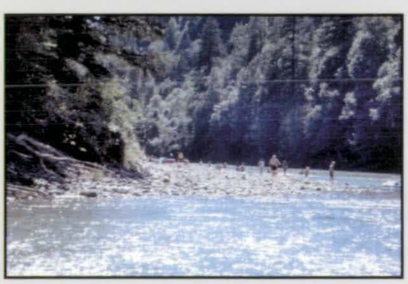
Morphology and Dynamics of the Sandy River at the Boat Ramp in Oxbow Regional Park, Oregon

Metro Regional Parks and Greenspaces



Final Report
December 2000

~~ClearWater West~~
Portland, Oregon

The Sandy River at Oxbow Park, Oregon

Morphology and dynamics in the vicinity of the boat ramp

Prepared for

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Final Report / December 2000
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Cover aerial photograph from:
Metro RLIS Aerial Photography
for Multnomah County
T. 1 S., R. 4 E., September 1997

Executive Summary

The problem. Riverbank erosion in Oxbow Regional Park on the lower Sandy River in Multnomah County, Oregon, is undermining a boat ramp and an adjoining handicap fishing platform, and threatens the integrity of these facilities. The ramp and platform provide access to a regionally significant steelhead fishery. The site is the upstream launch site for drift boats on a 6-mile reach of the Sandy River above Dabney State Park, the closest take-out facility. It also serves as the only publically-accessible take-out for a much-used launch site for rafters, tubers and kayakers 7 miles upstream at Dodge Park. In addition, the site at Oxbow Park is a popular recreation destination both within the park and within the Portland metropolitan area (population 1.8 million). In the summer, it serves as an important recreation amenity for kayakers, canoeists and rafters paddling down river from Dodge Park, and as a put-in site for tubers, rafters, drift boats and other water craft transiting the park and the 12 mile reach of the lower river.

Significance of Oxbow Park in the Portland metropolitan region. The park is situated within the Sandy Wild and Scenic River and State Scenic Waterway corridor, recognized for its outstandingly remarkable natural resource values. The region's parks program, Metropolitan Regional Parks and Greenspaces (Metro Greenspaces), manages the park's grounds and facilities for least possible impact to fish and wildlife. About 250,000 people visit the park each year to participate in natural history interpretation programs, to see the park's old-growth forests, to camp, picnic, fish, swim, hike, horseback ride and take part in other outdoor recreation activities. Metro Greenspaces wishes to preserve the boat ramp and handicap fishing platform because of the relatively rare opportunities they provide for river access, recreation and education in the Portland metropolitan area.

Focus and methods of this study. This study investigates factors influencing erosion at the boat ramp and handicap fishing platform and poses options for protecting these facilities. Information was gathered during numerous field visits, and by means of interviews and collaboration with people having specialized knowledge about the park and the river in this location, and by reviewing both published and unpublished studies, data, reports, maps and aerial photos concerning the Sandy River, its watershed and the reach in the vicinity of the boat ramp in Oxbow Park.

Summary of findings. The Sandy River in Oxbow Park is rapidly cutting down through deep deposits, largely composed of coarse sand and gravel, which were washed down river by runoff after eruptive episodes originating at Crater Rock on the south flank of Mount Hood approximately 200 years ago and 1,500 years ago. These sandy materials comprise the riverbed and banks in much of Oxbow Park, and are highly erodible. Current evidence of both lateral and vertical erosion processes are visible in the field, and include rapid and extensive loss of streambank in some areas, apparent channel incision in others, and, during high flow events, exhumation of former streamside forests that were buried by water-laid deposits from eruptive activities as recently as 200 years ago.

Natural erosion processes have resulted in incremental and chronic loss of riverbank upstream of the boat ramp. This appears to have exposed the ramp and vicinity to more direct flow energy than in recent decades. This has contributed to river erosion of sand and gravel that formerly were present on a point bar where the boat ramp and fishing platform are located. These erosional dynamics at the boat ramp appear to have been accelerated by the accumulation of large woody debris somewhat upstream from the ramp on the other side of the river.

The presence in the floodway of a paved vehicle maneuvering area, concrete launch ramp, and wood and concrete fishing platform appear to have exacerbated this erosion because they intrude into the zone of normal high water and their smooth surfaces are capable of amplifying and reflecting wave and current energy during high flows. These processes can create a zone of higher flow energy on the point bar, in which sand and gravel can be eroded during high flows.

Options to protect the boat ramp. There is no other site in the park that could be developed to provide the same uses, but without the potential for erosion problems. Options to protect site uses in their present location are limited by the erodible materials of the riverbed and banks, by the dynamic nature of the river, by potential damage to riverside structures from floating woody debris, by the limitations of funding, by permitting restrictions, and last, by the need to protect instream habitat.

Given these constraints, the remaining options for protecting these facilities involve the use of large rock or an engineered large woody debris jam to modify flow patterns and create a zone of slack water in the vicinity of the point bar. Properly engineered, either installation could allow the deposition of sand and gravel on the point bar, and buffer the launch facilities from high-energy flows.

However, the design parameters for such features would need to be developed by journey-level experts, and it is likely that the studies to develop engineering parameters will be involved and costly. Permitting requirements may call for analysis of several alternatives. In addition, a biological assessment would need to be undertaken to investigate the likely environmental impacts of the proposed action, particularly on fall Chinook salmon, of the preferred action. It is likely that mitigation for impacts of the action would be required under the Section 404 permit administered by the U.S. Army Corps of Engineers and the National Marine Fisheries Service.

In light of these findings, Metro may choose to seek assistance or enter into a cost-sharing agreement with another agency with interest in the continued operation of the boat launch and handicap fishing facilities.

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I. Introduction

Context and focus of this study

Metro Regional Parks and Greenspaces, the regional parks program for the greater metropolitan area of Portland, Oregon, owns and operates a boat ramp and handicap fishing platform at Oxbow Regional Park near River Mile 12 on the Sandy River *(please see Figures 1, 2 and 3 on the following pages)*. The tract on which the boat ramp is located was deeded to Multnomah County for park land by the Oregon Department of Fish and Wildlife (ODF&W) in 1962. A deed restriction specified that the boat ramp would be maintained, and access for anglers would be guaranteed in perpetuity, or the land would revert back to ODF&W.[1] The park subsequently passed into the regional parks system and the boat ramp remained an important access point to the fisheries and recreational opportunities afforded both in the park and in the lower 12 miles of river.

Extreme runoff events in February 1996 and November 1999 resulted in erosion of streambed and bank materials in the vicinity of the boat ramp, loss of a sandy beach that had extended both upstream and downstream of the ramp, and undermining of the ramp itself.[2] The beach is one of the more easily accessible places on the river within Oxbow Park. During warm weather, the shallow-shelving beach attracts picnickers, swimmers and young families. Its present skeletal (rocky) condition makes it difficult for people to move about freely and for crews of rafters and boaters to carry their craft to and from the water. The site is a popular year-round fishing spot and is an important location on the lower river for launching drift boats and putting in and taking out personal water craft. The Sandy River supports a nationally-renowned steelhead fishery; winter use of the boat ramp is especially heavy and continued erosion will endanger the ramp.

Managers at Metro Regional Parks and Greenspaces are seeking background information about the dynamics of the Sandy River in this location in order to consider options for repair and protection of the boat ramp and to make informed decisions about long-range shoreline management in the vicinity. This report focuses on the fluvial processes operating in the reach and their effects both on erosion and deposition, and on channel position over time.

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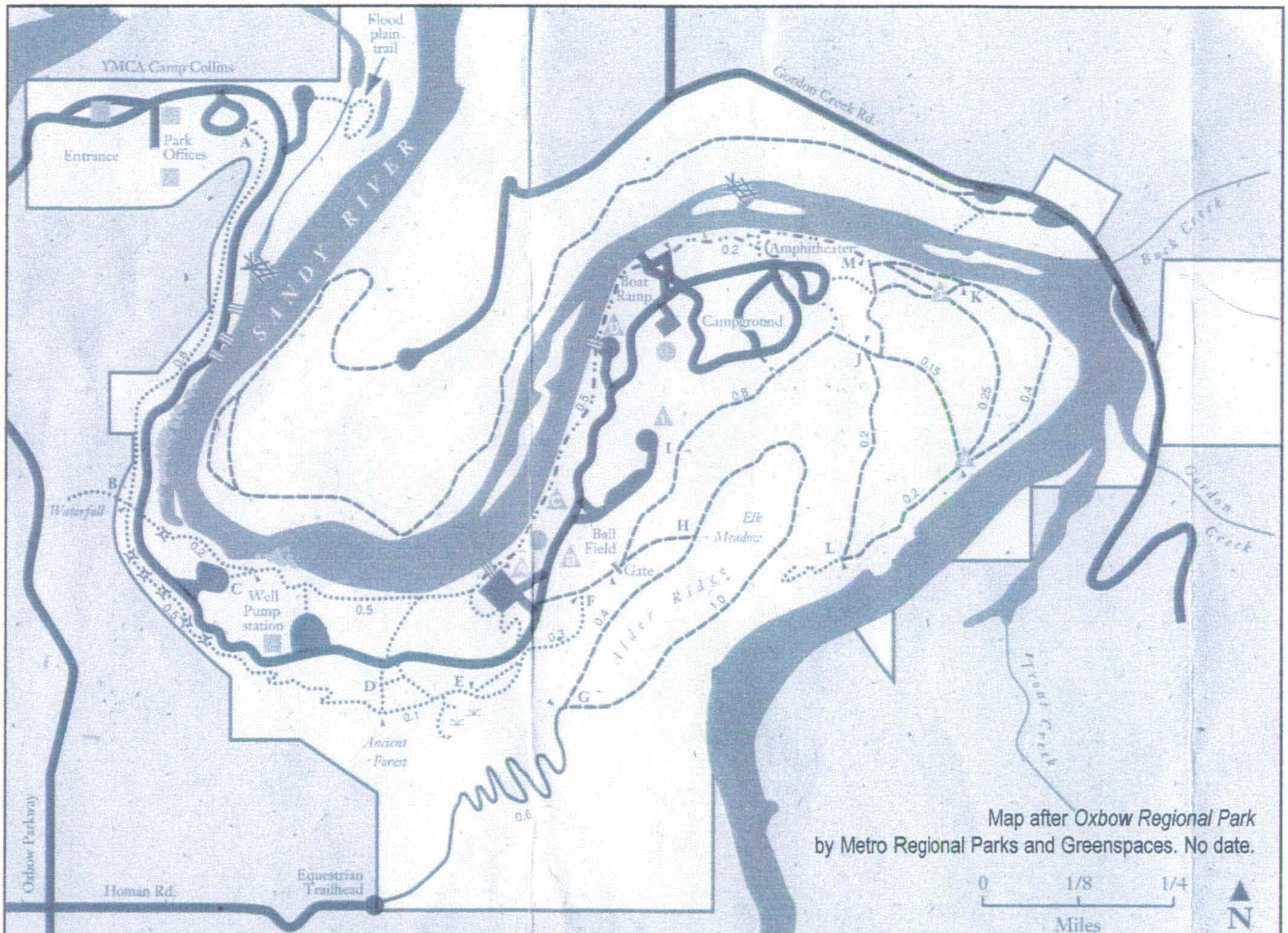
[1] Ciecko, 1982.

[2] Personal communication: Ciecko, Lind.

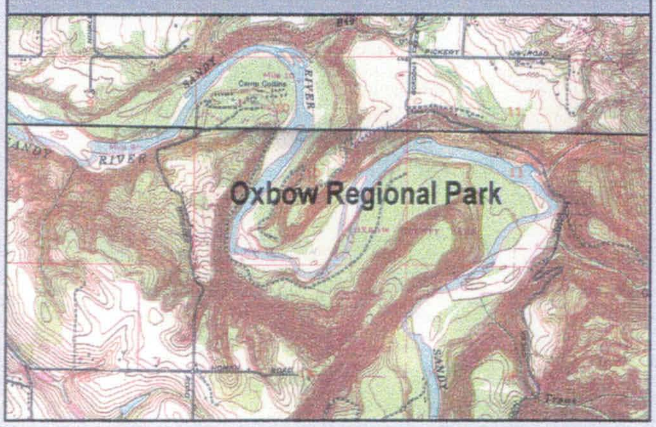
Figure 1: The Sandy River at Oxbow Regional Park, Oregon.



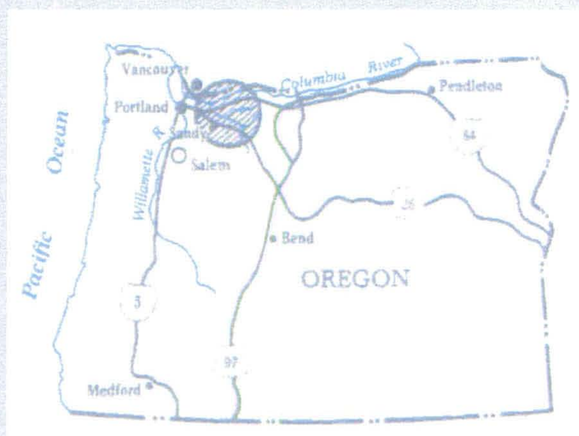
Map after *Oxbow Regional Park* by Metro Regional Parks and Greenspaces. No date.

The incised meanders or "oxbows" of the Sandy River are a striking landform in Oregon's north Cascades.

Map after Sandy, Ore. and Washougal, Wash. 7.5 minute topographic maps, by U.S. Geological Survey, 1985. No scale.

