Nearshore of the Central Strait of Juan de Fuca and Removal of the Elwha and Glines Canyon Dams: An Overview.

Shaffer, J.Anne [1], Pat Crain [2], Mike McHenry [3], Brian Winter[2], and Cathy Lear [4]

[1] Washington Department of Fish and Wildlife Habitat Program 332 E. 5th Street Port Angeles, Washington 98362. 360. 457.2634/shaffjas@dfw.wa.gov

[2] Olympic National Park, 600 E. Park Avenue, Port Angeles, Washington 98362. 360.565.3075 /Patrick_crain@nps.gov; 360.565.3051/brian_winter@nps.gov

[3] Lower Elwha Klallam Tribe, Fish Hatchery Road, Port Angeles, Washington 98362. 360.457.4012 x14 mchenry@elwha.nsn.us.

[4] Clallam County, 223 E. 4th Street Port Angeles, Washington 98362. 360.417.2361 CLear@co.clallam.wa.us

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Located on the north Olympic Peninsula, the Elwha River drains an area of 800 km^2, of which over 85% is within the Olympic National Park (National Park Service 1995; Figure 1). It is an region of high variability. Mean winter flows average 2,000 cfs, while mean summer flows average 600 cfs. Peak flood events in the Elwha average 40,000 cfs while base summer low flows average 200 cfs. Annual precipitation in the basin is 220 inches in the upper reaches and 56 inches at the river mouth. The river has a bimodal flow pattern, with peak flows in November (rain on snow events) and June (snow melt) (National Park Service, 1995).

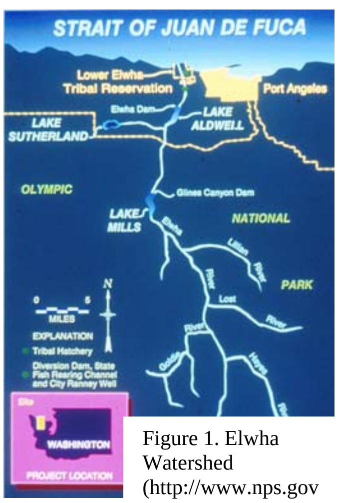


Figure 1. Elwha Watershed (http://www.nps.gov/olym/elwha/home.h

Since 1911, Elwha and Glines Canyon dams have blocked anadromous fish passage to more than 70 miles of the Elwha River and its tributaries, most within Olympic National Park. This has limited anadromous salmon and trout production to the 4.9 miles of the river below Elwha Dam, which in turn reduces nutrients for aquatic an (National Park Service 1995).

Figure 2. Elwha dams http://www.nps.gov/olym/elwha/home.html

All ten native Elwha River anadromous fish runs have been severely diminished and the ecosystem disrupted. At least one Elwha River salmon stock, the sockeye, may now be extinct while two stocks, the pink and spring chinook, may only be present in small numbers. Two species, Hood Canal/Eastern Strait of Juan de Fuca

Summer Chum and Puget Sound Chinook, are federally listed Endangered Species.

Much of the habitat degradation that has resulted in these losses is due to significant disruption of physical processes. In particular riverine sediment processes are severely disrupted by the dams. About 13.8 million cubic yards of sediment are trapped in Lake Mills, and up to 4 million cubic yards in Lake Aldwell. The dams have also resulted in a significant reduction in fluvially transported sediment to the lower river (Figure 2). Unconstrained, low gradient channel reaches in the lower river historically contained extensive side channel habitat with suitable substrate for critical fish use including eulachon spawning. Truncation of sediment transport to the lower river, along with channelization, and the systematic removal of large woody debris (LWD), has caused channel incision and an increase in bed substrate size (Pohl ,2000). Nearshore effects of this disruption are complex, as described below.

