Shoreline Erosion on Sauvie Island, Oregon: Perceptions and Management Practices

by

Season Long, MS Candidate
(Non-thesis)

Marine Resource Management Program
College of Oceanic and Atmospheric Science
Oregon State University
Corvallis Oregon, 97331

Presented June 18th, 2007

Funding of this project was provided by

OSU Sea Grant

MASTER'S PROJECT APPROVAL FORM

Student information

Student name: Season Long

Address: Redacted for Privacy

Telephone: [illegible] om

Project title: Shoreline Erosion on Sauvie Island, Oregon: Perceptions and Management Practices

Defense date: 6/18/07

Project committee members

1) Major project advisor: SAMUEL S. CHAN

Department: Fisheries & Wildlife ; College of Oceanic MRM and Atmospheric Scien

Signature: Redacted for Privacy

2) Committee member: Redacted for Privacy

Department: COAS MARINE RESOURCE MANAGEMENT

Signature: Redacted for Privacy

3) Committee member: JAMES W. GOOD

Department: COAS-MARINE RESOURCE MGT.

Signature: Redacted for Privacy

ACKNOWLEDGEMENTS

I am grateful for the knowledge and support that I have received while perusing my master degree at Oregon State University. I would first like to thank my major advisor Sam Chan for his support, guidance, and encouragement which allowed me to excel in this Master Program. In addition, I would like to thank Jim Good for contributing to my knowledge in the area of Marine Resource Management and for the direction he provided in shaping my project write-up. I would also like to thank Michael Harte for his insight and perspective on the many professional paths that are ahead in my career.

I would also like to extend a warm thanks to the residents of Sauvie island, many of whom opened there homes to me, as well as, enriched this project with there personal stories. I would also like to thank Oregon Sea Grant Extension for believing in me and this project enough to provide financial support.

Finally, I would like to thank my family and friends for there unwavering love, support, patience, and advice though out this process. I would not have been able to do it without you!

Table of Contents

Page

Tables and Figures

Figures

Tables

1. ABSTRACT

Sauvie Island lies at the confluence of the Columbia River and the Willamette River near Portland, Oregon. Flooding, erosion, and deposition of sediments have been part of the natural evolution of the island. However, with the construction of multiple dams in the Columbia River Basin, levees, and hardening of upstream banks, many natural river processes have been altered, resulting in increased erosion along the Island's shores.

The objectives of this project were to, (i) characterize shoreline erosion as perceived by waterfront landowners on Sauvie Island, (ii) determine the role of government agencies in shoreline erosion management, (iii) to "ground truth" property owner and agency perceptions of recent erosion problems, and (iv) to communicate project findings to all parties. The research involved surveying shoreline property owners, interviewing relevant government agency staff to determine their roles and responsibilities for erosion management, and the use of aerial and orthophotos to verify erosion "hot spots". The main findings of this study were that: 1) Columbia River residents are the most concerned about bank erosion, with nearly 25 percent of the respondents losing bank along the entire length of their property; 2) nearly half of the Columbia River respondents have installed some form of bank protection along their waterfront, however, only 25 percent believe that their revetment strategy has prevented further erosion; 3) aerial photo analysis revealed section of the Columbia River shoreline having (accumulative) erosion of up to 5 feet per year; 4) current regulatory jurisdiction for erosion monitoring and control along Sauvie Island is disjointed with no single agency responsible for the monitoring, permitting, and technical assistance landowner's need when installing revetment work. An intended outcome of this project is to encourage cooperative management of shoreline erosion by building understanding of the nature of shoreline erosion on Sauvie Island and to facilitate communication between landowners and government agencies regarding extent, management and mitigation.

2. INTRODUCTION

Sauvie Island lies at the confluence of the Willamette and Columbia Rivers, 12 miles from downtown Portland. The islands rich natural resources initially supported a thriving Native American population. In the 1850s Euro-American settlements began developing its rich agricultural land with crops and dairy farms. More permanent settlements followed after construction of flood-controls: dikes, levees, and dams in the 1940s. Today the island is comprised of important agricultural, residential, recreational, and wildlife areas (Figure 1).

Flooding, erosion, and deposition of sediments have been part of the natural evolution of the island throughout time. However, with the construction of multiple dams in the Columbia River Basin, levees, and hardening of upstream banks many of the natural processes have been altered. Today, increased human population, urban development, along with increased use of shoreline and water-related activities has led to concerns among property owners regarding shoreline erosion rates.

In March 2006, a property owner on Sauvie Island contacted Oregon Sea Grant and the local Soil and Water Conservation District (SWCD) about perceived erosion problems and what could be done to address them and the seemingly confusing, burdensome process of getting necessary permits and technical assistance. A team was assembled by Samuel Chan of Oregon Sea Grant. This included several SWCD members, and other concerned Sauvie Island landowners. A site visit was conducted. Local residents observed severe and continuing bank erosion. They showed the team examples of failure in expensive hybrid hard structure and bioengineered revetment structures (rip-rap). The US Army Corps of Engineers (ACOE) had finished dredging the channel to a depth of 43 feet in the fall of 2006 along this section of the Columbia shipping lane; this was discussed as a possible cause of increased erosion along part of the Sauvie Island shoreline. There were also concerns about large vessel traffic, causing wake-induced erosion, and a variety of other issues. Following this original meeting, Oregon Sea Grant agreed to undertake a study to more thoroughly characterize erosion issues along all

Sauvie Island shorelines and waterways, including Multnomah Channel to the west, the Willamette to the east, and the Columbia to the east and north (Figure 1).

The long term goal of this project is to encourage cooperative management. The project aims to build understanding of the nature of shoreline erosion on Sauvie Island and to facilitate communication between landowners and government agencies regarding extent, management and mitigation. The objectives of this project are to characterize, shoreline erosion held by waterfront landowners on Sauvie Island and to determine the role of government agencies in shoreline management. The research involved surveying shoreline property owners, interviewing relevant government agency staff to determine their roles and responsibilities for erosion management, and the use of aerial and orthophotos, to verify erosion i.e.“ hot spots” (determine by agency and resident responses) to ascertain long term changes over time. Following the completion of this report, a workshop is to be conducted by Oregon Sea Grant to bring together property owners and government agency staff to talk about potential solutions and improved communication and technical assistance.

The remainder of this report is organized as follows. The *Background* section describes the regional and local context for erosion along Sauvie Island shorelines, including the Columbia Basin and lower river region, and the island itself, including its origins, geology, soils, waterway hydrology, vegetation, and factors involved in shoreline erosion, both historically and in recent times. The *Research Design and Methods* describes how the project was undertaken and this is followed by *Results and Discussion.* Finally, several Conclusions and Recommendations are offered for consideration. A number of *Appendices* complete the report.

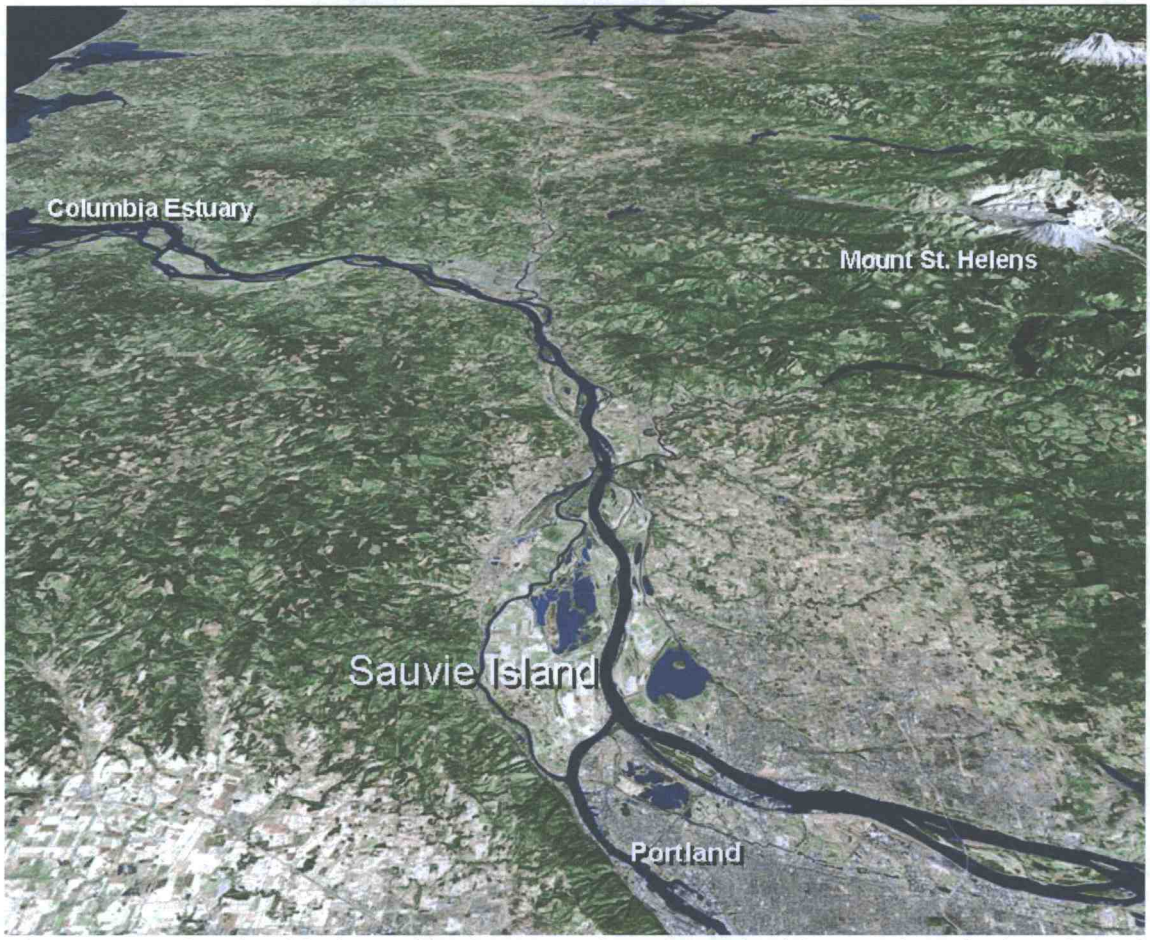


Figure 1 Sauvie Island in its regional panoramic context, looking north at the junction of the Willamette and Columbia Rivers (photo courtesy of William Bowen, 2005).

3. BACKGROUND

3.1 Regional Hydrology and Geology

The Columbia River is the largest river basin in the Pacific Northwest, with a 671,000 km^2 (259,000 mi^2) watershed which includes parts of seven states and one Canadian province (Figure 2). The Columbia River cuts through the Cascade Range and transports a large volume of sediment. Between the Cascades and the Coast Range lays the Willamette Valley. The Willamette Valley is comprised of alluvial and glacial deposits which make up the primary sedimentation layers. About 92 percent of the river basin lies east of the Gorge, but is responsible for just 80 percent of river flow. The remaining 8 percent of the basin west of the Gorge is comparatively wet, contributing about 20 percent of the river's flow at the mouth. The largest part of this west side river flow

comes from the Willamette River, which join the Columbia along the southeast shore of Sauvie Island (Figure 1).

Peak flows on the mainstem of the Columbia River primarily occur from April through July (BPA, 2001). This peak is predominantly due to snow melt in the Rocky Mountains and Cascade. Historically before the construction of dam and other revetment structures, spring flow would result in major flooding events throughout the basin. Conversely, the peak flows for the Willamette River occurs from November through February during winter storms, valley rainfall, and low lying snow on the western slopes of the Cascades (Figure 3). River discharge at the mouth averages about 262,000 feet^3/second, second only to the Mississippi River, in North America.

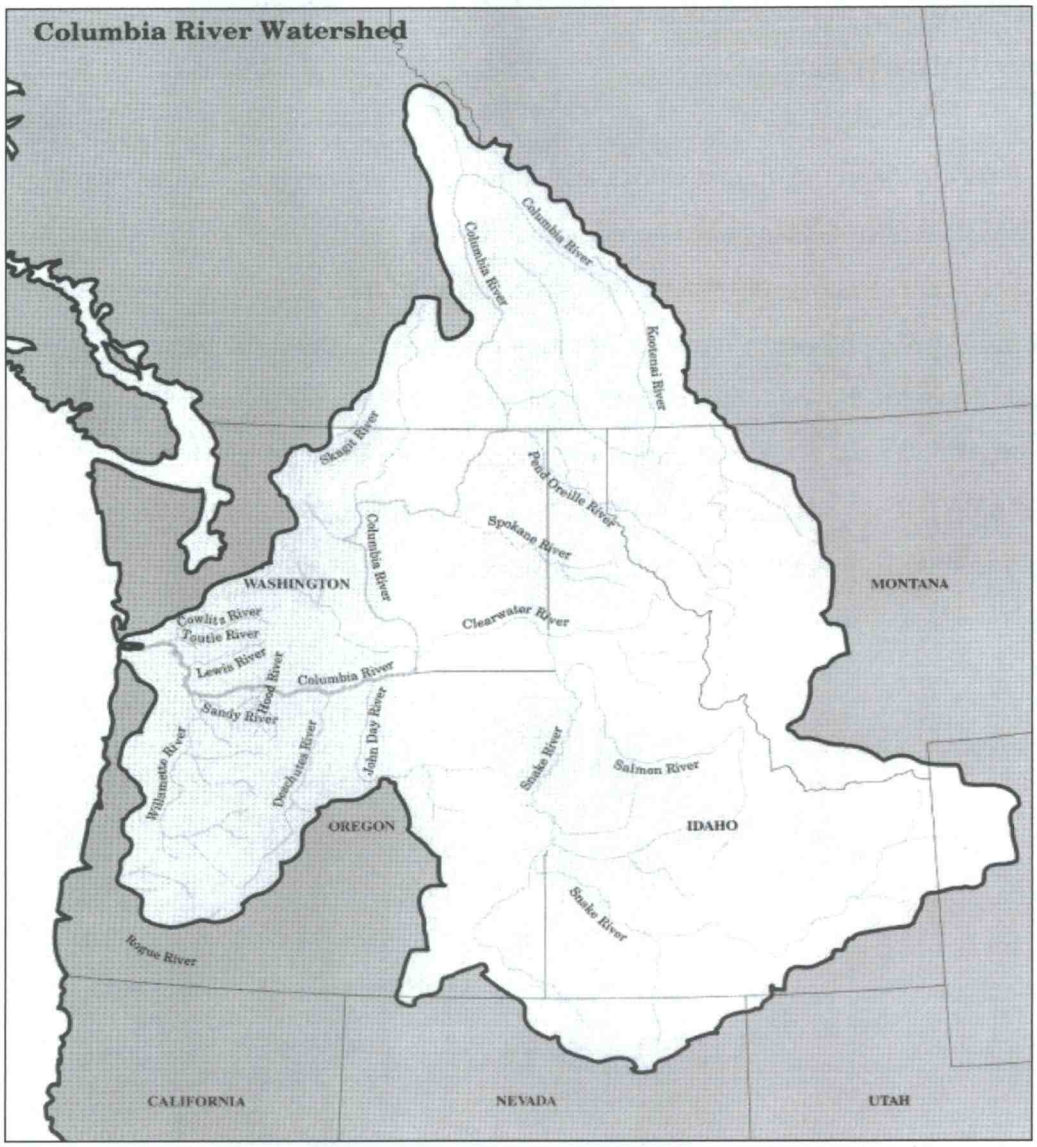


Figure 2 Columbia River Watershed spans seven states and one Canadian province before entering the Pacific Ocean via the Columbia River Estuary. (Bonneville Power Administration, 2007) *Image may be scaled down and subject to copyright.*

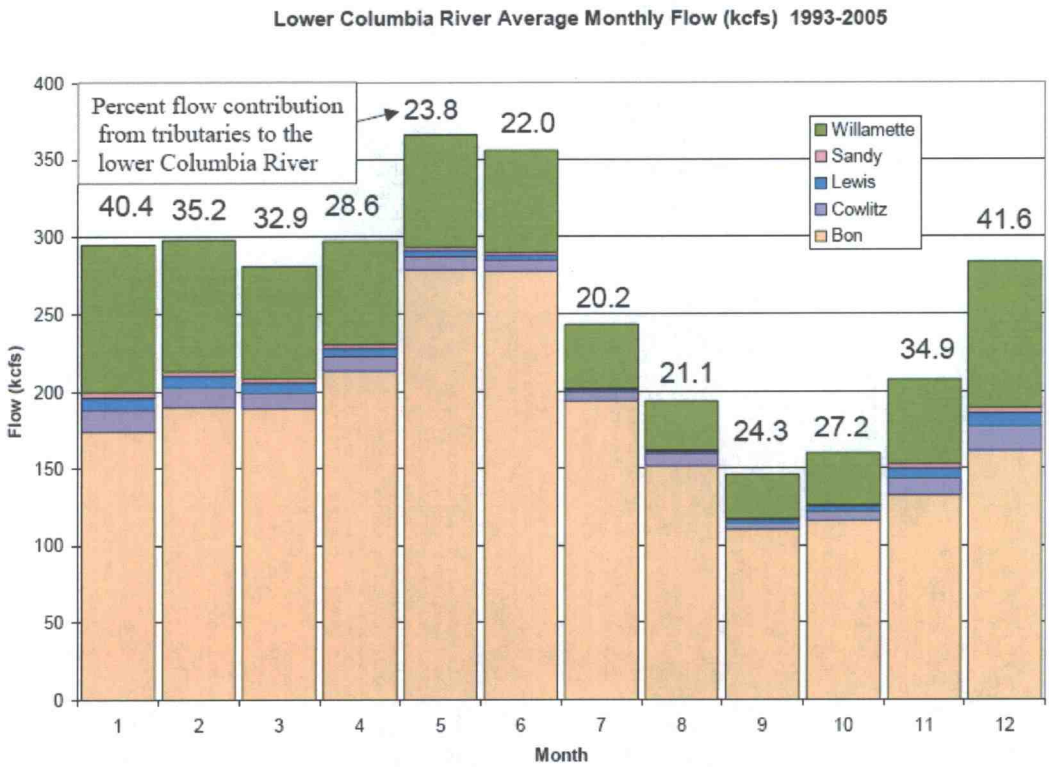


Figure 3 Lower Columbia River monthly flow and contributing river (US Army Corp of Engineers, 2006)

Today, there are 14 dams in the mainstem of the Columbia River and 130 more on its tributaries; many are operated by the ACOE and the U.S. Bureau of Reclamation (USBOR). River flows, and the release and storage levels of these dams are strictly regulated (Figure 4). Furthermore, much of the sediment coming down the mainstem Columbia has been interrupted and captured behind the dams, changing the pattern and amount of sediment in the Lower Columbia. Another factor affecting both river flow and sedimentation is the relatively flat gradient of the Lower Columbia, which drops just 0.2 feet per mile from the Bonneville Dam at river mile (RM) 146 to the mouth. As a result, tidal influence extends all the way to Bonneville Dam on the Columbia River and to Willamette Falls on the Willamette River. While these effects are weaker the further upstream you go, they still influence river currents, water levels, sediment transport, and erosion/deposition rates. All these factors result in the continual deposition and erosion of alluvial deposits along the floodplains of the Lower Columbia and Willamette Rivers. At the confluence of these two rivers, the valley floodplain is incised by a series of channels

and lakes in North Portland, Sauvie Island and the Vancouver lowlands (O'Connor, 2004).

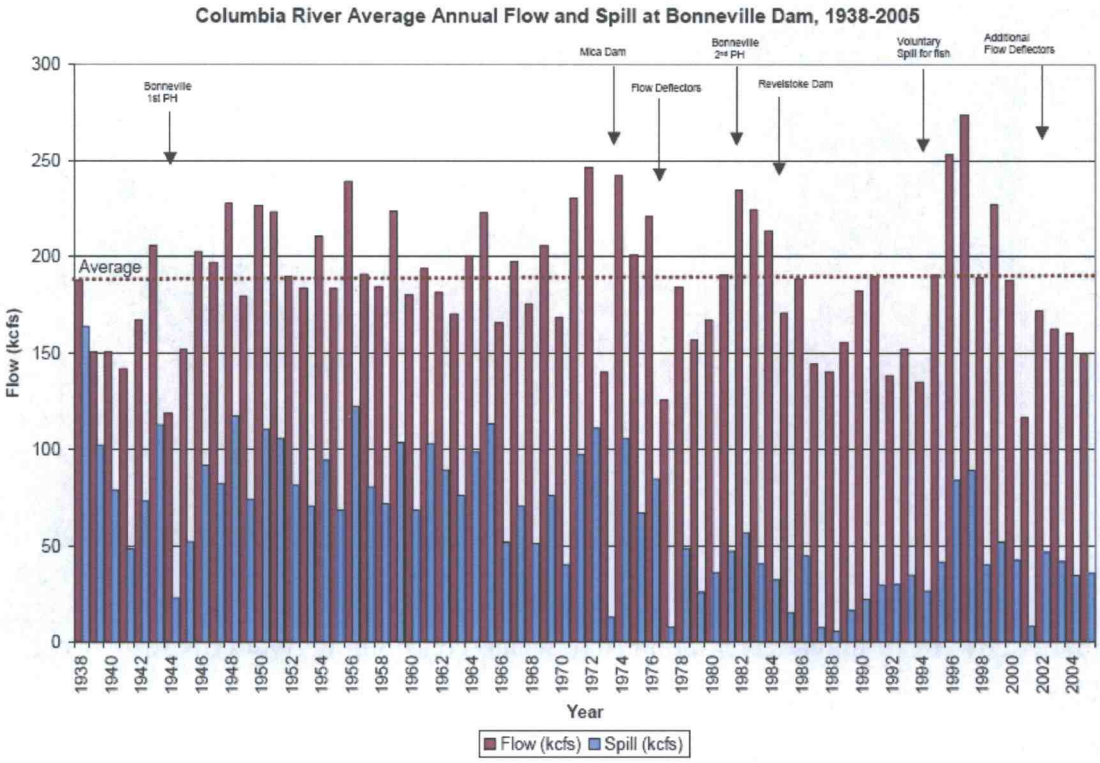


Figure 4 Average annual flow of annual flow at Bonneville Dam (US Army Corp of Engineers, 2006)

The primary sedimentation layers that form the islands and floodplains at the Columbia-Willamette confluence are derived historically from alluvial and glacial deposits laid down during and following the last ice age. Furthermore, volcanic activities, like the recent 1980 Mt Saint Helens eruption, and earlier eruptions in the Cascades have contributed to the sedimentary layers and dramatically altered the Lower Columbia River area (Spencer, 1950). Typically, alluvial and humic gley dominates the soil groupings in the Lower Columbia River. The alluvia soils have a simple profile (Figure 5), that include a well drained A horizon with dark organic materials, a B horizon is mottled with clay, and a C horizon composed of stratified layers of alluvium. The humic gley is present under wet meadow areas and is usually poorly drained. Low density sand and clay make

up the river banks and are easily eroded by tidal action, and waves generated by wind and vessel traffic. (US Army Corp of Engineers, 1986)

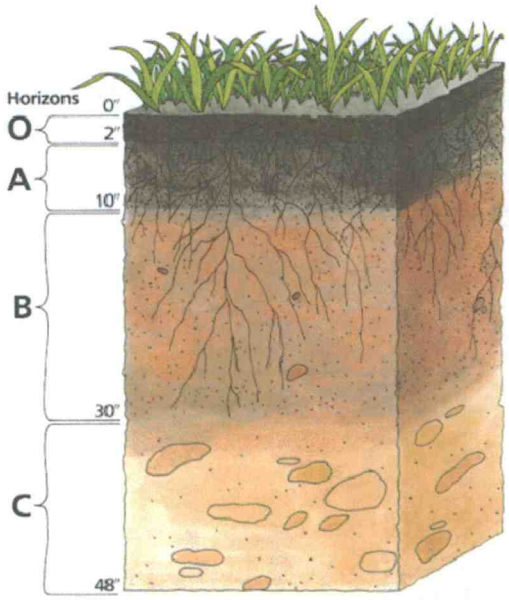


Figure 5 General soil profile describing the top 48 inches of loam (Pike County Conservation District, 2007)

3.2 Formation of Sauvie Island

Sauvie Island lies at the confluence of the Columbia and Willamette Rivers 12 miles northwest of Portland, Oregon (Figure 6). The island covers approximately 24,000 acres and was formed by alluvial deposits from both the Willamette and Columbia Rivers laid down over several thousand years. These deposits were built up along a rock ledge running north to south. This deposition was primarily caused by the fact that the Columbia River turns north near the mouth of the Willamette, causing the river velocity to slow down enough to allow sediment, logs, and debris to accumulate along this ridge (Cleaver, 1986). These alluvial deposits have built up over time and now consist of interbedded layers of sandy silt, silt sands, and fine sands that are underlain by coarser sand deposits (US Army Corp of Engineers, 1986).

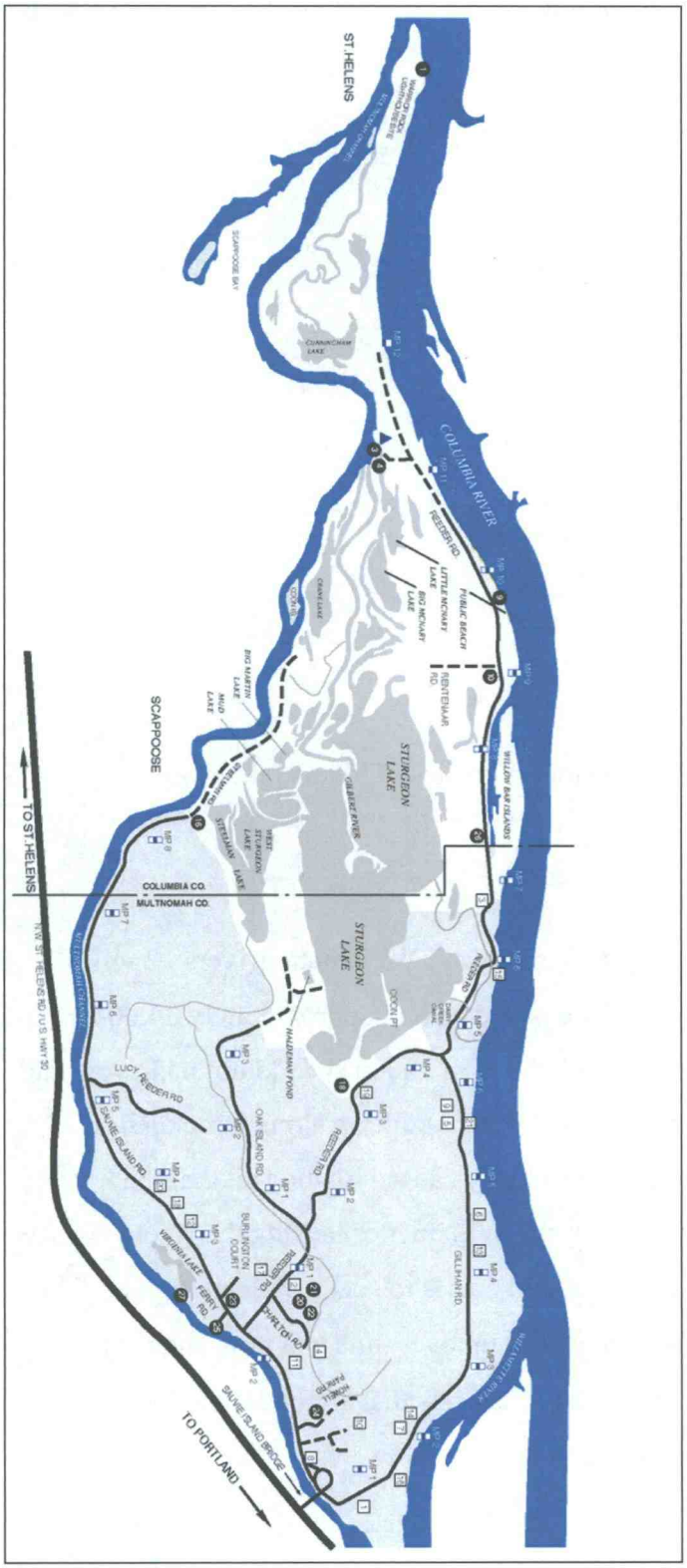


Figure 6 Sauvie Island map (Department of Fish and Wildlife, 2004)

A 1977 soil survey of Sauvie Island by the United States Department of Agriculture Soil Conservation Service (now the Natural Resource Conservation Service or NRCS), identified five different soil types: (1) Burlington Fine Sandy Loam, (2) Sauvie Silt Loam, (3) Sauvie Silt Clay Loam, (4) Moag Silty Clay Loam, and (5) Rafton Silt Loam. One limitation of the study is that it did not characterize the soils used in levee construction or for beach re-nourishment activities, which is important when determining erosion processes.

The rich soils of Sauvie Island and topographic variations have resulted in significant vegetative diversity with willows, cottonwoods, ash, and oak at lower elevations and fir, cedar, and hemlock on higher ground. The generally low elevation and natural inundation of the inland areas has also resulted in extensive emergent wetlands and other water-loving plants like salmonberry, skunk cabbage, and sword ferns (Christy, and Putera, 1992).

3.3 Early Human Settlement

Multnomah Indians, a Chinookan people, have played a role in the Sauvie island environment for thousands of years. The first historic account of island population was estimated at 800 individuals, documented by Lewis and Clark when they surveyed the island in 1806 (DeVoto, 1953). At this time, there were 15 villages located on the island, all active in the harvesting of salmon and use of other resources, such as the wapato, a potato-like tuber used for food and traded. Over the next 30 year, the Native American population was virtually wiped out by smallpox and malaria.

The first successful European settler was Laurent Sauvie, a French Canadian who established a dairy farm in the1840s to support the Hudson Bay Company (Cleaver, 1989). Later, in the 1850s, pioneers began homesteading the island, each making 640-acre claims. The most profound physical changes on the island occurred following Euro-American settlement in the mid-1800s, resulting in large-scale land use and vegetation changes (Canniff, 1984). However, population would remain low on the island until after

the Federal Flood Control Act of 1936, which created the federal Columbia River Dam System.

3.4 Influence of Flood Control Programs

The Food Control Act of 1936 allocated federal funding to build dams, dikes and levees to protect people, property and live stock from the annual flooding events that occurred along the Columbia River. This legislation allowed the construction of two dikes on Sauvie Island. The first dike, called the "Big Dike" was completed in 1941, and contains approximately 12,000 acres, about one-half the island's total acreage. The "Big Dike" was constructed using soil dug from "borrow pits" from the island and dredged material from the adjacent waterways. Upstream storage from dam and reservoirs and hardening of the bank were taken into account to determine the final height of the dike 33.8 feet upstream on the south end of the island and 32.5 feet downstream (US Army Corp of Engineers, 1960). The total height of the dike includes three feet of "freeboard", above the highest expected flood water level to allow for wave impact along the levee during these events. Since the original levees construction there have been many improvements including: filling and evening-out the surface slope (strengthening), increasing height to account from settling over time, and rip-raping (armoring with rock) the exterior river side of the dike to protect it from erosion (Jerry Christenson, US Army Corp of Engineers, 2007). Additionally, toe drains and a pumping station have been installed to control for seepage, especially when water levels are high in the winter and spring (Figure 7).