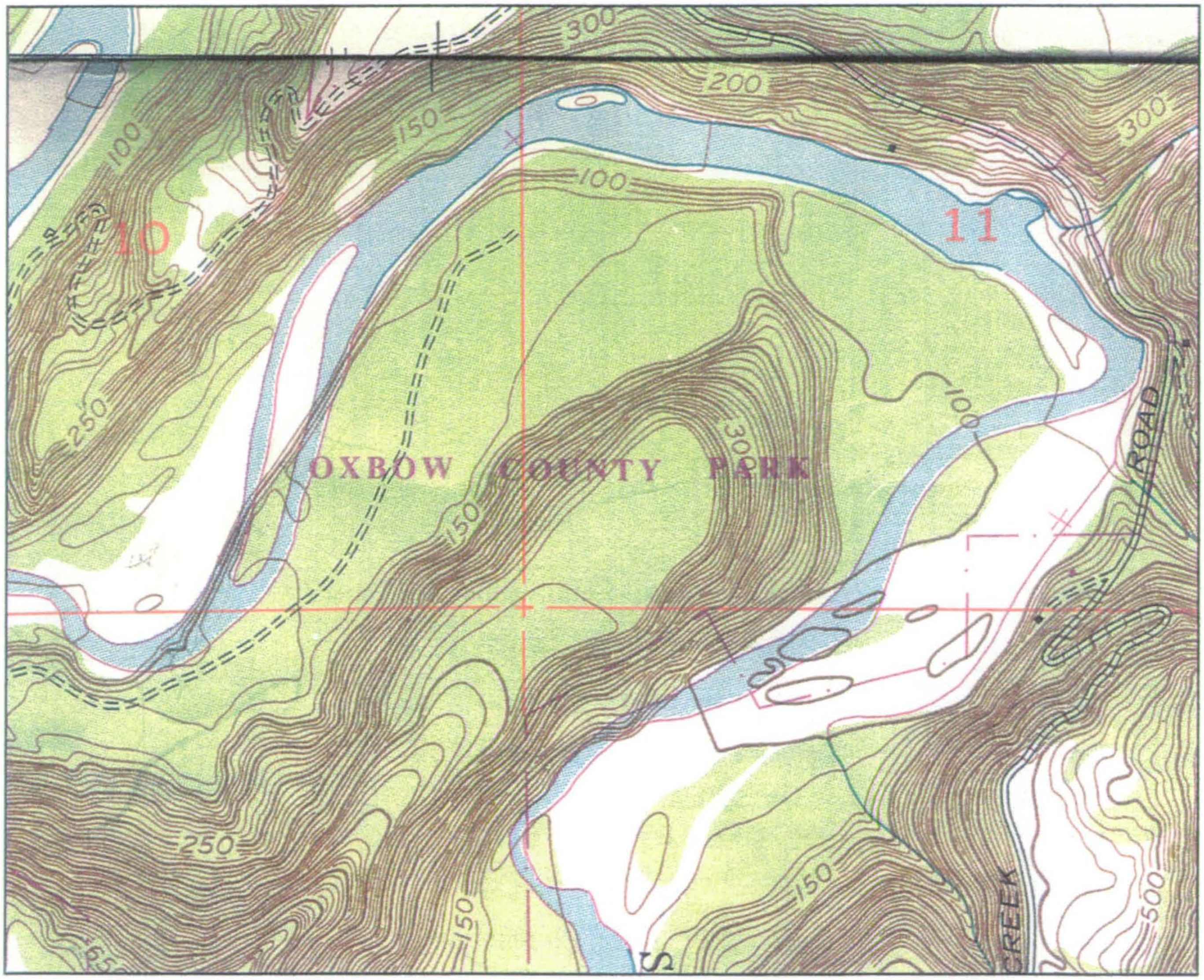


General location of the Sandy River in Oregon.



Location figure after *Sandy River Fishing Map*, by Amato Publications, no date.

Figure 2: Upper meander loop of the Sandy River in Oxbow Regional Park.



After Sandy, Ore. and Washougal, Wash. 7.5 minute topographic maps by U.S. Geological Survey, 1985. Contour interval is 10 feet. No scale.

This study focuses on the morphology and dynamics of the upper meander loop of the Sandy River in Oxbow Park. In the 15 years that have elapsed since the publication of this map, dynamic erosion and deposition have taken place in the reach where the river makes a sharp bend at the upper right of this map (direction of flow is from right to left). The flat, green surfaces near the river are deep, forested terraces composed of sand deposited in the channel by outwash from lahar flows at Mount Hood about 200 years ago. These terraces gradually are being washed out of the Sandy River Canyon.

Figure 3: The Sandy River around Alder Ridge in Oxbow Regional Park

Photo from Metro RLIS Aerial Photography for Multnomah County, 1997. No scale.

The bright areas along the river in this 1997 photo show areas of erosion and deposition after the 1996 flood. Dynamic bank erosion occurred in the vicinity of Group Camp #2, and dynamic deposition occurred on the downstream tip of the bar at the mouths of Gordon and Trout Creeks and created an extensive bar downstream of "The Point."

Questions central to this study

This study begins with an overview of the Sandy River watershed — its precipitation, elevation range, land and water uses, landforms, materials, geomorphic processes and flow regime — in order to answer the following questions:

- Are the extensive flat terraces on the west side of the Sandy River in Oxbow Park floodplain features?
- Are these features associated with river dynamics that occur during present-day climatic, hydrologic and geomorphic regimes, or are they relict features?
- In the vicinity of the boat ramp, is the present-day channel bottom at grade, or is it incising?
- What are the materials of the channel bed and banks in the reach above the boat ramp? What, if any, geologic controls to vertical and lateral channel movements are present in the reach?
- What has been the nature of streambank erosion, sediment transport and sediment deposition in this reach?
- What effects might human activities in the park have had on erosion and deposition in this reach?
- What happened to the sandy beach at the boat ramp?
- What erosional and depositional processes are likely to continue to operate in this reach?
- What measures might be taken to recruit sand to the beach and protect the boat ramp from being undermined by high flows?
- What concerns should be reflected in design parameters for potential solutions at the site?
- What suite of disciplines might need to be involved in selecting, designing and constructing such measures, and what additional studies might they need to undertake?
- What is the nature of probable permit restrictions for channel and streambank work at the site?

Study methods and field work

ClearWater West, consultants in erosion and natural resource planning, undertook a review of current literature as well as archival reports, maps and photos from various sources in order to gain broad understanding of the watershed and its geomorphic history. They interviewed technical experts and people familiar with the site and its physical and natural history. They visited the site and vicinity a dozen times between May 26 and July 23, 2000, to determine channel and channel margin materials, geologic controls, elevation of active river bars, sediment grain size, channel cross-section and alignment, degree of entrenchment and flood-prone areas and to gain an understanding of the dynamics of sediment production, transport and deposition in the reach.

For a complete listing of the literature, resources and people consulted for this report, please turn to *Appendix 2: References* at the end of this report. Every attempt has been made to provide brief definitions, in context, of technical terms used in this report. An alphabetical glossary of technical terms is provided as the first appendix of this report

Summary: Regional context and physical characteristics of the Sandy River watershed

- **Watershed size:** 508 square miles.
- **Major tributaries:** Salmon River, Zig Zag River, Still Creek, Creek, Bull Run.
- **Minor tributaries** in vicinity of Oxbow Park: Gordon Creek, Trout Creek, Buck Creek, Happy Creek, Big Creek.
- **Length of main channel** from the headwaters in the northern Oregon Cascade Range to the mouth at the confluence with the Columbia River: 55 miles.
- **Elevation range** within the watershed: approximately 10 feet at the mouth of the Sandy River in Troutdale, to 11,235 at the summit of Mount Hood.
- **Average annual precipitation** in the basin is 40 inches in the lower elevations to about 170 inches near the summit of Mt. Hood.[3, 4] Some of the upper watershed is in the snow zone; year-round glaciers are present above timberline in parts of the drainage. Runoff from snowmelt is an important contributor to summer flows.
- **Vegetation** of the basin consists of the native temperate coniferous rainforest assemblage below tree line, which is about 6,000 feet.
- **Fisheries:** The Sandy River supports a nationally renown anadromous fishery.
- **Water use:** The basin supplies domestic water to nearly 1 million people in the metropolitan Portland area.
- **Land uses** in the basin: timber production (both public and private forest land), wildland recreation, domestic water supply, agriculture, and urban areas. Forested lands predominate.
- **Character of the stream** in the vicinity of Oxbow Park: This is an incised, cobble-bedded system in an incised, alluviated canyon. In the 13 river miles between upper Oxbow Park to the mouth, the river loses approximately 90 feet in elevation, for an overall gradient in this section of about 0.131 percent.

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[3] USDA NRCS, 1996

[4] However, two different maps by the Oregon Climate Center maps show precipitation amounts at the summit of Mount Hood as 140 inches and 200 inches, respectively. The Oregon State Highway Division (1972) reports precipitation in the headwater area as 110 inches.

▪ **Nearest gauging station:** USGS gauge #14142500 below confluence of Bull Run River at River Mile 18.4, approximately 5 miles above Oxbow Park. Drainage area for this gauge is 436 square miles.

▪ **Extremes for period of record** at this gauge:

Lowest discharge: 45 cfs on Sept. 26, 1962..[5]
Maximum discharge: 84,400 cfs on Dec. 22, 1964.[6]
Extreme for 1996 flood (Feb. 7, 1966): Maximum discharge: 68,600 cfs.[7]
Extreme for 1999 (midnight,Thanksgiving Day, Nov. 25) flood: 57,300 cfs.[8]

▪ **Flow.** Flow regulated since 1915 by Bull Run Lake, since 1929 by Bull Run Reservoir Number One (station 14139000), and since 1961 by Bull Run Reservoir Number Two (station 14139900). Some fluctuation is caused by Bull Run power plant of Portland General Electric Company.[9] According to Doug Cramer, PGE fish biologist at the Faraday Dam station, the withdrawal of water for residential use by about 1 million people in the Portland metropolitan area does not have much effect on discharge or flow regime at Oxbow Park. [10] Minimum flows for fish, wildlife and recreation were guaranteed in about 1991 by the Diack Decision of the Oregon State Legislature. Land uses and urbanization in the Sandy River probably do not influence flow regime at Oxbow Park because the watershed remains predominantly in forest cover. [11]

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[5] USGS Open File Report 93-63, 1993.

[6] USGS Peak Flow Data: .../peak.cgi?statnum=14142500

[7] Ibid.

[8] Unpublished data from Jo Collins, USGS, Cherry Park office, Portland, Oregon.

[9] Ibid.

[10] Conversation with Doug Cramer, PGE fish biologist, 7-14-00: At gauge 14142500 (just below the confluence of the Bull Run River), late summer - early fall flows are about 150 cfs higher than natural flows would be. High flows (Dec.-Feb.) are not affected by withdrawals because the reservoirs are full and passing water at this time. The withdrawal makes the biggest difference during April, when existing flow at gauge 14142500 is 1500 cfs, but natural flow would be 1200.

[11] From conversations with hydrologists Julie Lou Clark at Portland DOGAMI (6-2-00) and John Barber at the Salem office of BLM (5-30-00).

II. A word about rivers

The introductory remarks in this chapter are intended to provide a general overview of the dynamics of streams such as the Sandy River, i.e., streams that rise in the mountains and erode steep channels in their headwater zones; which transport plentiful sediments through confined, bedrock canyons; and, as in the case of the Sandy River in Oxbow Park, are cobble-bedded systems in their lower reaches. *Chapter III*, following this chapter, contains a discussion of the dynamics of the Sandy River itself.

The sediment source zone

A stream rising in the mountains and flowing to a low-gradient lowland functions like huge conveyor belt to move earth materials from higher to lower ground. Thus, a watershed can be considered an open system in which energy and earth materials are moving toward the lowest place in the landscape.

In the uppermost zone of a watershed in mountainous terrain, materials are delivered to confined channels by gravitational or mass wastage processes: rock fall, debris avalanches, landslides, creep and ravel. Once in the channel, this rock material grinds, bumps and rubs against the streambed and banks, incising the bed and undercutting the slopes above. A channel that receives sediments by means of gravity is called a *colluvial* channel.

The channel materials may be so large in the sediment source zone that their presence in the channel makes water flow around them, further undercutting the steep hill slopes. These processes eventually result in back-wasting of the slopes that bound the channel and gradual widening of the channel and its valley.

Sediment deposition in the channel may occur in the sediment source zone, but deposition is forced by channel obstructions such as large rock and woody debris. These obstructions may be remarkably stable or may fail in large flow events, resulting in pulses of sediment being moved downstream all at once.

All of these conditions are present in the headwater zone of the Sandy River watershed, and they contribute sediments to the river in Oxbow Park, as will be discussed in greater detail later in the next chapter.

The sediment transport zone

An interesting and dynamic zone of stream sediment transport and deposition is present below the upper watershed's steep, turbulent, colluvial channel. This zone, sometimes referred to as an alluviated canyon, is different from the headwater zone in that it has more water and is not as steep. These factors combine in the alluviated canyon to erode the channel margin, which becomes veneered with boulders, cobbles, gravel and sand washed from higher up in the watershed and deposited there during high flow events. Although these deposits may be colonized by riparian plants, they are subject to periodic inundation and flood disturbance. When advanced successional stages of riparian plants are present on the floodplains of alluviated canyons, it may appear as if the floodplains are abandoned features no longer used by the river.