The two dams are slated for removal beginning in 2009. In this unprecedented restoration project to restore the Elwha ecosystem, dam removal will restore sediment transport processes and lead to improvements in spawning habitat. Approximately 2-3 mcy of course (sand and gravel) and 7-8 mcy of fine (sand/ silt) material are anticipated to be delivered to the sediment starved lower river and nearshore within 5 years of dam removal (Randle et al. 1996*)*

Understanding the nearshore component of this restoration requires a context of the nearshore it will occur in. The north Olympic Peninsula has extensive shorelines that border the Strait of Juan de Fuca and the Pacific Ocean. More than 80% of the water from Puget Sound and the Strait of Georgia flows through the Strait of Juan de Fuca (Mackas and Harrison, 1997). Direction of net water movement within the Strait of Juan de Fuca depends on depth. Net movement of cold oceanic deep water is to the east while net movement of fresher, warmer surface water is to the west (Mackas and Harrison, 1997; Strickland, 1983). The primary Elwha nearshore encompasses approximately 13 shoreline miles of the central Strait of Juan de Fuca (Figure 3). The Elwha nearshore habitat, delineated by the physical features of tidal influence and light limitation, is generally defined as the area that extends from treeline to –30 meters (90 feet) Mean Low Low

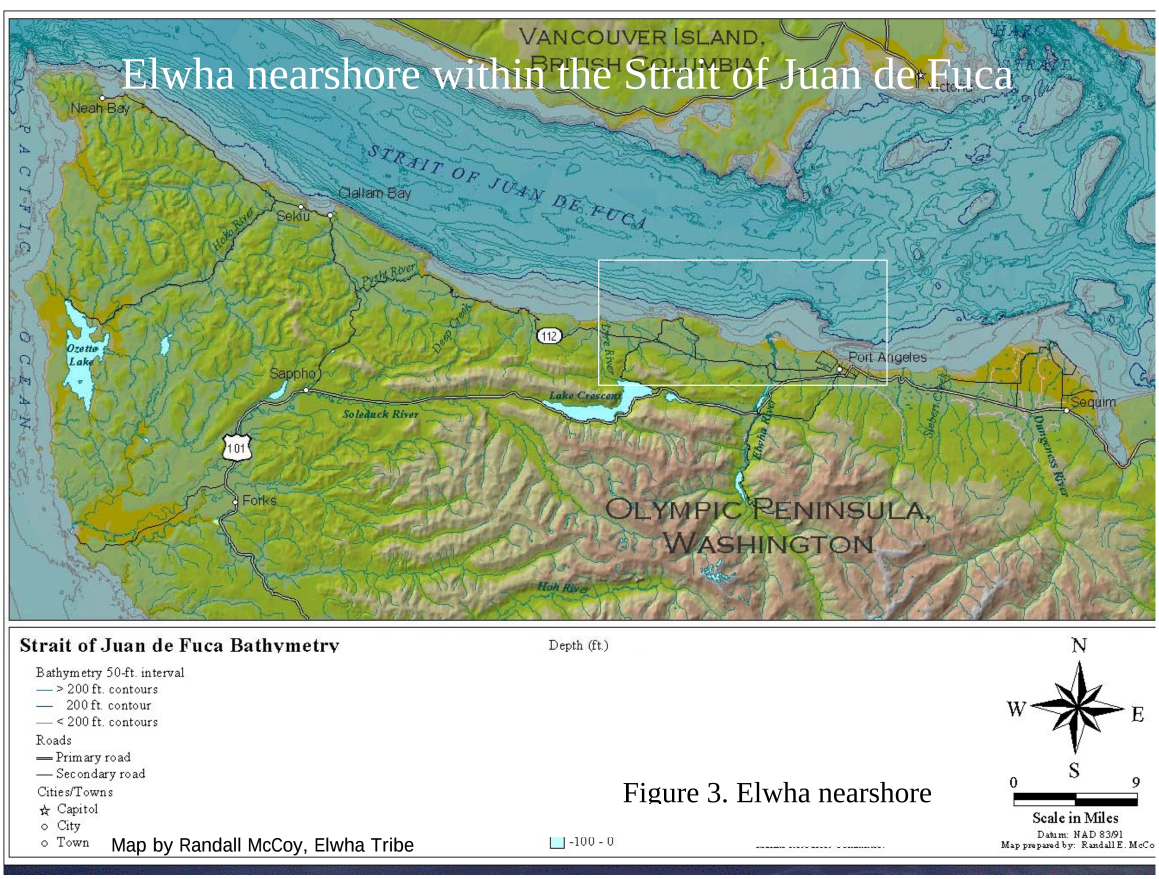


Figure 3. Elwha nearshore

Water (MLLW). The Elwha nearshore is a critical component in marine ecosystems, and as a component of the nearshore Strait of Juan de Fuca, is a critical component of a functioning Puget Sound ecosystem. It is the conduit for species migrating to and from inland marine waters of Puget Sound and British Columbia.