The second dike referred to as the "North Dike" was completed in the early 1940s, and contains approximately 1,600 acres. It was constructed in a similar fashion as the Big Dike using dredged material from adjacent waterway, as well as, sand from other locations. This 26 foot core of the dike was then covered with an additional foot of topsoil from adjacent land. Improvements have been done over the years to repair several breaches including: three breaches in 1996, two breaches in 1964, and one breach in 1946. Today the U.S. Army Corp of Engineers (ACOE) regularly monitors the integrity of the dike while the Oregon Department of Fish and Wildlife (ODFW) maintains

approved vegetation and reports any dike repair needs or issues to the ACOE for possible action.

As a result of flood protection actions taken over the last 60 years and improvements in access, particularly a bridge to the mainland over Multnomah Channel at the south end of the island, the full-time resident population of Sauvie Island gradually increased to more than 1300. It is still very rural, with most of the south part of the island designated for agricultural land use that supports a variety of "U-pick" farms that grow fruits and vegetables. The northern half of the island, some 12,000 acres, is maintained as a wildlife area and managed by Oregon Department of Fish and Wildlife (ODFW). This area supports more then 250 bird species and provides feeding and resting areas for bald eagles, great blue herons, black-tailed deer, and other mammals. The wildlife area also provides refuge for over 250,000 migratory ducks and geese each year. As a result, over 750,000 visitors spend their days hunting, bird watching, and enjoying the beaches, generating local visitor revenues of approximately $1.5 million annually (Oregon Wetland Joint Venture, 1994).

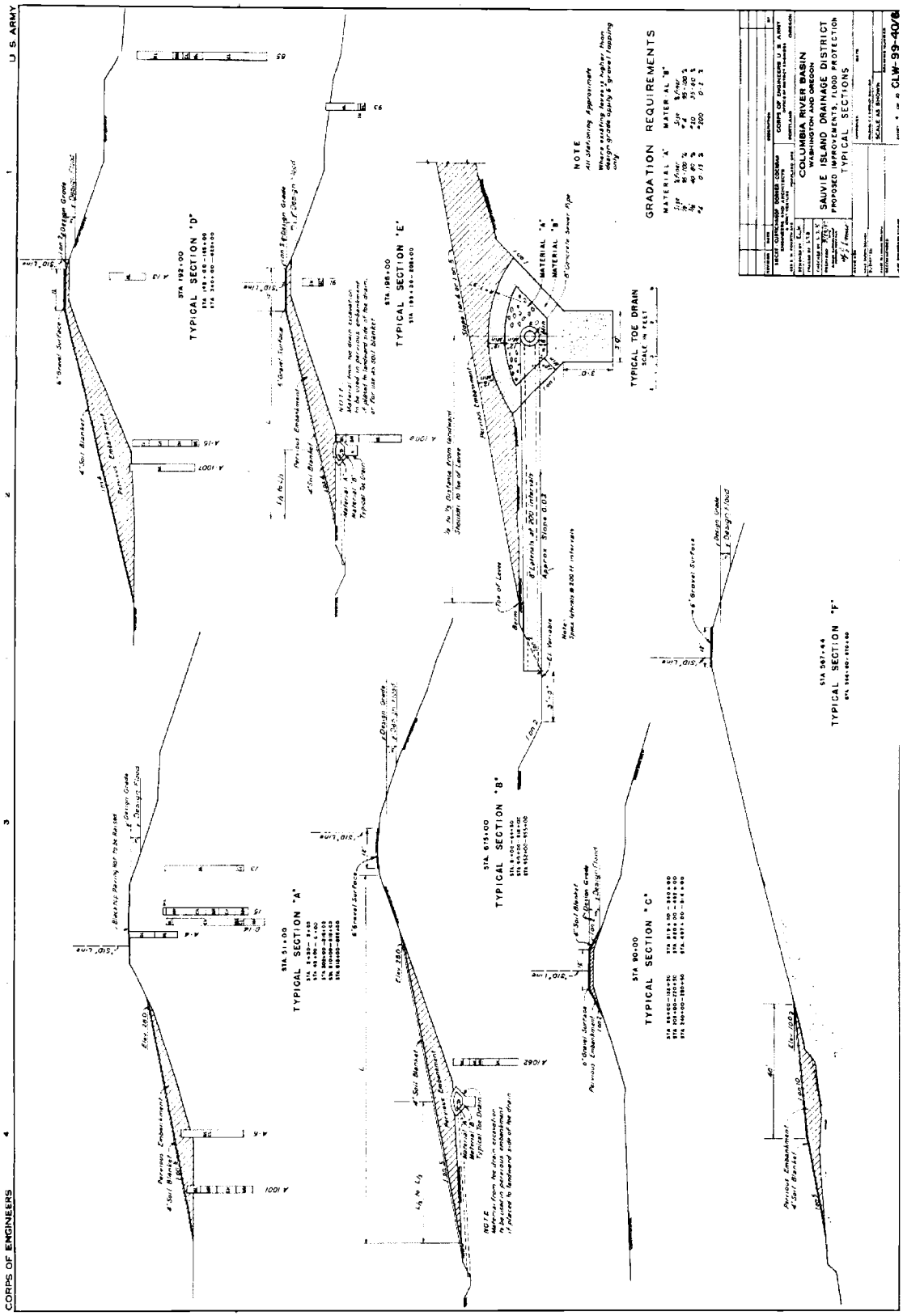


Figure 7 Selected levee improvements along "Big Dike" on Sauvie Island (US Army Corp of Engineers, 1960)

4.0 SAUVIE ISLAND BANK EROSION

Erosion, transportation, and deposition are all normal processes that occur along developed and undeveloped waterways like those surrounding Sauvie Island. These processes influence the shape of rivers and the landscape around them. This process occurs through a variety of methods including: hydrolic action, attrition (rocks interacting and breaking apart), abrasion (rocks impacting the riverbank), and solution (rocks dissolving overtime). On a large scale these processes allow rivers to evolve overtime, moving sediment from the headwaters and depositing them downstream in the valleys and floodplains. On a small scale, rivers will generally erode on the outside of the bend and deposit sediments along the inside, until they reach a state of dynamic equilibrium (Figure 8). Historically, processes including: seasonal run-off, flooding, and tidal forces established the natural erosion/ deposition regime of the Lower Columbia in and around Sauvie Island.

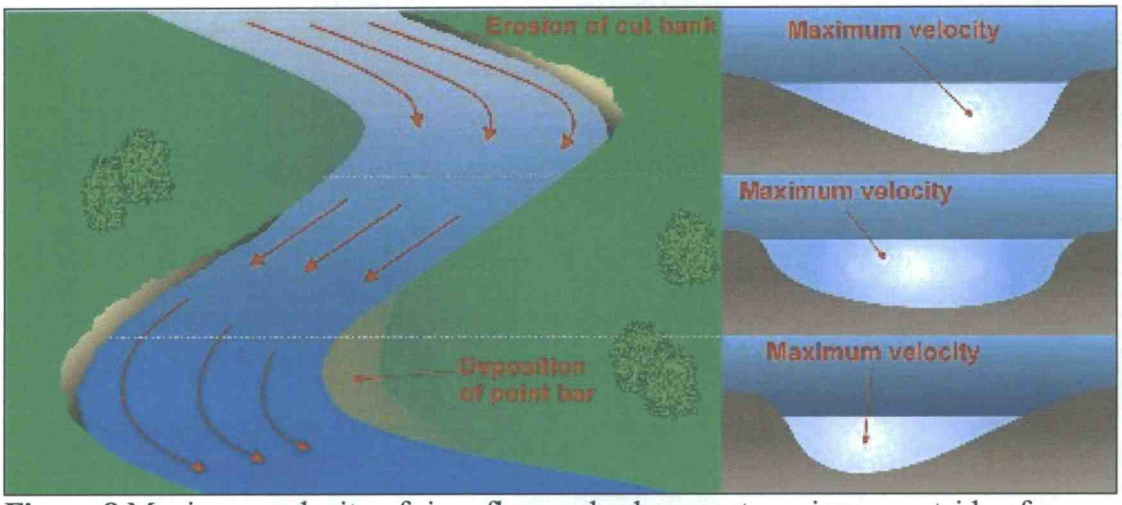


Figure 8 Maximum velocity of river flow and subsequent erosion on outside of the bend while deposition occurs along the interior (Idaho Department of Transportation, 2007)

Along the Columbia River these erosive processes illustrated in Figure 8 have been altered with the construction of dams producing hydroelectric production, while providing irrigation, flood control, and stable navigation channels. Along the lower river urbanization has lead to the construction of revetment structures, dikes, and sea-walls dramatically altered sedimentation processes. Navigation improvements have required increased dredging (expanding the channel to 600ft wide by 43 ft deep) from Astoria to Portland. These alterations to the natural system have dramatically altered the river flow, currents, and sediment distribution along Sauvie Island and the Lower Columbia River.

Factor effecting erosion along the shoreline of Sauvie Island can be divided into primary and secondary factors. *Primary factors* increase erosion independently of any other contributing factors; while *secondary factors* compound erosion rates only after a site is affected by a primary factor or factors. The primary factors effecting Sauvie Island include: dams, water levels changes, flooding, ship wake, wind generated waves, and looting. Secondary factors including: periodic dredging, structures in water way, tidal fluctuations, and wind. All these can alter the rate of sediment transport, deposition, and erosion along the shoreline.

4.1 Primary Factors Contributing to Sauvie Island Erosion

Primary factors contributing to shoreline erosion along Sauvie Island and elsewhere along the Lower Columbia River include upstream dams, flooding, ship wake, hardening of upstream banks, water level changes, wind generated waves, and unlawful excavation of Native American artifacts. However, it is the combination of factors impacting a particular site, over time which can result in increased erosion events.

4.1.1 Impact of Dams

The mainstream of the Columbia River has 14 dams, 3 in Canada and 11 in the United States (Figure 9). Eight of the dams have lock to facilitate navigation. Most of these structures were built after the Food Control Act of 1936 was passed. These dams have dramatically altered the natural flow of the river, creating a series of stair steps, and slack waters reservoirs. Although the construction of these dams has provided many benefits to

society they have also negatively impacted the physical and biological processes in the river system.

Figure 9 Private and federal dams located in Columbia River Watershed (BPA, 2001)

Peak river flows and, sediment transport has been substantially reduced by the construction of dams on the main stem and tributaries of the Columbia Rive. Historically, during peak flows and flooding events the river would discharge 90 percent of its sediments, inundating floodplains with nutrient rich water while depositing sediment,

rebuilding banks. Today, this sediment settles out in the slack water of the reservoirs and gets trapped behind the dams, reducing the overall sediment in the system while simultaneously creating a condition known as "nutrient loading" in the reservoir. Nutrient loading is a result of nutrient buildup behind the dam, which allows more aquatic microorganisms to live in a confined space as they consume the nutrients; the eventual decomposition of these plants and micro-organisms uses up available oxygen, resulting in hypoxic and anoxic conditions throughout the reservoir. Furthermore, gravel needed for fish habitat and reproduction is also trapped behind the reservoir, reducing spawning and rearing habitats (Northwest Environmental Advocates, 2007).

Of the Columbia River dams, the Bonneville Lock and Dam structures are the closest to Sauvie Island. The dam is located 40 miles east of Portland, Oregon, in what is now the Columbia River Gorge National Scenic Area. The dam was completed by the US Army Corps of Engineers in 1937, and is built from several structures to form one support structure across the Columbia River. The primary functions of Bonneville Lock and Dam system is to provide electrical power for the greater northwest region. However, the dam also provides secondary benefits of irrigation, flood control and navigation (BPA, 2001).

4.1.2 Flooding Impacts on Erosion

Historically, the Columbia River had biannual flooding events brought by two regional weather patters. In the winter, flooding is principally caused by rain fall runoff from the Willamette River and its tributaries. In spring, flooding is predominantly caused by snowmelt occurring throughout the Columbia River watershed (Figure 10). Rainfall runoff floods usually crest for 2 to 5 day while, historically "June Floods" would inundate 170,000 acres along the Columbia and Willamette Valley for a period of 60 days, major floods would nearly double these figures (US Army Corp of Engineers, 1960). Flood waters would rise 20-30 feet along Portland and Vancouver inundating most of the Northwest area of Sauvie Island for several months of the year (Christy and Putera, 1992).

Maximum water stages observed during 1894, 1876, and 1948 at river mile 99.3 were 34.5, 29.8, and 31.0 feet to the Mean Lower Low Water (MLLW) (US Army Corp

of Engineers, 1960). The 1996 flood was recoded at St. Helens at 23 feet and 29 feet in Portland, Oregon. Flood water would historically spill over into the floodplain creating backwaters which would slowly retreat leaving deposits of sand and silt on the island. While these regional runoff regimes still exist, the hydrology of the river has been strictly controlled by dams, dikes, and levees.

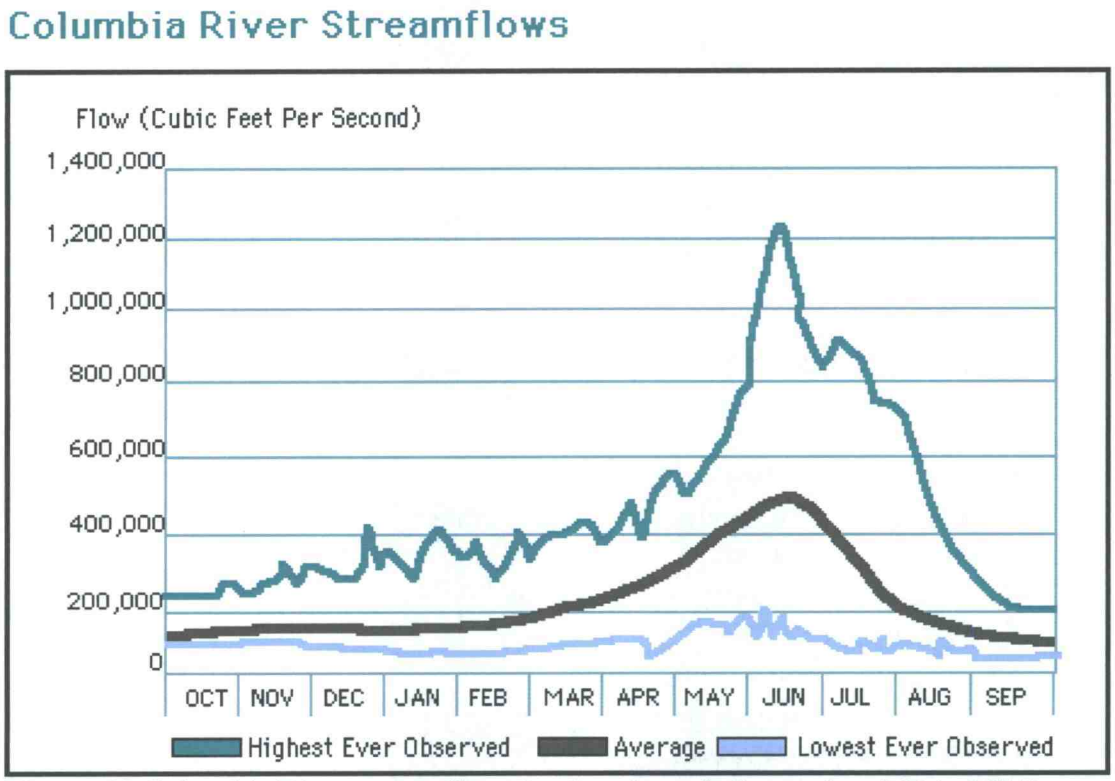


Figure 10 Columbia River streamflow October through September (BPA, 2001)

4.1.3 Vessel Generated Waves

Wave formation and shoreline interaction from vessel traffic is complex. Breaking waves form when friction from the shore slows the base of the wave relative to the height. Waves breaking on gentle slopes are scattered in random directions, while waves breaking on a steep slope release more energy directly onto the shore. In the short-term, this energy can affect a bank by creating boundary shear and pressure changes causing increased turbidity and offshore transport by river currents. In the long-term, waves generated from a vessel can impact a bank in three possible ways. First, waves can directly impact the bank, destabilizing it and washing it away. Second, waves can

periodically wash against the bank that has already been damaged by other causes, accelerating erosion which is already occurring. Third, waves can erode soil from the bank from slow, steady, and repeated impact overtime (WRP, 1998). See table 1 for a list of potential interactions between vessel wake and river bank erosion, and table 2 for cause of stream bank failure.

Table 1. Potential factors associated with motor boat induced streambank erosion (Klingeman, 1990)

Stream bank characteristics • Bedrock exposure • Composition of alluvial bank including types and size of alluvial material and the extent of cohesion/ tightness/ cementation • Lateral and vertical features and there variability • Bank slope, • Bank toe material • Presents of for beach "where the eaves a breaking" • Vegetation cover; and its ability to shield the bank or bind soil together to resist erosion
River Hydrology Characteristics • Water surface elevation and water discharge rate
River Hydraulic Characteristics • Water depth • Water velocity • Chanel slope in direction of flow • Shear stress extended by flow against bank
River Geomorphic characteristics • Plat form of channel • Bars and Island • Bank irregularities • Debris
Boat wave characteristics • Wave height, wave length • Angle of wave to bank • Interactions of wave with for bank • Interactions of wave with irregularities • Influence of boat distance from bank • Amount of boat traffic • Relation of bank characteristics to bank features
Boat design characteristics • Influence of motor type, size, haul shape, boat speed, and passenger/cargo load

Table 2. Causes of stream bank failure (Klingeman, 1990)

Decrease in Shear Strength	Increase in shear stress	Flow
As the bank absorbs water it increases the groundwater pressure against the bank, resulting in cracking and soil creep along the shore. This can develop in to cracks that run parallel to the shore. Vegetation can either help bind soil together and prevent sluffing or accelerate the process if large trees lean over the water and put additional stress on the bank.	Shear strength increase with changes in channel shape, water that has eroded the bottom off the bank causes undercutting and increase the top load of the bank which can result in sluffing.	The faster and deeper the channel is the stronger the shear force becomes along the bank. The speed of the flow depended on the gradient of the river, depth, roughness of the stream bank, and morphology of the river. More energy is required to overcome initial bank resistance; however, once the threshold is breeched erosion can proceed quickly.

There are two types of waves generated from vessels; bow and stern wake. Bow wake is produced when water is pushed out of the way by the hull of the ship; while stern wake is produced by water filling up the space where the boat just left. The magnitude of ship wake is influenced by the type of boat (e.g., barge, tugboat, and powerboat), characteristics of the vessel (hull, bow shape, and ship draft), and the speed of the vessel (Asplund, 2000). These wave generating factors can also affect "drawdown" which is caused by ship propellers forcing large amounts of water from beneath the boat. On the shoreline the displacement of water from the vessel results in water being pulled away from the shore, resulting in offshore transport of sediment. Furthermore, the proximity of the vessel to the shoreline and characteristics of the bank (boundary conditions, soil type, and steepness), can effect their intensity and untimely the degree of shoreline impact (Figure 11).

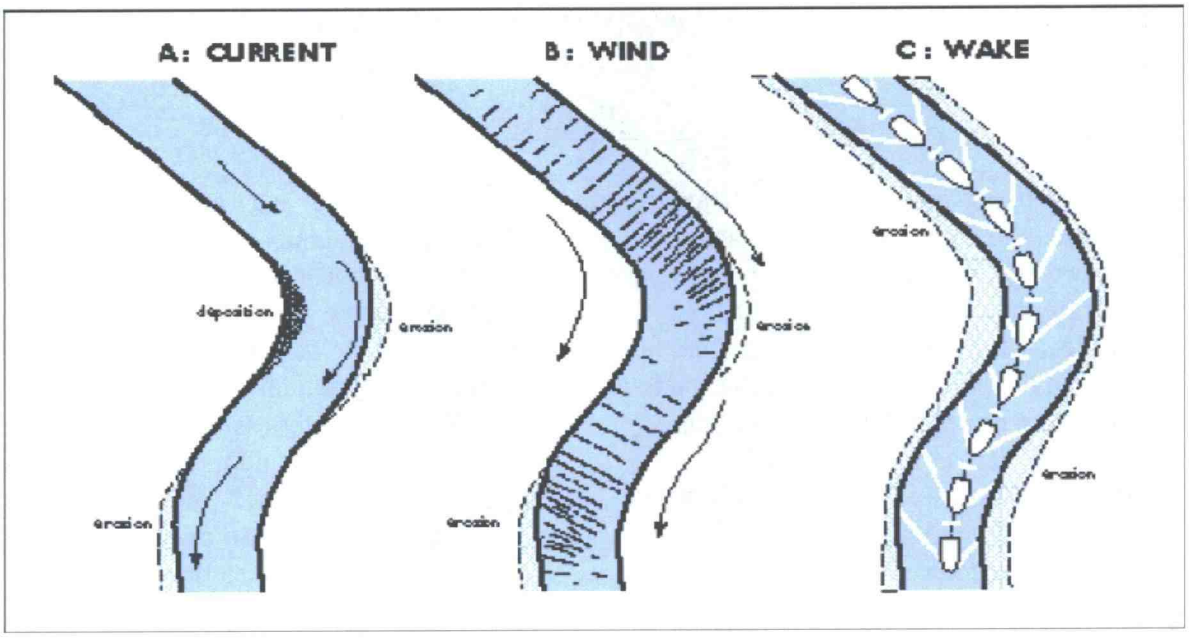


Figure 11 Erosion and deposition patterns dependent on type of erosive interaction; current, wind, and wake. (Department of Primary Industries, Water and Environment, Tasmania, 2007)

A wave generation model for ocean going vessel was developed in 1986 to determine wave impacts along Sauvie Island. Using data collected from the USCE Hydro Survey of Morgan Bar, a maximum ship generated wave can reach up to 2.8 ft high (US Army Corp of Engineers, 1986). While no recreational motor boat wave studies have been done along the Columbia River, a study on the Saint Lawrence River found that recreational boats can generate up to 40 waves per pass, reaching heights of 1.6 feet. Other studies have established that sustained recreational boat traffic traveling between 7-10mph can create continuous waves along a beach (Bishop, 2003). Furthermore, small boats traveling fast can reach "hull speed", allowing the boat to break out of its own wave system, triggering the stern and bow waves to merge producing a single large wave. While shoreline erosion is not quantitatively calculated in these studies, it is clear that recreational traffic and ocean going vessels can both generate waves sufficient in height and duration to cause erosion along the shoreline (Wtrwy, 2002).

A third vessel-related threat to shoreline stability is the use of jet skis. There are approximately 13,000 jet skies registered in Oregon out of those 2 percent are registered in Columbia County while 17 percent are registered on Multnomah County. The only

research effort conducted on the impacts to turbulence was done for the Personal Watercraft Industry Association. This organization indicates that jet skis have no effect on water clarity in estuaries of 21-28 inches deep; however they did find some re-suspension sediments in shallow water (Continental Shelf Associates, Inc., 1997). While no studies have been in the Columbia River it is important to note that jet skis can operate in as little as 12 inches of water creating a scenario that could cause re-suspension of partials along the bank and erosion in shallow waters (Asplund, 2000).

4.1.4 Upstream Erosion Control Impacts

Upstream erosion control (logs and rip-rap) has long been thought to impact downstream erosion rates. Hardening of upstream banks can destabilize the downstream shorelines by deflecting the river current energy towage the adjacent riverbank (Figure 12), and/ or also accelerated flows just adjacent downstream of revetment structures (Figure 13). (Department of State Lands, 2006)

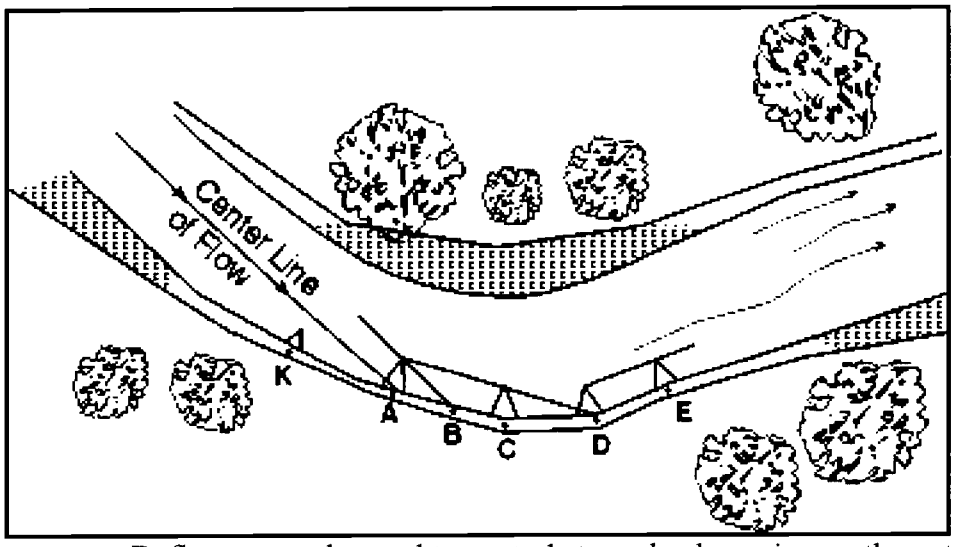


Figure 12 Deflectors can be used to control streambank erosion on the outside bends of meanders, however, this current can then impacting adjacent bank downstream (USDA, 1996)

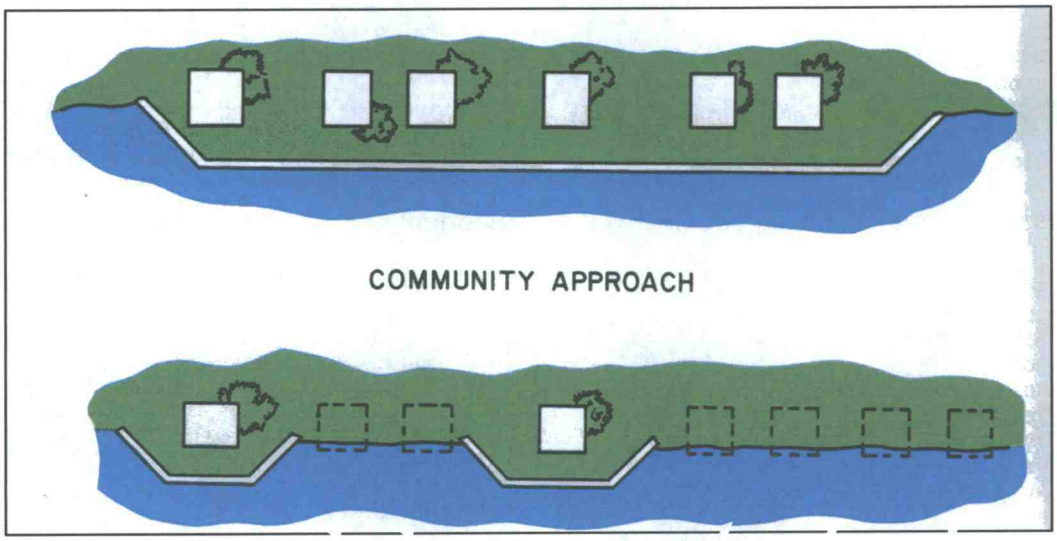


Figure 13 Accelerated bank erosion can occur downstream of revetment structures denoted by arrows (US Army Corp of Engineers, 1981)

4.1.5 Water Level Changes

Changes in water levels along the Columbia River are influenced by seasonal weather patterns and dam release schedules. While seasonal weather patterns are predictable, dams have impacted the natural rise and fall of the river on a daily, weekly and seasonal basis in order to produce electricity. The construction of eight reservoirs has increased the storage capacity of the system by seven million acre feet of water. Furthermore, because of reservoirs and dams seasonal water flows have also been affected; the average winter water height is now lower, while the summer levels remain higher than historic levels. These changes insure that there is enough water year round to meet the hydroelectric, and ecological needs of the system (i.e. salmon runs) (BPA, 2001).

4.1.6 Wind Generated Waves

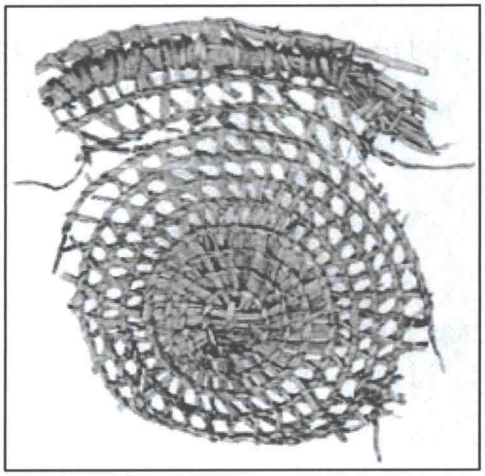
Wind can have a direct effect on the surface velocity of a river. Wind-generated waves are influenced by three independent factors: wind speed, duration, and fetch. The longer the wind blows over a flat surface, the more likely a small, fetch-limited, low energy waves will form (Bishop, 2003). A wind generated wave model was constructed using information collected along Sauvie Island in 1986. Using southwest winds (which blew

the longest over the greatest area, 2.6 miles) a wind generated wave of 1.2- 2.8 feet can form along this section of the Columbia River (US Army Corp of Engineers, 1986).

4.1.7 Cultural Site Disturbances

Sunken Village is one of 15 Native American villages Sauvie Island documented by the Lewis and Clark expedition in 1806. This well preserved Chinook settlements dates back to 1250-1750 AD. The Chinook Indians, were successful hunter-gatherers, there success allowed populations to reach approximately 800 individuals on the island. The sunken village site is on the Multnomah Channel side of Sauvie Island and is one of the most intact representations of North American aboriginal life discovered in the area. Items such as stone sculptures, knives, carved animal bone, and trade goods such as copper and glass beads have been excavated. As a result, looters have dug into the existing levee, compromising its stability. This repeated action forced the Sauvie Island Drainage Improvement Company to request a permit from the Corp of Engineers to secure the levee with rip-rap to prevent further degradation of the site. After archeologist and several Native American tribes retrieved the remaining artifacts the site was rip-raped in the fall of 2006 (Figure 14). Information regarding the 14 other sites is not made available to the general public, due to the potential for looting and concerns for the private property rights of affected landowners (Bogan, 2006).

Sunken Village Site September 1 2006



(Bogan, 2006)
Artifacts Recovered from Sunken Village Site

Post Rip-rap Sunken Village Site (Winter, 2007)
Figure 14 Sunken Village artifacts, pre rip-rap, and post rip-rap photos

4.2 Secondary Contributing Factors to Erosion to Sauvie Island Erosion

4.2.1 Dredging-induced Erosion

The Lower Columbia River navigation channel has been dredged to maintain a minimal depth to insure the safe navigation of ships (US Army Corp of Engineers, 1998). Dredging has been primarily done by the Army Corp of Engineers, which began in 1878, with a 20 foot deep channel along the lower 178 kilometer of the Columbia River. The navigation channel was increased to 25 feet deep in 1899, and then to 30 deep in 1918, to accommodate larger ships. In 1976 the channel was increased again to 600 ft wide x 40ft deep. The latest dredging project, completed in the fall of 2006, increased the channel depth to 43 feet from the mouth of the Columbia River to the confluence of the Willamette. This project used both a hopper and pipeline dredge to remove the eight million cubic tons of sediment to create the channel, and will require the removal of an additional three million cubic tons per year to maintain it (Hulse et al. 2002). The deep-draft channel can be dredged up to 5 feet deeper, and up to 100 feet wider than the authorized channel dimensions. This allows time for the sediment and bedload (waves of sand reaching 4 to 8 feet high and 300 to 400 feet long) to fill back in up to the authorized dimensions over the course of the next year (US Army Corp of Engineers, 1998). The dredging maintenance schedule is determined by cross section and channel lines which determine where the sediment has filled in the channel (Figure 15). The current dredge channel is approximately 230-700 feet from the Sauvie Island shoreline. Additionally, dredging has also occurred along the Willamette River portion of Sauvie Island; however, due to the presents of toxic materials at near by "Superfund site" no dredging has occurred along the Lower Willamette River in over 10 year.