But in fact, the sediments stored at the river's margin in alluviated canyons are usually in temporary storage during long-term transit down the river corridor. The corridor may be understood as a dynamically balanced system in which, over time, the amount of sediment entering this zone is roughly equal to the amount being transported out. After a big flood event, floodplain deposits and the active channel bars may appear to have remained in place, but in actuality, much sediment has been carried downstream and has been replaced by fresh sediment transported from upstream.

The Sandy River in Oxbow Park is in an alluviated canyon, as will be discussed in greater detail in the next chapter. Sediment sources are plentiful and sediment transport through the canyon is dynamic.

The sediment deposition zone

Large rivers typically erode their uplands and transport the rock detritus of this erosion downstream to the point that decreased gradient allows its deposition. In this way, floodplains are developed. When a stream in its floodplain overtops its banks, it spreads out. The resulting loss of velocity allows it to drop its load, and in this way, floodplains continue to be built. Floodplains and riverbanks in these low-gradient, alluvial settings also continue to be reworked by stream energy; this reworking is evident as streambank erosion and sediment deposits after high water events.

As discussed in the section above, the lower Sandy River through Oxbow Park is confined in an incised, alluviated canyon. The stream has a very low gradient in the park, and lateral erosion processes have created limited floodplains in some river reaches in the park. Yet very deep deposits of fine-grained channel margin alluvium confine flood flows to the channel in other reaches, resulting in dynamic bank erosion at some locations during high flow events. After these events, dynamic sediment deposition occurs in other channel locations. The next chapter of this report explains the source of this alluvium and its effect on the dynamics of the river in Oxbow Park.

Factors governing channel shape

Four major variables define the shape of an alluvial river channel: discharge at bankfull stage, the amount and particle size of sediments, and the gradient of the stream. When one factor changes, the others will adjust. Contrary to former belief, channel shape is controlled not by catastrophic events, but by bankfull flow. This is the dominant high flow conveyed by the channel — the one that occurs about once each year.

Bankfull discharge moves the most sediment and water for the least amount of energy. At low flow, the slope of the water in pools is much flatter than the slope of the water in riffles. This phenomenon accounts for the pool-and-drop nature of many low-gradient streams during low flow. But during bankfull flow, the differences in the slope become balanced out. Thus, bankfull flow achieves an efficiency to convey both discharge and sediments.

In alluvial streams (streams that cut their channels through materials previously transported and laid down by rivers), the meander is the most efficient way in which gradient and velocity are balanced under varying conditions of discharge, sediment load and channel roughness. The meander enables large rivers to run rapidly on the gentle slopes of their lower reaches. Contrary to popular belief, mountain streams cascading down their steep, bouldery channels flow at about the same speed as alluvial streams on floodplains — about 3 to 5 feet per second.

Streams deposit sediments in zones where there is less velocity. Thus, channel bars can regulate channel efficiency by confining the flow to an efficient shape with the least frictional surface and the greatest depth. Here's how it works: As discharge from storm runoff decreases, sediments begin to settle out because the stream's competence to carry them is diminishing. Where sediments are deposited in a bar, the bar contains the diminished flow within a smaller and more efficient channel.

Both upstream and downstream of the boat ramp in Oxbow Park, mid-channel bars occupy part of the active channel during low flow conditions. These deposits regulate the channel cross-section, allowing efficient conveyance of discharge with minimal frictional resistance.

Flow and channel dynamics in alluviated canyons

The direction of flow during big events in alluvial systems can be surprising. When the discharge no longer fits within the sinuous low-flow channel and spreads out to occupy the floodplain, the channel is effectively straightened and steepened. This can result in flow direction during a big event being 90 degrees or more different in some areas than direction of flow during low flow.

Shear stresses on the banks during large events can result in dynamic bank deformation in places where it may not be expected. Yet cobble- and gravel-bedded streams are characterized by having deformable boundaries. Other characteristics of such streams include: 1) a channel bed surface that is frequently mobilized (each 1-2 years); 2) periodic channel bed erosion and fill; 3) periodic channel migration; and 4) infrequent channel resetting floods (10-20 year recurrence).[12] The larger materials of cobble-bedded systems tend to become armored by the deposition of smaller grains between them. It takes a threshold, mobilizing flow to dislodge the packed materials, and when this occurs, the entire bed to a depth of several grain diameters may be moving.

Deformable bed streams are expected to cyclically reset their channels. The new channel will have the same radius of curvature, width, pool-riffle ratio and gradient as the old. The dynamics involved in avulsion (a channel-resetting event) can also disturb riparian plant associations, and this contributes to habitat diversity in the alluvial stream corridor.

The Sandy River at Oxbow Park is a cobble-bedded stream having dynamic sediment transport and channel materials capable of rapid adjustment to changes in discharge. The next chapter discusses the sediment sources and their relation to the morphology (change) of the river and channel margin areas in Oxbow Park.

III. The Sandy River

A "gravel-rich" system

A quick glance at a topographic map or aerial photo of the landscape west of Mount Hood in the northern Oregon Cascades reveals the strikingly deep canyon of the 55-mile long Sandy River and its equally striking incised meanders at Oxbow Park. About 2 million years ago, the river meandered freely at about sea level along the eastern edge of the Portland Basin. Tectonic movements and up-arching of the

[12] Trush, Bill; Rocky Mountain Research Station, Stream Systems Technology Center, January 2000.

Cascade Range caused the river to cut downward, creating the Sandy River Gorge [13] and entrenching the river's former meanders in stone (*please see Figure 4 on the following page*).

Downcutting exposed geologic strata in the canyon walls, from the most recent basalt lava flows of the volcanic Cascades and Columbia Plateau, to massive gravel deposits from the ancestral Columbia River, to 10 million-year-old fine-grained lake deposits of mudstone, sandstone and siltstone. [14, 15] The rising Cascades created a steep gradient for the short river, which allowed it to cut down through these materials.

Various sediment sources

Direct stream erosion of gravel-bearing strata is one source of sediments to the modern-day Sandy River system. Landslides and debris flows on the steep inner gorges of the river is another (*please see Figure 4, next page*).[16] Glacially-derived sediments are transported into the system from moraine deposits in the Brightwood area and other locations in the upper watershed.[17] Channel downcutting and valley widening processes also add rock detritus to the river system. All these sediments are transported downstream to the lower reaches of the river where decreased gradient and velocity allow their deposition. The relatively low gradient of the river and the moderate valley confinement at Oxbow Park make this reach of the Sandy a dynamic zone of sediment deposition and transport.

An important additional sediment source is recent volcanic activities originating near Crater Rock on the south flank of Mount Hood. Eruptions in this vicinity produced two periods of lahar flows: one episode associated with the Timberline eruptive period at around 1400 to 1800 years before the present,[18] and the

[13] Allen, 1983.

[14] Oregon State Highway Division, 1972.

[15] Oregon State Parks, 1983.

[16] USFS, 1996.

[17] Swanson, 1989.

[18] Cameron and Pringle, 1986, 1987.

Figure 4: The inner gorge of the Sandy River.

This image of the inner gorge of the Sandy River in the vicinity of Alder Ridge (top) and several miles of river upstream, is a printout of a GIS data layer provided by the Mt. Hood National Forest. Data layers for trees, roads, political boundaries, etc. have been turned off, accentuating the steep, incised nature of the gorge. No scale. Date unknown.

other episode associated with the Old Maid eruptive period, as recent as 1750 to 1800.[19, 20] These relatively recent eruptive periods influence river margin topography and channel morphology throughout Oxbow Park.

The flows occurred when portions of a growing lava dome collapsed, producing hot rock avalanches (also known as "block and ash flows") that rapidly melted snow and ice in their paths. The resulting rapid downslope flows mobilized these volcaniclastic materials together with material derived from glacial activity on the mountain and other sediments and rock detritus. The fast-moving mixture of water and rock quickly became very dense slurries, almost like wet concrete. [21, 22] Some of these very viscid flows from the Timberline eruptive period may have extended all the way to the Columbia River and their sediments may have been much larger than those of the Old Maid flows.[23] The debris flows from the Old Maid period extended to about the Brightwood area, although runout deposits have been noted as far downstream as the community of Alder.[24]

In the years following the lahars, runoff and subsequent high stream flows moved large quantities of the readily erodible unconsolidated volcaniclastic sediments far downstream in the Sandy River system. These materials and other sediments that were mobilized were rapidly deposited as massive, deep deposits in the river channel and, where they were present, in the adjacent floodplains.[25] The depth of these deposits in the Sandy River system have been noted as 40 feet or more.[26] This aggradation raised the level of the channel considerably.

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[19] Pierson, personal communication, June 12, 2000.

[20] Cameron (1986) notes that radio carbon dating and dendrochronological work places the Old Maid Eruptive period between 180 and 300 years before the present. Cameron also identifies a third eruptive period: the Zig Zag period, between 400 and 600 years before the present.

[21] This kind of lahar is often termed a debris flow.

[22] Pat Pringle gives a first-hand account of a lahar flow on Mount St. Helens on May 14, 1984 in USGS Professional Paper 1586.

[23] Pierson, personal communication, August 1, 2000.

[24] Cameron, 1991.

[25] Pierson, personal communication, June 12, 2000. Pierson notes that sediment mobilization by post-eruption rainfall can result in dramatic vertical aggradation of downstream riverbeds. Pierson's studies of Mount St. Helens, (Washington) and Mount Pinatubo (Philippines) show that river-beds can show net rises as much as 20 meters to 30 meters within only a matter of months and within 50 km of the source.

[26] Cameron, 1991.

Geologists now think that Lewis & Clark's 1805 description of the mouth of the Sandy River (like quicksand; very shallow and 200 yards wide at the narrowest part) [27] accurately portrays what this area must have looked like in the years following the Old Maid lahars.[28] The large delta at the mouth of the Sandy River, veneered with 200-year-old sediments, is evidence of thousands of years of this dynamic transport and deposition.[29]

Rapid, recent burial of streamside forests, and subsequent rapid river incision

As the Sandy River cut down through these massive river valley deposits in the vicinity of Oxbow Park, terraces were eroded, corresponding to periods of erosional incision. Geologist Tom Pierson of the U.S.G.S. Cascades Volcano Observatory in Vancouver, Wash., is studying and mapping these terrace surfaces at the park. This work is being undertaken as part of a regional hazards analysis of downstream effects of future eruptive activity at Mount Hood.

Pierson has identified five to six distinct terrace surfaces in Oxbow Park. The terraces from the 1500-year-old Timberline eruptive period are the highest in elevation. The highest, terrace remnant L6, is at the point where the main park road leaves Group Picnic Area A and comes to the top of the first low rise heading west.

Three lower-elevation terraces stem from river erosion of massive deposits from the more recent (200 to 250 year-old) Old Maid eruptive period.[30, 31] Stream-side forests were quickly buried by the deposition following the Old Maid lahars;[32] these have been partially exhumed in the park by the high flows of 1964, 1996 and 1999.[33] Photos of Oxbow Park after the 1964 event show exhumed trees in upright, growth positions in the vicinity of present-day Group Areas 'A' and 'C' (*please turn to the project photo pages in the*

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[27] Lewis and Clark's description of the mouth of the Sandy River in is cited fully in Ciecko, 1982.

[28] Cameron, 1987; Pierson, personal communication, June 12, 2000.

[29] Pierson, personal communication, August 1, 2000.

[30] Pierson, personal communication, June 12, 2000.

[31] Pierson has located two additional depositional surfaces in the park that are relicts of other catastrophic events: the Missoula floods and the Bridge of the Gods landslides.

[32] Cameron, 1991.

[33] Pierson, personal communication, June 12, 2000.

appendix of this report to see these images). There is a newly-exposed tree in an upright position off-shore of the present-day riverbank just downstream of Group Camp #2 (*please see photo pages in the appendix).*The surface on which this tree is growing is below the present-day riverbed. Other exhumed forests have been recorded both upstream and downstream of the park.

Upstream in the park, Pierson's preliminary field analysis and mapping indicate episodes of river erosion that have created stepped-down terracing close to and parallel with equestrian trail 'L' - 'J.' A person driving the maintenance road to Group Camp #2 cannot help but notice this stair-step descent of the terraces. About midway between trail points 'J' and 'M,' terraces L4, L3 and L2 disappear because they have been obliterated by river erosion.

Terrace L1, the lowest-elevation terrace, is being actively eroded in the vicinity of Group Camp #2 and downstream to "The Point," which is opposite the outcropping of Boring lava near the mouth of Trout and Gordon creeks. A comparison of aerial photographs spanning the 63 years between 1935 and 1998 shows marked loss of riverbank in this vicinity. Pierson's preliminary mapping suggests that terraces L1, L2 and L3 have already have been removed by river erosion in the vicinity of the boat ramp.

A person kayaking from above Oxbow Park to the lower park take-out can observe how the river becomes more deeply incised in the terrace material on the way downstream. This is consistent with what would be expected of a river in the process of cutting down through alluvium to a new base level. Headcuts migrate in an upstream direction. The lowest-elevation terraces in the park already have been removed by erosional processes which, incrementally, are moving upstream.

There is an extensive floodplain on the Diack property just above the park that is easily inundated by high flow events and is only a few feet in elevation above the active channel bar. Several feet of sand were recruited to this floodplain during the '64 flood event. The '96 and '99 events also saw some action on this active floodplain.[34] Other active floodplains are present on the reach of river between Dodge Park and the Diack place.