Physical processes within the Elwha nearshore are complex, and variable. The Elwha nearshore, as a component of the Strait of Juan de Fuca, is a wind-dominated system, with currents changing dramatically within hours in response to both regional and larger-scale oceanic winds (Hickey, 1996; Strickland, 1983). Strong seasonal storms contribute pulses of both freshwater and sediment to the Strait of Juan de Fuca. These pulses form large lenses of very low salinity and very high turbidity within the nearshore zone along the majority of the shoreline of the Strait of Juan de Fuca. These lenses appear to occur primarily during winter and spring months (Figure 1; Shaffer pers. obs.). Due to deep oceanic water and strong wind and current mixing action, as well as seasonal strong contribution of riverine nutrients, the water of the main basin is well-mixed, cold, and nutrient-rich throughout the year (Mackas and Harrison, 1997). This is in direct contrast to shallow, enclosed embayments of the Strait of Juan de Fuca, which may be seasonally stratified and, in some instances, nutrient-limited (Mackas and Harrison,1997; Newton, pers. comm.). While highly variable, net shore drift within the Elwha drift cell is to the east (Schuartz 1994).

Habitats structure of the Elwha nearshore are equally diverse. **V**egetated habitats are dominant and are found along at least 60% of the shoreline. Nearshore vegetated habitats include kelp beds, eelgrass beds, drift algae, and rocky/cobble shorelines with Laminarian cover. In total, kelp beds of the Strait of Juan de Fuca, which are found along at least 40% of the shore, make up the majority (78%) of Washington's coastal kelp resources. Three dominant species of algae, *Macrocystis integrifolia* (giant kelp), *Nereocystis luetkeana* (bull kelp), and *Pterygophora californica* (an understory kelp), which have dramatically different life histories, make up these extensive beds. *Zostera marina*, or eelgrass, a vascular plant, occupies at least 20% of the Strait of Juan de Fuca shoreline (Thom and Hallum, 1990; VanWagenen, 1998) .

Nearshore habitat function of the Strait of Juan de Fuca, including the Elwha nearshore, is also diverse and complex (Carter and VanBaircom,1998; Miller et al., 1980; Simenstad et al., 1988; VanBlaircom and Chambers, 2003). In general, Strait of Juan de Fuca nearshore provides a critical feeding, refuge, and migration corridor for many species. These include three federally- and/or state-listed salmon (Puget Sound Chinook, Strait of Juan de Fuca/Hood Canal Summer Chum, and Bull Trout), as well as sockeye, pink, and chum salmon, many rockfish species (including copper, quillback, and black rockfish) and bottom fish, including halibut. Forage fish, including eulachon, surf smelt, sand lance, and herring, use the Elwha shorelines for spawning, feeding, and migration. Their use, as well as that by juvenile salmon, is complex, may be highly variable from year to year, and depends on physical and biological features (Shaffer, 2004, Shaffer et al. 2003). Abundant shellfish species found in the Elwha nearsrhore include crab, shrimp, geoduck, abalone, scallops, native and Pacific oysters, as well as urchin and sea cucumber. Elwha nearshore wildlife assemblage include alcids (marbled murrelets, tufted puffins, rhinoceros auklets and others), sea otters, Dahl’s porpoise, Harbor porpoise, and Orca and Gray whales. Understanding these highly variable and diverse nearshore habitats is imperative to defining nearshore restoration response to dam removals.

Sedimentation is a defining process of the Elwha nearshore (Downing, 1983). Along the Elwha nearshore, coastal bluffs have been documented to historically contribute in excess of 70% of shoreline material. Rivers provide the remaining amount. (Schwartz 1994; USCoE, 1971).

Disruption of sediment processes, including sediment sources and transport, has had a profound effect on the Elwha nearshore. A 9000' bulkhead, installed in the late 1950's along the shoreline to protect the City of Port Angeles industrial water line, has disconnected a critical feeder bluff that is estimated to have formerly provided over 70% of beach material to central Strait of Juan de Fuca beaches (Figure 4). Further limiting sediments, the Elwha and Glines Canyon dams have resulted in large-scale sediment starvation to the nearshore of the Elwha nearshore for almost a century. Combined, the dams and bulkhead have resulted in significant long-term erosion along the nearshore from the mouth of the river to Port Angeles Harbor (Figure 5; USCoE, 1971; Downing, 1983; Harring, 1999; Schwartz, 1972; Figure 6a). Comparing the shorelines of Ediz Hook, with armored feeder bluffs and accelerated chronic erosion, to those of Dungeness Spit (approximately 10 miles away), which has intact feeder bluffs and sediment transport, clearly illustrates the impact of disrupting sediment processes along the Elwha nearshore (Figure 6b).