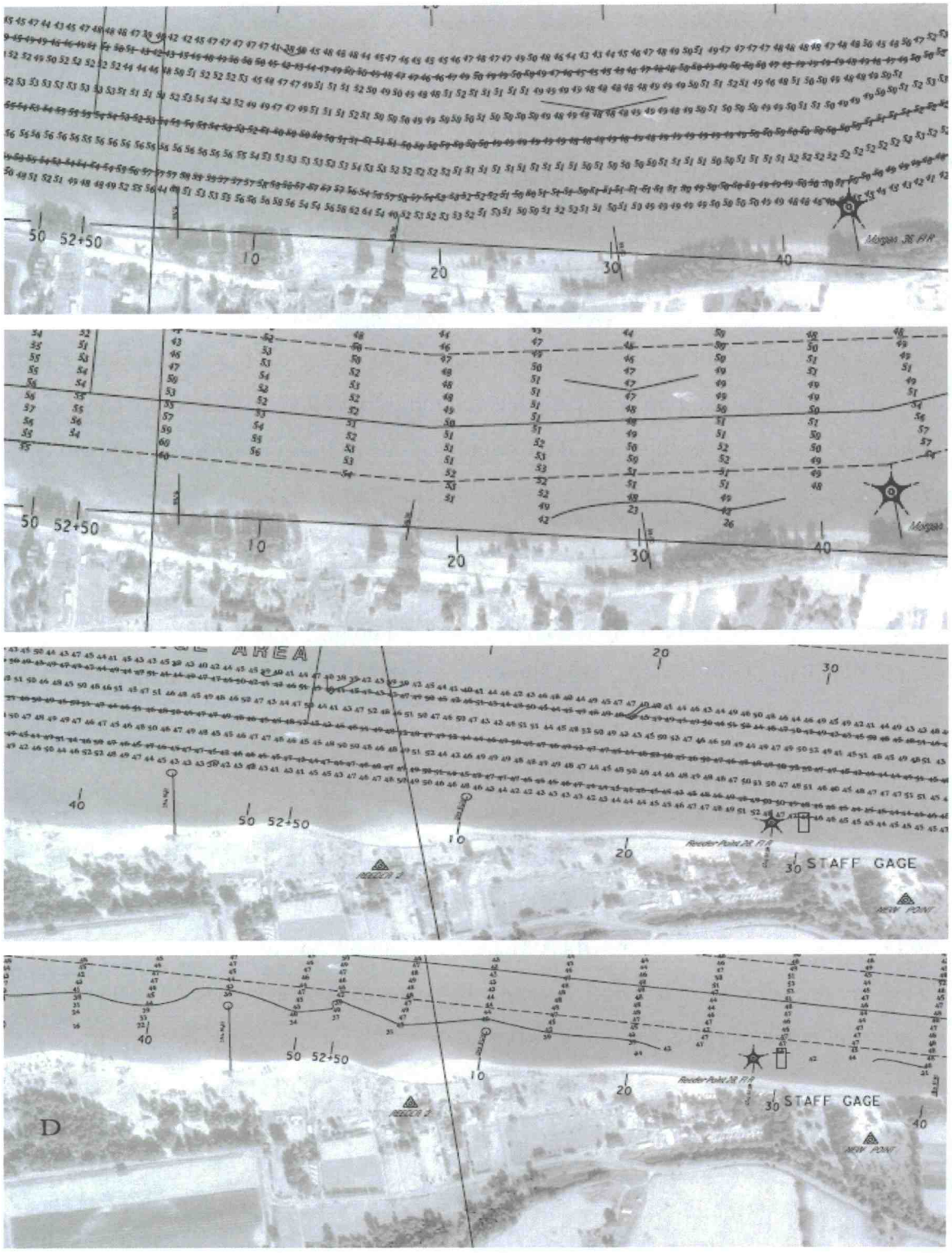


Figure 15 Cross lines and channel lines are used to determine dredging maintenance on the Columbia River. Here are two locations along Sauvie Island that have been surveyed A) Channel-line Morgan Bar B) Cross-lines Morgan Bar C) Channel-lines Willow Bar/ Reeder Beach D) Cross-lines Willow Bar/ Reeder Beach (US Army Corp of Engineers, 2007)

4.2.2 Beach Renourishment

Dredging of the deep-draft shipping channel of the Columbia River has required disposal of massive quantities of sediment, resulting in creation of new islands, filling of many wetlands, and changes in historic shoreline sedimentation. Some of dredge sediment has been used for beach renourishment projects, including sections of Sauvie Island (Figure 16, Table 3). These projects added large amounts of sand to the shoreline, ranging from 10-15 feet high and up to 150 feet wide. This changed the bank compositions to a much larger grain size which ultimately may be contributing to accelerated erosion in these areas (US Army Corp of Engineers, 1975). However, with the increasing concern for shallow water salmon habitat dredge spoil operation along the Sauvie Island shoreline have ceased, the last beach re-nourishment project along limited section of the island occurring in 1986.

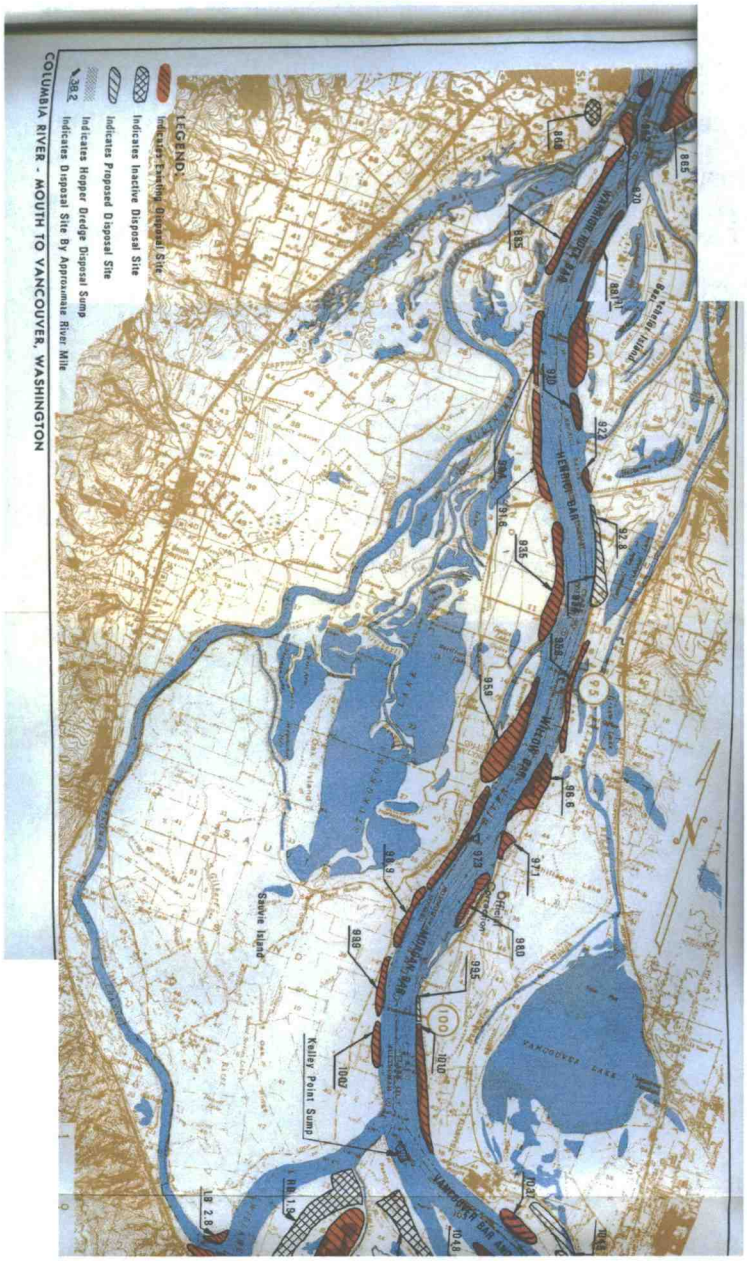


Figure 16 Beach renourishment sites along Columbia River in 1975 (US Army Corp of Engineers, 1975)

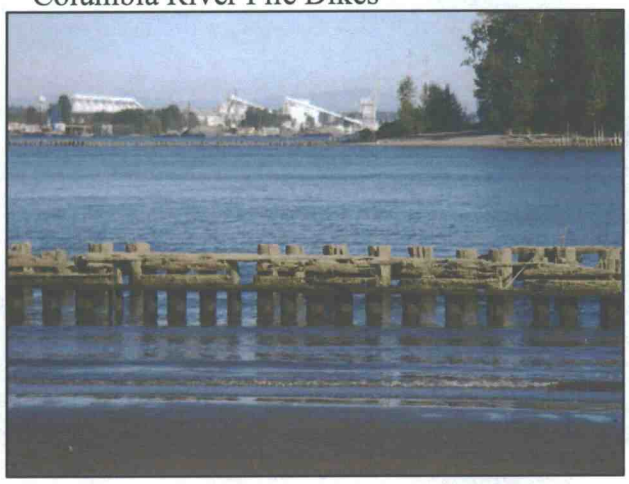
Table 3 Beach renourishment sites (in cubic yard) carried out from 1960-1997 along Columbia River section of Sauvie Island (US Army Corp of Engineers, Personnel Communication 3/18/07)

Site river mile	86.2	87	88.5	89.8	90.4	91.6	93.5	95.9	97.3	98.9	99.9
year											
1960	21,000										
1961					370,320	242,370	316,265				
1962	54,561850	119,590							496,012		
1963					228,432					160,675	
1964									692,376	154,580	
1965								282,763			
1966								59,440	252,820	14,265	
1967	6059,823							284,145	410,097		
1968	36,530		36,530		222,885	431,240	305,166				
1969							40,187	134,299			
1970										99,897	
1971				286,036	415,311	275,929					
1973								66,615			
1974								264,849			
1975				128,822							
1976				197,188		144,067			163,210		
1977						57,752	132,470		44,023		
1979				129,775							
1985	272,958					135,459	209,125				138,521
1986								20,000	77,000		
1989	113,651										
1990	193,574										
1993	120,763										
1997	273,878										

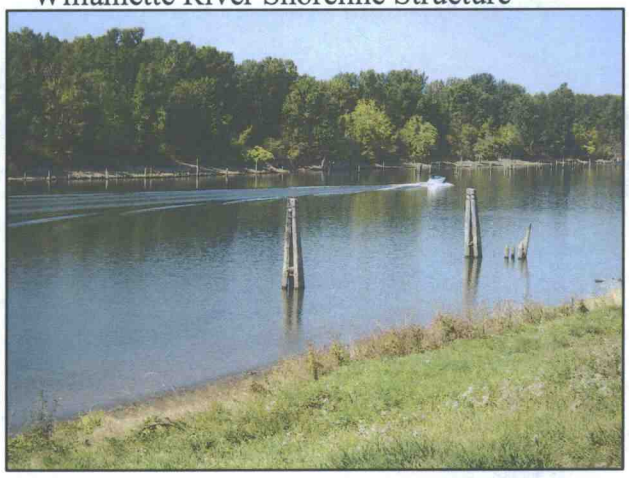
4.2.3 Waterway Structures and Erosion

In 1871 the Portland District of the ACOE set out on a multipurpose project to improve the navigation from the mouth of the Columbia River to the Willamette River, a distance of more then 100 miles. In addition to dredging, tree snag removal, and revetment work; man-made structures were built into the channel to improve the shipping lane. Wing dams (also know as pile dikes), extend only part way into the river, forcing water into a fast-moving channel. This reduces the rate of sediment accumulation in the channel, while allowing sand and sediment to collect near the bank where the water is moving more slowly (Wenyi and Puqing, 2002). However, studies have found that while accumulation results upstream of the pile dike, downstream there can be sediment depletion (US Army Corp of Engineers, 1981). As of 1980 there were 198 pile dikes located along the Lower Columbia River, including several that still exist along Sauvie Island (Figure 17). Ten pile dikes were placed along the lower Willamette River at Sauvie Island between 1926 and 1931 (Hulse et al. 2002). Historically, these structures were used to maintain the channel depth as an alternative to additional dredging. However, this method is no long used because predatory fish can use these structures as hiding spots to prey on salmonid fry.

Columbia River Pile Dikes



Willamette River Shoreline Structure



Multnomah Channel Log rafts and Dolphins

Figure17 Shoreline Structures along waterways bordering Sauvie Island

4.2.4 Tidal Influence on Erosion

Tidal influence plays a significant role in sedimentation and river flow rates, as far upstream as the Bonneville Dam. The Columbia River experiences a semi-diurnal tidal cycle, with two high tides and two low tides of different heights. The tidal cycle affects the river hydrology, chemistry and sedimentation in three ways: intrusion of salinity (important for vegetation), river flow reversal, and water level fluctuations (velocity of the river). A maximum salt water intrusion occurs with a high tide and low river flow volume, reaching approximately 20 miles upstream. This varies with tidal stage and river flow volume, and reversals have been observed as far upstream as Sauvie Island (personally communication, 2 local residents). As the ocean water advances the river will reach slack tide and eventually a reversal. Flow reversal can impact shoreline erosion by repeatedly transporting large logs and debris, which can scour the bank as they move up and down the river with the tide, however, the true impact of these repeated events is unclear. Tidal changes along Sauvie Island range from 2-3 feet, compared with 7-8 feet at the mouth of the Columbia River, and 1-2 feet at Bonneville dam, (US Army Corp of Engineers, 1986).

4.2.5 Wind-Generated Erosion

Wind can significantly contribute to shoreline erosion and often works in conjunction with water erosion. Water action cuts into the upper bank creating a vertical incision; wind will quickly modifies the scarp by blasting the face of the vertical slope and transporting the sand down hill in micro-bajadas or mini alluvial fans (Abbe, 1990). Additionally, wind erosion can be particularly important if there is a long fetch or straight distance across which wind can blow, generating speed and erosive potential.

4.3 Interaction of Primary and Secondary Erosion

Interactions of primary and secondary erosion factors can change erosion rates in river systems. Dams and reservoirs along rivers have greatly decreased the natural process of sediment transport from the upper reaches of the watershed to the lower floodplains and the ocean. However, they have also reduced the volume and impact of flooding events. Furthermore, dredging the river changing the benthic topography, impacting river

currents, water speed, and wave strength. While hardening of riverbanks with rip-rap and sea walls protects the immediate shoreline it has been shown to increased the flooding potential downstream. Additionally, rapid water-levels changes and flooding events affect a bank in three ways as water rise, crests, and recedes. Shoreline including: the toe, slope and face of the bank are repeatable impacted by the river currents, ship wake and passing debris, leading to scaring and sluffing of the bank. These physical disturbances, along with bank features (soil type, gradient of the slope, and ground cover vegetation) and land use, all interact to determine bank stability and erosion rates.

4.4 Shoreline Protective Structures

There are a variety of methods to mitigate shoreline erosion including: rip-rap, bioengineering, or hybrid structures. Given the right conditions, each of these alternatives has the potential to slow or stop erosion along a sensitive shoreline.

Rip-rap is the most common revetment structures used along the Columbia River. In order to be successful rip-rap must be placed on stable, usually strengthened soil; therefore the underling soil must have an even slope and be properly compacted. Rip-rap is comprised of three components: the armor layers (usually composed of rock or concrete blocks), filter layer (allows drainage/seepage and prevent settling), and toe protection (to prevent settling and undercutting) (US Army Corp of Engineers, 1981). Selection of stone size is determined by the project engineer. Along the Columbia River Class II Rip-rap has been approved for personnel projects and has the following gradation requirements: 75% of the stone's weight needs to be between 50-250 lbs., 30% size by weight ~ 150 lbs., and 10% less then 25lbs. by weight. A filter layer or fabric is also important for three reasons, it allows even drainage and reduces sediment from filtering through the structure which could destabilize it over time; it also helps evenly distributes the weight of the rocks. When designing rip-rap it is also important to reinforce the flank and the base of the structure to minimize scowering at these two critical locations. For example, it is suggested that the rip-rap blanket be doubled at the base of the structure to prevent undercutting. Some of the most common reasons for bank failure include: flanking, overtopping and scouring of the rip-rap structure, destabilization of the structure

due to improper settling, and undersize stones displaced by large waves or currents. (US Army Corp of Engineers, 1998)

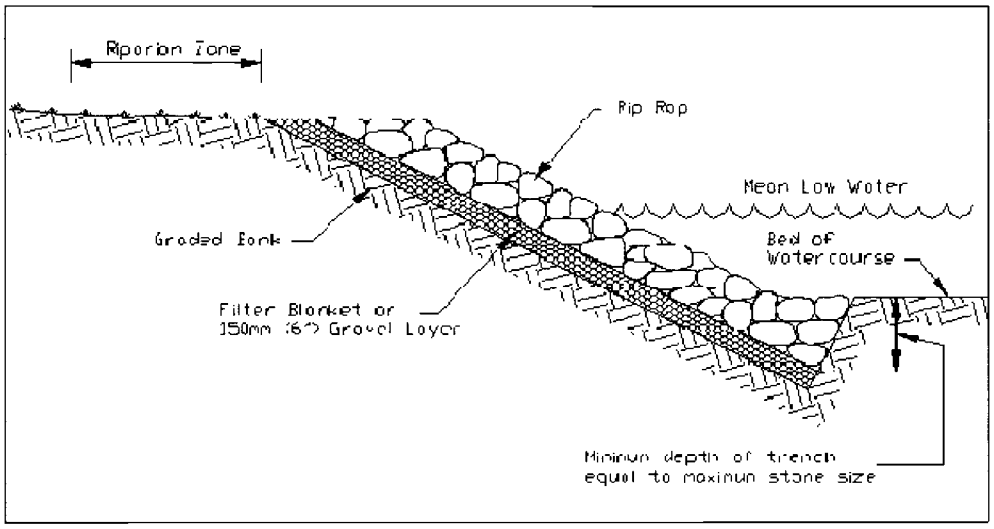


Figure 18 Typical cross section of rip-rap streambank protection
(The New Brunswick Department of Agriculture, 2007)

When live stakes are used with riprap, the process is called a joint planting, and creates a living structure (Figure 19). The live stakes should be planted into the soil below the riprap (between the rocks) and below the filter layer (Sotir et al.1995). Joint planting can provide a considerable amount of shade and cover, trapping sediment, improve drainage (by removing moisture), and eventual binding and reinforce soils with root balls. To increase the success rate of plantings it is important to use vegetation (ASDA, 1996) that is 1.5 inches in diameter and sufficiently long enough to reach soil behind the rip-rap. Joint planting along this area may include: willows, red osier dogwood, cottonwoods and grasses can then be planted along the benches or on the slop of the rip-rap.

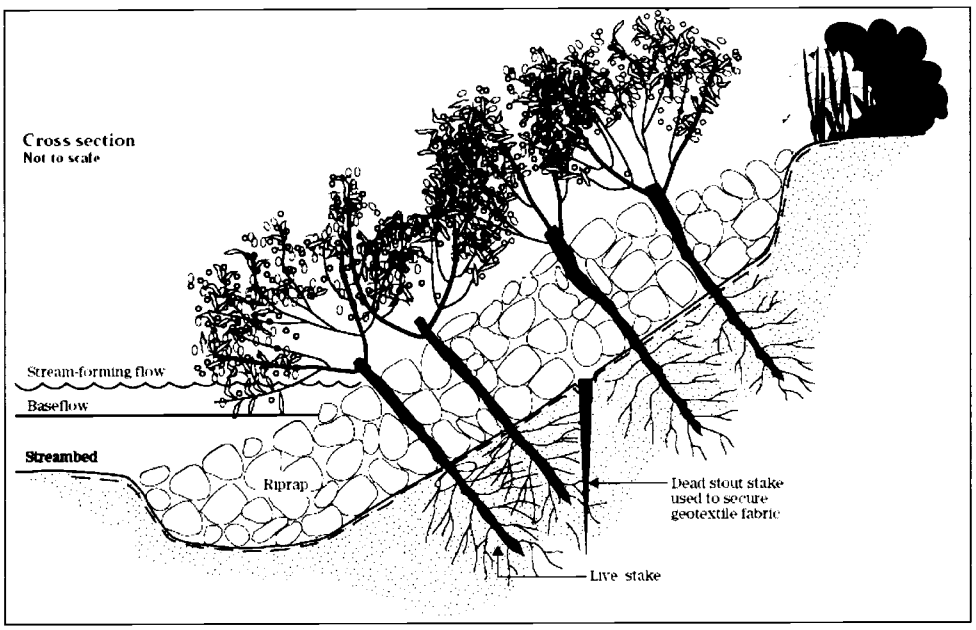


Figure 19 Cross section of rip-rap structure showing intermittent planting of vegetation (USDA, 1996)

Bioengineering is the processes of using living plants to control for erosion and for restoring riparian habitat. Willows and cottonwoods are widely used along stream bank because they grow easily from stem or root cuttings. Live staking (figure 20) consists of planting stem cut to between 2.0 -2.5 feet inserted into the stream bank at a right angle, allowing only 20% of the stake to be exposed. Other important elements of bioengineering include: grading/ or terracing the bank before planting, flow deflectors or bank armoring (Oregon Department of State Lands, 2007).

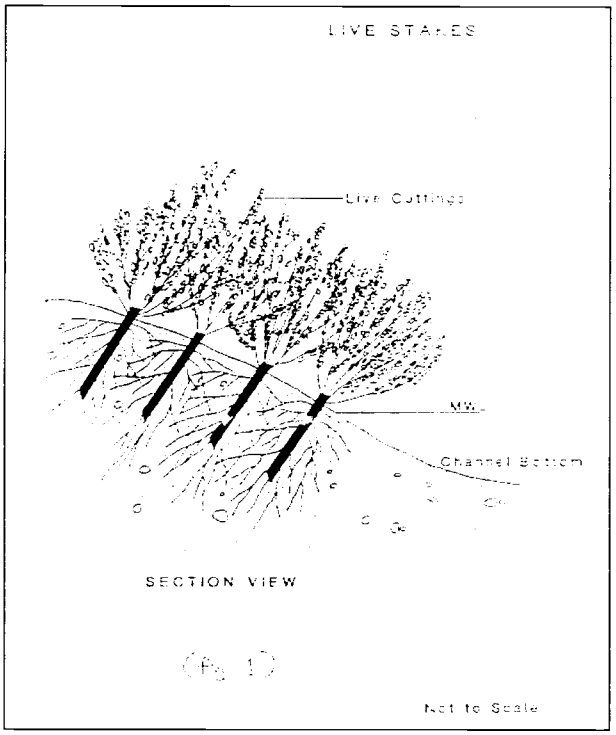


Figure 20 Live stakes: example of live bioengineering project (Oregon Department of State Lands, 2007)

5. RESEARCH DESIGN AND METHODS

5.1 Overview

The overall goals of this project are to encourage cooperative management of Sauvie Island erosion by building consensus and understanding of the problem and to increase communication between landowners and relevant government agencies. To achieve these goals, several objectives were established:

1. To understand property owner perceptions of shoreline erosion and the history of the problem.
2. To document the roles, responsibilities, and operational procedures of the government agencies involved in regulating, advising, or providing other assistance to property owners with erosion problems.
3. To "ground truth" property owner and agency perceptions of recent erosion problems.
4. To communicate project findings to all parties.

The methods used to achieve these outcomes include: surveying shoreline property owners to better understand their perceptions of erosion problems, interviewing relevant government agency staff to determine their roles and responsibilities for erosion management, and the analysis of aerial photos and other images to determine erosion "hotspots."

5.2 Property Owner Survey

The landowner survey was generated following the methods in *A Guide to Coastal Erosion Processes and Identifying Your Shoreline Erosion Problems*. In designing the survey questions, complex environmental issues were simplified and broken down into specific physical processes so that each of there components could be assessed by the landowner independently. Three types of survey questions were used: closed, open ended, and likert scale questions. To address technical issues, diagrams were provided. There were five primary issues addressed in the survey: background information, perceptions of erosion, contributing factors to erosion, the instillation of protective devises, and government involvement in shoreline management choices (Appendix A, Survey).

5.2.1 Sample Selection

Tax lot numbers, associated with all three river banks of Sauvie Island (Multnomah Channel, Willamette River and Columbia River) were used to generate a list of shoreline landowners to send the survey to. Agencies were contacted based on regional jurisdiction and not necessarily based solely on shoreline management jurisdictions. This was done to ensure all stakeholders were represented. Finally, a comparison of aerial photos across two time points (1972, and 2004; and 2005 orthophoto) was used to qualitatively compare shoreline erosion at sites indicated by landowners and agency personnel.

5.2.2 Survey Distribution

Surveys were distributed by mail on August 8^{th,} 2006, based on addresses associated with tax lot numbers for shoreline properties along all three Sauvie Island waterways

(Multnomah Channel, Willamette River and Columbia River). Each envelope enclosed an individual signed cover letter, a pre-stamped business envelope and the survey. Landowners were given the option of not participating in the study by simply sending a blank survey back. The cover letter stated the recipient's response was important for the success of the research, and if there was no response, a site visit may result.

On August 16th, 2006 a reminder postcard was sent to the residents that had not responded to the survey. The postcard contained contact information, in case the landowner needed a second copy of the survey. The postcard also reminded the landowner that if they did not respond within two weeks there would be additional canvassing of the area, and it would specifically target survey non-respondents.

5.2.3 Survey Analysis

Completed surveys were separated by their geographic locations, i.e., Columbia River, Willamette River, and Multnomah Channel in order to analyze any unique characteristics which contribute to erosion along these shorelines. Each question from the survey was analyzed independently. The open-ended written responses were presented to the residents as a way for them to expand on any aspect of the survey. Open ended questions were used to increase understanding and interpretation of the issues, but were not quantitatively analyzed.

5.3 Government Agency Interviews Concerning Erosion

Government agencies in the region with potential involvement in erosion control or management—local, state, and federal groups were contacted and 15 agency representatives were interviewed. Four questions were used to determine the agency level of management involvement concerning shoreline erosion along Sauvie Island. The following questions were asked:

1. Are you aware of erosion occurring along Sauvie Island?
2. Is your agency involved in monitoring erosion on Sauvie Island?
3. What do you feel the contributing factors are to bank erosion along Sauvie Island?

4. Does your agency have any "best management practices" or guidelines for shoreline management along Sauvie Island?

If agency respondents knew of specific location where erosion was a concern, a map of the island was faxed to them, and they were asked to indicate where they believed accelerated shoreline erosion was occurring and what the contributing factors were at each site. These responses were compiled and mapped.

5.4 Image Analysis of Erosion

Aerial photographs of Sauvie Island from 1972 and 2004 were obtained from the ACOE and georeferenced to each other in GIS. Unfortunately, due to technical issues (discussed in section 8) these images could not be accurately overlaid, therefore these images were visually compared, and long term shoreline changes noted. Later, a single rectified orthophoto image of Sauvie Island from 2005 was obtained from the U.S. Geological Survey (USGS) (An orthophoto is an aerial photography that has been geographically modified to account for the tilt of the camera and breaks in the terrain. This process ensures a uniform scale throughout the photo). This orthophoto covered approximately 80 percent of the island, including the entire Multnomah County portion. The 1972 and 2005 photo were the primary images used to compare shoreline changes over time. Additionally, one 2004 images was used instead of the 2005 when the sites location was out of rang of the 2005 orthophoto.

Erosion "hot spots" were determined through the agency and resident responses. Agency responses were based on verbal and map responses. All property owner survey responses were mapped in GIS to determine larger regions affected by erosion. These sites were the primary focus of the aerial photo analysis portion of this project.

6. Results

6.1 Survey Results

6.1.1 Survey Response and Subsequent Site Visit

There are approximately 155 properties along the shoreline of Sauvie Island. Of these, 73 are along the Columbia, 31 along the Willamette, and 51 along the Multnomah Channel. Thirty-three of these parcels were removed from the study for a variety of reasons including: 17 (11 percent) state-owned properties, 12 (8 percent) because of insufficient address information, and 4 (3 percent) residents who declined to respond to the survey. Of the 122 property owners surveyed, there were 79 respondents; a 65 percent response rate. Responding landowners that held multiple properties were thus included as respondents for each property owned. This relatively high response rate (for a mail survey) is likely due to persistent follow-up by the survey administrator.

Several survey respondents invited the author to visit their properties and learn more about particular erosion problems. Three sites along the Columbia and one on Multnomah Channel were visited (Figure 21).

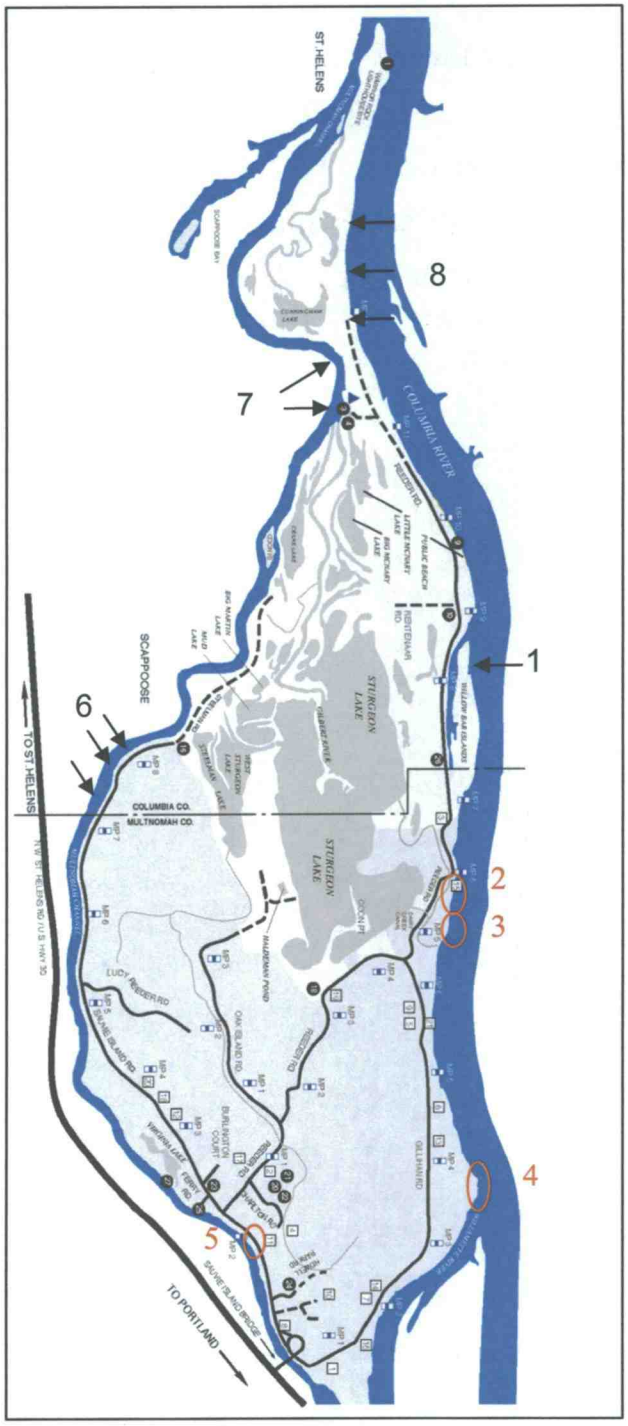


Figure 21 Sauvie Island master site map includes site visits and observed erosion by agency personnel. Site labeled 2-5 (highlighted in Orange) were visited by survey administrator, these sites include: (2 Reeder Beach, 3 Farm House, 4 Confluence of Willamette and Columbia River's, 5 Sunken Village). Site 1, and sites 6-8 (in Black) were not personally observed by survey administrator but were documented as eroded sited by agency personnel.