Continuing down-river from the Diack floodplain to the vicinity of Group Camp #2, the riverbanks are higher and less easily inundated. Shear stresses on the low-cohesion sand banks during normal bankfull events (as well as during flows of greater magnitude) are eroding the banks. In the Thanksgiving Day 1999 event, lateral erosion not only removed a significant amount of bank, but exhumed a tree in growth position that presumably was buried in the sediments washed downstream and deposited after the Old Maid Lahar. The surface on which this tree was growing is below the elevation of the present-day riverbed.

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[34] Sam Diack, personal communication, June 15, 2000.

What these findings mean with respect to current streambank erosion

These findings suggest that the Sandy River in Oxbow Park has not yet incised down to the elevation of the channel prior to the Old Maid deposits which raised the elevation of the channel in the park. Incision appears to be proceeding in an upstream direction, as would be expected. The lower river (from Oxbow Park to Dabney State Park) drops about 8 feet per mile over a length of 4.5 miles, for an overall gradient of 0.15 percent.[35] However, the amount of fall in the river between River Mile 13.5 (near the upper park boundary) and River Mile 11 (in the vicinity of the pump station) is 38 feet[36, 37] for a local gradient of 0.28 percent, about twice as steep as the gradient of the lower river. Terraces L1 and L2 are actively eroding in upper Oxbow Park. Below 'M', these terraces already have been removed by erosion. Therefore, terraces L4 and L5 are the actively eroding terraces below 'M'. This is consistent with the 63-year record in aerial photographs as well as anecdotal evidence concerning the 1964 flood.[38] Pierson is still collecting data to map terraces downstream of the pump station in the park.

Aerial photographs for a 63-year period suggest that the floodplain at Camp Collins is dynamically stable. The photos show that cottonwoods, alder and other floodplain vegetation appear to grow, flourish, and undergo various levels of disturbance due to flooding. The channel changed location after the 1964 flood, when it moved north about 1/4 mile, against the confining canyon wall. Remnants of the pre-1964 channel are present today as a high flow channel on the back of the floodplain. Students in the Watershed Resources class at Mt. Hood Community College have surveyed transects from the edge of the present-day channel in this vicinity, which cross the relict channel, and end at the terrace above it. These surveys show that the present-day channel bottom is below the elevation of the relict channel bottom. These data suggest modern-day incision in this reach.

It is interesting to note that the flood events of 1996 and 1999 did not result in erosion of the terrace in the vicinity of Camp Collins. In contrast, "The Point" in the vicinity of Group Camp #2 is incrementally losing ground. This appears to be the result of meander compression where the river encounters resistant geologic material on river right near the mouths of Gordon and Trout creeks. The bar just upstream of this

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35 River Descriptions. Http://kayak.physics.orst.edu/~tpw/kayaking/d.htm

36 USGS, 1926; USGS topographic quadrangle for Sandy, Oregon, 1985.

37 These are not exact elevations due to the age and coarse contour data available.

38 Oxbow Park Supervisor Jim Lind notes that the main park road had to be relocated after the '64 flood because sections of it were obliterated between the pump house and Group Picnic Area 'A'. The road was nearer the river than in is today, on terrace L 4/5.

point appears to be forming as a result of the backwater effect of this constriction. The bar below "The Point" appears to be the result of expansion after the constrained point has been rounded.

Relation of geologic controls and confinement to riverbank erosion

As a kayaker rounds "The Point" and proceeds downstream to the boat ramp, it is apparent that the riverbanks get higher and that there are resistant bank materials all along river right in this reach.[39] Shear stresses during bankfull and greater discharges appear to be causing chronic bank retreat on river left in this location. This is notable, because the inside bend of a generalized stream would be expected to be a shallow-shelving zone of deposition and temporary storage of sediments. However, fresh trees are down all along the vertical inside bank from approximately 'M' to the boat ramp. Bank materials are coarse, angular gray lahar sands with a few cobbles, gravels and small boulders. The foot of the bank is armored by lag deposits, which are the heavier rock materials that are left behind after the lighter ones have been transported away by high flows. The lag materials themselves also are subject to being transported downstream by the increased velocities of high flows. Thus, chronic bank erosion occurs as shear stresses erode the easily eroded materials in the *inside bend of the river* in this location, and the resulting over steepening of the bank causes slumping of the low-cohesion sands of which the bank is composed. Trees fall as the bank becomes undercut, and the bank retreats.

Moving downstream past the boat ramp, it is interesting to note the extensive mid 1960s concrete bag revetment that extends to approximately the vicinity of Group Picnic Area 'A'.[40] The revetment functions somewhat like the natural geologic controls on the opposite bank just upriver, in that it limits bank deformation during high flows. There is a long mid-channel bar opposite the revetment. Beyond the bar on river right in this location, there is an extensive, low floodplain, which serves to accommodate and dissipate high flows in this reach. The reduction in channel confinement in this reach is important because it allows dissipation of flood flows which otherwise would rise higher on the sand bank near Group Picnic Area 'A'.

The terrace above the revetment (which is terrace level L4 /5, according to Pierson) is high above the river. The revetment, 30 or more courses high, appears to have served its purpose in armoring the steep, sandy bank from chronic erosion and collapse. However, it appears that shear stresses at the foot of the

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[39] These materials include outcroppings of Boring lava, Troutdale formation and Sandy River mudstone. Floodplain development in this reach is minimal.

[40] Park archives relate that the 1/4-mile bank protection structure was a Youth Conservation Corps project implemented in the wake of the 1964 flood.

revetment may have undermined it in sections, causing the structure to settle. Flanking behind the revetment is beginning to occur in places. The fact that each "unit" of this remarkable bank protection facility has the capability to move independently of the others may have contributed to its surprising longevity. Ironically, the hard surface here may keep the thalweg (deepest part of the channel) close to this bank. This typically occurs because hard surfaces at the water's edge do not dissipate wave and current energy but reflect them, which enhances the capability of the stream to transport sediments here.[41] Thus, local scouring becomes the unintended result of bank hardening.

Sediment transport and deposition in the channel

A review of aerial photos between 1935 and 1998 allows some broad conclusions to be made about the morphology (change) of the channel during this 63-year period. Fifteen historic aerial photos are included in *Appendix 3* of this report so that readers can refer to them while reading this section. *Figure 3* on page 4 can also help orient readers. Please note that absolute comparison between photographs is not possible due to the differing river stages at which they were taken, as well as differing photo points and flight elevations for each photo. The locations of points 'C', etc. can be found on the excerpt of the Oxbow Park map in *Figure 1* on page 2. The apparent changes during this 63-year period include (beginning from upstream):

- There has been steady erosion of the inside bend of the river in the vicinity of Group Camp #2 on the upstream side of "The Point" of Alder Ridge due to compression of a meander loop by resistant geologic materials at the mouths of Gordon and Trout creeks. Although it is not possible to make absolute comparisons of these changes among the available aerial photos of the site, three photos by Bergman for the years 1974, 1977 and 1988 can be compared. During this 14-year period, the distance between the bank and an individual tree in the vicinity of Group Camp #2 diminishes from about 120 feet to 60 feet.

  Channel incision also appears to be taking place in the vicinity of Group Camp #2, where the '99 event exhumed a bole in growth position. This stump is in the present-day low-water channel, but is rooted below the present-day level of the channel bottom.

- Concomitant with this change is steady growth of a river bar opposite this bank in the vicinity of the mouths of Trout and Gordon creeks. This bar appears to have been formed by deposition forced by

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[41] Reflecting the relationship between hard surfaces and local stream competence, the pool just offshore of the Boring lava outcrop opposite "The Point" measured 16 feet deep on June 24, 2000.

a narrowing of the channel where the river encounters resistant geologic material at the mouth of Gordon Creek and is forced to take a sharp bend to the northwest. Over the period of record, the bar has been growing in the downstream direction as well as laterally, into the channel. The 1935 and 1956 photos show the downstream tip of this bar roughly half-way between the mouths of Gordon Creek and Trout Creek. By the 1998 photo, considerable deposition has occurred on the downstream end of this bar, so that Gordon Creek must now flow north behind the bar before entering the main channel of the Sandy River.

- The growth of this bar forces the main channel against the opposite bank (river left), which has resulted in a shift in channel alignment (and corresponding bank erosion) in this section of river during this period. The shift is west and north, toward Alder Ridge. It is interesting to note that the radius of curvature of this section of river has remained the same, however, except around the tight point.

- Riparian corridor vegetation gradually has become established on the bar at Gordon and Trout creeks. The 1935 and 1956 photos show no vegetation at all on this bar. The 1966 photo shows the bar almost swept clean by the 1964 flood. The abundant riparian forest vegetation present on this bar today suggests that the flood events of 1996 and 1999 did not attain high enough depths or velocities to significantly disturb the older vegetation on the higher portions of the bar. It is possible that incision is taking place in the river channel in this location. The 1999 event exposed a tree stump in the channel near this bar. The tree was probably buried by lahar outwash from the Old Maid eruptive period, and is rooted below the level of the present-day channel. Also exposed in the cannel in this location were a line of large boulders, possibly derived from the coarser-grained Timberline lahar, or eroded from the Troutdale or other materials of the canyon walls.[42] These conditions suggest that the channel is incising in the vicinity of the Trout Creek-Gordon Creek Bar.

- A low, crescent-shaped forested terrace including and extending upriver from the boat ramp appears to have become narrower and less extensive over the aerial photo period of record. This is consistent with the preliminary terrace mapping in the park by geologist Tom Pierson, which indicates an L4 terrace remnant in this area. This terrace level has already been eroded away upstream of 'M'; in recent years, chronic bank erosion has undermined sections of trail between the boat ramp and' M.'

- A narrow, channel-margin beach or shingle (a steep beach consisting of cobbles) upstream of the boat ramp *may* have disappeared over time. However, differing photo points and different river stages at the time the photos were taken could account for this apparent change. Present-day field evidence

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[42] Conversation with geologist Tom Pierson, June 12, 2000.

indicates that the bank is retreating slowly in this section of the river, as discussed in the bullet item above.

- A mid-channel bar has formed in the river upstream of the boat ramp opposite this retreating bank. The bar presently confines the active channel nearest the south, or retreating bank. In summer, the deepest part of the channel was observed to be close to the mid-channel bar.[43] However, those familiar with the river in winter note that the deepest part of this reach is near the retreating bank.[44]

- A jam of large woody debris has grown upstream of the boat ramp on the opposite bank.

- The channel is narrowest in the vicinity of the boat ramp, where it is directly confined by geologic materials on the outside bend (river right). A toe-point sediment sampling transect of the channel about 200 feet above the boat ramp found that bed materials have greater embeddedness and imbrication than bed materials on a broader reach several hundred feet below the below the boat ramp in a broader reach of the channel. This condition reflects the higher velocities in the upstream location — velocities that erode a deep pool at the base of the outcropping Sandy River mudstone opposite the boat ramp. Park Supervisor Jim Lind notes that this pool, formerly with a summer depth of about 14 feet, has become somewhat shallower in recent years. He also notes a *decrease* in the elevation of ordinary high winter flows opposite the pool on the point bar where the boat ramp is located. These conditions suggest both incision *and* pool filling in this reach.

- Just downstream of the shingle (rock) beach at the boat ramp, the channel widens, velocity lessens, and deposition is possible. Park personnel note that there has been dynamic deposition in this area in recent years.

- Below this point, a long, mid-channel bar begins. This bar extends downstream to approximately opposite Group Picnic Area 'A'. In the 1966 photo (after the 1964 flood) this bar is bare. However, in photos after 1988, the bar is vegetated. Young alder and ash remained undisturbed after the flood events of 1996 and 1999. It is interesting to note that the downstream sides of this bar are vertical and well above the river, not shallow shelving, as is the downstream tip of the mid-channel bar that ends just upstream of the boat ramp. These conditions suggest channel incision in this portion of the river.

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[43] This entire reach can be waded. The deepest part of the channel during summer flow conditions is only about a foot deeper than average channel depth.

[44] Lind, 6-6-00; Ciecko, 8-15-00.

At the downstream tip of this bar, an orange, stained horizontal layer in a vertical exposure suggests a former bar elevation at which oxidation and reduction processes have taken place in the presence of groundwater. Also present in this vertical exposure is a striking imbricated cobble layer overlying sand — a textbook example of characteristic channel armoring. The exposure of these features well above ordinary water level strongly suggests that channel incision is taking place in this section of the river. This incision would be expected to be moving upstream, possibly contributing to forces undermining the concrete revetment.

The bank opposite the revetment bounds an extensive floodplain where, during overbank flow events, sediment deposition takes place. Deposits here may be *forced* by the backwater effect of a low ledge of very large angular boulders that extends into the channel just upstream from the park pump station at 'C'. It is likely that sediment generated upstream will be deposited in this location, possibly crowding the active channel closer to the revetment. However, if deposits here accumulate to the point that they prograde into the channel, it is possible for the main channel to shift away from the revetment.

IV: What these findings mean with respect to dynamics at the boat ramp

Where the sand goes

Present-day conditions at the point bar where the boat ramp is located are not conducive for the recruitment of sand despite evidence of plentiful sand in the transport system. Several factors appear to be contributing to this: back beach hardening, naturally occurring erosion of the immediately upstream of the boat ramp, locally increased velocities and channel incision.

Back beach hardening. Hardened surfaces (asphalt and gunnite) in the back beach area of the point bar have very little surface roughness. Therefore, during periods when high flows cover the bar, flow velocities may be magnified. Where high flows formerly rose over the point bar, they gradually became shallower. Because of the decreased velocity in the shallow zone, they dropped their load of sand. Now, however, high flows likely are accelerated along the hard, smooth surfaces. This increased flow energy has the potential pick up the sand and transport it away. A skeletal beach is left behind, composed only of boulders and cobbles too heavy to be transported by the flows velocities here.[45, 46].