Figure 4. 1929 installation of Elwha industrial pipeline at the base of Elwha feeder bluffs Subsequent armoring have resulted in sever sediment starvation along the Elwha nearshore. Photo provided by Dean Reed, Nippon Paper Company

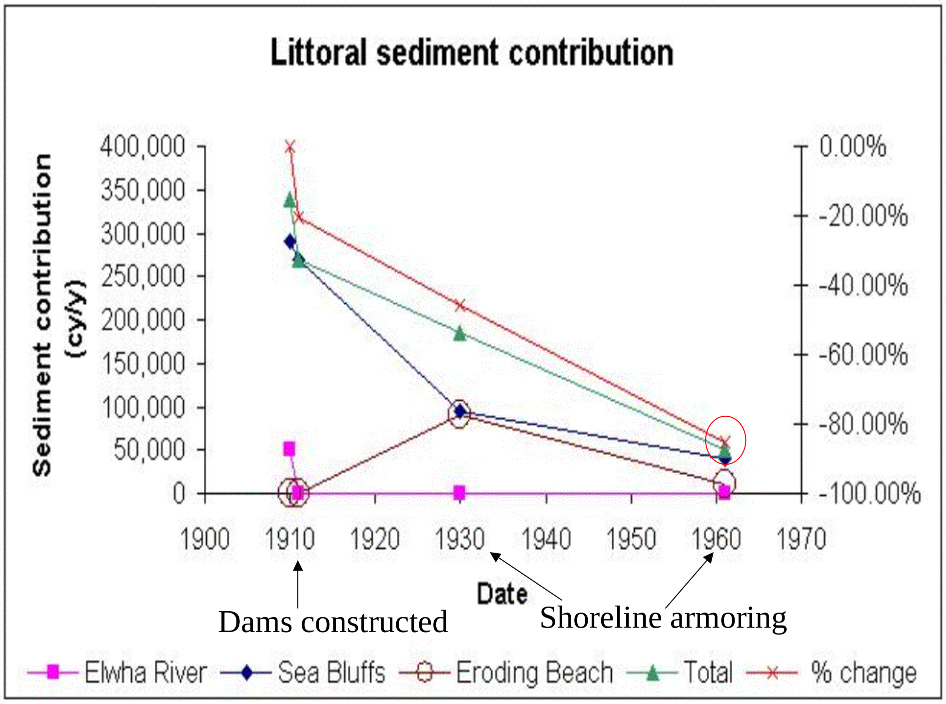


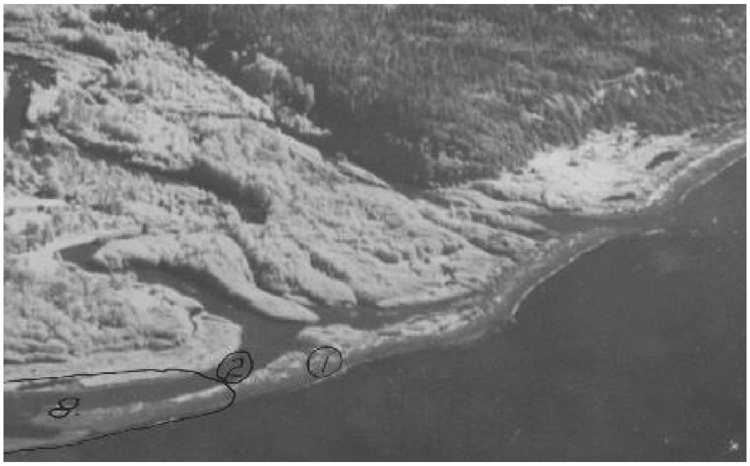
Figure 5. General choronology of change in Elwha nearshore littoral sediment contribution (USCoE, 1971).