6.1.2 Survey Respondent Characteristics

The survey spanned two counties (Multnomah and Columbia Counties) with a majority of the population living in Multnomah County. The 79 property owners participating in the survey covered 65 percent of the privately-owned shoreline frontage along Sauvie Island (Figure 22), including 60 percent along the Columbia shorelines, 65 percent along the Willamette, and 31 percent along Multnomah Channel.

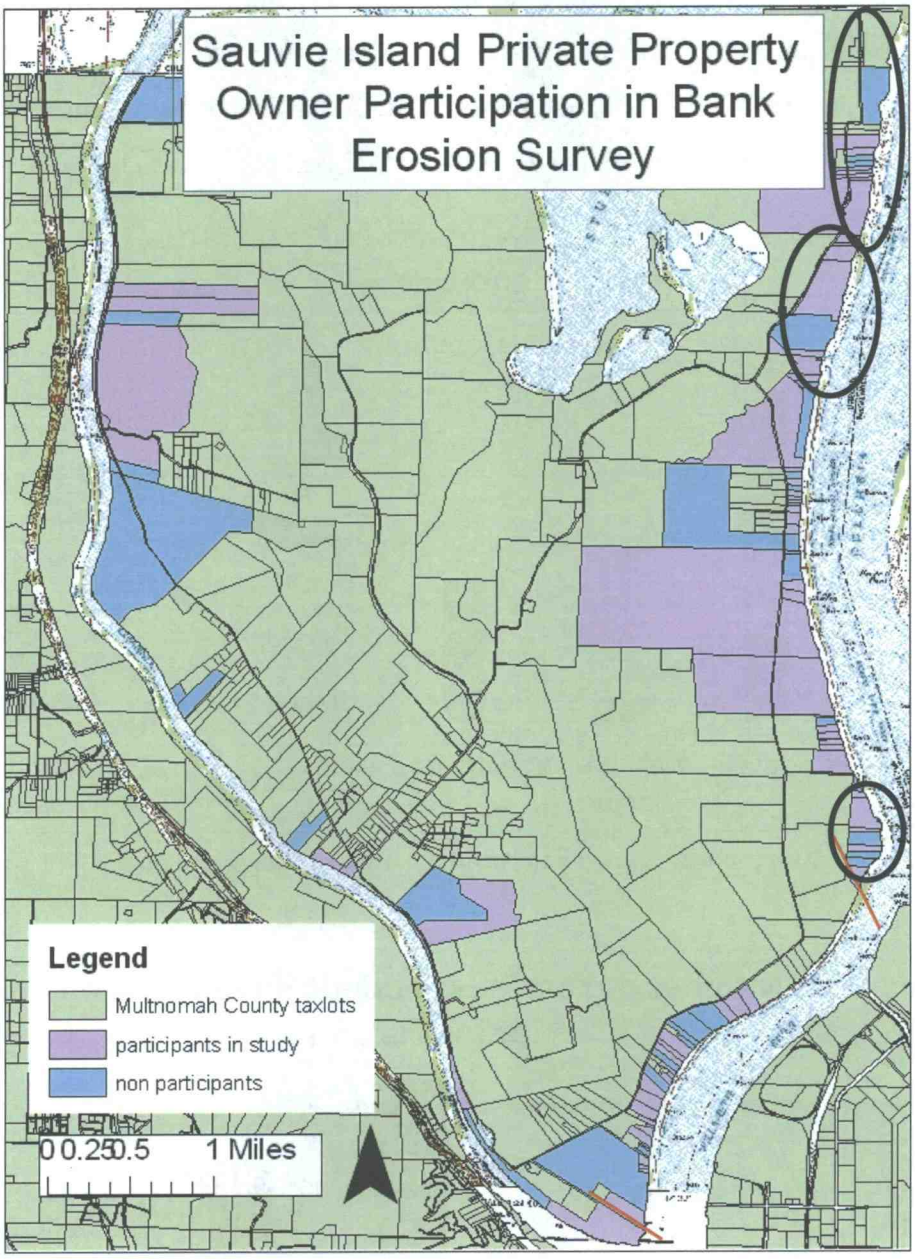


Figure 22 GIS map of Sauvie Island property owners who participated in the Sauvie Island shoreline erosion survey. Note: circled areas denote properties outside the protection of a dike; lines denote three geographic locations (Multnomah Channel, Willamette River and Columbia River)

Most respondents (90 percent) stated their shoreline properties are their primary residences, although many also indicated they use their land for other purposes, including agriculture (38 percent). While businesses, rentals, and vacation homes each comprise less than 10 percent of shoreline land uses (Figure 23). Many are also long-time residents—42 percent for more than 20 years and 77 percent at least 10 years (Figure 24).

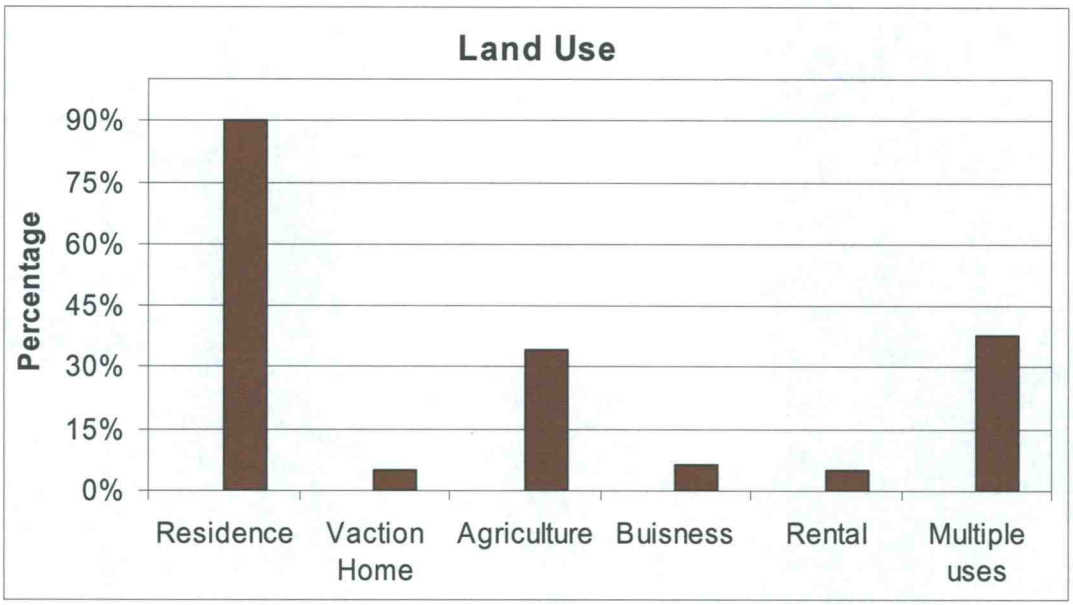


Figure 23 Existing land use types determined by survey respondents (100% response rate)

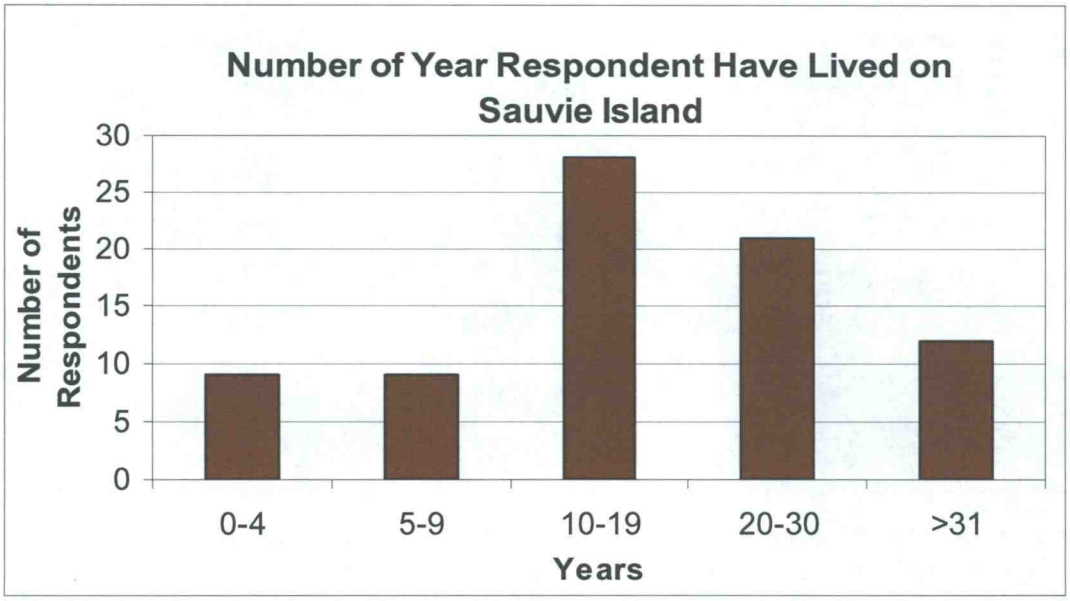


Figure 24 Distribution of resident's length of time owned shoreline property (94% response rate)

6.1.3 Shoreline Erosion Concerns and Observed by Respondents

Resident concerns were divided into three geographic locations: the Columbia River, Willamette River, and Multnomah Channel. This was done to better understand the physical processes effecting each location. In each location property owners were asked to evaluate a number of issues regarding their shorelines including: observed bank erosion since 1990, what there level of concern was regarding bank erosion, and how much shoreline has been lost. Answerers varied based on geographic location.

The survey results indicated that erosion was most prevalent along the Columbia River with 78 percent of respondents indicating some erosion had taken place on their property since about 1990. Multnomah Channel respondents were spilt on this issue. Fifty-six percent of the respondents had noticed erosion on their property, while only 5 percent of the Willamette River residents had observed erosion along their banks.

The most notable concern regarding bank erosion was along the Columbia River. Sixty-one percent of these respondents were either "very concerned" or "concerned" about shoreline bank erosion. However, 81 percent of the Willamette River and 63 percent of Multnomah Channel respondents were "not concerned" about shoreline erosion. (Figure 25, Figure 26). For the 33 Columbia River survey respondents who had actually observed erosion at their property, the number who reported being "concerned" or "very concerned" was about 51 percents (22/43). This contrasted markedly with property owners along Multnomah Channel, 19 percent (3/16) of whom reported being "concerned" or "very concerned" about erosion there, while 5 percent of the residents on the Willamette River noting erosion and being concerned about it (Figure, 27).

Respondents were also asked to identify the amount of shoreline lost since 1990, however, due too the low response rate the question could not be analyzed. Conversely, it was easier for them to identify *how many specific sites* along their property had been affected by erosion. The Columbia River not only has the most sites identified as having erosion, but also has the highest rate of the three waterways examined. Columbia River respondents also indicated that they had lost more vegetation higher on the bank then the

other locations. Of particular interest is that nearly a quarter of Columbia River respondents are loosing the bank along their entire shoreline (Figure 28).

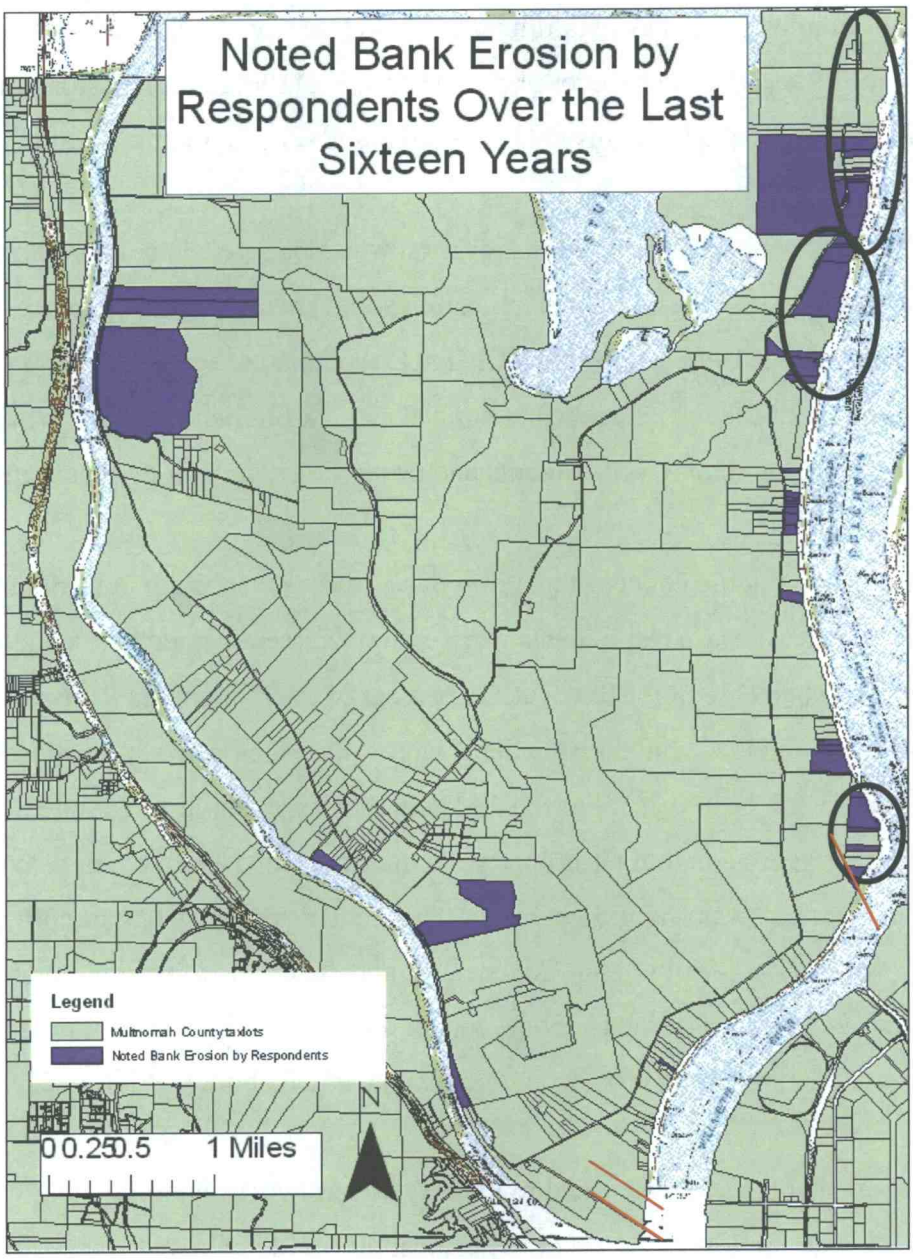


Figure 25 GIS map of Sauvie Island properties where bank erosion has occurred since 1990, as reported by survey respondents. Note: circled areas make where properties are outside the protection of a dike (98% response rate)

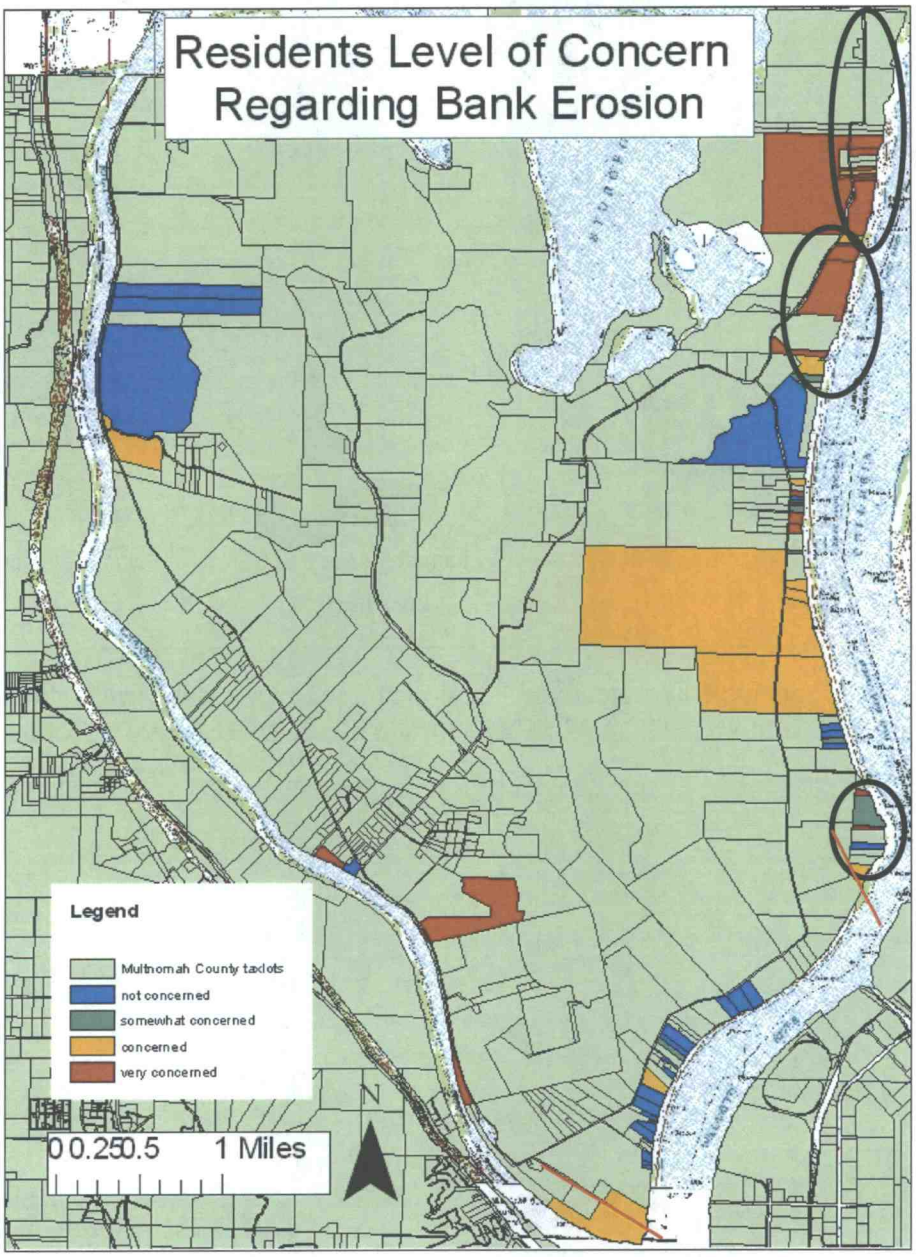


Figure 26 GIS map resident's level of concern regarding bank erosion, oven designation represent properties outside of the protection of the levee Note: circled areas make where properties are outside the protection of a dike (99% response rate)

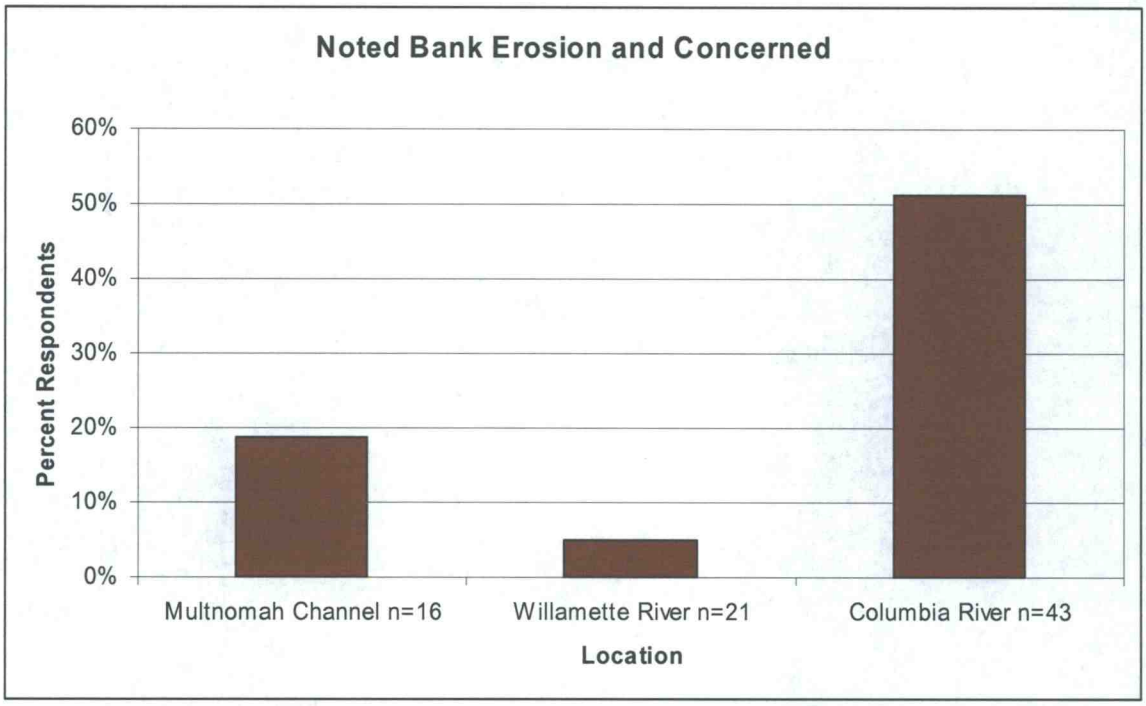


Figure 27 respondents who noted bank erosion and who were concerned about it (response rate Multnomah Channel 88%, 100% Willamette River, 99% Columbia River) total= 96%

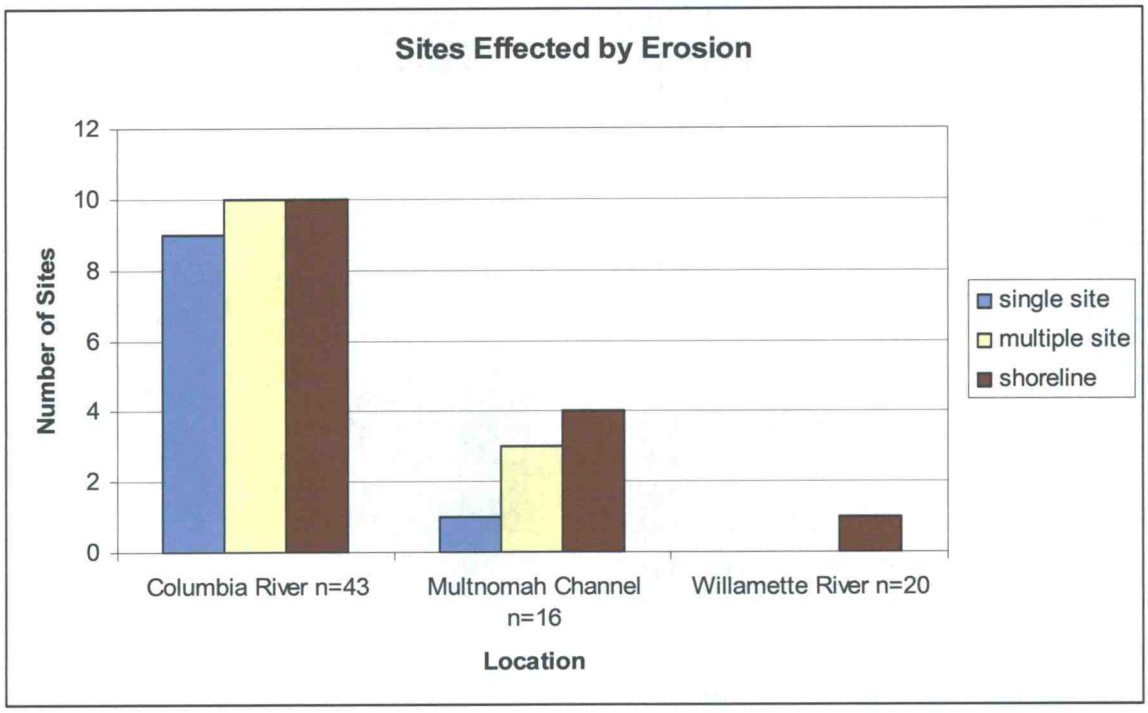


Figure 28 The amount of erosion effecting individual properties along the three waterways boarding Sauvie Island (response rate 50% Multnomah Channel, 10% Willamette River, 72% Columbia River) total= 52%

6.1.4 Factors Contributing to Shoreline Erosion

Respondents who reported erosion problems along their property were asked what they believed the contributing causing to erosion might be, a variety of choices were listed including: flooding, ship wake, dredging ext. Most of the property owners on all shoreline believed that flooding, ship wake, and increased water levels (e.g., dam releases) were the primary causes of bank erosion. In addition, on the Columbia River respondents also identified dredging and upstream control structures as prominent cause of erosion. The Willamette River and Multnomah Channel respondents were primarily concerned with flooding events and ship wake (Figure 29).

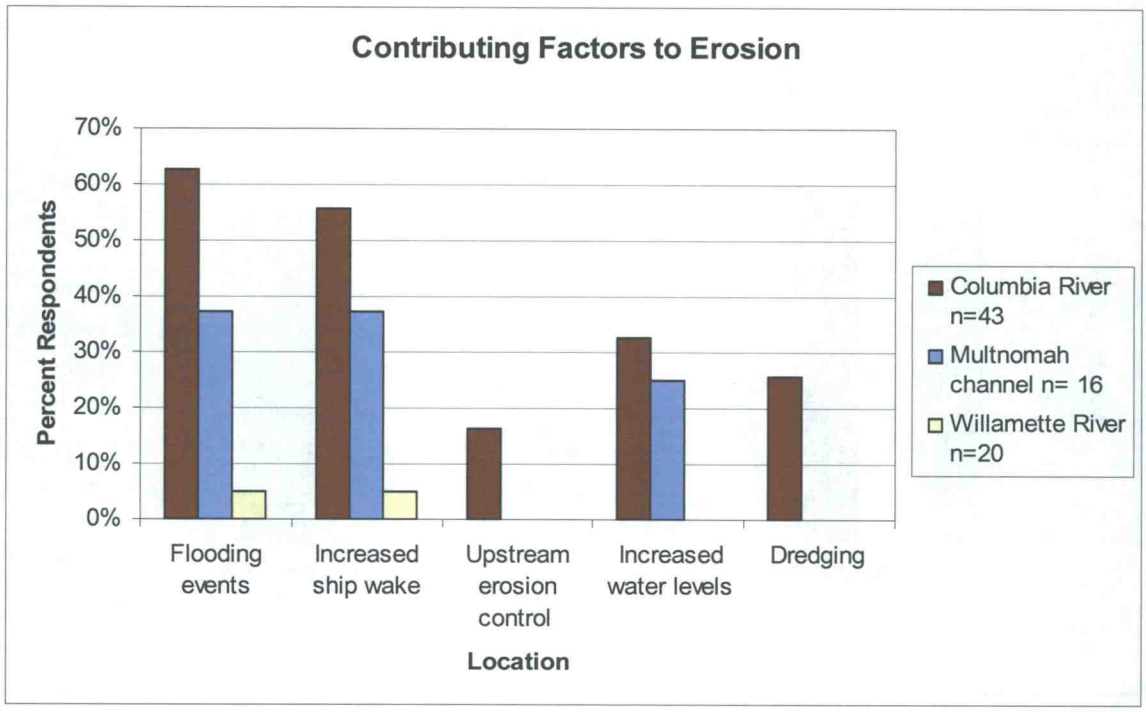


Figure 29 Relative level of property owner concern regarding bank erosion for Columbia River, Willamette River, and Multnomah Channel shorelines. (99% response rate)

6.1.5 Other Issues of Concern for Property Owners

Property owners were also asked about other erosion-related issues of concern, including sand and soil deposition along their property, high water levels, and the speed of the current. Columbia River respondents expressed the most concerned about each of these issues, while Willamette River residents were the least concerned about all three issues. Again, Multnomah Channel resident were split, with water levels at the shore being slightly more of a concern than the current speed along the channel.

6.1.6 Shore Protective Structures and their Effectiveness

A comprehensive survey of shore protection structures along all shorelines was *not* part of this survey. However, the survey did examine whether or not private property owners had installed any bank stabilization methods along there shoreline, and if so, how effective were they in preventing further erosion.

On the Columbia River, 20 respondents indicated that they had installed bank stabilization. Thirteen had installed rip-rap, 3 had installed bioengineering, 3 other installed bioengineering in combination with rip-rap, and one had installed a partial

seawall. (Figure 30, Figure 31); 11 of 13 residents indicated that they had personally installed the rip-rap. However, only four of the eleven residents who installed rip-rap thought that it had prevented further erosion on their Columbia River properties. Only one of the three residents that had installed both rip-rap and vegetation said that it was working (Figure 31). Furthermore, planting vegetation seems to be successful in some locations along the Willamette River. The preservation of large trees along some riparian areas of the Columbia River had minimized erosion.

Although not examined in this survey, virtually all of the Willamette River shoreline of Sauvie Island is rip-rapped, most likely by the Corps of Engineers to prevent erosion adjacent to the deep-draft ship channel. Furthermore, one resident along the Multnomah Channel indicated that rip-rap was going to be installed in the fall of 2006, probably at the Sunken Village site.