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[45] The following excerpt from the seminal work of the Washington Department of Ecology on coastal zone erosion is offered, with the caveat that although river erosion processes vary significantly from coastal processes, the physics of the impacts of back beach hardening remain the same.

Washington Dept. of Ecology, Shorelands and Coastal Zone Mgmt. Prog., Oct. 1991
Coastal Erosion Management: Annotated Bibliographies on Shoreline Hardening Effects, Vegetative Erosion Control, and Beach Nourishment
By Terich, Thomas A. et al, Washington State University:

"The proliferation of sea walls and other hard erosion protection structures has prompted researchers to study their possible impacts to beaches. A review of the contemporary literature shows that a majority of the published work on the subject finds sea walls in some way aggravate the pre-existing erosion of beaches. Researchers commonly concluded that sea walls change a dissipative beach into a reflective beach (Rosenbaum, 1976) leading to increased wave reflectivity and beach scour (Griggs, 1988). Silvester (1978) found the presence of sea walls to double the applied littoral energy to the sedimentary bed leading to increased scour both in front of the wall and some distance downcoast. Fosher (1986) concluded that the beach in front of sea walls all but disappears due to increased wave scour. In both laboratory and field investigations, (McCougal,1987) measured the excess depth of scour erosion to approximate 10 % of the seawall length. Similarly, Birkemeier (1980) indicates a one to one relationship between the depth of toe scour and incoming wave heights.

"Increased littoral zone turbulence and beach scour leads to a general lowering of the beach profile (Dean 1983) and possibly a narrowing of the beach as well. However, narrowing might also result from a reduced

Channel incision. The second condition that may contribute to the sand-starved condition of this point bar is recent channel incision in this reach. Field evidence strongly suggests that channel-resetting flows and channel incision occurred in portions of the channel in the 1964, 1996 and 1999 events. In channel resetting events, the entire riverbed is mobilized by high shear stress, saltating (bouncing) bed load and high flow forces. The imbricated (packed together) boulders and cobbles that armor the bed are knocked loose by these forces and go into transport. When the high flow subsides, the bed materials "re-set" in a changed vertical and/or horizontal location.

Three areas with evidence of active, current channel incision were noted in the park during this study: one at the lower take-out, one at the lower end of the mid-channel bar opposite the revetment and one in the vicinity of Group Camp #2. Anecdotal evidence suggests that incision may be taking place in the vicinity of the boat ramp. If this is the case, late spring and early summer flows would not extend as far onto the point bar as formerly. Therefore, the portion of the bar normally inundated by these flows would be beyond reach of summer sand movements.

Summer sand movements are an important factor in beach nourishment. During late spring and early summer, when water levels are still somewhat high but velocities have diminished, a veneer of river sand is deposited in the foreshore area before the water level drops. These river sands are finer, more rounded and lighter in color than the large, angular, dark gray sand of the lahar terrace. Late spring sand shoaling was observed during this study behind the mid-channel bar just upstream of the boat ramp and at various other

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sediment input due to the presence of a structure (Hansen, 1986). Clayton (1988) concluded that up to 70 % of the natural beach sediment supply had been reduced due to sea walls along a stretch of the English coast.

"Sea walls also appear to have adverse impacts to adjacent beaches. Wave reflection and scour transfers energy stresses and reduced sediment inputs to nearby unarmored beaches (Griggs, 1988). Laboratory data revealed an along coast length of erosion to be approximately 70 % of structure length (McDougal,1982) (Komar, 1988)."

[46] Classic cases of beach starvation due to construction of hard surfaces in back beach areas can be seen at Kelley Point Park and Sellwood Park in Portland. In the mid-1980s, Sellwood Park on the Willamette River was re-designed and upgraded. New structures in the park included retaining walls in the back beach areas. These retaining walls created a clear boundary between the beach environment and non-beach uses directly inland. The walls were well beyond the reach of summer waves. The depth of the sand on the beach came to within a foot or so of the top of the retaining walls. Within a few years, however, the park's sandy beach began to disappear. Today, almost all of the sand from the beach is gone. The beach now consists of gravel lag deposits overlying a residual, erosion-resistant silty clay layer. Large rock has been brought in to defend the walls from being undermined by wave attack. The same cycle of degradation has occurred, ironically, at sites hardened to withstand wave attack, at Kelley Point Park on the Columbia River in Portland.

places. Park managers commented that ordinary summer river levels at the boat ramp are not as high as in the recent past and that the amount of sand migrating onto the foreshore is not as great as in prior years.

The downstream end of the mid-channel bar below the boat ramp has high, vertical banks revealing an oxidized layer and imbricated cobbles. These features suggest that this channel bar may be a remnant of the former channel surface in this zone. This is consistent with the photographs of the '64 flood in this area, which show exhumed trees uncovered by this flood in this exact location.

Naturally occurring streambank erosion immediately upstream of the boat ramp. The 63-year record of aerial photos suggests an on-going retreat of this bank, even before the area was developed as a boat ramp. Pierson's preliminary mapping of terraces in the park shows a very limited terrace L4 in the vicinity of the ramp. Park trails at the river's edge on this terrace repeatedly have been washed out in recent decades. This evidence suggests that terrace L4 downstream of the ramp already has been removed by erosion and that erosion will continue to diminish the extent of the remaining portion of L4 upstream of the ramp. The continuing loss of the sheltering bank upstream of the boat ramp has resulted in more direct flows over the point bar and subsequent transport of fine materials off the bar. This is discussed in greater detail below.

Locally increased velocities. In the reach between the mouth of Gordon Creek and the boat ramp, there is very limited or no floodplain. The river is confined on the outside bend by geologically resistant materials and on the inside bend by the terrace. Because of these conditions, discharges up to about the 25- or 30-year event are contained within the river banks. This confinement results in high shear stresses on the banks; hence, chronic retreat of very highly erodible banks on river left upstream of the boat ramp, as discussed above. Chronic erosion of this sandy riverbank generates sand, which is transported downstream. Some sand would be expected to be deposited on the shallow-shelving point bar at the boat ramp. However, this appears not to be the case.

A mid-channel bar formerly present below Buck Creek disappeared in the recent high water events. This suggests that velocities increased in this section of channel, probably due to the deposition of a several-acre expansion bar downstream of "The Point." This large, high, expansion bar literally squeezes the channel against the far bank (river right), which is composed of geologically resistant materials: Boring lava, Troutdale formation and Sandy River mudstone. The river bounces off these hard materials and swings back to the straight, inside bank, where, it grinds away, chronically eroding the bank all the way down to the boat ramp.

As stated above, in the 63-year record of aerial photos, this bank consistently has a bright, fresh appearance. The earlier aerial photos show a remnant, crescent-shaped terrace extending upstream of the boat ramp. This is probably terrace L4, according to Pierson's preliminary mapping of terraces in the park. In more recent photographs, this terrace is somewhat obscured by more mature vegetation and is difficult to identify in aerial photos. However, Pierson's preliminary mapping shows this terrace to be less extensive than it appears in the 1935 aerial photo.

All of these factors point to slow, steady and ongoing erosion of the terrace upstream of the boat ramp. It appears that erosion of this terrace may have resulted in increased near-bank velocity immediately upstream of the point bar, diminishing opportunity for deposition of sand in this area.

The mid-channel bar that tails out just above the boat ramp appears to have been present, in greater or lesser form, during the entire aerial photo period of record (63 years). This suggests that the reach between "The Point" and the boat ramp is functioning as a somewhat stable sediment transport reach, meaning that velocities are adequate here to transport the sediments delivered to it. The channel in this reach is widening but the mid-channel bar maintains the main flow against the sandy riverbank.

Summary. In summary, sediment production processes appear to be generating sand upstream of the boat ramp, and transport processes are moving it downstream. However, shallow and low velocity flow conditions no longer exist in the back beach that would allow the deposition of sand here. In addition, the level of the channel bottom may also have become lower, due to incision, leaving the higher elevations of the point bar less accessible to late spring-early summer processes that might otherwise deposit sand there. Incremental erosion of the terrace upstream of the point bar has left the point bar more vulnerable to erosion from more direct flow.

V: Options for protecting the ramp and platform

The factors contributing to erosion conditions at the boat ramp can be separated into those occurring because of natural agents and those caused by people. The preceding chapters of this report have focused on natural processes and dynamics affecting channel and riverbank changes in the vicinity of the boat ramp. In summary, ongoing bank erosion is to be expected in the reach just above the boat ramp and beach. Riverbank materials are highly erodible and discharges less than about the 25 to 30-year event are contained within the banks. The ongoing erosion of the "sheltering" upstream bank appears to be contributing to higher-energy winter flows in the vicinity of the boat ramp. These, in turn, contribute to erosion of beach materials. Finally, periodic incision of the channel during channel re-setting flows appears to be occurring and is expected to continue.

Regarding cultural factors affecting the river in this area, little, if any influence on site dynamics appears to be exerted from distant human activities, for example, upstream vegetation removal, changes in sediment supply, modifications in the hydrologic regime due to water control structures, roads, watershed land uses, or similar other human activities.

There appear to be cultural influences on conditions at the boat ramp, however. Cultural features in the vicinity of the boat ramp include: an asphalt approach road and vehicle maneuvering area; a backfilled retaining wall composed of concrete bags covered with gunnite; an asphalt-covered path at the top of bank that leads upstream to an outhouse; and a fixed fishing platform constructed of a backfilled seawall. The presence of these man-made hard surfaces in back beach and foreshore areas may diminish the capacity of the point bar to recruit and retain sand. This may be complicated by changes in flow direction, depth and velocity associated with natural erosion of the riverbank upstream of the boat ramp. This chronic, natural erosion of the upstream bank appears to have exposed the area of the boat ramp to greater flow energy in recent years.[47]

The hard surfaces on the bar also appear to have blocked a high-flow channel formerly present at the back of the bar. A downstream remnant of the high flow channel remains, but dynamic transport of sediments to and through it appears to have been interrupted by the asphalt vehicle maneuvering area and handicap fishing platform.

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[47] Park maintenance staff note that until recent years, sand was recruited annually to the bar — in some years, well into and beyond the back beach area. The boat ramp has been in place since the mid-1960s.

Options to protect site facilities and enhance recruitment of sand can be grouped in several broad categories as follows:

1: Retrofit exiting facilities
2: Install floating or suspended launch facilities
3: Initiate a program of beach nourishment
4: Install measures to deflect current, create a zone of slack water to protect streambanks from erosion and recruit sand
5: Maintain current facilities and operations

Each option has advantages, disadvantages, risks and concerns. These are outlined below, with the following caveats:

- It is important to note that the hydraulics generated by the large size of the watershed (about 450 square miles above the boat ramp) and the erodible nature of the bed and banks in this vicinity pose extreme limitations to the success of channel and bank modification efforts.
- Field evidence suggests that the flood-prone area of the channel is contained entirely within the banks in the vicinity of the boat ramp. Shear stresses at flood stages would be expected to be quite high.
- The selection of options by park managers will need to be based on the understanding that some treatments will be experimental, or only will be stable at discharges less than certain thresholds.
- Because of the dynamic nature of the site, facilities located here are likely to require ongoing maintenance and repair.
- Cost comparisons of options should consider present and future expenses for maintenance and repair.
- The selection and design of most of the options listed below will require the coordinated input of several disciplines by people with journey-level depth in their fields of expertise.
- It is possible for some options to be implemented in tandem with others. Again, this will require coordination of diverse technical experts.
- Finally, because of the presence in the Sandy River of habitat for cold water and anadromous fish listed as endangered by the National Marine Fisheries Service, permitting requirements may limit options and should be considered early in the selection of options and their conceptual design.

Option 1: Retrofit existing facilities

This group of options entails increasing surface roughness and decreasing flow velocities at the existing facilities. This group of options shares some common benefits:

Common benefits for a. through c. below:

- Handicap fishing access, which is rare in the region, and is present in only one place in the park, would be preserved.
- The existing access road and parking area to support this use would be preserved, and no new disturbances would be needed to develop these facilities elsewhere in the park.
- The road and parking facilities support a wheelchair-accessible trail and fishing platform, the only such facilities in the park and on the lower Sandy River.
- Together, these amenities provide federally approved ADA access to a wild and scenic natural resource rated "outstandingly remarkable" by state and federal management agencies.

a. **Face existing water's-edge structures with large rock** to dissipate current energy.

Benefits:

- This option may be the most straight-forward and cost-effective approach to protecting the existing facility.

Concerns:

- Disturbing natural streambed armoring to place large rock — which must be keyed below the surface of the channel — can result in local scour erosion.
- Where channel materials beneath the armor consist of sand and gravel, scouring may cause a headcut to develop in the channel, which would pose the risk of upstream migration.
- Some waterfront managers feel that large rock at the water's edge can be a hazard to people swimming and entering and leaving the water. Issues of safety would need to be explored by a qualified firm. ClearWater West is not qualified to assess facility safety.
- Placement of large rock has become a permitting issue; the fisheries agencies increasingly favor large wood, instead of rock.

b. **Interplant this rock material with vegetation** to dissipate velocity during high flows and encourage deposition.[48]

Benefits:

- Bio-technical engineering has become a popular method to reinforce streambanks while providing additional values of vegetation near the water.