A. *Elwha Bluffs from Dry Creek to Base of Ediz Hook. Note armoring and erosion in aerial photos, high wave energy of land photo.*

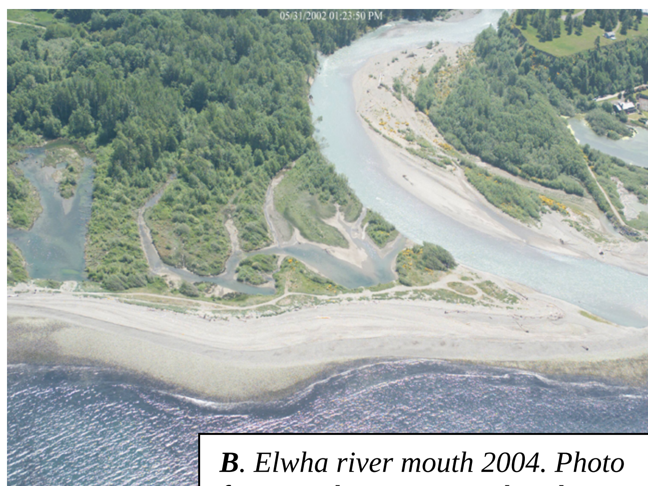
B. *Dungeness Bluffs to Dungeness Spit. Note lack of armoring, low wave energy, and intact beaches of the Dungeness Spit in both aerial and land photos.*

Figure 6a&b. Coastal sediment processes of Elwha shorelines and impact of armoring on nearshore features, including spits. Images are from same flight line, same day (aerial photography Washington State Department of Ecology shorelines data, flown June 1994; land photography 12 March, 2004.)

Alterations in the lower Elwha river also have had a significant effect to the nearshore (Figure 7), including altering and restricting use of tidal influenced estuary and sediment trajectory in the nearshore. Fish use in the eastern portion of the river mouth is extremely high-little to no fish use occurs in the west river mouth due to large dike constructed in the 1950's that blocks fish access.



***A**. Elwha River mouth 1956. Photo courtesy of National Archives..*



***B**. Elwha river mouth 2004. Photo from Washington DoE shorelines*

Figure 7a&b. Elwha lower river in 1956 and 2004. Note straightening of lower river and dike along west river mouth.

Dam removal will result in only a partial restoration of the nearshore. Management of the nearshore, which includes a wide spectrum of local, city, county, state, tribal and federal jurisdictions, also plays a key role in nearshore restoration. Nearshore restoration associated with dam removal provides a potential benefit to both the community and the ecosystem. Citizen participation in all elements of this nearshore work is critical for success. This requires intensive field and modeling efforts, in addition to intensive public outreach (See Shaffer et al 2005 for a discussion). Efforts focusing on the technical element of nearshore restoration have revealed four key steps to defining Elwha nearshore ecosystem response:

1) Define the geographic and temporal fate of the sediment once in the nearshore;

2) Define historic habitat conditions and resource distribution;

3) Define current habitat distribution and resource use and;

4) Use the information from these first three to model future conditions.

This information then may be used to define large scale restoration efforts (Shaffer et al 2005). These steps are being addressed in varying degrees. Modeling and mapping of coarse sediment in the nearshore is currently being conducted by the Elwha Klallam Tribe, Bureau of Reclamation, and United States Geologic Society (USGS). Fish distribution in the Elwha river mouth is being defined by the Elwha Tribe, Washington Department of Fish and Wildlife, NOAA, with Peninsula College and Western Washington University partnerships. However large scale sampling of habitats and fish use, as well as historic mapping and final modeling remain to be addressed. Water quality and fate of fine sediments need to be addressed. The reader is referred to the Elwha nearshore newsletter (clallammrc.org) for the latest activities and collaboration opportunities.

Removal of the Elwha dams is a restoration opportunity of unprecedented scale and scope. It will restore a number of salmonid stocks critical to the culture of the Elwha Klallam Tribe and the northwest region. It will also provide techniques for future dam removal projects. Dam removals will only result in a partial restoration of the severely degraded nearshore of the Elwha. Understanding the complex nearshore component of this restoration is critical for optimizing the upcoming event and so the recovery of the sediment starved central Strait of Juan de Fuca and the ecosystem is supports. Dam removal is slated to begin in 2009, making timing of this sorely needed nearshore work critical.

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