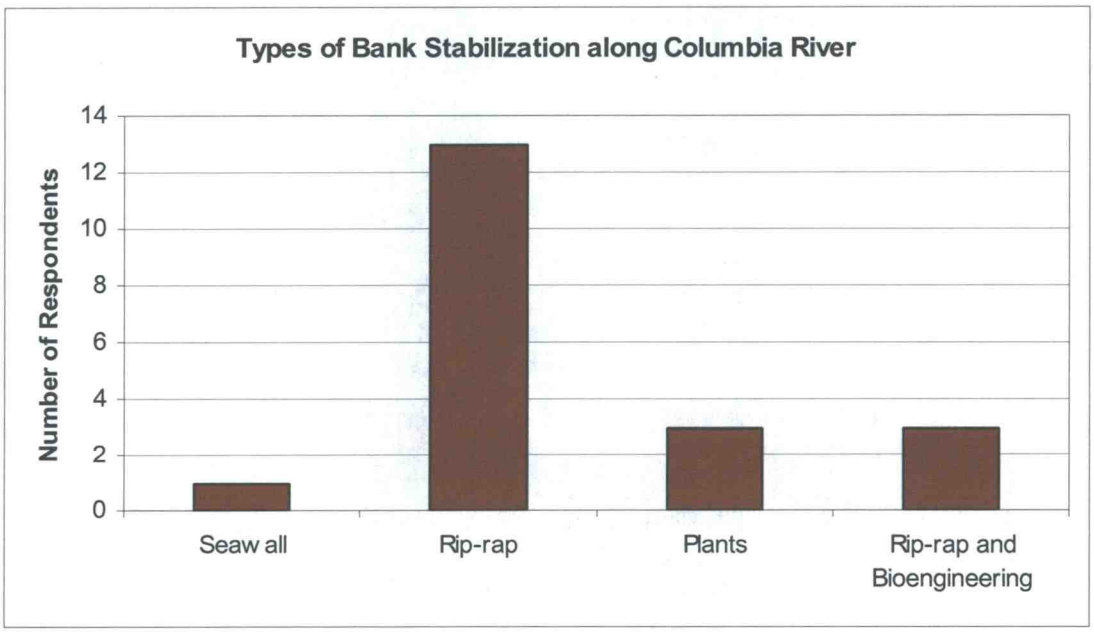


Figure 30 Types of protective structures installed along the Columbia River to prevent shoreline erosion, location of these revetment structures can be see in Figure 30

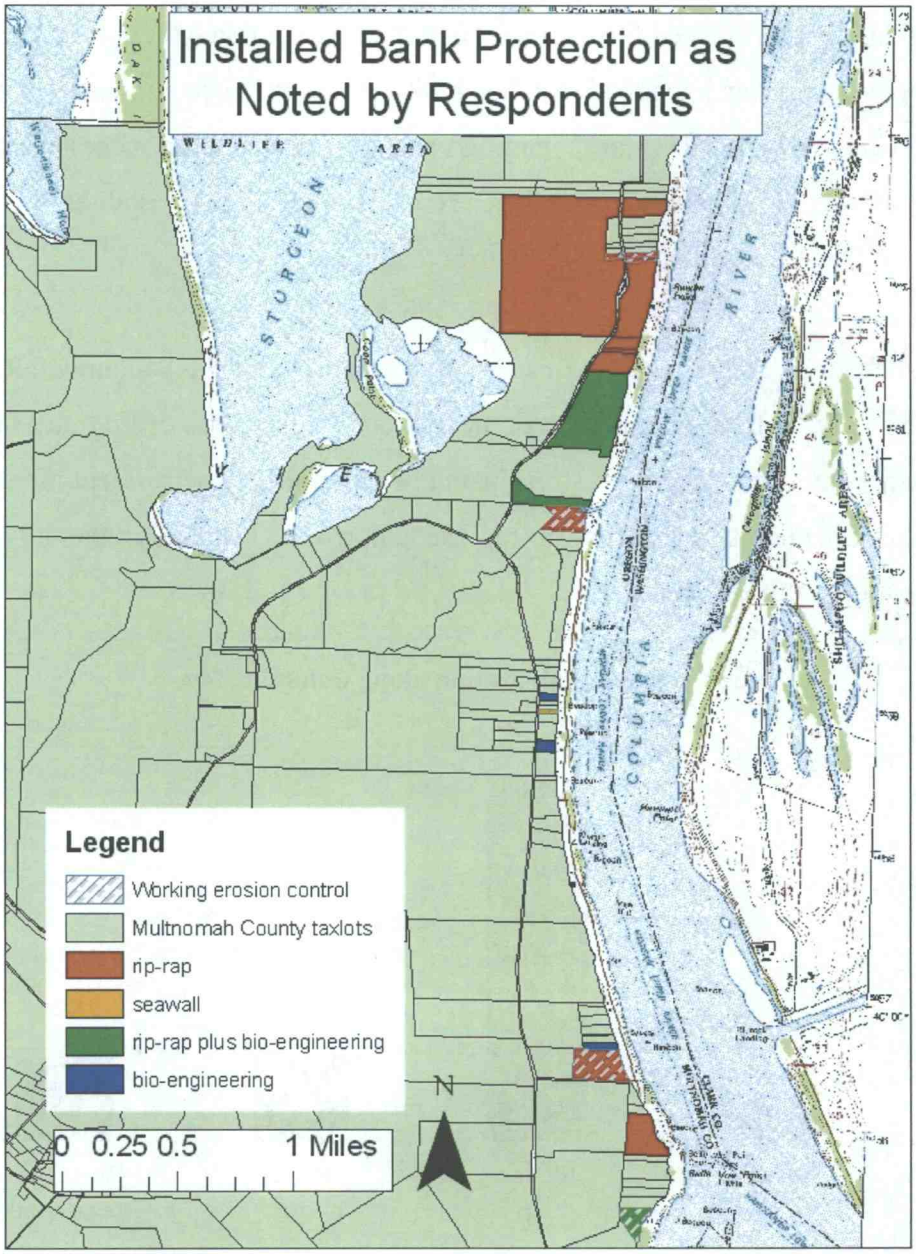


Figure 31 Installed bank protection and success rate along Columbia River as noted by respondents

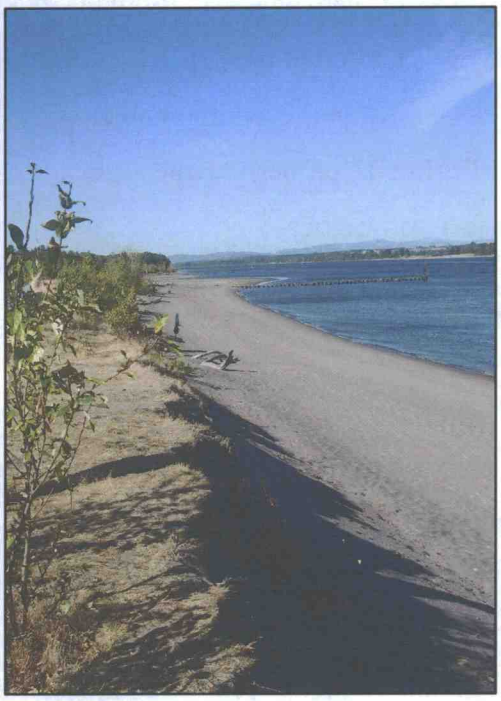
6.1.7 Respondents and Agency interactions

Respondents were also asked if they received any additional information on erosion or erosion control from any government agency in the last year. Although only three respondents answered this question, two agencies including the Sauvie Island Drainage District Company, and Multnomah County Planning office had contacted residents. The Sauvie Island Drainage District Company now send out an annual report on the status of the levee, while the Multnomah County Planning office is required to send out notification to property owners, regarding the instillations of revetment structures on adjacent properties.

6.1.8 Site Visits to Selected Erosion Areas

Four sites where erosion was occurring were visited by the author at the invitation of property owners, three of which were along the Columbia River and one along the Multnomah Channel (Figure 32). At Reeder Beach, there was evidence of recent erosion; a rip-rap revetment had been installed in fall 2006. At Farm House, also on the Columbia River, circular backwash, probably due to ship wake, was carving out the bank. Upstream at the confluence of the Willamette and Columbia Rivers, extensive debris that has accumulated there is impacting the shoreline, particular during high water events, causing loss of vegetation and affecting the bank recovery process. Finally, along Multnomah Channel at the "Sunken Village" Native American village site, there was evidence that cultural artifact looting had damaged the shoreline. In the fall of 2006, a rip-rap revetment was installed to protect the levee and remaining artifacts. Site visits were conducted again at Reeder Beach and at Sunken village in the winter of 2007 to document revetment instillation (Figure 33).

Confluence of the Willamette River and Columbia River



Reeder Beach

Farm House

Sunken Village

Figure 32 Site Visits to Reeder Beach, Farm House, the Confluence of the Willamette River and Columbia River, and Sunken Village

Reeder beach

Reeder Beach

Sunken Village

Sunken Village

Figure 33 Site Visits to Reeder Beach, Farm House, the Confluence of the Willamette River and Columbia River, and Sunken Village after modifications (3/18/07)

6.2 Government Agency Role in Shoreline Erosion Management

Sixteen government agencies were interviewed to determine their roles and responsibilities regarding erosion management along Sauvie Island. Agencies were asked four primary question: 1) their level of awareness regarding erosion along Sauvie Island, 2) if so, what they believed the principal contributing factors to erosion were, 3) if their agency was responsible for conducted any monitoring of erosion on Sauvie Island, and 4) whether or not they used a particular set of "best management practices" in conducting their work or during consultations with land owners. If agencies were aware of specific erosion problems on the island, they were asked to provide exact locations and other details.

Of the agencies interviewed, *four* have direct regulatory control over the installation of shore protection structures —the US Army Corps of Engineers (ACOE), the Oregon Department of State Lands (DSL), Multnomah and Columbia Counties, Sauvie Island Drainage Improvement Company (SIDIC). (**Table 4**). (For additional details regarding the permit process please refer to Appendix B).

One of these agencies—DSL—also manage a portion of the property upon which part of the shore protection device is placed; the beds and banks of navigable state waters (below ordinary high water) are under state, not private or federal ownership (Figure 34, Figure 35). A lease from DSL may therefore be necessary to place rocks or other shore protection material along these banks.

Two agencies—the Oregon Department of Fish and Wildlife (ODFW) and the Sauvie Island Drainage Improvement Company (SIDIC) regularly monitor or visually inspections of certain shorelines they are responsible for, and *four* provide other technical advice or assistance, particularly for bioengineering (vegetative) stabilization alternatives. These include ODFW, DSL, NRCS and the West Multnomah Soil and Water Conservation district (WMSWCD) (Table 4).

Eight other agencies interviewed neither directly regulate, monitor, or provide erosion control technical advice. These include the US Geological Survey, the US Coast Guard (USCG), the Oregon Water Resources Department (WRD), the Oregon Department of Land Conservation and Development (DLCD), the Oregon Parks and Recreation Department (OPRD), the Oregon Department of Environmental Quality (DEQ), the Oregon State Marine Board (SMB), and Metro (the regional planning agency for the Portland metro area). The responses of all interviewed agencies to a standard set of questions are compiled in Appendix C. Figure 19 identifies specific sites where agencies noted erosion problems. Regulatory, monitoring, and technical assistance roles and responsibilities of these agencies are discussed further below.

Table 4. Agency Roles and Responsibilities in Sauvie Island Erosion Management.

	Regulatory	**Proprietary (ownership)**	**Monitoring**	**Technical Assistance**
Federal Agencies				
Army Corps of Engineers	**X**			**X**
State Agencies				
Department of Fish Wildlife			**X**	**X**
Department of State Lands	**X**	**X**		**X**
Local Agencies				
Columbia County	**X**			**X**
Multnomah County	**X**			**X**
Sauvie Island Drainage Improvement Company (SIDIC)	**X**		**X**	**X**
West Multnomah SWCD				**X**
Nation Resource Conservation Service (Oregon NRCS)				**X**

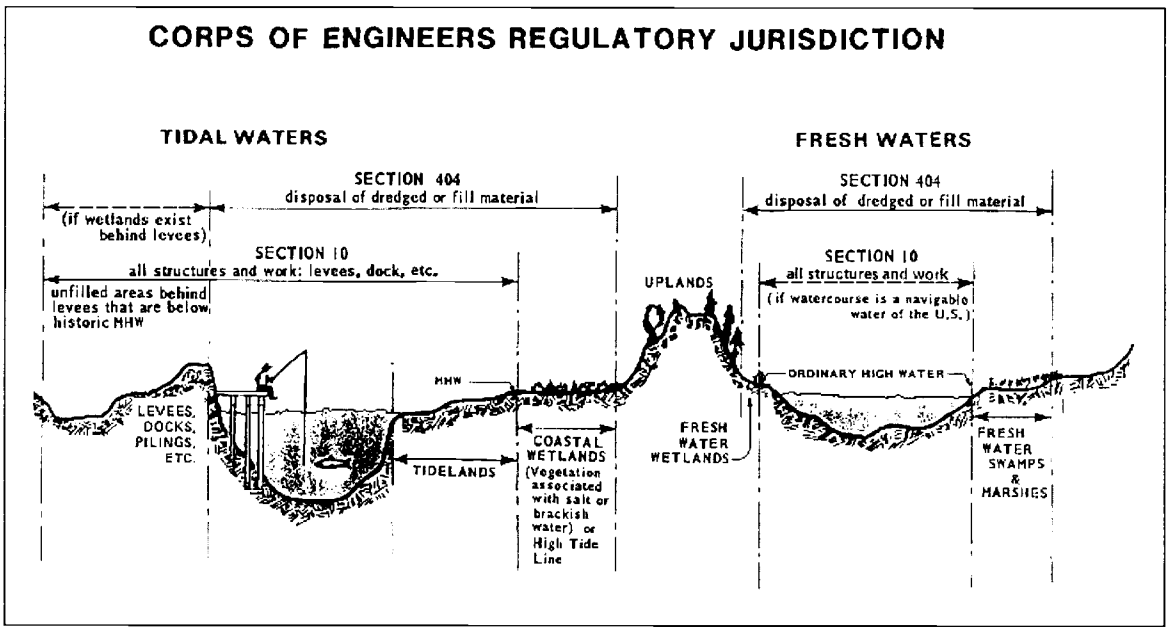


Figure 34 US Army Corps of Engineers combined regulatory jurisdiction under the Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act (U.S. Army Corp of Engineers, Undated)

Quick Reference: State Permits and Reviews for Common in-Water Projects

The following matrix is a quick guide to state agency permits or reviews that are, or may be, required for some common in-water activities. This matrix is a preliminary tool for assessing state permit/review needs and should not be used as a definitive assessment of permit requirements for your project. If your in-water project does not match one of the common activities listed below, please contact the Department of State Lands resource coordinator serving your county for further guidance.

Yes = typically required for most projects in waterways or wetlands.

Maybe = sometimes required depending on whether the activity is located in an area regulated by the particular program.

Agency	Program	Common In-water Activities									
		Streambank stabilization	Instream gravel removal	Wetland fills	Bridges and culverts	Piling projects	Maintenance dredging	Water diversions	Utility lines & outfalls	Wetland or stream restoration	Dams & impoundments
DSL	Removal-Fill Permit	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Proprietary approval	Maybe	Maybe			Maybe	Maybe		Maybe		
DEQ	Stormwater Permit			Maybe	Maybe					Maybe	
	Water Quality Certification	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ODFW	Fish passage requirements				Yes					Yes	Yes
	In-water timing guidelines	Yes	Yes		Yes	Yes	Yes	Yes	Maybe	Maybe	Yes
	Habitat mitigation recommendations	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Scientific Take Permit	Maybe			Maybe			Maybe	Maybe	Maybe	Maybe
	In-water Blasting Permit									Maybe	
	Fish screening requirements	Maybe	Maybe		Maybe		Maybe	yes	Maybe	Maybe	Maybe
OPRD	Ocean Shore Permit	Maybe		Maybe	Maybe	Maybe	Maybe		Maybe	Maybe	
	Scenic Waterway Permit	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe
	Archeological review	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
WRD	Water Use Permit	Maybe		Maybe	Maybe			yes		Maybe	Yes
DLCD	Coastal Zone Certification	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	Yes	Maybe	Maybe	Maybe

State Agency acronyms:

DEQ	Oregon Department of Environmental Quality	ODF	Oregon Department of Forestry
DLCD	Oregon Department of Land Conservation and Development	ODFW	Oregon Department of Fish and Wildlife
DOGAMI	Oregon Department of Geology and Mineral Industries	OPRD	Oregon Parks and Recreation Department
DSL	Oregon Department of State Lands	SHPO	State Historic Preservation Office
ODA	Oregon Department of Agriculture	WRD	Oregon Water Resources Department

Figure 35 State permitting in-water activities (Oregon Department of State Lands, 2006)

6.3 Agency Knowledge of Erosion on Sauvie Island

6.3.1 Federal Agencies

The US Army Corps of Engineers

The Army Corp of Engineer personnel has detailed knowledge of the erosion problem at Sauvie Island. The Corp has been involved in several projects along Sauvie Island include: levee construction and repair (including rip-rap installation) and beach re-nourishment. More information on Army Corp of Engineers project dating from 1960-85 along Sauvie Island are outlines in the Lower Columbia River Bank Protection, 1986. This work along the Sauvie Island shorelines has lead to several studies including a Sauvie Island Erosion Study.

The Sauvie Island Erosion Study was conducted at river mile 99. This study determined that a majority of the erosion is confined to shallow water, beach and level slope. Erosion rates varied between 0.3 feet per day with excessive erosion reaching 1.5 feet per day. These results were determined from erosion models which took into account various factors along this section of the Columbia River. The natural sediment load of the system has been dramatically altered by dams dredging and upstream bank protection. The primary cause of bank erosion is ship wake, river currents, and transverse dispersal (movement of sand from the beach to the channel) is also a factor, to a lesser extent. Nevertheless, these factors result in a permanent loss to the shallow bank area which will eventually cause severe upper bank erosion (US Army Corp of Engineers, 1986). However, even with this detailed knowledge of erosion in this area it is out of the scope of the ACOE mission to monitor and mitigate erosion. Instead it is up to the local land owner to contact the ACOE to obtain a permit and install shoreline revetment.

6.3.2 State Agencies

Department of State Lands (DSL)

DSL personnel are aware of erosion occurring along both the Multnomah Channel and the Columbia River shorelines. The primary contributing factor to erosion along the Multnomah Channel is upstream erosion control structures, and summer boat traffic (wake). Furthermore, this channel was historically dredged creating an artificial flow pattern which may still be affecting erosion rates today. The Columbia Rive faces slightly

different contributing factors including, loss of native riparian vegetation, large vessel wake, and on a more localized level upstream rip-rap effecting down stream properties. Although the DSL is well informed of the erosion issues facing Sauvie Island it is out of the scope of the agency to monitor erosion or mitigate it independent of a landowners permit request.

Oregon Department of Fish and Wildlife (ODFW)

ODFW personnel are aware that erosion is an issue on the Columbia Rive shoreline of Sauvie Island. The main contributing factors effecting erosion rates along this section of Sauvie Island are "Ship wake and high stable water levels, for example in 1998 and 1999 the water level stayed between 11-12 feet (that when it did most of the damage), typically the water level will go down in the summer and the wake will hit a particular section of the bank and then rise again in the winter and hit the bank at a different level, but in these year the water stayed high and it hit the soil level and causing damage to the banks on Sauvie Island" (personnel communication, Mark Nebeker, ODFW, fall 2006). There is also site specific erosion occurring along section of Multnomah shoreline including sunken village and areas further done stream by the public boat ramp.

6.3.3 Local Agencies

Columbia County

Columbia County personnel are not aware of "any particular problem of erosion on the island, there has been alteration of terrain due to human influence like building road and bridges, other on site improvements (construction), erosion during construction seems to be the largest issue, then shoreline erosion.... the only other factors prevent run off during rainy season to prevent turbidity in stream is under state jurisdiction not ours" (personnel communication, Todd Dugdale, Columbia County, fall 2006). With regards to shoreline erosion they were unaware of any specific sites or contributing factors affecting the shoreline of Sauvie Island.

Multnomah County

Multnomah County planning office personnel are aware of erosion issue along Sauvie Island. Planning office personnel have personally observed "wave action from large cargo ships as well as steep channel leading to shallows shoreline quickly, with dramatic results. In addition, with no bed rock only sand along these high energy waves area leads to erosion" (personnel communication, Adam Barber, Multnomah County Land use Planner, fall 2006).

Sauvie Island Drainage Improvement Company (SIDIC)

Sauvie Island Drainage Improvement Company personnel conducts visual inspection of the levee 4 to 6 times a year and therefore has intimate knowledge of erosion along Sauvie Island and the contributing factors which affect erosion rates. When asked about erosion rates along the Island agency personnel responded "erosion rates depend on location, some area erosion has accelerated, for example there is a bench on the Multnomah channel that had increased erosion as the bank sluffed off the bench became heavier and heavier accelerating erosion, but I don't think there are any natural effects except for water flow of high water at certain time of year". When asked about contributing factors, agency personnel noted "the biggest thing that hinder us in not necessarily water height but the rapid rise and fall for example in December and January, the river went up and down several times accelerating erosion". When asked specifically about boat wake as a contributing factor to erosion "boat wake really doesn't cause that much erosion, because the most traffic travels on the river during the summer time when the water is low, some problem but not a major concern" (personnel communication, Josh Townsley, Sauvie Island Drainage Improvement Company, fall 2006).

The West Multnomah Soil and Water Conservation District SWCD is aware of erosion along Sauvie Island "there are problems with erosion along the Columbia River, the confluence of the Columbia River and Willamette rivers, and sections along the Multnomah Channel" (personnel communication, Jim Robinson, WMSWCD, spring 2007). The primary contributing factors to erosion along the island are small and large

boat wake and hardening of upstream banks. Furthermore, the removal of log booms along the Multnomah Channel has increase erosion along this section of Sauvie Island.

Nation Resource Conservation Service (Oregon NRCS)

Oregon NRCS personnel are aware of erosion occurring along Sauvie Island. In personnel communication with agency personnel two sites were distinguished as having erosion the Multnomah Channel, and the Confluence of the Willamette. Contributing factors were discussed for each location. the Multnomah Channel "soil is weak and levee can't handle large vegetation because eventual root would weaken the structure...furthermore, its hard to establish vegetation below mean high tide line, resulting in carp burrowing into the side of the levee to spawn" when asked about contributing factors along the confluence "Difficult to plant vegetation along bank because of tidal influence, additionally, 1996 bioengineering project got washed out, rocks and then plan trees over it, 80% of reference site washed up". When asked about Columbia River erosion. When asked about the Columbia River this side was referred to as "stable" (personnel communication, Steve Feje, NRCS, 2006). Issues affecting all the shorelines along Sauvie Island include tidal influence and ship wake.

6.4 Monitoring and Technical Assistance Agencies

6.4.1 Federal Agencies

The US Army Corps of Engineers

The US Army Corps of Engineers (ACOE) has broad responsibilities including providing technical consultation services for permit applicants. Applicants can contract the local ACOE office prior to filling out a permit to discus if a permit is necessary and the "type of permit" process that applies to their proposed action. Technical assistance may also include a site visit or pre-application meeting. The purpose of these meetings is to discuss possible problems and solutions expediting the permit review process. However, because of the large volume of applications, applicants are encouraged to look at the permit requirements and submit an application.

The ACOE only monitors the Sauvie island levee once a year however the local drainage district, currently know as the Sauvie Island Drainage Improvement Company is in charge of monitoring the levee 4-6 times a year, and will report any issues to the ACOE. Furthermore, if there are any structural repair that need to be done to the levee the Drainage Improvement Company can request a permit from the ACOE to do small project or they can enlist the help of the ACOE to do larger projects.

National Resource Conservation Service (Oregon NRCS)

National Resource Conservation Service (NRCS) is a nation wide organization which offers technical assistance to property owners interested in bank stabilization. The NRCS works closely with land owner to determine long term management planes for private properties. Technical assistance offered to land owners includes: site visits, engineering consultations, bioengineering, and best management practice guidelines. The NRCS usually works with larger properties but can offer some assistance to smaller properties as well. The NRCS can offer financial assistance to property owners through several programs including: the Conservation Reserve Program and the Conservation Security Program. The NRCS also works closely with the SWCD and a variety of other organizations including: Oregon State University Extension, Farm Service Agency (FSA), Oregon Department of Agriculture, Rural Development (RD), The Oregon Association of Conservation Distinct, UDSA, and the US Geological Survey to name a few.

6.4.2 State Agencies

Oregon Department of Fish and Wildlife (ODFW)

ODFW monitors' bank erosion on there properties around Oregon including sections of Sauvie Island, and addresses the issue of erosion on a case by case basis. If excessive erosion is detected ODFW notifies the ACOE and request a permit for revetment instillation, which the ACOE will then install. Additionally, they also advise property owners on different bioengineering techniques. Furthermore, ODFW field staff on Sauvie Island are available for site visits and one on one consultations regarding bioengineering. ODFW coordinates with the following agencies DSL, ACOE, DEQ, NRCS, SWCD, US

Fish and Wildlife. While there is no direct funding provided by ODFW for riparian restoration there are several programs that they can refer landowners to depending on the project.

Department of State Lands (DSL)

DSL Resource Coordinator is available for consultations regarding the use of bio-engineering as an erosion control method. The DSL website also offers multiple general management guides and consideration when deciding which bioengineer method will best fit a property including: grading/ terracing, root wad-log cribs, flow deflectors and bank armoring. The DLS has additional guidelines on there website under general authorization and bank stabilization and implementation of bioengineering, however these guidelines to not extend to engineering advise. DSL coordinates there activities with the following agencies: ACOE, National Marine Fisheries Service (NMFS), US Fish and Wildlife; state: ODFW, DEQ, Oregon State Marine Board, Department of Agriculture, DLCD, State Parks, State Historic Pervasion Office; county: all planning organizations.

6.4.3 Local Agencies

Sauvie Island Drainage Improvement Company (SIDIC)

SIDIC conducts visual inspections of properties within their jurisdiction associated with the main levee on Sauvie Island. The Sauvie Island Drainage Improvement Company monitors the condition of the levee 4 to 6 times a year. This monitoring also includes sections of shoreline where the SIDIC right of way extends to the river. If the levee is threatened by erosion, an application for revetment work will be sent to the ACOE.

The West Multnomah Soil and Water Conservation District (SWCD) works with land owners west of the Willamette River within Multnomah County and all of Sauvie Island (including Columbia County residents). This organization will work closely with land owners to develop a long term management plan for their property. There assistance includes: bioengineering, planning and monitoring (project dependent); guidelines and publications. They can also facilitate consultation with other agencies to help with

engineering plans. West Multnomah SWCD can also help landowners financially through the small grant program. SWCD has several partnerships including: ACOE, ODFW, DEQ, Oregon Department of Agriculture, and OWEB.

Columbia and Multnomah County

Columbia County provides one on one consultation with a county resource planner in order to meet requirements of the Storm water and Erosion Control Ordinance. In addition, when asked about additional material regarding bank erosion guidelines "wetland protection ordinances, and state administered wetland removal and fill rules defined wetland and county set back rules buffer ordinances prevent removal of vegetation along bank and streams, no program to deal with erosion occurring naturally without alteration made by man, anything else done along the bank or pertaining to a wetland would be handled by Department of State Lands, and ACOE" (personnel communication, Todd Dugdale, Columbia County, fall 2006). Multnomah County also has a planning office that offers consolations and extensive management guidelines (Portland land use planning for erosion control) for resident seeking shoreline erosion mitigating measure. Additionally, they will conduct a site visit at the location where a permit is being considered to determine the extent of the erosion and gauge what appropriate action should be approved.

7. AERIAL PHOTO DATA RESULTS

7.1 Aerial photos Overview

Residents and agencies indicated the location of highly erosive areas on the island. These areas were the focus of the ARC GIS site selection. However, due to georeferencing difficulties this method was not viable (detailed below). Instead visual comparisons between time point in Multnomah County using a 2005 orthophoto and 1972 aerial photos were completed. The same could not be done for Columbia County since the 2005 orthophoto only covered the southern end of Sauvie Island; instead a 2004 aerial photo was used. In addition to these side by side comparisons another method of overlaying transparencies of the 2004 and 1972 aerial photos was also done along each site to verify

results of the visual side by side comparisons. A master map illustrating all investigated sites can be found in Figure 36.

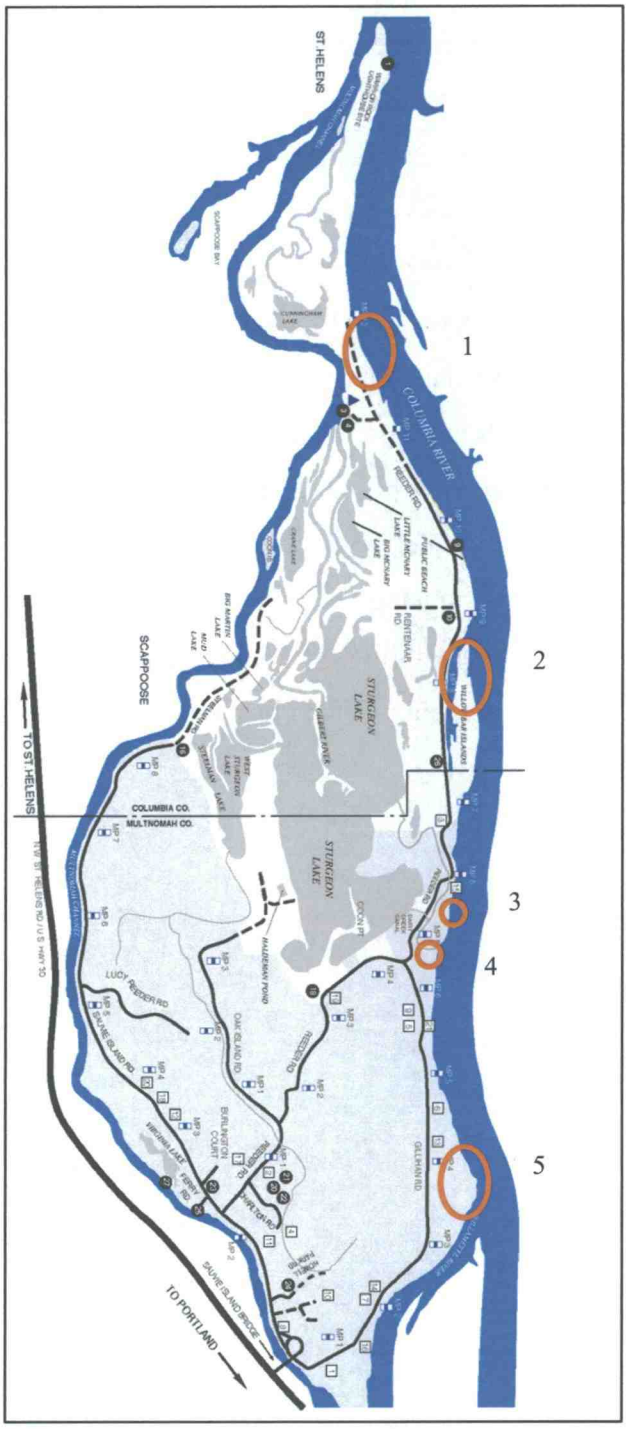
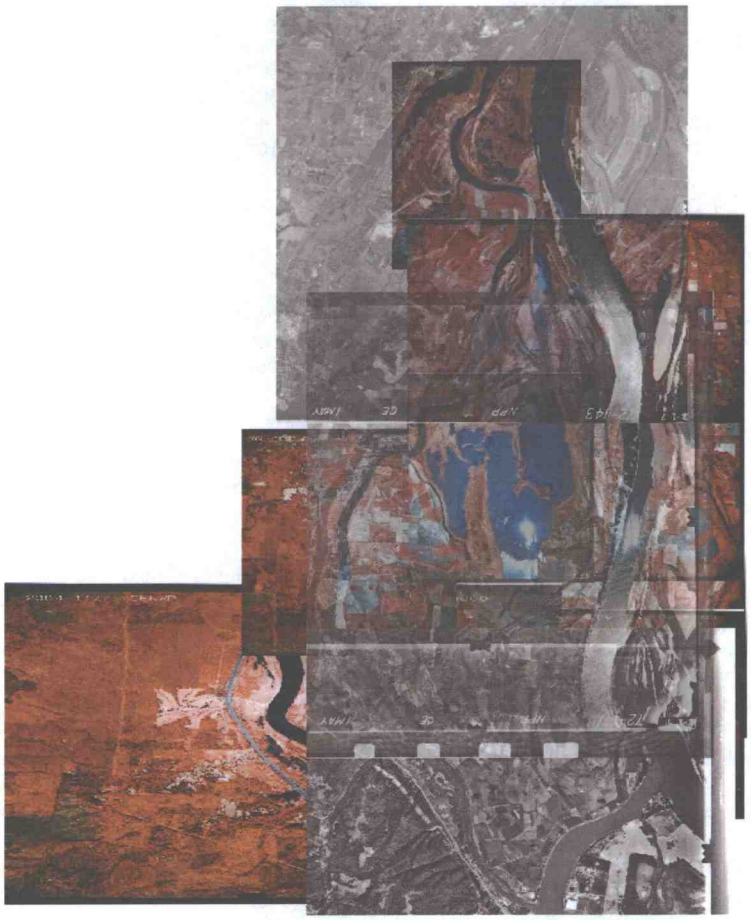


Figure 36 Sites 1-5 illustrates sites viewed and erosion noted from 1972, 2004 and 2005 aerial photos. Site one is ODFW property located on Wildlife Area Property, Site 2 Willow Bar, site 3 Reeder Beach, Site 4 Dairy Creek, site 5 the confluence of the Columbia River and Willamette River.