Concerns:

- Because flood events are contained within the banks in the reach upstream of the boat ramp, and because the bank materials are non-cohesive and highly erodible, bank vegetation would be inundated during ordinary bankfull events, and also would be subject to abrasion and disturbance by floating logs and woody debris.

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48 In cursory conversations with Dale Darris of NRCS's Plant Materials Lab in Corvallis, he suggested a plant palette that includes a locally occurring willow, Salix fluviatilis, that can withstand inundation.

- Erosion of rooting substrate (the sandy bank) is likely.
- Vegetation in this location may not be capable of withstanding the erosive impacts of high flows such as those of the '96 and '99 events.
- Mature, dense, native vegetation upstream of the boat ramp is not capable of withstanding the stream forces acting on the bank.

c. **Plant denuded nearshore upland areas** with species that can provide some velocity dissipation during overbank flow events.[49]

Benefits:

- Floodplain vegetation increasingly is being recognized for its ability to slow the velocity of flood flows, encourage deposition of sediments and decrease the erosive energy of streams at high flows and overbank flow events.

Concerns:

- Because flood events are contained within the banks in the reach upstream of the boat ramp, and because the bank materials are non-cohesive and highly erodible, bank vegetation would be inundated during ordinary bankfull events, and also would be subject to abrasion and disturbance by floating logs and woody debris.
- Erosion of rooting substrate (the sandy bank) is likely.
- Vegetation in this location may not be capable of withstanding the erosive impacts of high flows such as those of the '96 and '99 events.
- Mature, dense, native vegetation upstream of the boat ramp is not capable of withstanding the stream forces acting on the bank.

Option 2: Install floating or suspended facilities

a. Floating or suspended facilities.

Benefits:

- Under this scenario, floating or suspended structures would allow access to the water for boat launching. The floats could be designed to ground at low water, but be leashed or towed to a protected area during high flow periods.

Concerns:

- Floating facilities would be subjected to damage by floating logs and woody debris during storm events. The amount and size of large woody debris transported through this reach during

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[49] Darris also suggested using various lupines, of which the upland species Lupinus albicaulis has been used successfully for stabilizing secondary sand dunes, logging roads, and dredge spoils.

high flow events is considerable and the outlook for continued recruitment is very high, due to the presence of extensive old-growth forests upstream. Large, dynamic debris jams are present in many channel-margin locations throughout the park.

- During storms such as the Thanksgiving Day 1999 event, when the river came up quickly at night, there would not be sufficient time to uncouple, tether or tow floats to areas where they could be protected during the high flows.
- There is no place to tow and secure floating facilities during high water events.
- Highest recreational boat usage occurs in winter, when river stages are variable. It would not be workable to repeatedly remove and replace floating facilities during the highest-use period.

Option 3: Initiate a long-range program of beach nourishment

a. Beach nourishment.

Benefits:

- This option entails hauling sand to the point bar every one to three years from a nearby source and spreading it several feet deep on the skeletal beach (including under the water, continuing the angle of the original beach profile).
- Alternately, the beach could be nourished with a coarser material than the local river sands, in order to retain more beach material under the present energy regime of the point bar. Some beach managers import quarry screen reject material for this purpose.

Concerns:

- Long shore movement of this sand out of the area would be expected if hardened surfaces continue to be present in the nearshore and backshore areas.
- Nourishment would be required every one to three years.
- There is not a source of sand nearby; haul costs could make nourishment economically unattractive.
- The permitting agencies may not look favorably on deposition of sediments in the water, particularly given the proximity of salmonid spawning and rearing habitats.

Option 4: Install measures to deflect current, create a zone of slack water to protect streambanks from erosion and to recruit sand

This option has the same overall benefits as Option 2, namely:

- Handicap fishing access, which is rare in the region, and is present in only one place in the park, would be preserved.

- The existing access road and parking area to support this use would be preserved, and no new disturbances would be needed to develop these facilities elsewhere in the park.
- The road and parking facilities support a wheelchair-accessible trail, the only such facility in the park. More hard-surfaced trail in the vicinity is envisioned in the park master plan.
- Together, these amenities provide federally approved ADA access to a wild and scenic natural resource rated "outstandingly remarkable" by state and federal management agencies.

a. Install rock barbs.

Benefits: [50]

- Rock barbs redirect flow and thereby modify flow patterns and bed topography.
- Properly designed and placed, rock barbs disrupt velocity and create a zone where sediment deposition is possible.
- Barbs are often used in conjunction with vegetation, which also serves to dissipate flow energy.
- They are also used to protect streambanks, intensify scouring of point and lateral bars, to narrow channels, and to influence deposition patterns. Sediment deposition typically occurs *upstream* of the barb. Barbs are typically placed on the *outside* bend of a river to force the thalweg away from the bank. Rock barbs must be keyed into the channel bottom and into the riverbanks.

Concerns:

- Disturbing bank and bed materials to install rock barbs may leave streambanks and channel bottom vulnerable to erosion.[51] It is possible that bank erosion can flank behind the barb.
- Local scour erosion caused by the barbs can contribute to bed erosion and possible channel incision.
- It is important to note that if the thalweg is not near the bank in question, other measures should be considered.
- The permitting agencies may not favor rock.

b. Install vortex rock.

Benefits:

- A vortex rock treatment consists of large, widely spaced boulders placed in a 'V' or 'W' alignment in the channel to re-direct the thalweg and maintain the highest-energy portion of the flow well away from areas of the bank that need to be protected.

Concerns:

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[50] The benefits of rock barbs are summarized from the work of Janine Castro in NRCS *Engineering Design Note 23: Design of Stream Barb Structures,* January 5, 2000 23.

[51] Castro, Janine. Op. cit.

- Local scour around the large rock may initiate a channel headcut.
- A channel re-setting flow could strand the vortex rock.
- It could be difficult or impossible to access the channel with large machinery to place the rock.
- There would be serious concerns about pollution of the river from hydraulic equipment operating in it.

c. Install a created log jam upstream of the area to be protected.

Benefits:

- Some successes have been claimed in protecting streambanks from erosion by installing created log jams (not cabled) upstream of areas to be protected. Sometimes, an area of decreased flow energy can be created, allowing for the deposition of sediment in this zone.

Concerns:

- The site to be protected is on an extremely erodible bank on a dynamic reach of the lower mainstem of a large river. These conditions typically do not make ideal sites for controlling river processes.
- Logs cabled to the bank upstream of this site were not capable of withstanding the discharges associated with the 1996 and 1999 events.

d. Install biotechnically engineered banks upstream to abate bank erosion and possible flanking of the boat ramp area.

Benefits:

- Bio-technical engineering has become a popular method to reinforce streambanks while providing additional values of vegetation near the water.

Concerns:

- Existing mature vegetation on this bank appears unable to withstand the abrasion, disturbance and erosion associated with high flows in this reach.
- A bio-technically engineered solution may provide temporary stability under certain flow thresholds; however, channel re-setting flow could result in undermining of the toe; local flow conditions could result in failure of such an installation in some locations.

Option 5: Maintain current facilities and operations

a. Maintain current facilities and operations.

Benefits:

- Under this option, current site uses and operations would be continued.

Concerns:

- Continued deterioration of the facility due to erosion may create potential site safety hazards, such as undermining by erosion and exacerbation of the vertical drop-off at the outside edge of the vehicle maneuvering area. The potential for such hazards should be evaluated by a qualified professional. ClearWater West is not qualified to evaluate site safety hazards.
- Winter damage may require increasingly larger annual expenditures for emergency repair and activities.

Evaluating the preferred option or options

The options above can be evaluated by their ability to meet requirements for recreational access, handicap access, likelihood of being permitted, initial cost, durability, and environmental protection. The table on the following pages provides an initial comparison of the options listed, with the caveat that some concerns may be minimized by design; others may not have ready solutions. These considerations need to be factored into the final decision.

Table 1: Options and selected evaluation criteria

Option ↓	Evaluation criteria →	rec-reational access	permit-ability	initial cost	durability, maintenance	handicap access	potential safety issues [52]	environ-mental protection
1) Retrofit existing facilities		would remain about the same	depends on materials, placement	moderate to high cost	large rock may induce local scour; introduced vegetation (bio-engineering) may not be capable of withstanding high flows	platform no longer provides access to fishable water in summer; retrofit would not change this	placement of rip rap may result in potential for swimming or other hazards	operation of hydraulic equipment in and near the water would be a WQ concern; impact of large rock on instream habitat

[52] Potential safety hazards listed here are speculative only and should be analyzed by a qualified professional. ClearWater West is not qualified to assess safety hazards.

Option ↓	Evaluation criteria →	rec-reational access	permit-ability	initial cost	durability, maintenance	handicap access	potential safety issues [53]	environ-mental protection
2) Install floating or suspended launch facilities		would remain the same	agencies may not permit over-water structures and/or pilings	high cost for eng'g, materials, con-struction	expect severe damage annually from large woody debris during high flow events	floating ramp angles may inhibit wheelchair access at some water levels	potential swimming hazard; potential for pilings to trap LWD, which could result in facility failure	operation of hydraulic equipment in and near the water would be a WQ concern
3) Initiate a program of beach nourishment		would enhance attractive-ness of beach	depends on volume of materials; agencies may not permit	on-going expense each 1-3 years	expect materials to out-migrate; on-going need to maintain this treatment	N/A	sand used for beach nourishment may not be adequate to protect base of ramp from scour erosion	potential impact of sediments on instream habitat could be a permitting concern
4) Install measures to deflect current and create a zone of slack water		would enhance beach	depends on materials, placement, instream habitats	high	potential measures would be designed to perform up to a specific discharge	Enhanced sedimentation in this vicinity would not bring facility closer to fishable water	failure of measures or breaching behind them may result in downstream damages	impact of changed channel dynamics on instream habitats
5) Maintain current facilities, O & M		launch facility likely will undermine d and this use would be lost	N/A	least cost option; however, may cause on-going maint. costs to be higher	it is unlikely that current O&M will be capable of protecting the facilities from further degradation	appears that both handicap and vehicular access eventually will be lost	possible unseen undermining of structure could cause failure during use	N/A

A word about permitting

As of Sept. 8, 2000 and the Final 4(d) Ruling by the National Marine Fisheries Service, activities that "very likely" would result in "take" of salmon and steelhead or their habitats are subject to stringent review by NMFS. ClearWater West had preliminary discussions with NMFS in the fall of 2000 about erosional dynamics at the boat ramp and learned that in general, proposed land use activities to be undertaken in riparian areas, unstable areas and streambeds that might increase sediment delivery to streams, or alter

[53] Potential safety hazards listed here are speculative only and should be analyzed by a qualified professional. ClearWater West is not qualified to assess safety hazards.

gravel or other physical structures essential for the habitat of listed fish, will require an analysis of alternatives, a biological assessment and preparation of mitigation plans.

Considerations for design

To select a preferred option, the parameters for its design, and a strategy for managing the site and facility, it will be essential for a pre-design team to have a thorough understanding of the dynamics affecting the site. This study has identified that the reach of the Sandy River in the vicinity of the boat ramp is limited in its ability to attain equilibrium by massive deposits of fine-grained sediments deposited in the stream corridor by runoff carrying these materials from recent lahar flows higher up in the watershed. The river is still making its way through these sediments, and, on flows of magnitude, is still flushing them out of its former floodplains in this reach. The river has not attained lateral or vertical stability and is in a state of dynamic, short-term change. Any built solution to problems at the boat ramp must be undertaken with these conditions in mind and an understanding of the history and context for site uses.

ClearWater West assembled technical and permitting experts from several agencies and consulting firms to participate in pre-design site review to observe and discuss site characteristics and dynamics. These individuals possessed journeyman-level expertise in fluvial morphology and hydrology, waterfront and waterway engineering, geomorphology, fisheries biology and habitats of the site, and waterway permitting. They visited the site and were asked to consider the following questions:

▪ **Bed-mobilizing discharge.** The bed-mobilizing discharge should be identified in order to answer the design question, *"How will introduced materials or structures behave in a bed-mobilizing flow?"*

▪ **Scour depth.** Scour depths should be calculated for large rock or other hard surfaces that are considered for placement anywhere in the channel or the flood-prone area of the stream, in order to answer the design question, *"How will scour around the bases of these surfaces affect vertical bed stability?"*

▪ **Hydroperiod.** The hydroperiods for prospective plants should be identified and correlated with their planned elevations in prospective bio-technically engineered installations in order to answer the design question, *"Will these plants be able to withstand periodic inundation for varying amounts of time?"*

▪ **Abrasion.** The capability of introduced plants to withstand abrasion by high flows and floating debris should be ascertained.

▪ **Impact forces of large floating debris.** The capability of floating or suspended structures to withstand impact forces of large woody debris should be considered.

▪ **Stream responses to changed flow.** Stream responses (erosion, sediment transport and sediment deposition) to artificially changed thalweg location and depth should be ascertained in order to weigh potential solutions and identify both short- and long-term benefits and risks. The design question, *"How will this treatment affect channel erosion, sediment transport and sediment deposition?"* should be answered, particularly with respect to nearby instream habitats for fall Chinook, winter steelhead and coho.

