelines Design Guidance

Approximately 200 times each year, someone in Puget Sound applies for a permit to either build a new bulkhead or replace an existing one (Carman and others, 2010). For each of these cases, one might ask the following questions: Given conditions in the drift cell and at the site, is a particular bulkhead necessary? If it were built, what would be its impacts to biota and natural processes at the site? How would you determine those impacts? Would an alternative protection technique be as effective and have a lesser adverse impact? Can we use beach nourishment in this instance? How could you improve a traditional bulkhead design to reduce its impacts? How do you mitigate for lost functions? These are the sort of questions that would be answered by the MSDG.

For example, a shoreline property owner wishes to replace his failing concrete bulkhead – the footing has been undermined and the wall has fallen over onto the beach. He hires an engineer, or a marine contractor, to design a replacement. His consultant determines, through standard calculations, the instability of his unprotected bank under the soil and wave conditions present at the site, and the proper design of a new footing and wall to replace the failed one. These are accepted procedures in the industry. When MSDG becomes commonly available, the landowner can obtain a copy, his consultant should already have a copy, and the permit writer has a medium to communicate the important concerns and alternatives to simple replacement of the failed structure. For instance, this is a high energy beach (MSDG has criteria for determining this) and a structural solution is necessary, but a rock bulkhead has fewer impacts (MSDG has tables to associate techniques with impacts) and requires less mitigation than concrete, the height of the rock can be reduced (MSDG has design criteria for rock revetments), and riparian vegetation can be planted on the top portion of the bank to partly mitigate for the wall. MSDG also might help the owner and his contractor determine that a structural alternative is not necessary and that restoring a natural bank with native vegetation might be effective, acceptable, and attractive.

With the publication of MSDG, we would expect the percentage of bulkhead removal projects to increase, beach nourishment to become more common, and rock and concrete bulkheads to become less common.

MSDG will follow an outline similar to that used in the successful ISPG. ISPG begins with the concepts of bank protection and moves through site and reach assessments. With this background, the designer is led through a selection process that weighs benefits and impacts of different techniques. Finally, the techniques themselves are described in detail with engineering criteria, drawings and example projects. The remaining one-third of the document is devoted to appendixes that provide the scientific and technical underpinnings of effective and environmentally responsible design. MSDG will reverse this order of considering topics somewhat by placing the scientific background up front.

MSDG will be a comprehensive assessment and design methodology, not simply a catalog of techniques or best management practices. One must understand the context in order to properly apply a technique, and MSDG would provide the Puget Sound perspective. The following is a description of the proposed document. Aquatic Habitat Guidelines documents have sought to integrate the civil engineering design with its environmental context. MSDG will cover coastal science relevant to Washington’s marine shorelines in order to establish the background for a process-based approach to shoreline modification design.

The permitting process is one way through which society protects natural resources and the rights and property of those affected by an activity. MSDG will describe how the proposed project fits into this regulatory framework at the federal, state, and local level. It will list relevant permits and regulations that apply to marine shoreline projects, and make the connection between regulation and the protection of natural resources. A goal of the guideline is to properly design projects that have the greatest likelihood of meeting permit requirements and mitigating for impacts.

Successful hydraulic projects begin with a good grasp of the conditions at the site. A site assessment describes the conditions that create the need for the project and the mechanisms that underlie it. Site assessments also describe the natural resources and the human infrastructure within the project area and their respective risks. Effective project plans also must consider how the project fits in a broader geomorphologic and ecosystem context, the process unit. A process unit consists (longitudinally) of the drift cell, and in elevation extends from the upland extent of the drainage system down to -10 m depth. The process unit assessment thus looks at the project site in the context of larger processes, such as the source, transport, and deposition of beach sediment. A single project may have profound influence on an entire drift cell, and it is this sort of project that will be closely examined in this assessment. The process unit assessment also needs to be part of larger planning processes, both at the county level and in the Puget Sound, to coordinate restoration and planning activities and to consider issues of cumulative impacts.

A complete project design integrates the assessment with risk management, mitigation for impacts that cannot be avoided, and the specific requirements of the proponent. MSDG will offer alternative approaches or techniques to solve the engineering problems at the site in an environmentally responsible way. Any given technique has costs and benefits, impacts, and enhancements. The goal of a project designed through this guidance is to balance these factors such that the project avoids or minimizes impacts and maximizes benefits to the owner with the lowest level of risk and overall cost.

Case studies of existing projects will show the shoreline community specific examples of tested alternatives to current techniques as well as well-constructed traditional bulkheads with compensatory mitigation. The alternatives may not be ones that one can be directly used at a given site, but they will help to develop confidence in the design approach selected for the example projects.

Conclusions

Design guidance documents, like those produced by the Aquatic Habitat Guidelines group, have been successfully used to improve the outcomes of aquatic projects. The conditions in Puget Sound are unique when compared to those on the open coast setting , which underlies the bulk of current coastal engineering experience. Putting all the information necessary for an environmentally responsible design process in one volume is an effective way to coordinate assessment, permitting, design, and construction. Although there is probably no perfect time to compile a document such as that proposed here, the amount of our marine shoreline that has been stabilized and the pace of bulkhead construction is high enough that we should start now to stem the tide.

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Suggested Citation

Barnard, B., 2010, Developing a guidance document for Puget Sound marine shorelines, *in* Shipman, H., Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and Dinicola, R.S., eds., 2010, Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009: U.S. Geological Survey Scientific Investigations Report 2010-5254, p. 205-212.

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