7.2 ARC GIS Inconsistencies

Although the images provided in this section are the most current information available, there were still complications with generating the primary GIS map. First, when geo-referencing the 1972 Sauvie Island image to the 2005 orthophoto, complications with formatting resulted in irregularities in the positioning of the 1972 photos in relation to the 2005 orthophoto. This was likely caused by differences in camera angle, location, and elevation. To rectify this problem as many as 15 to 18 geo-referenced points were added to each map. However, the map remained approximately 1000 feet off-center in some cases (Figure 37). The main contributing factor to this problem was the disproportionate magnitude of reference points between the north and south sections of the island. The northern 12,000 acres is primarily composed of the Sauvie Island Wildlife Area, which had very few reliable geographic points to references, which were crucial in order to align photos. Second, shadowing from trees and shrubs, and the reflection of the sun off the river surface, made it difficult to distinguish a continuous shoreline in some areas. For these reason, only visual observation using the Arc GIS measuring tool were calculated.



Georeferenced Sauvie Island Photos 1972 and 2004

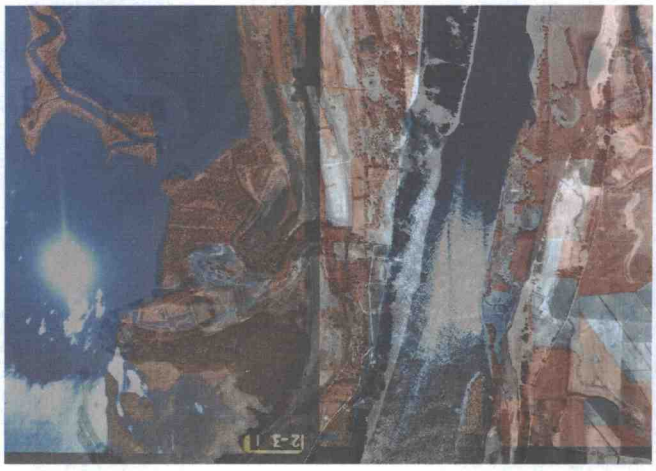
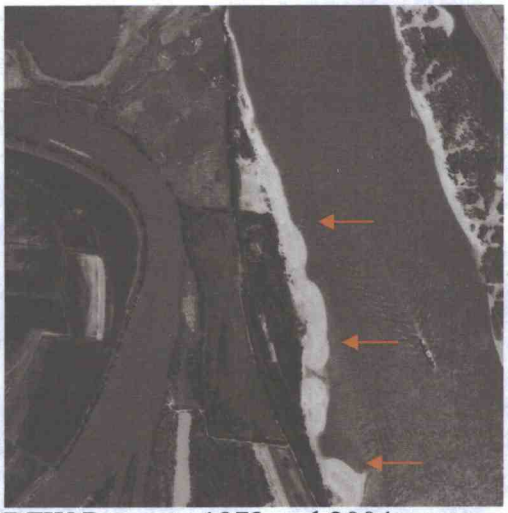
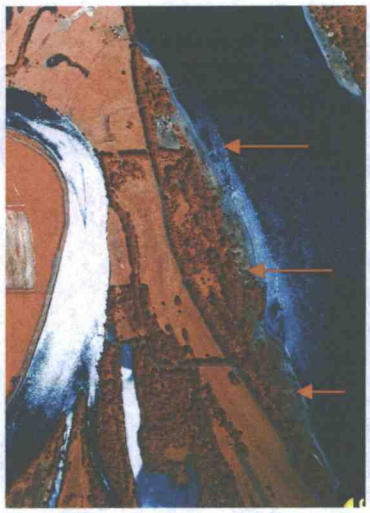


Figure 37 GIS Referenced Maps 1972 and 2004, map A shows larger overall view of goereferenced photos containing all of Sauvie Island, maps B and C are close-ups of map A highlighting demarcation between year classes

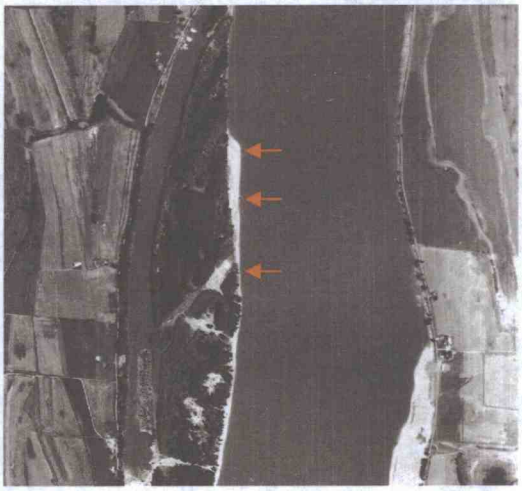
7.3 Aerial Photo Results

At sites 1-5 there seems to be notable erosion along a majority of the sites indicated by the arrows. However, upon closer inspection there area also changes in vegetation patterns which made it difficult to determine erosion using only a side by side comparison. Therefore, transparencies of both time points were made to scale and overlaid to verify visual interpretations. Although all 5 sites were reviewed using both methods only the Reeder Beach area consistently showed losses using both methods. While, visual comparisons over time revealed this section had the longest visibly impacted shoreline, as well as, the most notable incising along the shoreline. Overlaying transparencies also revealed a loss of 165 over a 32 year period, or an average loss of 5.16 feet/ year. Although the other sites may have increased erosion rates this method is limited by the low resolution at higher magnification. Additional challenges or problems with the analysis include: water level difference between years (tidal and or seasonal), shadowing caused by vegetation, and glare from the sun reflecting off the water making shoreline difficult to distinguish. For example, the photos from 1972 appear to be taken at low tide, while the 2004 appear to be taken at high tide. The actual time of day each photo series was taken is not known. A rough back-calculation of the tidal height could be calculated, but it is difficult to determine the extent of the landward inundation of water, given the uncertainty and variation in shoreline slope and physical feature. Uncertainties of this nature make this method of analysis difficult, and while it can provide some insight into large shoreline changes, smaller shoreline changes are difficult to determine using this method.

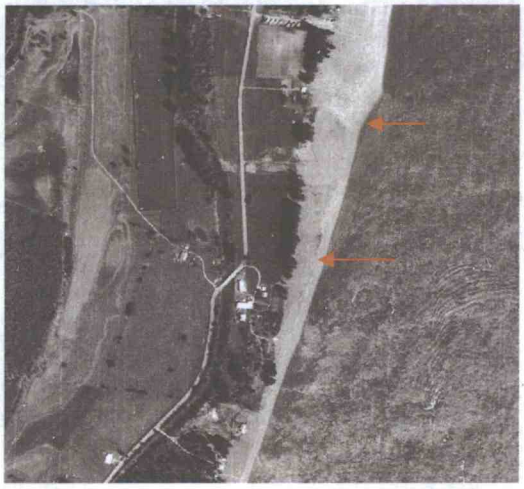


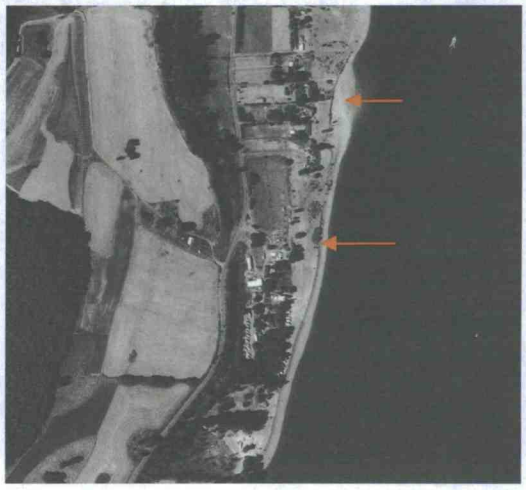


ODFW Property 1972 and 2004



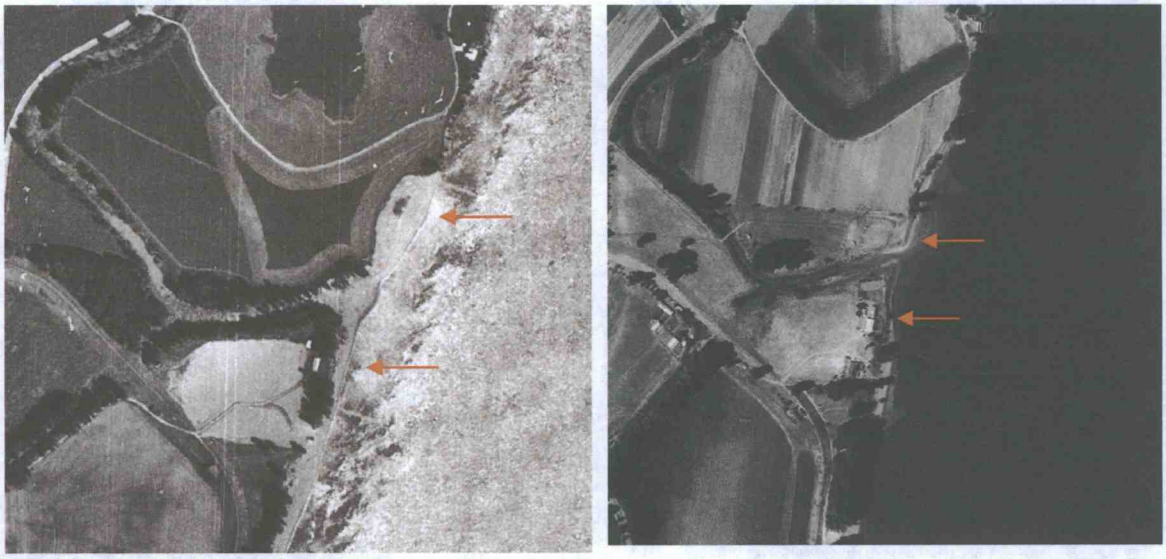
Willow Bar 1972 and 2005



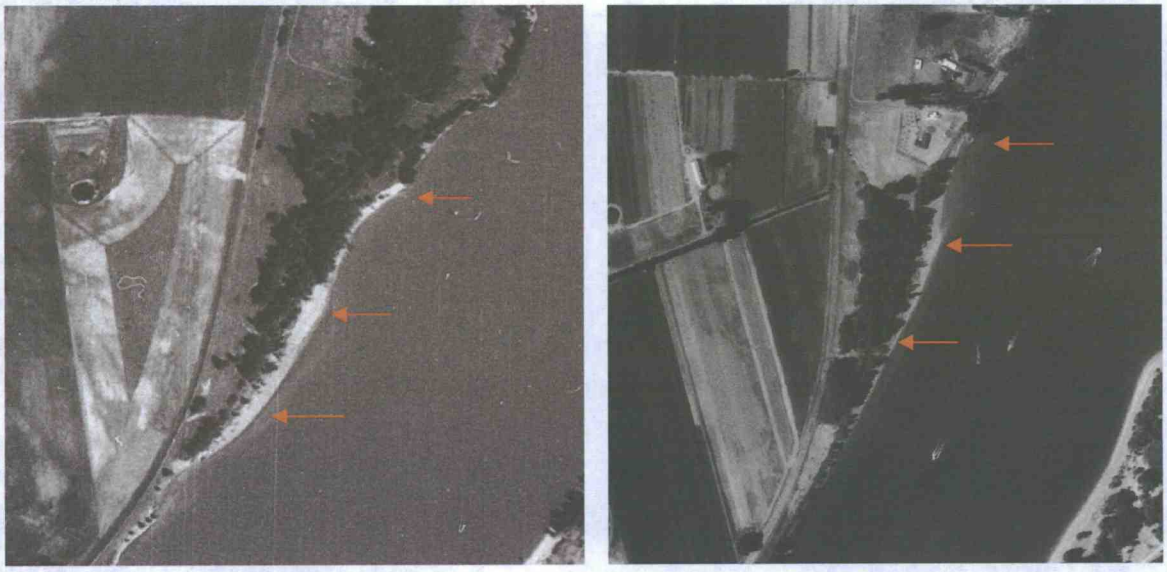


Reeder Beach 1972 and 2005

Figure 38 Aerial Photo Comparisons ODFW, Willow Bar and Reeder Beach from 1972, 2004 and 2005. Noted bank erosion indicated by arrows.



Dairy Creek 1972 and 2005



Confluence Willamette River and Columbia River 1972 and 2005

Figure 39 Aerial photo comparisons continued Dairy Creek and the Confluence of the Willamette River and Columbia River 1972 and 2005. Noted bank erosion indicated by arrows.

8. DISCUSSION

8.1 Discussion Overview

Erosion problems along the three waterways surrounding Sauvie Island—the Columbia River, the Willamette River and Multnomah Channel—are very different, both in severity and factors involved. The most serious problems are along the Columbia River shoreline, while the least notable are along the Willamette. Erosion "hotspots" occur along the Multnomah Channel, but are relatively minor, when compared to the Columbia shores. Drawing on the results presented in previous sections, erosion and potential causes and solutions are discussed below for each of these shorelines.

8.2 Columbia River

Columbia River Erosion Interactions

The Columbia River shoreline has the highest rate of erosion along Sauvie Island. This was confirmed by the resident, agency, and aerial photo comparisons. There are two underlying causes for increased erosion rates along Sauvie Island. First, the primary factor is the gradual reduction of sediment due to upstream dam construction. The dams have two sediment related impacts; first they trap the downstream transport of sediments along the river bottom. Second they regulate river flow, reducing historic peak flows that caused annual flooding. Another important factor is the construction and maintenance of the adjacent shipping channel; regular maintenance dredging and channel deepening, in combination with flow control structures, and shoreline hardening upstream increase river current velocity. These processes restrict the natural sediment deposition process that originally created the island, and cause erosion along the shorelines. These hydrologic changes have impacted the sedimentation regime along Sauvie Island. Other primary factors involved include: rapidly changing water levels (due to daily tidal influence and dam releases), flooding, and ship wake. Secondary factors that exacerbate erosion include: debris, wind, and shoreline features like (i.e. bank composition and pile dikes). All of these factors interact spatially and temporally to accelerate erosion along specific Columbia River locations of Sauvie Island.

Columbia River Observed Erosion Events

Erosion events have been observed by residents and agency personnel along the Columbia River section of Sauvie Island. Flooding events (which primarily happen in spring) are distinguished by a rapid rise, cresting and subsequent retreat of water levels. This process can take days, eroding the face of the bank and causing scouring and sluffing of soil, resulting in loss of vegetation. Ultimately this impacts the vegetation filtration capacity and stability of the bank long after the flooding events, have passed. Second, rapid water level changes (occurring year round from tides and dam release for power peaking) impact the slope, toe and face of the bank, which then allows ship and wind generated waves, as well as debris to erode river banks, cutting and steepening them over time. Third, during low water-levels that occur in the winter and more often in late summer (and at low tide), the steepened banks from previous erosion are reshaped by wind, causing a redistribution of sand from the top of the bank down hill in the form of alluvial fans, leaving the sand susceptible to downstream transport.

Resident and agency personnel recognize that wake from the thousands of ocean-going vessels that travel along the Columbia River each year is a continuing complex factor impacting bank erosion along Sauvie Island. Dredging has increased the width and depth of the Columbia River shipping channel allowing large vessels to navigate upstream. The channel adjacent to the Sauvie Island has two relatively sharp turns that come to within approximately 230 feet of the Sauvie Island shoreline (Figure 16). This channel design may accelerate the ship wake on the outside of the turns, impacting the adjacent shoreline with accelerated force, and thus increasing erosion. Although, these ocean going vessels can be found on the river year-round, they are most detrimental to the system during high water events (e.g., spring flows, dam releases, and high tides or combinations of these). Initially high water levels impact the bank at more sensitive locations, including the slope and face. Furthermore, with average river currents approximately averaging 4 knots (3.5mph); ships must be traveling faster than the current in order to maintain steerage. Maintaining vessel steerage when moving downstream becomes increasingly difficult during high water events when river currents increase significantly. This combination of increased water levels, faster moving vessels, and

larger ship wake can cause sensitive portion of the bank to be exposed to higher energy waves (Figure 40).

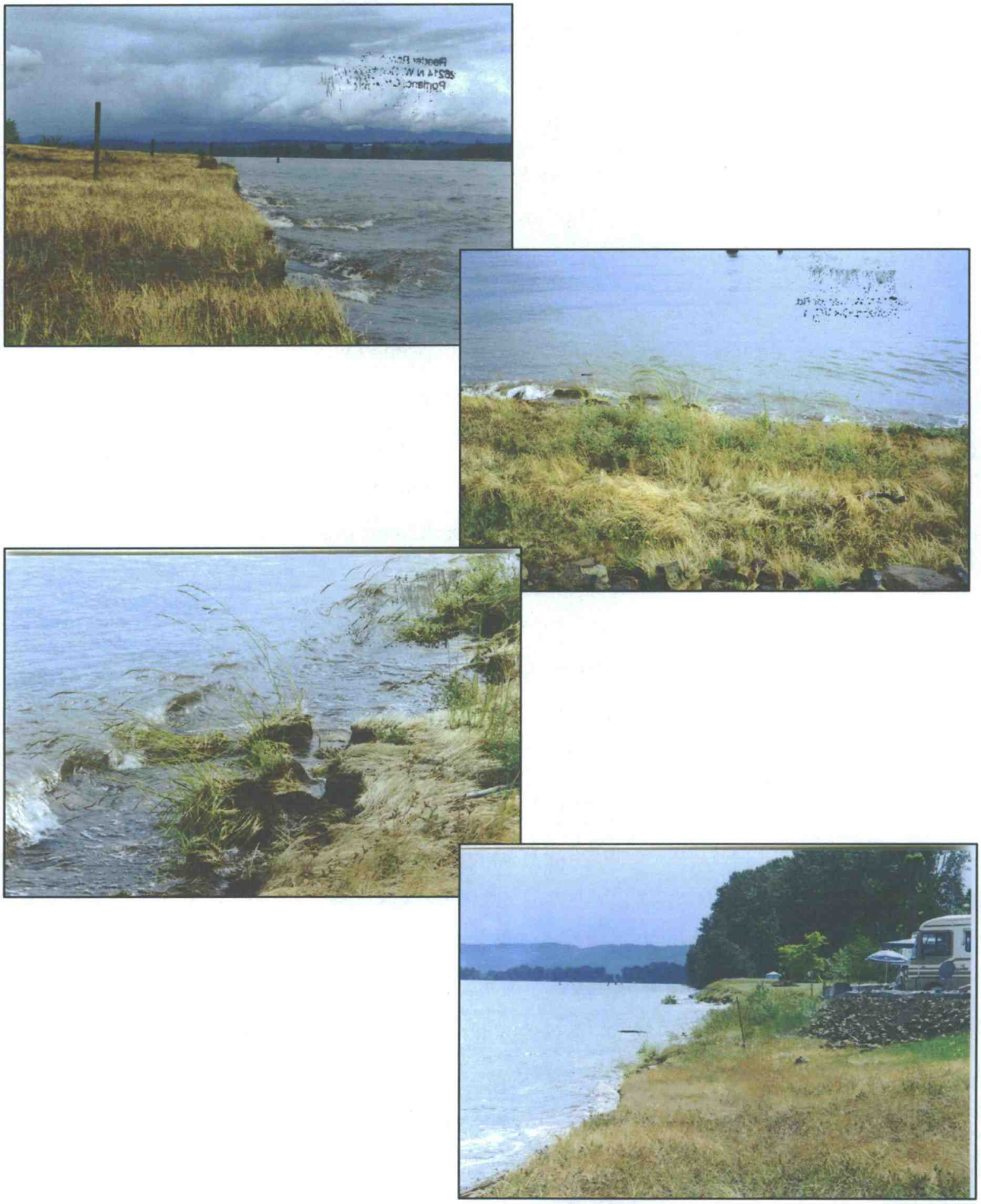


Figure 40 Reeder Beach 1997 Flood crest (20 feet at St. Helens in 1997, and 23.5 feet in 1996 (Portland 23.5 and 28.6) (Water and Climate Center Home Page, 2007)

Columbia River Mitigation

The Army Corp of Engineers has been involved in many aspects of erosion control along Sauvie Island including: levee construction, repair, and revetment installation along the Columbia River (US Army Corp of Engineers, 1986). Erosion control alternatives to revetment installation include: speed limits for passing ships, re-vegetating the river banks, and beach renourishment using sand from the channel dredging and maintenance projects. All have been discussed and rejected for various reasons listed below (US Army Corp of Engineers, 1998).

Large commercial vessels often travel at speeds that cause strong wake interactions along the shoreline. The ACOE has jurisdiction in this area when federal property (e.g. levees) might be damaged, especially during high water events. However, their current policy is to strengthen levees rather than impose speed restrictions which could affect shipping. Additionally, the US Coast Guard is responsible for keeping vessels at reasonable speeds. However, ship speeds of just 5 knots (5.8 mph) can cause damaging wakes and recall the need for vessel to maintain speeds sufficient for steerage. The difficulty and cost of enforcement and potential disruption of commerce make reducing shipping speed limits an unlikely solution to Sauvie Island erosion problem.

Vegetation cover has proven to be moderately successful in preventing erosion along some sections of the Columbia River, while in other cases it has failed. The most sensitive area to erosion is the beach and toe of the bank just below the mean high water mark. During high water events, these areas are often submerged for long periods of time, killing upland vegetation and destabilizing the bank. For this reason, bioengineering using vegetation alone is often an impractical option for bank stabilization.

Lastly, beach renourishment is only financially feasible if pipeline dredging is already occurring in the area. Beach renourishment involves redistributing dredged sand from the shipping channel and placing it along shoreline in order to minimize the effects of erosion. However, sand can only be placed on wide shallow sections of the bank (1 vertical to 10 horizontal); otherwise, there is a risk of destabilizing the slope of the dredge

channel. Along Sauvie Island, dredged material has long been used for beach renourishment and is recommended in the ACOE report as the primary means to mitigate the effects of erosion along Sauvie Island and other Columbia River sites (US Army Corp of Engineers, 1986). However, the number of beach re-nourishment sites has been reduced since 1975 EIS. This reduction has occurred for several reasons, lack of need, and the listing of the Snake River salmonids in 1994, with the Endangered Species Act (ESA), Section 7 consul National Marine Fisheries Service, all dredge material disposal sites were re-evaluated to determine there significant as potential valuable juvenile salmonid rearing habitat. Sixty two sites were evaluated based on there shallow water productivity and subsequently three were designated as suitable dredge material disposal sites based on there highly erosive behavior (RM86 at Saint Helens, RM33 at Skamokawa Vista Park, and at RM 23 Miller Sands). Under these new guidelines all of the Sauvie Island dredge material deposition sites were suspended. The most recent beach renourishment project along Sauvie Island was in 1976. These beaches have been steadily eroding since then. This is due primarily to the lack of sediment input from upstream, and the erosion of the large and heavy, dredged sand grains (~ 1900 g/liter) from earlier renurishment projects, (Figure 40, Figure 41)

Revetments are thus the method of choice for controlling erosion along Sauvie Island's Columbia River shoreline. Rip-rap is the most common type of revetment installed on both public and private properties along this section of the Columbia River. However, this study found that this type of shoreline protection has met with variable success along Sauvie Island. Poor design, construction or end of design life, are all reasons for rip-rap failure. Poor design can include not using a filter fabric or filter rock layer which then allows the sand based to be washed out from behind the rip-rap, destabilizing it over time. Additionally, structures can be design to withstand a fifty year flood, however, if a hundred year flood occur (1996), and the rip-rap fails it is not considered a deign failure. Furthermore, planting or even joint planting can be very successful, strengthening and stabilizing the soil over time, however, the problem arises with larger river system where not only the river current are impacting the bank but there is also additional stress from large ship wake. In many areas along the island, rip-rap

combined with planting vegetation has been flooded during high water (in combination with ship wake), washing out the vegetation and either undercutting the rip-rap or washing it out from behind or along the exposed edge. One solution is vegetated benches which allow wave energy to dissipate before hitting the sensitive portions of the bank. However, larger and more carefully engineered structures may thus be needed to prevent failure. Of course, this means the cost will rise rapidly, as well as, increased potential damage to downstream properties.

Multnomah Channel Erosion Interactions

Multnomah Channel is a much smaller waterway and unlike the Columbia and Willamette is not dredged. Nevertheless, the Multnomah Channel shoreline suffers from periodic erosive or "hot spots" as noted by agency personnel and private property owners. Although most of the clay banks along the Multnomah Channel are relatively stable, some primary erosion factors contributing to bank failure include: small boat wake, periodic flooding, other water-level fluctuation (dam releases and tides), and human disturbances of cultural sites (which play a more direct role in this location). Secondary erosion impacts include: removal of log rafts, the hardening of the upstream bank, weak soils caused by loss of vegetation, and invasive species, especially carp and nutria (personnel communication, Steve Fedje, NRCS, fall 2006).

Observed Erosion

Historically, the banks and shoreline along the Multnomah Channel were inadvertently protected by the numerous in-water log rafts placed along the channel to store logs until local mills were ready to process them. However, in the 1970s, with the implementation of the Oregon Forest Practices Act, the federal and state Endangered Species Acts, the federal Clean Water Act, and the National Forest Management Act, logging and the need to store extra logs along the river on log rafts decreased dramatically. Water quality effects of the practice also contributed to the decline in their use (Personal communication, Jim Good, June 2007). Today most of the log rafts have been removed; the few that remain require a leasing permit by the Division of State Lands for the anchors used to hold the log rafts in place. Furthermore there is a moratorium on

construction of additional moorages along the Multnomah Channel and the construction of log rafts due in part to the harboring of predatory fish that can eat salmonids.

Another factor affecting erosion along certain sections of the Multnomah Channel is the extensive use of rip-rap along the mainland (western) shoreline of the channel. Many studies have documented that hardening banks can exacerbate erosion on the adjacent shoreline (WRP, 1998). On the Sauvie Island side, the Sauvie Island Drainage Improvement Company restricts use of larger woody vegetation along the levee because it impedes visual inspection and can cause damage to the levee. Large woody vegetation can impact the structural integrity of the levee in three ways: first, roots can extend through the levee causing piping during flooding events; second, woody vegetation attracts burrowing animals which can compromise the levee; finally, if large trees become unstable and fall they can extract large section of soil creating weak spots. Consequently, only native grasses are planted on the levee, however unnatural conditions (e.g. water levels changes) make it very difficult for these plants to survive along the shoreline. Furthermore, the absence of large vegetation has allowed carp to burrow into the clay bank to spawn, further eroding and weakening the bank (personnel communication, Steve Fedje, NRCS, fall 2006).

Mitigation Multnomah Channel Shoreline Erosion

The rapid growth in the number of floating homes and moorages along the Multnomah Channel in the 1980s created two secondary benefits, resulting in bank stability. First, the homes protected the bank from boat wake and debris during high water, similar to the log rafts described earlier. Second, the five mph speed limit-required within 200 feet of the moorages, reduces the size and impact of the wake on the adjacent shoreline. However, once a motorboat is 200 ft away from the floating homes, there are no speed limit restrictions. This leaves some areas exposed to heavier boat wake.

In addition to physical and biological impacts, there are also human activities that effect erosion along the Multnomah channel. One location, Sunken Village, contains the remains of a Chinook Native American village. Artifact looters have been pillaging the site since the early 20th century. The construction of the "Big Dike" at the site in 1936 did

not hamper this activity. Instead, looters began digging directly into the levee to collect the artifacts. The cumulative impacts finally reached a critical point when the structural integrity of the levee became a concern to the local drainage improvement company. Sauvie Island Drainage Improvement Company installed rip-rap along this section of the Multnomah Channel in the fall of 2006. Additionally, rip-rap has been installed at several locations along both sides of the Multnomah Channel, and seems to be preventing erosion.

8.4 Willamette River Discussion

There are several factors contributing to the relative stability of the lower Willamette River where it boarders Sauvie Island. First, the bank is made of clay, which is less susceptible to erosion due to its ability to adhere together. Second, much of the shoreline is rip-rapped to prevent shoreline erosion due to passing ships; this has effectively stabilizing the bank. Furthermore, the remnants of pile dikes along the shoreline reduce the impact of ship wakes at certain water levels. Although some residents are concerned about shoreline erosion along this stretch of Sauvie Island, the shoreline seems to have remained relatively stable over the last 30 years.

9. Conclusions

The erosion problem along Sauvie Island has resulted from a combination of human influences and dynamic natural processes. The construction of dams in combination with increased dredging activities along the Columbia River has reduced natural sediment deposition. Furthermore, these activities have increased international commerce allowing larger ocean-going-vessel to travel up the river. However, dredging and flow-control structures have channelized and steepened the underlying bathymetry allowing less time for the wake from large vessel to dissipate before hitting the bank. This large wake can be especially destructive during high water event, impacting the face of the bank causing scowering and instability. These banks are then susceptible to wind reshaping during low water levels. Additionally, bank hardening (e.g. levees, dikes, and revetments) have decreased site-specific erosion, but; also led to increased water levels and higher downstream erosion rates. All of these factors result in permanent loss of

shoreline along the Columbia River shoreline of Sauvie Island, while the rest of the Sauvie Islands' shorelines remain relatively stable (except for very localized areas along the Multnomah Channel which are suffering from boat wake and rapidly changing water levels).

Additionally, several agencies have approved rip-rap revetments and/or vegetation stabilization along Sauvie Island. However, this study revealed that several of these approved structures did not survive the rapid-changing shoreline environment and were washed out in as little as one year. This loss indicates that there is still no clear successful mitigating strategy for controlling erosion in these "hot spots". Additionally, this study found, in some areas a buffer zone of mature vegetation including: Cottonwood, Ash, Willow, and Dogwood can stabilize the bank more effectively then trying to replant an area after erosion has occurred. This is primarily due to the rapid changes in water level especially during the dry summer months where newly planted vegetation can become disconnected from the receding water table. These dry conditions make it difficult to allow roots enough time to secure them selves before they are subjected to winter river currents. A possible solution is to use drip irrigation along new planted riparian vegetation during the dry summer season to allow roots balls to form faster and deeper. One possible method is the use of PVCP pipe buried adjacent to the plantings; allowing moisture to go underneath the root system encouraging the roots to grow deeper.