ClearWater West toured the site on two dates with the invited experts and representatives of permitting agencies, with a goal of working with them to pursue the following decision-making steps:
1) Evaluate options, and refine
2) Identify risks and concerns for the preferred option
3) Identify permitting issues
4) Select and refine an alternative, if appropriate
5) Determine what additional studies would be needed to develop design parameters for the selected option
6) Develop a budget and schedule for completion of these studies
7) Develop preliminary budgets and schedules for design and construction
8) Identify project funds and budgets

Conclusions and next steps

In the course of site visits and technical discussions, it became apparent that due to the more stringent permitting requirements recently promulgated by the 4(d) Rule, the scope and costs of additional studies to support any alternative would be far greater than the project owner had anticipated. Hydraulic and sediment transport studies would be required to ascertain existing conditions at various river stages. Modeling would be required to assess probable downstream impacts of several project alternatives. A biological assessment and mitigation plan would be required.

Any option selected should be pursued with the knowledge that Metro may not be able to fund it and therefore may choose to seek assistance or a cost-sharing agreement with another agency with an interest in the continued operation of the boat launch and handicap fishing facilities.

Appendices

Appendix 1: Glossary of technical terms used in this report

Appendix 2: References

Appendix 3: Aerial photos from a 63-year period ending in 1998

Appendix 4: Project photos

Appendix 5: Technical Notes for Stream Barbs and Rock Weirs, NRCS

Appendix 6: Project correspondence summarizing selected site visits

Appendix 7: Peak flow data for the Sandy River at Sta. #14142500 below the Bull Run River

Appendix 1: Glossary of technical terms used in this report

aggradation: The process of sediment building up, as when it is deposited in a stream channel or floodplain. When boulders, cobbles, gravel, sand, silt and clay are transported and deposited by streams, they are considered to be *alluvial* sediments (see next entry).

alluvium: Unconsolidated, fragmented earth materials (boulders, cobbles, gravel, sand, and finer materials) laid down by a river in forms such as channel bars, floodplains and alluvial fans .

alluvial channel: A channel that is reworking alluvium; as in a floodplain.

avulsion: a natural re-setting of an alluvial channel. Sometimes avulsion occurs because sediments deposited in the channel force flow to a lower-gradient topographic position; avulsion may also occur after a bed-mobilizing flow.

backshore: The section of a beach that extends back from the level of normal high water. The backshore is affected by waves and currents during extreme high water events. Also *back beach.*

back-wasting: A process of lateral recession or parallel retreat of slopes in which there is no loss of steepness. Also *slope retreat, bank retreat.*

beach: The zone or littoral environment at the junction of the land and a water body, sometimes in the form of an accumulation of unconsolidated materials lying between the lowest level of the water and the highest level reached by storm waves. Beaches are generally of low gradient with a gently concave profile. The character of beach deposits and their rate of accretion (accumulation) or removal are influenced by vertical angle of the shoreline, wave and current energy, wind characteristics and the composition of the surrounding shoreline rocks.

bed load: Coarse materials carried along a streambed by rolling, pushing or bouncing.

bio-technical engineering: A method of designing a bank stabilization structure that will hold up under specific physical stresses but that possesses a live vegetative component.

bole: tree trunk; main stem of a conifer tree.

bulkhead: A vertical partition, such as wall or sheet pile, constructed in the water or at the water's edge and often backfilled with earth on the landward side, to make a stable boundary between land and water. Also *retaining wall.*

cobble-bedded: a stream whose channel bottom is armored with particles intermediate in size between gravel and boulders (between 64 mm and 256 mm particle size, Wentworth scale). Typically, grain size *beneath* the cobble layer is much finer (sand and gravel) than the cobbles. Cobble-bedded streams are susceptible to avulsion (re-setting) during discharges that are capable of putting bed materials into transport.

cohesion: The property of a material or materials to stick together or adhere.

colloids: The finest soil particles. Colloids have electrically charged surfaces that determine the soil's cohesiveness.

colluvial: Earth materials transported by gravity (as opposed to *alluvial* materials, which are transported by water.

competence: The ability of a stream to move particles of a particular size. According to Hopkins' *Sixth Power Law*, the largest particle that can be transported increases with the sixth power of the stream velocity.

confinement: the degree to which valley walls constrict lateral movement of a stream; expressed as a ratio between channel width and valley width. *Confined: valley width is less than 2 times channel width; Moderately confined: valley width is 2 times to 4 times channel width; Unconfined: valley width is greater than 4 times channel width.*

discharge: The rate of flow of a river at a particular moment, related to its volume and velocity; expressed in volume per unit of time (cubic feet per second).

drift sill: An underwater berm of rock constructed to attenuate wave or current energy and prevent the offshore transport of beach materials in the wave back swash.

dynamic equilibrium: A more or less steady state condition in which the forces building up are balanced by the forces breaking down.

embedded, embeddedness: The degree to which the spaces between the coarse sediments of a river channel are filled with finer sedimentary materials.

erosion: The processes of denudation by glaciers, wind, rivers, waves and currents that wear away the land surface by mechanical action.

flanking: erosion behind a structure or revetment at the river's edge.

glacial ablation zone: The area in front of a glacier's terminus, comprised of glacial outwash sediments and earth materials derived from glacial melting.

glacial till: Glacially derived earth materials left behind as subglacial deposits after the glacier has melted.

glacial moraine: Ridges of glacially-derived earth materials that have been pushed forward or abraded from the valley sides during glacial advance.

groundwater piping: As water from waves saturates a bank, interstitial pressure develops which can pump soil fines out of the bank. This processes is known as groundwater piping and can result in chronic, low-grade erosion, particularly of exposed or cut banks.

highly erodible: The state of an earth material such that it is easily moved by wind or water due to low mass or cohesion, steep slope, or other variables.

imbricated: a sedimentary "fabric" in which the long axes of cobbles are tightly packed together , inclined in the direction of the current which deposited them.

interfluve: The valley sides and ridgetops between streams.

lag deposit: A coarse sedimentary deposit left behind on stream bed or beach due to selective out-transport of the finer sediments.

mass wastage: The downhill movement of surface materials under the influence of gravity.

moraine: An accumulation of heterogenous rock material, including angular blocks of rock, boulders, pebbles and clay, that has been transported and deposited by a glacier.

overland flow: The initial, shallow, sheeting of stormwater before it converges in rills, which are the smallest category of concentrated flow. Also *sheetflow, sheetwash.*
quiescent water: A zone where wave or current energy is buffered.
reflected wave energy: Wave energy that is reflected off a rigid surface.
rip rap: Large rock laid on a bank to lessen the erosive force of waves.

river right: throughout this report, reference to riverbanks is given from a downstream-facing orientation.

rock barb: A feature constructed of rock and placed perpendicular to the shore in a near off-shore environment for the purpose of refracting and dissipating wave energy, and sometimes, to create a zone of quiet water where beach materials can accumulate.
saltation, saltating: The process by which a particle, picked up by the stream current, is flung upward, and, being too heavy to remain in suspension, drops to the stream floor in a spot downstream. Sediments bouncing along the stream bottom.
sand starvation: A condition in which sand moving into an area is arrested, resulting in non-replenishment of sand which is moving through the area, usually by means of waves and long shore drift.
scour: scour is caused by features in the channel that disrupt natural flow patters and increase turbulence, thereby creating a localized area of erosion.
sediment: rock detritus of all sizes that has been transported and deposited by water; common sediment grain sizes are boulders, cobbles, gravel, sand, silt and clay.
shingle: a beach comprised of gravel or coarser water-worked sediments; generally steeper than a sand beach.
shoreline hardening: Usually incremental construction of retaining walls, bulkheads and similar structures along a shoreline for the purpose of limiting the reach and effect of waves and currents on beaches and back beach environments.
skeletal: a beach or riverbed composed only of materials too large to be transported by flows; a condition resulting from the out-transport of fines.
thalweg: the deepest part of the channel.
undermining: The removal of earth materials from beneath a structure by means of piping and/or wave erosion.
veneer: An earth material lying over another, e.g., a sand beach lying over a wave-cut bench or other surface.
volcaniclastic: volcanic rocks built up of fragments of pre-existing rocks and transported and deposited elsewhere.
watershed: All the land area, from ridgetop to ridgetop, contributing runoff, sediments and organic materials to a given point of a river system.
wave defraction: The spreading out of energy as water waves impinge upon an obstacle such as a headland or breakwater, usually leading to a considerable reduction in wave height.

wave refraction: The process by which wave crests change direction as they approach a shoreline, owing to the shallowing of the water. The wave front is retarded, for example, at headlands, and is refracted (curved). Thus the wave front approaches the shoreline of an embayment from a different direction than its initial line of advance at the headland.

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U.S. Geological Survey
▪ *Statistical Summaries of Streamflow Data in Oregon: Vol. 2: Annual Low and High Flow, and Instantaneous Peak Flow* (Open-File Report 93-63)

▪ *Plan and Profile of Sandy River from Mouth to Marmot, Oregon*
Water Supply Paper 348. (Contour interval on water surface is 5 feet)
Surveyed in 1926

▪ *Flow data for Sandy River below Bull Run, Oregon, Station 14142500*
http://waterdata.usgs.gov/nwis-w/OR/?statnum=14142500

Washington Department of Fish & Wildlife
▪ *Draft Integrated Streambank Protection Guidelines: Bank Erosion Assessment and Technique Selection Guidance*
April 28, 1998
. . . and Inter-Fluve, Inc.
▪ *Draft Abbreviated Version: Integrated Streambank Protection Guidelines*
February 16, 2000

Washington Forest Practices Board
▪ *Standard Methodology for Conducting Watershed Analysis Under Chapter 222-22 WAC*
Version 4.0, November 1997.

Weaver, William and Hagans, Danny K.,
Pacific Watershed Associates, Arcata, California
▪ *Aerial Reconnaissance Evaluation of 1996 Storm Effects on Upland Mountainous Watersheds of Oregon and Southern Washington: Wildland responses to the February 1996 storm and flood in the Oregon and Washington Cascades and Oregon Coast Range Mountains.*
Prepared for the Pacific Rivers Council, Eugene, Oregon.
May 1996.

Aerial photographs

Bergman Photographic
▪ *Infrared, 1' = 2,000 feet*
1989.

Metro Regional Services, Metro Data Resource Center
▪ *RLIS Aerial Photography for Multnomah County, T.1 S., R. 4 E., A; September 1997.*

Multnomah County
▪ *Rural Lands Series,* scale 1"-200 ', T.1 S. R. 4 E., Sections 10 and 11, by Bergman Photographic
June 1986, October 1977, April 13, 1974.

Oregon Department of State Lands
▪ *1971 Low oblique aerial by John Lily.*

Oregon State Highway Department
▪ *Aerial Photograph of the Sandy River in the Vicinity of Alder Ridge, various scales. Three images, April 1972.*

U.S. Army Corps of Engineers, Portland District
▪ *Coverage of the Sandy River from Indian John Island to below Camp Collins, images 458, 479, 480; 1935.*
▪ *Coverage of both incised meander loops of the Sandy River in Oxbow Park; CE NPP 66-2854, 2855, 2856; 1966.*
▪ *Image of both incised meander loops of the Sandy River in Oxbow Park, 1972..*
▪ *Infra-red image of incised meander loops of the Sandy River in Oxbow Park, 1989.*

U.S. Department of Agriculture
Natural Resources Conservation Service,
Office of the Multnomah District Conservationist
Aerial photography of site and vicinity; various scales:
▪ *DFO-1LL-238, June 24, 1970.*
▪ *DFO-1LL-241, December 1976.*
▪ *DFO- 1LL-93, December 1976*
▪ *DFO 1LL-81, December 1976.*
▪ *DFO 1LL-239, December 1976.*
▪ *DFO 1LL-240, December 1976.*
▪ *DFO 1LL-83, May 1977.*
▪ *DFO 1LL-239, June 24, 1970.*

- *DFO 1LL-93, May 24, 1970.*

U.S. Army Corps of Engineers (from files of Multnomah County Planning Department)
- 91-1687, 1991.
- 66-2854 and 66-2856, August 21,1966.

U.S. Department of the Interior
Bureau of Land Management,
Salem District Office, Oregon
- *Aerial photography of site and vicinity; various scales:*
Five images, 1956.
July 8, 1988.
Two images, July 8, 1993.
August 24, 1993.
June 31, 1998.

Maps

Frank Amato Publicatons
▪ *Oregon Fishing Map: Sandy River*
No date.

Metro Regional Parks and Greenspaces
▪ *Oxbow Regional Park.*
No date.

Multnomah County
▪ *Park Site 34-C, 1" = 1,000'*
December 1962.

▪ *GIS topographic relief layer for the Sandy River in the vicinity of Oxbow Park.*
No date.

Department of Environmental Services, Parks Services Division
▪ *Oxbow Park*
1988.

Planning Commission
▪ *Sandy river Oxbow Project, tentative development plan.*
April 1962.

National Flood Insurance Map Series
▪ *Panel 450; Multnomah County*
June 1982.

Pierson, Tom; Cascades Volcano Observatory
▪ Unpublished, preliminary mapping of Old Maid lahar terraces in Oxbow Park.
Circa 2000.

▪ *"Aggradation following ~200 yBP eruption, Sandy River (Mt. Hood), Oregon, USA; Oxbow Park and Dabney Park.*
Preliminary cross sections of lahar terraces in Oxbow and Dabney parks.
No date. Transmitted by the author to Marty Mitchell on 6-12-00.

State of Oregon

Division of State Lands *with* The Nature Conservancy of Oregon

▪ *Programmatic Biological Assessment, Section 7 Consultation Pursuant to Federal Endangered Species Act (16 U.S.C. 1531 et seq.), State of Oregon's Removal-Fill Program, Map Atlas Sets A and B.*
Feb. 26, 2000.