While both residents and agency personnel agree that significant erosion is occurring at two primary sites along the Columbia River (Reeder Beach, and the confluence of the Columbia River and Willamette River). There is a disconnect in awareness between the government agencies involved in regulation, agencies involved in monitoring, and agencies involved in technical assistance, regarding the severity of erosion and where it is occurring. The ACOE has carried an erosion study along Sauvie Island founding peak erosion rates reaching rates of 0.3-1.5 feet/ day at RM 99 at specific locations and under certain conditions (US Army Corp of Engineers, 1986); an average loss of 2-5 ft/year (at sites related to this study). Many of the officials I spoke with at

other agencies were not aware of the amount of land being lost annually. Furthermore, it was not always clear where the most severe erosion is occurring. For example, some agencies referred to the Columbia River shoreline as "stable" while other believed it was affected by the highest rates of erosion averaging 0.3 feet per day (US Army Corp of Engineers, 1986).

In order to understand the problem and begin to develop a comprehensive management plan to address these issues the local residents and government agencies will need to work together toward the common goal of bank stabilization.

- In order to accomplish these goal three primary groups will need to work together: ACOE, Sauvie Island Drainage Improvement Company (SIDIC), and the local community.
- The ACOE needs to take a more centralized role in the erosion control permit process. This reorganization of the permitting process would allow applicant to submit there application to the ACOE who would coordinate with other federal, state, and local government offices to insure the purposed project adhere to all regulatory authorities (this is similar to what they do now but on a larger scale).
- In addition to this restructuring the ACOE should complete a comprehensive Environmental Impact Statement (EIS) along the entire Columbia River shoreline of Sauvie Island. This EIS in combination with 2-3 accepted management plans approved by all regulatory agencies would dramatically speed up the permitting process.
- A comprehensive monitoring strategy including GIS, aerial photos and visual observations should be conducted by the Sauvie Island Drainage Improvement Company.
- The local community should consider forming a Bank Stabilization District or Association. This council would represent the local community by creating an advisory group for bank stabilization and erosion awareness, along with promoting the conservation of shoreline habitat and shoreline improvements. This organization could also be the primary mechanism for local residence to voice there concerns and organize politically to make community discussion on

bank stabilization and other resource issues. The primary responsibility of this organization would be to take resident concern under advisement while providing the public the latest information from the ACOE and the SIDIC monitoring program, and determine a comprehensive management plan.

- Government agencies and local residence will need to work together, to educate each other on the scope of the problem, which contributing factors are the primary erosive factors at individual sites, and begin to discuss potential community solutions. A workshop presenting this report will be the first step in bringing these two stakeholder groups together to discuss these issues.

10. Recommendations

10.1 Long Term Cooperative Management

1) Current regulatory jurisdiction for erosion monitoring and control along Sauvie Island is disjoint and cumbersome. As management agencies are each responsible for an independent part of the erosion mitigation process i.e. revetment permitting, monitoring, and consultation. In order to streamline the mitigation process the Army Corp of Engineers should be the central agency responsible for erosion mitigation and management along the Columbia River. The ACOE is the most natural choice for this responsibility since every other organization must adhere to the federal umbrella of regulation and authority. Reorganizing the process and having a lead agency means landowners will no longer have to contact and work with several organizations but rather a single agency who will be representative from determining the involvement of other federal, state and local agencies.

2) Along with this centralized management concept there also needs to be an integrated solution for monitoring erosion. Monitoring is essential to determine the extent of erosion along Sauvie Island. Collecting quantifiable data will be valuable in making long-term management decision and determine the best management practice for mitigating eroded sites. The objective of the monitoring regime should include the following:

Short Term Goals:

1) Illustrate specifically the magnitude of the shoreline being lost.

2) Identify and map risk.

3) Identify priority sites for stabilization.

4) Map existing response to erosion and detailed how effective they have been.

Long Term:

1) Achieve more predictable stabilization results.

2) Produce long term and adaptive responses.

3) Strengthen the knowledge and information sharing of the planners.

This monitoring and data collection protocol should incorporate aerial photo and visual observations, as well as, GPS protocols monitoring specific locations. Using a similar monitoring protocol to the Shoreline Erosion Monitoring, Colorado State Parks Stewardship Prescription, 2005 (Appendix D) could be the first steps in acquiring long term data concerning erosion rates along the Columbia River.

3) The natural choice to conduct the monitoring is the Sauvie Island Drainage Improvement Company which already inspects the levee four to six times a year. These visual inspections determine the structural integrity of the levee by monitoring erosion at the base of the levee, seepage, and settling. I purpose that they increase there monitoring responsibilities to include the shoreline along Sauvie Island, Using the Shoreline Erosion Monitoring, Colorado State Parks Stewardship Prescription, 2005, or a similar monitoring regime. These results should be reported to the ACOE and the public in an annual meeting to the local residents.

4) The amount of time it takes for the Corp of Engineers and other agency to process a permit can be problematic. Applicants are told that there is a 30 day inter-agency review process plus a 30 day review period, totaling a 60 day process. However, permits that are more complicated can require an Environmental Impact Statement (EIS) which can take as long as 18 months to prepare. This time delay can affect the projects over all budget and delay the project pasted permit authorized time line. In order to streamline this process one comprehensive EIS study should be done by the U.S. Army Corp of

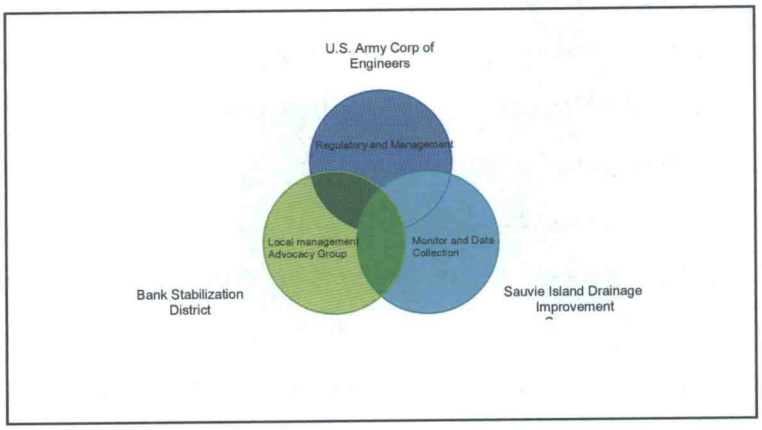
Engineers detailing the biological and geological effects of revetment installation along Sauvie Island. The completion of the EIS would not mean that all resident would have to put in revetment project but if they choose too the EIS would have already been approved for two to three accepted management strategies.

5) Two to three pre-approved management strategies by all four permitting agencies is needed to streamline revetment structures installation along the Sauvie Island shoreline. By completing a comprehensive EIS using data collected in the field as well as, existing Columbia River shoreline residents designed and installed specification two to three accepted management plans can be created and provided to simplify the engineers and planning stage of the permitting process. These strategies could include integrated solutions: both bioengineering and structural engineer solutions (i.e. rip-rap). To take into account site specific erosion factors individual analysis would still need to be done, but on a much smaller scale and cost to the landowner.

6) The current management practices can decrease overall property values. In order to tackle this in a political setting a Bank Stabilization District should be created as an advisory group for bank stabilization and erosion awareness, as well as, a mechanism for local residence to voice there concerns and organize politically to make community discussion on bank stabilization and other resource issues. This group could also be a leader in community education and outreach by involving local organization like the Sauvie Island Drainage Improvement Company and the West Multnomah Soil and Water Conservation District to discuss there community projects and long term community goals.

7) Alternatives to bank hardening can be re-examined including beach re-nourishment and speed corridors for large ocean going vessels. The Oregon Department of Fish and Wildlife should reexamine the use of dredge material to re-nourish lost beaches from excessive erosion. Additionally, the ACOE has jurisdiction on vessel speed when federal property is being damaged, likewise the U.S. Coast Guard has jurisdiction on speed limits for ocean going vessels, under the fish and wildlife coordination act. This jurisdiction

could allow speed limit safety corridor be enforced during times of high water along areas adjacent to erosion prone shores along the Columbia River section of Sauvie Island to protect the beaches and levees along this area. Although the speed restriction would be subject to the necessity to maintain steerage it would prevent excessive speed during sensitive times.



10.2 Short Term Changes

1) Agencies should clearly outline their involvement in erosion control permitting and regulatory requirement. This could be done on a webpage or fact sheet.

2) The Army Corp of Engineers should send out an annual news letter, notifying residents of levee inspections and the status of the levee.

3) A list of appropriate native vegetation that can be planted on the levee should be provided by the drainage district. This would encourage compliance with regulation increase native vegetation populations (For example, if people want to remove invasive species like blackberry, and replace it with native vegetation this document could help guide them)

4) Cooperation is needed between landowners to install large sections of shoreline revetment across multiple properties. This would reduce coast and potentially be more effective then individual installations, as rip-rap can cause downstream erosion on neighboring lands.

6) Personal water craft and recreational boaters are restricted from entering section of the Multnomah Channel during certain times of year. These restrictions should be well posted and adhered too.

7) Boaters should be encouraged to keep a good distance from the erosion prone bank whenever possible.

8) Boaters should be warned of damage caused by boat wakes, and to use speeds that minimizes wave height whenever possible.

9) Boaters need to reduce speed and wake when approaching or leaving a bank.

10.3 Needed studies

1) Since 1986 no shoreline erosion studies have been done on Sauvie Island. With new orthophoto and GIS technologies, a detailed analysis of shoreline changes over time can be done without intensive fieldwork.

2) Much additional work is needed to examine the full range of impacts from jet skis and other recreational activities along the three shorelines of Sauvie Island. While jet skis pose similar threats to aquatic environments as motor boats; their unique propulsion system allows them to operate in 12 inches of water, causing unique impacts on turbidity (re-suspension of sediments).

3) It is also important to take into account climate change and potential sea level rise on this system. These two factors could increase storm activity or change the time of year high water effects Sauvie Island. These changes could bring more water and flooding increase the pressure on the bedload and ultimately increasing erosion. It is important to understand the impact these changes will have on the integrity of the beaches and dikes along Sauvie Island so that decision maker can plan accordingly.

4) Re-examine some of the structural designs approved by the Army Corp of Engineers. On several properties along the Columbia River residents had installed approved rip-rip or vegetation and rip-rap that did not survive the impacts of the river. In some cases within 1 year the rip-rap/ bioengineering was washed out leaving the exposed bank vulnerable to erosive forces once again. The land owner is then required to resubmit an application for a permit to reinstall the lost rip-rap. An evaluation is needed to determine which engineering plans are the most successful and if indeed standard design replicas are being installed or if there is a case by case design process.

5) In depth social and economic justifications for increase the channel depth have been done extensively by the ACOE. However, there has yet to be an in depth comprehensive study quantifying the social economic impact for dredging vs. shoreline loss. This study should include: loss of acreage or damage to property cause by increasing channel depth and subsequent ship wake impact to the shoreline. Expense of erosion control material and instillation should be included in the analysis. Furthermore, social cost including loss of aesthetic qualities to the shoreline and recreational use of shoreline, as well as, ecological cost of loosing riparian habitat would need to be addressed.

10.4 Multnomah County Sauvie Island Rural Plan

The Rural Area Plan for the Sauvie Island/ Multnomah Channel Rural Area is part of the overall Multnomah County Comprehensive Framework Plan which was completed in 1997. This plan is a guide to decision making with regard to land use, capital improvements, and physical development (or lack thereof) of the community over the next 15 to 20 years. It will be used by the County, other governmental agencies, developers and residents of the area. Although many aspect of the plan have been implemented there are a few key issues that have not been addresses including:

POLICY 6: The County should participate in educational information and programs to better educate Channel users on safety issues and required laws including no wake and buffer zones.

Update: not know

POLICY 33: Encourage property owners to control vegetation along Sauvie Island levees through methods that are least environmentally damaging as determined by the Sauvie Island Drainage District in coordination with the Oregon Department of Fish and Wildlife.

Update: no would defer to Drainage district

POLICY 34: Post signs prohibiting trespass on drainage waterways where they intersect with public roads.

Update: not implemented

POLICY 36: Support the Sauvie Island Drainage district in its efforts to control vegetation growth in the district's drainage canals.

Update: not implemented

POLICY 37: Assist the Sauvie Island Drainage District in reviewing and changing assessment practices order to encourage fair assessment of all properties on Sauvie Island which benefit from the activities of the district.

Update: not implemented

POLICY 38: Take measures to protect Sauvie Island levees from bank erosion in a manner which protects fish and wildlife habitat and passage.

Update: would defer to Drainage district

11.0 Workshop Outline (Rough draft)

Title

Shoreline Erosion on Sauvie Island: An educational workshop to facilitate community-based solutions

Join us for a community workshop:

The workshop will address four major results from the research project: shoreline erosion survey, agency involvement in erosion, aerial photos comparisons over time, and over all recommendations. Second, the workshop will also include guest speakers from the US Army Corp of Engineers and the Soil and water Conservation district to share their perceptions and expertise on the topic of erosion.

Scope

Sauvie Island lies at the confluence of two dynamic rivers the Columbia and the Willamette, near Portland, Oregon. Flooding, erosion, and deposition of sediments have been part of the natural evolution of the island. However, with the construction of multiple dams in the Columbia River Basin, levees, and hardening of upstream banks, many natural river processes have been altered, resulting in increased erosion along the island's shores.

A Master Project was completed addressing the issue of erosion on Sauvie Island. The main findings of this study were that: 1) Columbia River respondents are the most concerned about bank erosion, with nearly 25 percent of the respondents losing bank along the entire property; 2) nearly half of the Columbia River respondents have installed some form of bank protection along their waterfront, however, only 25 percent believe that their revetment strategy is prevented further erosion; 3) aerial photo analysis revealed section of the Columbia River shoreline eroding as fast as 2-5 feet per year; and 4) current regulatory jurisdiction for erosion monitoring and control along Sauvie Island is disjointed with no single agency responsible for the monitoring, permitting, and technical assistance land owner need when installing revetment work.

Why you may want to attend this workshop

An intended outcome of the workshop is to encourage cooperative management of shoreline erosion by building understanding of the nature of shoreline erosion on Sauvie Island and to facilitate communication between landowners and government agencies regarding extent, management and mitigation. Through participating in the workshop landowners will gain knowledge of the scope of the problem, effective shoreline management practices, and begin to connect with agencies personnel which will foster cooperative management for mitigating shoreline erosion in the future.

Participants

Workshop will be open and free to all resident of Sauvie Island with a special request for the participant in the shoreline erosion survey to attend. Additional participants include: Season Long (graduate student attending Oregon State University), Jim Robison (West

Multnomah Soil and Water Conservation District), and Kathryn Harris (US Army Corp of Engineers.

Workshop Materials and Cost

A free manual detailing the findings of the erosion perception study will be availed at the workshop. If you are unable to attend the workshop but are still interest in the free manual please contact Season Long. Refreshment and snacks will also be provided.

Preliminary Outline of Workshop

- General Welcome
  - Introduction of guest speakers
  - Outline of workshop

- Shoreline Presentation Erosion Study
  - Background of project
  - Shoreline erosion survey results
  - Government agency responses
  - Aerial photo comparisons
  - Recommendations

- Speaker or panel from the community

- US Army Corp of Engineers
  - Introduction to Erosion Control Permit Process
  - Perception of Erosion on Sauvie Island
  - Possible solution to issue

- US Fish and Wildlife
  - Observation of Erosion on US Fish and Wildlife properties
  - Possible Solutions

- Soil and Water Conservation District
  - Observation of Erosion on US Fish and Wildlife properties
  - Possible Solutions

- Facilitate discussion
  - Answer resident questions and concerns
  - Facilitate discussion

- Summary/ Conclusions

Training Provided by: Sea Grant Extension
For additional information please contact:
Season Long

12.0 Glossary (Adopted from: Washington State Department of Transportation, 2007)

Accelerated Erosion- Erosion caused or increased by human activity, as apposed to naturally occurring erosion.

Beach profile
1) Toe of Bank- lower surface of the bank turns into a horizontal or meets the existing round slope
2) Face of Bank- front of bank characterized by steep slope
3) Slope of Bank- between the toe and the face, characterized by slope angle

Bed load- is a term used to describe the larger particles (relative to the suspended load) that are carried along the bottom of a stream. Generally, bed load is smaller downstream because the sediment has been warren down and rounded by friction from the river, channel and, other sediment

Bioengineering- Combination of vegetation and structural practices to prevent erosion or stabilize slope or bank.

Channelization- Alteration of a stream channel by widening, deepening, straightening, clearing, or paving certain areas to change flow characteristics.

Confluence- where two bodies of water merge

Erosion- The wearing away of the land surface by running water, wind, ice, or other geological agent. Soil and water detaches and move soil and rock fragments by waste, wind, ice, or gravity.

Fetch- The distance over water which the wind blows to generate water waves

Hydrologic Soil Groups- a soil characteristic classification system defined by the U.S. Soil Conservation Service in which a soil may be categorized into one or four soil groups (A, B, C, or D) based on filtration rates and other properties.

Log Raft- is a log transportation or storage method in which logs are tied together into rafts and drifted or pulled across a water body or tied to dolphin along water bodies for long or short term storage.

Primary Erosion- a single erosive process that can cause erosion on it own without any other factor

Revetment- A facing of stone, bags, blocks, pavement, etc. Used to protect or armor a bank against erosion.

Revetment Structure- structures placed on banks or cliffs to protect the bank by absorbing the energy of incoming water. They are usually built to preserve the existing uses of the shoreline and to protect the slope. They include: sea walls, rip-rap, and groins.

Riparian- Pertaining to the bank of stream, wetlands, lakes or tidewater.

Rip-rap- A facing layer or protective mound of stone placed to prevent erosion or sloughing of a structure or embankment due to flow of surface and stormwater runoff.

Sediment- is any particulate matter that can be transported by fluid flow and which can eventually be deposited in a process called sedimentation. These particles may settle out of the water column depositing a thin layer of solid particles on the river bottom or may be re-suspended latter and more further down the waterway

Sediment Budget- is the process on a beach of either adding or removing sediment. If these processes are relatively balanced then no apparent changes in the beach will occur. However, it the beach is loosing more sediment then is being replenished then the beach will start to erode.

Scour- The erosion action of flowing water in streams that removes and carries away material from the bed and banks.

Secondary Erosion- is an erosive process that magnifies primary erosion, but can not cause erosion independently.

Seepage- Groundwater emerging on the face of a streambank

Streambank Erosion- removal of soil particles from a bank slope primarily caused by water action but also by climatic conditions, ice and debris, chemical reactions, and changes in land and stream use.

Toe of Slope- A point or line of slope in an excavation or cut where the lower surface changes to horizontal or meet the existing round slope.

Topography- a general term used to describe characteristic of the ground surface such as plain, hills, mountain, steepened or slope, and other physiologic features.

Wind erosion- Removal of soil particles by wind, causing dryness and deterioration of soil structure; occurs most frequently in flat, dry areas covered by sand and loamy soils.

Wing Dam-is a manmade barrier, which only extends partway into a river. These structures force water into a fast-moving center channel which reduces the rate of sediment accumulation, while slowing water flow near the riverbanks to reduce erosion.

Bibliography

1) Abbe, Timothy. *Sediment Dynamics on the Shore Slope of the Puget Island Reach of the Columbia River, Oregon and Washington.* Corvallis, Oregon: Oregon State University PhD. Dissertation. 1990.

2) Asplund, R. Timothy. *The Effects of Motorized Watercraft on Aquatic Ecosystems.* Wisconsin Department of Natural Resources, Bureau of Integrated Science Services, and University of Wisconsin- Madison, Water Chemistry Program. 2000.

3) Bishop, M. J. 'Making Waves. The Effects of Boat-Wash on Macrobenthic Assemblages of Estuaries', *PhD Thesis*, University of Sydney. 2003.

4) Brown, William. http://130.166.124.2/or_panorama_atlas/index.html California State University, Northridge.

5) Bogan, David. *Sauvie Island's "Sunken Village"- A Special Place Forever Preserved.* Cultural Heritage Courier News and Information from Heritage Programs- Oregon parks and Recreation Department. 2006.

6) Bonneville Power Administration. *The Columbia River Inside Story: Second Addition.* 2001.

7) Bonneville Power Administration. *The Power of the Columbia River.* http://www.bpa.gov/power/pl/columbia/stories/ . April 2007.

8) Canniff, Kiki. *Sauvie Island: A Step Back In Time.* Portland, Or. : Ki² Enterprises. 1984.

9) Christy, J.A. and Putera, J.A., *Lower Columbia River Area Inventory.* Oregon Natural Heritage Program. 1992.

10) Cleaver, J.D., *Island Origins: Trappers, Traders & Settlers. Sauvie Island heritage Series.* v. 1. Portland, OR: Oregon Historical Society Press. 1986.

11) Cleaver. J.D. *Island Life: pioneer homesteading.* Portland, Or. : Oregon Historical Society Press. 1989

12) Continental Shelf Associates, Inc. Effects of personal watercraft operation on shallow-water seagrass communities in the Florida Keys. Personal Watercraft Industry Association. 1997.

13) Department of Primary Industries, Water and Environment, Tasmania, http://www.dpiw.tas.gov.au/intertext.nsf/Attachments/LJEM-6J22X3/$FILE/Understanding%20Wave%20Wake.pdf , 6/2007.

14) De Voto, Bernard, ed. *Original journal of the Lewis and Clark Expedition. Selections, Boston, Houghton, Mifflin.* 1953.

15) Good, J.W., McKay, J.G., *Obtaining permits for waterway development.* The Oregon State University Extension Service.1982.

16) Hulse, D., Gregory, S., and B., Joan ed. Willamette. *River Basin planning atlas: trajectories of environmental and ecological change.* Corvallis: Oregon State University Press, Second Edition. 2002.

17) Idaho Department of Transportation. *Rocks and Roads.* http://www.enviro-explorers.com/rocksandroads_122302/unit1/unit1c.htm. May, 2007

18) Klingeman, P.C. Martin H. and Huang C.C. *Investigation of motorboat-induced stream bank erosion on the Lower Deschutes River.* Corvallis, Or else. : Water Resources Research Institute, Oregon State University. 1990.

19) New Brunswick Department of Agriculture. *Agriculture, Fisheries and Aquaculture-Stream Bank Protection.* http://www.gnb.ca/0173/30/0173300008%2De.asp. 4/2007.

20) Northwest Environmental Advocates. *Source of Pollution,* http://www.northwestenvironmentaladvocates.org/index.html. March 2007.

21) O'Connor, J.E. *The Evolving Landscape of the Columbia River Gorge Lewis and Clark and Cataclysms on the Columbia.* Vo. 105, No. 3. Oregon Historical Quarterly, 2004

22) Ohio Department of Natural Recourses. Guide Number 19. *Ohio Stream Management Guide: Deflectors.* 2007. http://www.dnr.state.oh.us/water/pubs/fs_st/stfs19.pdf

23) Oregon Department of Fish and Wildlife. Sauvie Island (map). Sauvie Island Booster Inc. 2004.

24) Oregon Department of State Lands. Wetlands/Waterways Removal-Fill: Riparian Restoration: Bioengineering. http://www.oregon.gov/DSL/PERMITS/bioengineering.shtml, 3/2007.

25) Oregon Department of State Lands. *State Water Related Permits: User Guide,* November, 2006)

26) Oregon Wetland Joint Venture. *Lower Columbia River, Northern Oregon Coast.* 1994.

27) Pike County Conservation District. Pike County Natural Resource Learning Site. http://www.pikeconservation.org/SoilProfile.htm. 5/2007.

28) Soil Profile Gallery. United States Department of Agriculture. Natural resource Conservation Service. http://www.mo15.nrcs.usda.gov/features/gallery/gallery.html 3/2007.

29) Sotir, R.B. and Nelson, R.N. *Use of Riprap in Soil Bioengineering Stream bank Protection.* River, Coastal and Shoreline Protection. 1995.

30) Spencer, Omar C. *The Story of Sauvie Island.* Oregon Historical Society. 1950.

31) State of Oregon. *Oregon Department of State Lands, State Water Related Permits: User Guide.* http://www.oregon.gov/DSL/PERMITS/docs/SWRP_userguide12_06.pdf. 2000.

32) U.S. Army Corp of Engineers, Portland District. Design Memorandum Sauvie Island Areas "A" and "B" Lower Columbia River Improvement to Existing Works Oregon and Washington. 1960.

33) U.S. Army Corp of Engineers, Portland District. *Columbia River Willamette Environmental Statement.* 1975.

34) U.S. Army Corp of Engineers. *Low Cost Shore Protection a Property Owner's Guide.* 1981.

35) U.S. Army Corp of Engineers, Portland District. *The Lower Columbia River Bank Protection.* Supplement No. 3. Sauvie Island Drainage District, Oregon. 1986.

36) U.S. Army Corp of Engineers. *Integrated dredging material management plan and supplemental environmental impact statement: Columbia and Lower Willamette River federal navigation channel: final.* (Columbia River DMMS and SEIS). 1998.

37) U.S. Army Corp of Engineers, Portland District. Total Dissolved Gas Characterization of the Lower Columbia River below Bonneville Dam, 2006.

38) U.S. Army Corp of Engineers. Columbia Rive Survey. https://www.nwp.usace.army.mil/op/nwh/home.asp. 4/2007.

39) USDA, Natural Resource Conservation Service. "Stream bank and Shoreline Protection." Engineering Field Handbook, Chapter 16. 1996.

40) WRP Technical Note HS-RS-3.1. *Wetland Shoreline Protection and Erosion Control: Design Considerations.* January 1998.

41) Washington State Department of Transportation. Publication and Journal for Erosion and Sediment Control Professionals (IECA). http://www.infratrans.gov.ab.ca/INFTRA_Content/docType372/Production/refmatglsry2.pdf 4/2007.

42) Water and Climate Center Home Page. http://www.wntc.nrcs.usda.gov. 5/2007.

43) Wtrwy. J., "Estimating Boat-Wake-Induced Levee Erosion using Sediment Suspension Measurements." *Port, Coast., and Oc. Engrg.*, Volume 128, Issue 4, pp. 152-162. 2002.

44) Yao Wenyi, Wang Puqing, and Chang Wenhu. 'Research effects of deposition falling with tranquil flow of permeable pile dike from bank protection and scouring process around the pile position.' *Journal of Sediment Research*, Volume 2, pp. 26-31. 2002.

Appendix A – Sauvie Island Survey

COLUMBIA RIVER, WILLAMETTE RIVER, AND MULTNOMAH CHANNEL SHORELINE EROSION SURVEY

General Description of Property

Q1. How many years have you lived on this property? _____Years

Q2. Please indicate current use of this property.

	Yes	No
a. As a residence	___	___
b. As a vacation home	___	___
c. For agriculture purposes	___	___
d. Other business	___	___
e. As a rental property	___	___
f. Other_____		

Q3. Please indicate man-made structures along your shoreline.

	Yes	No
a. Seawalls	___	___
b. Rip-rap	___	___
c. Jetties	___	___
d. Boat ramp/ Docks	___	___
e. None	___	___
f. Other _____		

Q4. Please tell me the length of your shoreline (in feet)? _____feet.

Q5. How concerned are you about the following issues?

a.	Bank Erosion	___Very concerned	___ concerned	___ Somewhat concerned	___Not concerned	___Not sure
b.	Soil and sand deposits	___Very concerned	___ concerned	___ Somewhat concerned	___Not concerned	___Not sure
c.	Amount of water (volume)	___Very concerned	___ concerned	___ Somewhat concerned	___Not concerned	___Not sure

d.	Speed of water (current)	___Very concerned	___ concerned	___ Somewhat concerned	___Not concerned	___Not sure

EXTENT OF EROSION ON YOUR PROPERTY

Q6. During the last 16 years (1990-present) has the bank on your property eroded?

a. Yes, it has eroded _____ → **Continue to question 7**
b. No, it has not eroded _____ → **Skip to question 21 on the last page of the survey**

Q7.What is the average erosion that has occurred (in feet) for each of the following years?

Year	Width	Depth
1990-1995		
1996		
1997		
1998-2000		
2001-2003		
2004-2006		
Total Lost		

Q8. Are there single or multiple locations on your property that have eroded?

a. Single site _____
b. Multiple sites _____ How Many _____

POTENTIAL CAUSES

Q9. Please tell me if you feel any of the following have contributed to erosion on your property.

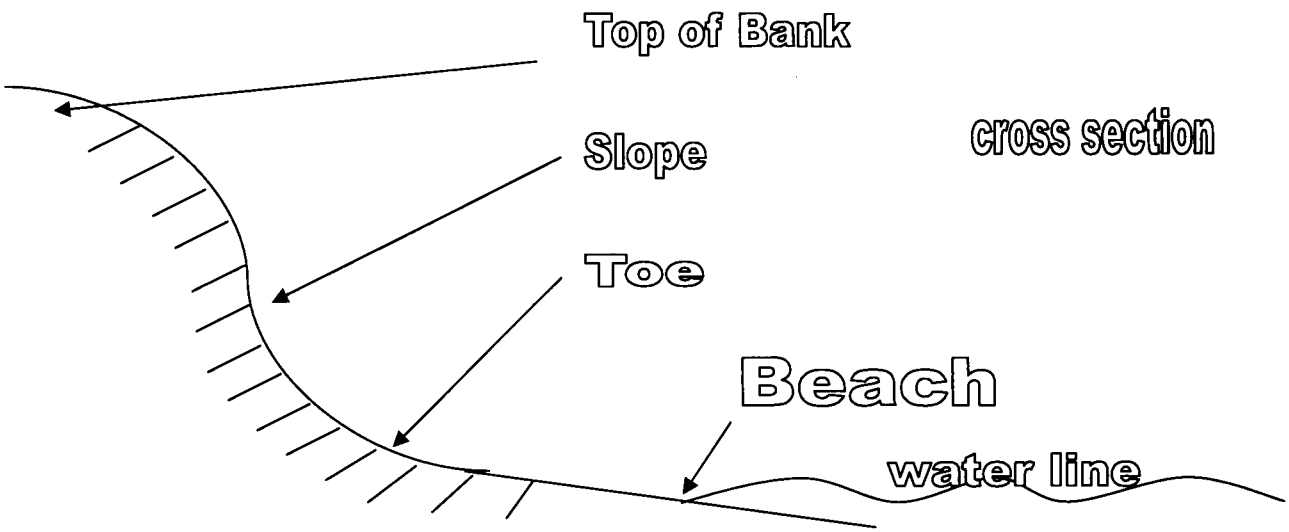
		Yes	No
a.	Flooding events	___	___
b.	Increased boat/ship wakes	___	___
c.	Upstream erosion control structures	___	___

d. Increased water levels ___ ___

e. Dredging ___ ___

f. Other

Q10. Do any of the following factors affect your property?



	Yes	No
a. Excessive wave action on your beach?	___	___
b. Excessive wave action on the toe of the levee?	___	___
c. Excessive wave action on the slope of the levee?	___	___
d. Are there visible sings of runoff on your property (e.g. ruts and/or gullies)?	___	___

Q11. Are any of the following features on your property?

	Yes	No
a. Are there drainage pipes coming from your home or garage?	___	___
b. Are there sprinklers or an irrigation system on your property?	___	___
c. Do you own a septic tank?	___	___
d. Does ground water flow out of the slope of the levee		

on your property? ___ ___

Do any of the features above contribute to erosion on your property? (please check):

	a. Drainage pipes
	b. Sprinklers or irrigation systems
	c. Septic tank
	d. Ground water flow
	None, contribute to erosion
	Don't know if they contribute to erosion

Q12. Is there a decrease in vegetation cover along your bank?

a. No ____ → **please go to question 14**
b. Yes____ → **please go to question 13**

Q13. (If you answered "yes" to question 12) please tell me where vegetation has been lost and what type of vegetation has been lost (please check all that apply)

Top of bank	_____ grass	_____shrubs	_____trees
Slope	_____ grass	_____shrubs	_____trees
Toe	_____ grass	_____shrubs	_____trees
Shoreline	_____ grass	_____shrubs	_____trees

PROTECTIVE STRUCTURES

Q14. Have you taken any action to prevent further erosion on your property?

		Yes	No	year it was installed	Has it stopped erosion? yes	no	don't know
a.	Rip-rap						
b.	Seawall						
c.	Plants						
d.	Others						

Q15. Are shore protection structures in good condition?

____ Yes _____ No _____ Don't have protective structure

Q16. Are there shore protection devices on adjacent property?

____ Yes _____ No

Q17. (If you answered "yes" to question 16) please list what type or types of protective devises are on the adjacent property?

_____

SUPPORT

Q18. In the last 12 months have you received any written or verbal information from a government or non-government agency concerning erosion control?

a. No ____ → **please go to question 21**
b. Yes____ → **please go to question 19**

Q19. Please write down all the agencies that have sent you written information or verbal communication about erosion control?

_____.

_____.

_____.

Q20. Did you find this information helpful?

_____ Yes _____No

Q21. Would you be interested in acquiring more information on erosion control?

_____Yes _____ No

Q22. If yes, please read the following list and indicate with a "1" and a "2" you're two most favorable way to receive this information.

- [ ] A pamphlet
- [ ] A manual
- [ ] A workshop
- [ ] A poster
- [ ] A website

Q23. What else would you like to tell me about erosion on your property?

Appendix B

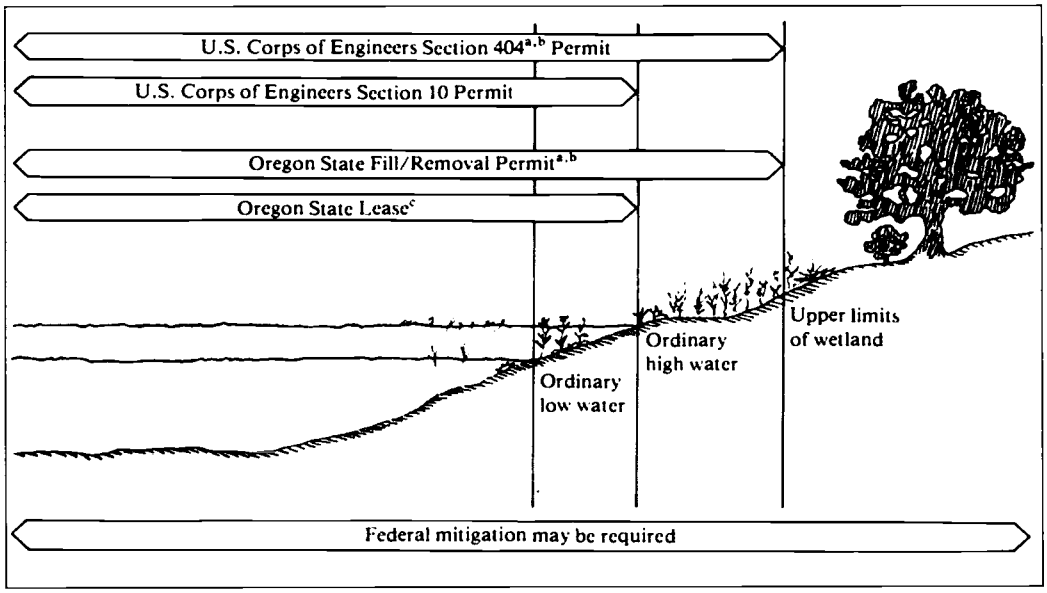
Agency Responses

Agency	Department Contacted	Agency role?	Is erosion occurring along Sauvie Island?	You're your agency monitoring erosion along Sauvie Island?	What are the contributing factors to erosion along Sauvie Island?	Does you agency have any best management practices for mitigating erosion on private or public lands?	Map
U.S. Army Corp engineers	Maintenance Navigation channel		yes	no	Did not know	Engineering manual, design of revetment structures	No
U.S. Army Corp engineers	Regulatory branch	Revetment permitting	yes	no	Ship wake	no	No
U.S. Army Corp engineers	Levee Maintenance		yes	no	Ship traffic wake, wind generated waves,	Defer to regulatory service	no
Columbia County	Land Development Services	Revetment permitting	yes	no	Don't know	Addressed on a case by case basis	no
Metro		none	yes	no	Flood 1996, high water 2005	no	no
Multnomah County	Land Use Planner	Revetment permitting	yes	no	Ship wake combine with sandy shores	Portland land use plan has erosion control guidelines which Multnomah county has adopted	no
Sauvie Island Drainage Improvement Company/ (formally: Sauvie Island Drainage Improvement Company)		Monitoring levee	yes	Yes monitor the levee but not the shoreline unless the levee is effected	Rapid rise and fall of water levees in high flow months Dec.-Jan	Addressed on a case by case basis	yes
ODFW		Monitor ODFW property	yes	Not officially	See map	no	yes
ODFW		Monitor ODFW property	yes	no	Ship wake coupled with high stable water levels, particularly damaging is when water stays at soil level	Addressed on a case by case basis	No

Oregon water resource department	hydrologist	none	Not aware of any erosion	no	Don't know	Don't know	No
USGS	Water Resource Division	none	yes	no	Ship wake, loss of sediment transport due to dams, possible subduction at site of sunken village and northern tip of island	no	No
Natural Resource Conservation services	bioengineer	none	yes	no	Multnomah channel: soil is weak levee, carp burrow into levee and spawn, Confluence: high water levels, tide and ship wake problem all over island contributing factors weak soil and no vegetation, unnatural water levels hard to establish vegetation	Stream and shoreline protection	yes
Division of State Lands	Regulatory Assistant		yes	no	Wake from ships, flooding	Yes, with application for revetment work	no
West Multnomah soils and water conservation District	planner		yes	Yes once land owner has implemented shore protection (bioengineer is preferred) the project can be monitored, but this resident driven, there is no active storewide monitoring of erosion	Multnomah channel is increased ship wake and absents of log rafts, and up stream river bank hardening will increase erosion down stream	Yes, there is no manual but we can go to the property and meet with the land owner to determine a conservation plan for the site (case by case basis)	no
Oregon Department of Land Conservation and Development	Planning service division/ Natural resource specialist		Not within the scope of their department				
Oregon department of water quality division			Don't know	no	Don't know	Yes for construction and industrial sites: Best Management Practices for Storm Water Discharges Associated with Industrial Activities, and Best Management	no

						Practices for Storm Water Discharges Associated with Construction Activities	
Oregon Parks and Recreation Department	Natural resource program		Not within the scope of this agency				
Oregon State Marine Board	Public information officer		yes	Not within the scope of their department, rely on other agencies to determine	Tidal change, ship wake	No management guidelines to minimize erosion however there are three working groups involved in * wake working groups (establish dialogue between boaters and land owners) * Clean Marina Program * Sustainable boating company	no
Coast Guard			yes	Not within the scope of their department, rely on other agencies to determine	Tidal change, ship wake, weather conditions	Not within the scope of their department	

Appendix C Government Agency Regulatory Authority and permit Process



[a] These permits are also required for nonnavigable waters.

[b] Federal 404 jurisdiction may extend beyond that of the state to include forested and shrub-covered tidal and nontidal wetlands.

Figure 32 Navigable Rivers and lakes (Good, W.J., et. al 1982)

Regulatory Agencies

The two principal agencies that regulate the installation of shore protection structures—the US Army Corps of Engineers, Portland District (covers all of Oregon) and the Oregon DSL— which have a joint permit application form and extensive agency-to-agency coordination and consultation. Their goal with this joint application form is to "streamline" a complex process, especially for the uninitiated property owner. Both agencies also have two classes of permits—individual permits (for larger projects) and general permits (for smaller projects that meet prescribed conditions).

Individual permits (IP) from both agencies take longer to get because they require careful evaluation and review by other agencies with responsibilities that may be affected

(e.g., fisheries, endangered species, water quality). Adjacent property owners and other private interests may also become involved in the public review process.

For smaller projects, *general permits* (GP) can usually be approved quickly after a completed joint application is received, certified as complete, and approved. The Corps general permit for shore protection is called Nationwide Permit 13: Bank Stabilization; the Corps' Portland District has added regional conditions as well. The DSL general permit is called General Authorization: Streambank Stabilization. These are discussed in detail later.

Local governments—Multnomah and Columbia Counties for Sauvie Island residents—also have requirements and standards for bank stabilization. Prior to beginning construction, property owners need to comply with all county requirements for bank stabilization as well, regardless of whether or not they have obtained State and Federal permits.

Requirements for obtaining Federal and State individual permits and general permits, and for local government approvals are discussed more fully below.

Federal Jurisdiction, Permits, and Regulations: US Army Corps of Engineers

The US Army Corps of Engineers has broad responsibilities for providing engineering services to the United States, including designing, building, and operating dams and navigation projects (e.g., the Columbia River Channel Deepening project), and designing and managing the construction of military facilities for the Army, Air Force, and other federal agencies. The Corps of Engineers also has regulatory and enforcement responsibilities for activities in the Nation's waterways and wetlands. This work is primarily conducted by the Corps of Engineers Regulatory Program whose primary function is to protect the Nation's aquatic resources, while allowing reasonable development through fair, flexible, and balanced permit process.

Federal Jurisdiction, Permits, and Regulations: Other Federal Agencies

A variety of other federal agencies are involved in the regulating and development of both private and public waterways they including: the Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS).

Corps of Engineers Regulatory Authority and Jurisdiction

One of the major responsibilities of the Corps of Engineers is to administer the consolidated Federal permit program for activities in navigable waterways and adjacent wetlands. Provisions of two federal laws provide the authorities and jurisdiction for this program—Section 10 of the Rivers and Harbors Act of 1899 (codified in Chapter 33, Section 403 of the United States Code) and Section 404 of the Clean Water Act of 1972 (codified in Chapter 33, Section 1344 of the United States Code) **(Table 5).**

Section 10 of the Rivers and Harbors Act gave the Corps authority over navigable waters of the United States. Navigable waters are defined as "those waters that are subject to the ebb and flow of the tide and/or are presently being used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce." Section 404 of the Clean Water Act authorized the Secretary of the Army to issue permits for the discharge of dredged and fill material in waters of the United States. Together, these laws give the Corps broad regulatory jurisdiction over in-water construction activities, dredging, disposal of dredged or fill material, installation of shore protection, and other related activities in navigable lakes, rivers, stream and there tributaries, interstate waters and their tributaries, and wetlands adjacent to navigable waters (**Figure 33**). In considering applications for permits, the Corps balances the reasonably foreseeable benefits and detriments of proposed projects, and makes decisions that recognize the essential values of the Nation's aquatic ecosystems to the general public, as well as the property rights of private citizens who want to use their land.

Table 5. Jurisdiction and Required Permit Activities

Section 10 of the Rivers and Harbors Act of 1899	**Section 404 of the Clean Water Act**
Requires approval prior to the accomplishment of any work in or over "navigable waters" of the United States, or which affects the course, location, condition or capacity of such waters. Typical activities requiring Section 10 permits are: construction of piers, wharves, bulkheads, dolphins, marinas, ramps, floats intake structures, and cable or pipeline crossings, and dredging and excavation.	Requires approval prior to discharging dredged or fill material into the "waters of the United States". Typical activities requiring Section 404 permits are: 1) depositing of fill or dredged material in waters of the U.S. or adjacent wetlands. 2) Site development fill for residential, commercial, or recreational developments. 3) The landward regulatory limit for non-tidal waters (in the absence of adjacent wetlands) is the "ordinary high water mark". The ordinary high water mark is the line on the shores established by the fluctuations of water and indicated by physical characteristics.

Source: U.S. Army Corps of Engineers https://www.nwp.usace.army.mil/op/g/types.asp, accessed 4/20/07.

Corps of Engineers Permitting System (The material in this section has been adapted from the ACOE website https://www.nwp.usace.army.mil)

The ACOE can authorize project under one of three permit categories: a General Permit (GP), Letter of Permission (FOP) or a Standard Permit (SP). The general permit is a "pre-issued" permit under the Nationwide Permits (NWPs) or Regional General Permits (GPS) regulation suite. Both the standard and general permits can be applied for using a single joint application form which both the ACOE and DSL will accept. This form and general instruction can be obtained from either agency.

General Permit (GP)

Under the NWPs a general permit may be issued if the proposed activities fall within certain categories of action which are similar in nature and can be accomplished with minimal accumulative or individual impacts. These permits may already authorize proposed work, but you may be required to obtain verification of authorization from the ACOE prior to commencing the activity (see below). Some examples of activities covered by the general permit include: wetland restoration, placement of large wood and boulder in streams, and bank stabilization. If an activity is authorized under the general

permit system, a verification letter will be issued within 45 days following the full review of your application.

Nationwide Permits 13 Bank Stabilization: Conditions, Information and Definitions
"Bank stabilization activates necessary for erosion prevention, provided the activities meet all of the following criteria: a) No materials is place in excess of the minimum needed for erosion protection; b) **the activities is no more than 500 feet in length along the bank**; c) **the activity will not exceed an average of one cubic yard per running foot placed along the bank below the plane of the ordinary high water mark or the high tide line**, unless this criteria is waived in writing by the district engineer; d) the activity does not involved discharge or fill material into specific aquatic sites, unless this criterion is waived in writing by the district engineer e) no material is of the type, or is placed in any location, or in any manner, to impair surface water flow into or out of any water of the United States; f) no material is placed in a manner that will be eroded by normal or excepted high flows (properly anchored trees and treetops may be used in low energy areas); and g) the activity is not a stream channelizations activity."

"Notification: the permittee must submit a per-construction notification to the district engineer prior to commencing the bank stabilization activity: 1) involves discharge into special aquatic sites; 2) is in excess of 500 feet in length; or 3) will involve the discharge of greater than an average of one cubic yard per running foot along the bank below the plane of the ordinary high water mark or the high tide line."

Under the ACOE Portland District Regulation office additional requirements may need to be considered including: in-water work windows, upland disposal, fish passage, riparian vegetation protection and restoration, and erosion control.

In particular for "Bank protection: rip-rap shall be clean, durable, angular rock. The use of other materials such as broken concrete, asphalt, tires, wire, steel posts or similar materials is not authorized. The project design shall minimize the placement of rock and maximize the use of vegetation and organic materials such as root wads to the extent practicable. Riparian plantings shall be included in all projects designed unless the permittee can demonstrate they are not practicable. The permittee must notify the District Engineer in accordance with nationwide permit general condition #27 for any activities that include bank stabilization."

Standard Permit

If a project does not fall under a general permit application or a letter of permission, then an individual permit (IP) may be necessary. The IP allows a full public interest review, coordination with federal, state and local resource agencies and Tribes, and evaluation by Corps regulatory staff. A public notice is distributed to all known interested persons. A

period of normally 30 days is provided for public comment (county specific). The proposed project is individually reviewed and evaluated in accordance with the requirements including: the Clean Water Act, National Environmental Policy Act, Endangered Species Act and Historic Preservation Act. Standard permits under the ACOE are normally issued within 120 days; this timeline includes review by resource agencies, and local land use agencies. However, this process can be longer if federal consultation with the National Marine Fisheries Service or the U.S. Fish and Wildlife is required under the Endangered Species Act (i.e. if protected or endangered species might be affected by the action). Some common regulated activities which fall under this category include: excavating or dredging, channel changes relocation or realignment, construction of piers, seawall, beach, placement of fill, rip-rap, construction of dams, bank protection (bank stabilization, jetties, and revetment).

Note: This process may take 6 month to one year. Work must be planned to ensure there is time to address any unexpected problems. Applicant should also consult ODFW to take into account the in-water work period when some activities may be prohibited during certain times of the year due to fish and wildlife impacts.

Outline of Application Process for Standard Permit

1) Permit applicant are encouraged to look at the Nationwide Permits 13 Bank Stabilization Guidelines and determine which permit fits their proposed action.

2) Applicants can contact the Corps Regulatory Project Manager for the county in which the proposed work will occur and/or the DSL permit coordinator for general questions. Additionally, applicants are encouraged to contact their local county planning office to discuss additional regulations and requirements.

3) Permit applicants need to develop a detailed project proposal. The ACOE has examples of maps of project sites including: drawings of the water line, river mile, proposed changes, the amount of material, demotions to name a few. Additionally, the following information is also required for review by the ACOE:

a) Name, address, and phone number of applicant

b) Complete description of the proposed project, including the purpose, type and quantity of material to be discharged

c) All related activities. Is this a multiphase project? Have additional permits been applied for or received?

d) A list of all adjacent property owners and their addresses

e) The project location. This should be clearly marked on a road map and a description of the directions should be included. In addition to the map and directions, you should submit the Section, Township and Range and the latitude and longitude of the site.

f) Has the application been signed?

g) And be sure to include a full set of drawings on 8.5 inch by 11 inch format. These should include plan view, section view, elevation view, profile, and grade drawings. Please use match lines where necessary.

4) After the application is complete send a copy to the ACOE, DSL, as well as, keep a copy for yourself. (Remember the DSL and ACOE has a joint permit application form and instructions, however, they do not have the same jurisdiction so sending copies to both agencies. (Faxes are accepted, however, hard copies or e-mail are preferred)

5) After the application is received in the ACOE office, it will be assigned an identification number; this number will be the reference number to track the application. At this point the application will be reviewed for completeness. A request for additional information may be sent to the applicant by the ACOE regarding any additional information the ACOE or other federal agencies reviewing your application may need.

6) Within 15 days of receiving all the required information the ACOE will issue a public notice and a 15-30 day comment period issue. The proposal is then reviewed by the ACOE, local, state and other Federal agencies, special interest groups and the general public allow at least 60-120 days for this stage of the process.

7) When all considerations are satisfied, the District Engineer will make a decision to either issue or deny the permit application. If a denial is warranted, you will receive a written explanation.

State Jurisdiction, Permits, and Regulations: Department of State Lands

Oregon's Removal-Fill Law (ORS 196.795-990) requires people who plan to remove or fill material in waters of the state to obtain a permit from the Department of State Lands. The DSL issues an expedited state permit called a General Authorization which generally covers small projects for stream and wetland enhancement activities as well as erosion control and road building projects. To be eligible for the General Authorization for streambank stabilization, a project must: be in an area of active erosion, be for the purposes of streambank protection, and meet the following minimum criteria:

- Involve no more than 1,000 cubic yards of material placed in a 1/4 mile reach of a stream or more than 2,000 cubic yards for multiple-related projects within a sub basin.
- Where structural techniques are unavailable, the project shall include a nonstructural component such as slope pull-back, willow mats, rock barbs, re-vegetation with native plant species and log and boulder deflectors to the maximum extent possible.
- Where revetments, riprap and/or any other hard structural techniques are unavoidable, they shall be used in combination with nonstructural or bio-engineered approaches to streambank stabilization.
- Only clean, durable rock shall be used as riprap. Riprap used for the toe material shall be placed in an irregular pattern using large boulders or rock clusters.
- No material shall be removed in excess of the amount required to construct a toe trench, key material to the bank, or slope the bank.

If projects do not meet the criteria for the general application permit an individual permit may be necessary including: Projects involving channel relocation or gravel bar alteration; Projects consisting entirely of structural stabilization methods (e.g., rip-rap, bulkheads); Projects involving fill in wetlands exceeding 0.2 acres. This permit includes standard and special design and operating conditions that are intended to ensure the protection, conservation and best use of the state's water resources and prevent harm to fishery and recreational uses of the waters. DSL will take recommendation form the Department of Fish and Wildlife, Departed of Land Conservation and Development.

State law requires DSL to determine whether an application for a joint removal-fill permit is complete within 30 days of receipt and to issue a decision within 90 days of the completeness determination. However, applicant are encouraged to fill out the joint application 6-12 month is advance of the project start date. DSL has several management plans outlining stream bank erosion control measures.

Local Jurisdiction, Permits, and Regulations: Multnomah and Washington Counties
Columbia County and Multnomah County are both involved in the permit process within their respective jurisdictions. Multnomah County also has erosion control and minimum impact orientation guide, as well as, the Multnomah Rural Management Plan, detailing best management practices for this area.

Outline of Application Process for Standard Permit

2) Applicants can contact the Corps Regulatory Project Manager for the county in which the proposed work will occur and/or the DSL permit coordinator for general questions. Additionally, applicants are encouraged to contact their local county planning office to discuss additional regulations and requirements.

3) Permit applicants need to develop a detailed project proposal. The ACOE has examples of maps of project sites including: drawings of the water line, river mile, proposed changes, the amount of material, dimensions to name a few. Additionally, the following information is also required for review by the ACOE:

a) Name, address, and phone number of applicant

b) Complete description of the proposed project, including the purpose, type and quantity of material to be discharged

c) All related activities. Is this a multiphase project? Have additional permits been applied for or received?

d) A list of all adjacent property owners and their addresses

e) The project location. This should be clearly marked on a road map and a description of the directions should be included. In addition to the map and directions, you should submit the Section, Township and Range and the latitude and longitude of the site.

f) Has the application been signed?

g) And be sure to include a full set of drawings on 8.5 inch by 11 inch format. These should include plan view, section view, elevation view, profile, and grade drawings. Please use match lines where necessary.

4) After the application is complete send a copy to the ACOE, DSL, as well as, keep a copy for yourself. (Remember the DSL and ACOE have a joint permit application form and instructions, however, they do not have the same jurisdiction so sending copies to both agencies. (Faxes are accepted, however, hard copies or e-mail are preferred)

5) After the application is received in the ACOE office, it will be assigned an identification number; this number will be the reference number to track the application. At this point the application will be reviewed for completeness. A request for additional information may be sent to the applicant by the ACOE regarding any additional information the ACOE or other federal agencies reviewing your application may need.

6) Within 15 days of receiving all the required information the ACOE will issue a public notice and a 15-30 day comment period issue. The proposal is then reviewed by the ACOE, local, state and other Federal agencies, special interest groups and the general public allow at least 60-120 days for this stage of the process.

7) When all considerations are satisfied, the District Engineer will make a decision to either issue or deny the permit application. If a denial is warranted, you will receive a written explanation.

Appendix D

Colorado State Parks

COLORADO STATE PARKS
STEWARDSHIP PRESCRIPTION

Date Created: April 25, 2003
Revised: April 1, 2005
Author: Curt Harvey
Parks Affected: Reservoir Parks

Shoreline Erosion Monitoring

Stewardship Rx

Introduction to protocol

As shoreline and stream bank erosion continue to be a concern at certain Colorado State Parks, the following document is intended to outline an effective, easily followed, and consistent method to long term monitoring of shoreline erosion. If this method is to be implemented, more formal and specific guidelines may be developed in cooperation with park staff. This approach will provide a means for collecting quantifiable data that will be valuable in making long-term management decisions for a threatened resource.

Source: Stewardship Team, 2000

Purpose

Contributing factors to shoreline erosion may be large seasonal fluctuation in water levels, soils with low cohesive strength, poor vegetative protection and anchoring of shoreline, as well as wind and wave action. Until a semi-permanent or permanent solution can be made, shoreline loss should be monitored consistently. The purpose of such a monitoring program will be to assist in #1 illustrating more specifically, the magnitude of the shoreline loss, #2 identifying priority areas for stabilization, #3 achieving more predictable stabilization results, and #4 assisting in more successful and cost effective remedies. The data collected will be an integral component for analyzing erosion trends and rates, more effectively than simple observations and photo-documentation alone, by;

- Developing long term permanent GPS'd monitoring locations
- Quantifying soil loss over *time* (seasonal and annual intervals) and *area*.
- Providing insight into identifying levels of priority among different areas.
- Providing available data for analytical applications useful to contractors.
- Indicate more concretely, actual amounts of shoreline soil lost.

In addition, the data collected may be stored in an Arcview GIS project for park staff to access and evaluate trends at each monitoring location, identified by the associated GPS point.

Note: It is critical to line the pupil of the eye, with sightline of the compass mirror, and the rod. All three must line up, in order to protect lateral accuracy for repeatable and consistent data collection.

The distance measured to the edge of the shoreline will be recorded on the data sheet provided (see figure #2). Subsequent measurements will be made at 10-degree intervals on both sides of that perpendicular bearing probably 3 to 4 measurements on each side of that perpendicular axis. All bearings will be permanently assigned to the data sheets. This will create approximately 3 to 4 foot intervals between measurements. The overall width of the shoreline at each monitoring point will be somewhere between 20 and 30 ft. If a longer representative section is preferred, simply set the fixed point farther away from the shoreline (40-50ft). This provides data on the rate of the shoreline receding over that distance of 20 to 30 ft. (or longer) In addition, the distance to the waters edge from the fixed monitoring point will also be recorded to compare erosion rates with corresponding lake levels or distance from waters edge to erosion line.

Implementing the third (Z) axis of monitoring (comprehensive approach) illustrated in diagram #2, will help indicate the difference in elevation using the fixed monitoring point as an elevation reference. Again, all measurements will be recorded in the appropriate data sheets for each point. An example of the data sheets is provided in Figure #1 and #2.

Diagram #1 Monitoring point measurement location

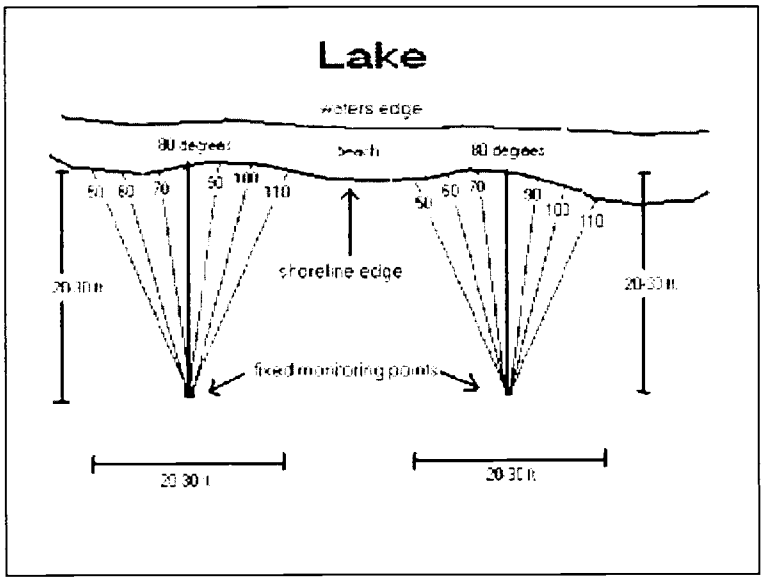


Diagram #2 illustrating height measurements

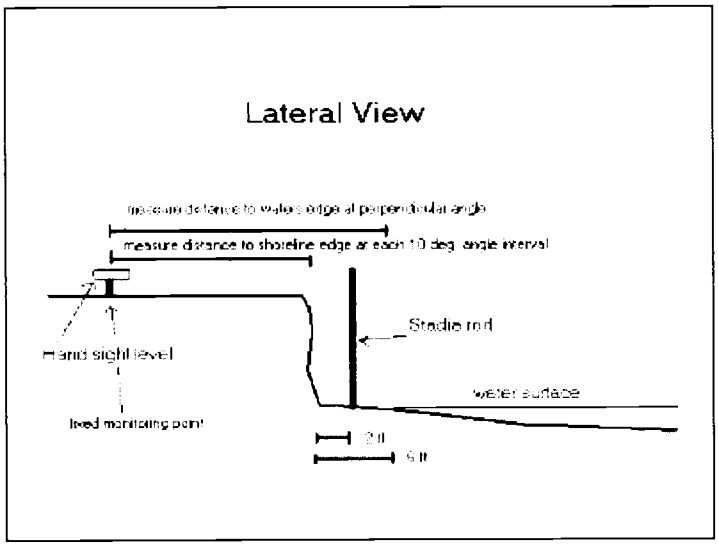


Figure 1: **Sample data sheets (Figures 1 and 2)– There should be one set of these data sheets for each monitoring point.**

Shoreline Monitoring Point A (one of several)

Example

Location: Lakeside CG #14

Recorded by:	Date:
Distance from fixed point to waters edge ft. in.	Camera and Photo #'s

	feet	inches
Measurement 1 (perpendicular to shore) Bearing = 60 degrees example		
Measurement 2 Bearing = 70 degrees "		
Measurement 3 Bearing = 80 degrees "		
Measurement 4 Bearing = 90 degrees "		
Measurement 5 Bearing = 50 degrees "		
Measurement 6 Bearing = 40 degrees "		
Measurement 7 Bearing = 30 degrees "		

Observation Notes Today

Notes on Previous Month

Figure 2: **Sample Data Sheet**

Example **Monitoring Site A**

Date	Dist. To Water (from perpen.)	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7
Distance From Fixed point in Inches (convert feet and inches from data sheet 1, to inches)								
5/9/01	504	474	479	497	554	479	522	545
6/10/01								
7/11/01								
8/12/01								
9/13/01								
10/14/01								

In addition to the measurements taken, photo-documentation with a digital camera or a standard camera with film developed on a disc for computer downloading will complete each monitoring effort. Photo reference locations will be pre-determined and consistent. Ideally, two photos should be taken - one with the farthest right (angle measurement point) at the bottom of the view/photo
frame, and another with the farthest left (angle measurement point) at the bottom center of the photo.

Finally, any additional notes or observations made at time of data collection should also be recorded on the data sheets (i.e. recent obvious slump failures, evidence of human impact, etc).

The frequency and dates of data collection will be ultimately determined by park staff, however the recommended frequency is a minimum of twice a year with a maximum of six times a year. Park management will also determine individuals or parties responsible for the monitoring. Park management is free to make any changes or adaptations to the methodology provided here.

Saving and Using the Data

With the collected data analysis and tracking conditions over time can be performed using Microsoft Excel for data storage and graphing capabilities. Additionally, an Arcview GIS project should be created with linked data sets and photographs, to each monitoring point. The results for each monitoring effort should be recorded electronically, in a Data Results Spreadsheet for graphing and analysis purposes. Management or contractors may develop other applications for the data.

Conclusion

This monitoring method should provide useful and quantifiable data for short and longer-term time periods. It will provide information on shoreline lost over a given distance at pre-designated, GPS'd representative monitoring locations. The data results can be reviewed and analyzed using appropriate Arcview projects and Excel spreadsheets. Adapting the specific parameters for this monitoring protocol, and the frequency of data collection, will be a cooperative effort between each State Park management team and the State Parks Stewardship Team.

Source: Stewardship Team, 2001

CONTACTS

Army Corps of Engineers:
http://www.usace.army.mil/

U.S. Environmental Protection Agency:
http://www.epa.gov/OWOW/NPS/MMGI/Chapter6/ch6-4.html

For shoreline stabilization:
http://www.extension.umn.edu/distribution/naturalresources/components/DD6946g.html