▪ **Oregon Climate Service**
Oregon Normal Annual Precipitation
From data: 1961-1990. Scale: 1:100,000
No date.

▪ **Water Resources Department**
Willamette Basin and Sandy Basin (Map No. 2,4)
1990.

U.S. Department of Agriculture

Soil Conservation Service

▪ *General Soil Map, State of Oregon.* Scale: 1:100,000.
January 1986.

▪ *Oregon Annual Average Precipitation Contours*
From NRCS SNOTEL station data 1961-1990.
Prepared by National Cartography and Geospatial Center, Fort Worth, Texas.
July 1996; prototype, advance copy.

Forest Service, Mt Hood National Forest

▪ *Upper Sandy Watershed Landforms*
Published in *Upper Sandy Watershed Analysis: Chapter 4: Current Conditions and Trends: Geology.*
1996.

▪ *Upper Sandy Watershed Stream Channel Stability*
Published in *Upper Sandy Watershed Analysis: Chapter 4: Current Conditions and Trends: Geology.*
1996.

U.S. Geological Survey
▪ 7.5-minute quadrangle for *Washougal, Wash.-Oreg.*
1961, photorevised 1970, 1975, 1993.

▪ 7.5-minute quadrangle for *Sandy, Oreg.*
1961, photorevised 1985.

▪ *Topographic Map of Mount Hood, Oregon,* Scale 1:100,000
1983.

U.S. Government Land Office
▪ *GLO Map for T. 1 S., R. 4 E., WSBM*
Approved by C.K. Gardner, Surveyor General for Oregon, 1855.

Photographs

Radcliffe, Bob
▪ *Panorama of Sandy River bank in the vicinity of Group Camp #2, Oxbow Park.*
1995.

Wimmer, J.
▪ *Eleven photos of buried forest on the Sandy River at Oxbow, taken Jan. 12, 1965 and transmitted with note to Mr. Bonney, Superintendent of Parks of Multnomah County, on March 11, 1965, following the 1964 flood, which exhumed lahar-buried trees in the vicinity of the swimming area* (this location may have been close to present-day Group Picnic Area 'A' and/or C).

Mitchell, Marty
▪ *Various photos taken February, May, June and July, 2000.*

Interviews

▪ Steve Fedje, USDA Natural Resources Conservation Service, Multnomah County District.
Re: Historic soils analysis, geology, aerial photos; possible design charette including NRCS personnel; raft tour of river from Dodge Park to Oxbow to investigate channel sediment sizes, floodplain connectivity.
5-1-00, 7-14-00, 7-21-00.

▪ Bob Ratcliffe, Recreation Planner, BLM, Salem Office.
Re: Historic aerial photos; reports on geology, fluvial morphology.
5-10-00.

▪ Tim Abbe, Fluvial Morphologist, Philip Williams & Assoc.
Re: Created debris jams.
5-22-00.

▪ Dale Darris, Conservation Agronomist
Natural Resources Conservation Service, Plant Materials Center.
Re: Native plants for sandy riverbanks.
5-26-00, 5-30-00.

▪ John Lilly, Senior Manager, Division of State Lands
Re: Gravel mining in vicinity; DSL archives; aerial photos; other contacts.
5-30-00.

▪ Ron Geitgey, Industrial Minerals Geologist, DOGAMI, Portland
Re: His recent inventory of potentially submersible floodplains in the Sandy system; availability of geologic mapping of area; gravel mining in vicinity; methods for comparing aerial photographs over time.
5-30-00.

▪ John Barber, BLM hydrologist for Sandy River
Re: Flow regime of Sandy; influence of development, agriculture, roads and logging; other resources.
5-30-00.

▪ Marvin Beeson, Professor Emeritus in Geology, PSU
Re: Statigraphy of Bonneville landslide, Bretz floods and Old-Maid lahar surfaces in the Sandy River Gorge; other contacts.
5-30-00.

▪ Jim O'Conner, Geologist, USGS Portland
Re: Terraces in Oxbow Park.
5-30-00.

- Tom Pierson, Geologist, USGS Vancouver, Cascade Volcano Observatory
Re: Statigraphic studies at Oxbow Park
5-30-00, 6-12-00, 8-1-00.

- Ken Cameron, Geologist, DEQ
Re: Studies of lahar terraces at Oxbow Park.
6-1-00.

- Pat Pringle, Geologist, Washington Department Natural Resources
Re: Studies of lahar terraces at Oxbow Park; buried forests in lower river.
6-1-00.

- Julie "Lou" Clark, Geologist, DOGAMI
Re: Studies of impact of urbanization and deforestation on the hydrologic regimes of rivers of various watershed sizes.
6-2-00.

- David Scofield, Geologist, Geotechnical Engineer, Scofield Engineering (retired AcoE)
Re: Landslides as a source of sediments in the Sandy River Gorge.
6-2-00.

- Val Lantz, Superintendent of Parks and Facilities,City of Troutdale
Re: Depositional dynamics of the lower Sandy River.
6-2-00.

- Jim Lind, Oxbow Park Manager
Re: Behavior of river and riverbanks in high flows of '96 and '99.
6-6-00, 6-12-00.

- Tom DeRoo, Geologist, Mt. Hood National Forest
Re: Landslide history of the upper Sandy River.
6-7-00, 6-14-00.

- Keith Jensen, Alder Creek Kayak Supply
Re: Alignment changes in river from '96 and '99 events; elevation of flooplain relative to active channel bar.
6-7-00, 6-24-00.

- Mark Filsinger, Manager, Surveying Department, KPFF Consulting Engineers
Re: Photo-rectification; sources of rectified photos for site.
6-8-00.

▪ Ian Madin, Geologist, DOGAMI
Re: Discuss whether Sandy River is in a graded state at Oxbow Park.
6-9-00.

▪ Derek Tokos, Planner, Multnomah County Planning Department
Re: archival photos, aerial photos, rectified photos, orthophotos, quarter section maps, GIS imagery.
6-13-00.

▪ Sam Diack, Long-time resident on Sandy River upstream from Oxbow Park
Re: Changes in river alignment, erosion and deposition after '96 and '99 events; Diack Decision.
6-15-00, 6-27-00.

▪ Chris Edwards, Portland Corps of Engineers, aerial photograpy and mapping
Re: Archival images of Sandy River from 1935 to present.
6-19-00.

▪ Rob and Amy Galasso, residents along the Sandy River above Oxbow Park.
Re: Floodplain elevation and channel incision between lower end of Indian John Island and lower takeout point in Oxbow Park; channel changes during and after '96 and '99 flood events.
6-24-00.

▪ Karen Reynolds, Health and Environmental Safety Coordinator, Mt. Hood Community College
Re: Interagency incident response planning for Mt. Hood eruptive activity; hazards mapping.
6-26-00.

▪ Paul Pedone, State Geologist, Natural Resources Conservation Service, Oregon State Office
Re: Channel bars, Sandy River in Oxbow Park.
7-7-00, 7-10-00.

▪ Doug Cramer, fish biologist, PGE
Re: Flow regime of river, accounting for Portland water supply.
7-14-00.

▪ Janine Castro, fluvial geomorphologist, Natural Resources Conservation Service, Oregon State Office
Re: Range of conceptual options for site; sediment survey protocol for sub-armor assessment.
7-17-00.

▪ Frank Rechendorf, sedimentation geologist; retired ACOoE.
Re: Morphology of channel bars; sediment sampling.
7-20-00.

▪ Jerry Mitchell, manager
KPFF Consulting Engineers, Civil Engineering Division
Re: Condition and operations at the boat ramp; assistance with toe-point sediment survey.
7-23-00.

▪ Tim Abbe, fluvial geomorphologist and principal
Philip Williams & Assoc, Seattle
Re: Created barbs, vortex structures and debris jams in cobble-bedded systems.
8-2-00

▪ Jo Collins, data and information
Water Resources Division
US Geological Survey, Portland
Re: Discharge data for the Sandy River
8-18-00

Appendix 3: Aerial Photos over a 63-Year Period

Meander bend of Sandy River around Alder Ridge, 1935. Month of photo unknown. Flow direction: right to left. No scale.

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Creating livable communities

The Sandy River at Oxbow Park, Oregon

Morphology and dynamics in the vicinity of the boat ramp

Aerial photo page 1

Aerial photo 1: Meander bend of the Sandy River around Alder Ridge, 1935. Photo from U.S. Army Corps of Engineers.

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Meander bend of the Sandy River around Alder Ridge, 1956. Month of photo unknown. Flow direction: right to left. No scale.

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The Sandy River at Oxbow Park, Oregon

Morphology and dynamics in the vicinity of the boat ramp

Aerial photo page 2

Aerial photo 2: Meander bend of the Sandy River around Alder Ridge, 1956. Photo from U.S.D.A. Bureau of Land Management.

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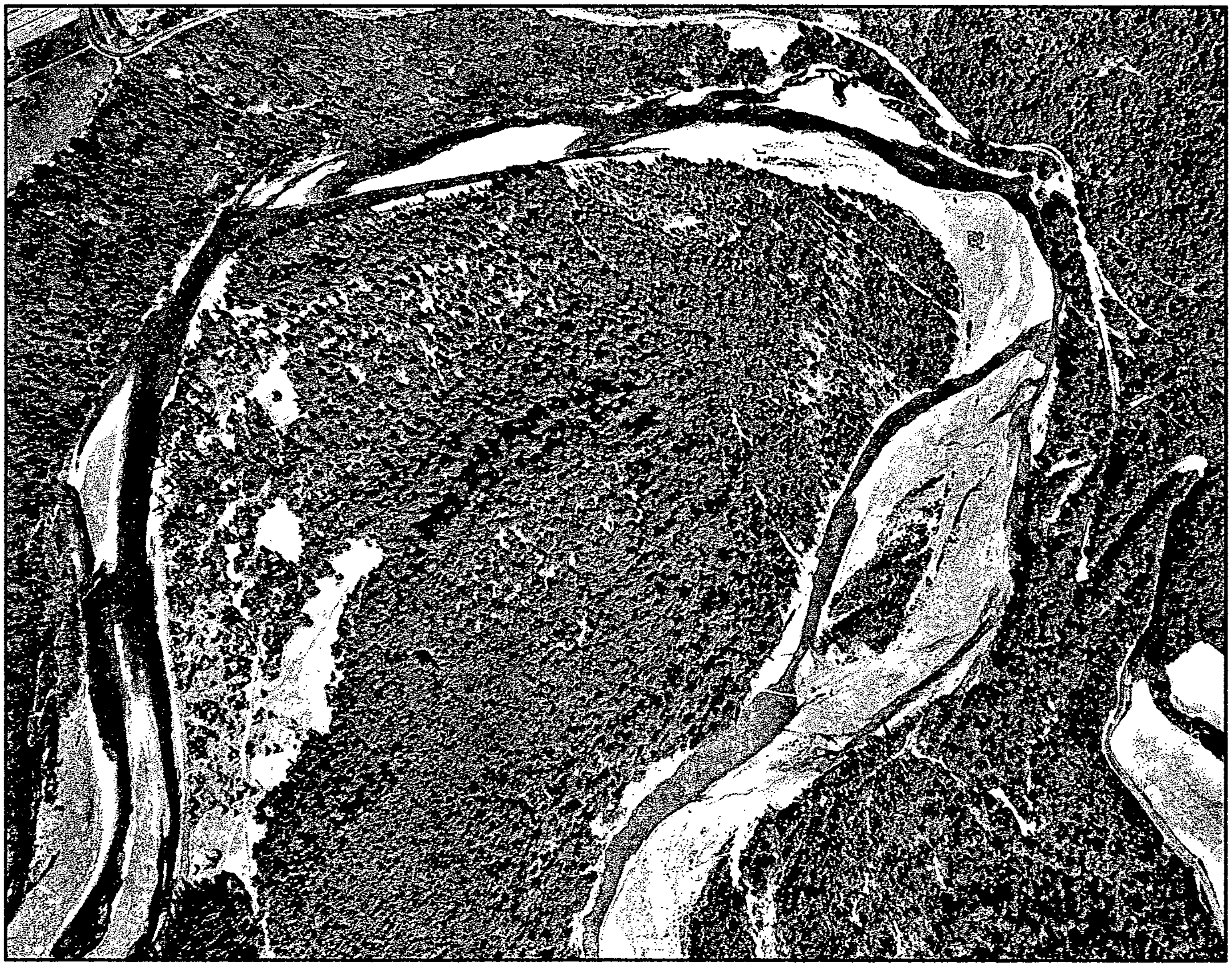

Meander bend of the Sandy River around Alder Ridge, 1966. Month of photo unknown. Flow direction: right to left. No scale.

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The Sandy River at Oxbow Park, Oregon

Morphology and dynamics in the vicinity of the boat ramp

Aerial photo page 3

Aerial photo 3: Meander bend of the Sandy River around Alder Ridge, 1966. Photo from U.S. Army Corps of Engineers.

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Meander bend of the Sandy River around Alder Ridge, June 24, 1970. Flow direction: right to left. No scale.

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The Sandy River at Oxbow Park, Oregon

Morphology and dynamics in the vicinity of the boat ramp

Aerial photo page 4

Aerial photo 4: Meander bend of the Sandy River around Alder Ridge, June 24, 1970. Photo from U.S.D.A. Soil Conservation Service.

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Looking upstream (right) to vicinity of boat ramp (upper right), 1971. Month of photo unknown. Flow is right to left. No scale.

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The Sandy River at Oxbow Park, Oregon

Morphology and dynamics in the vicinity of the boat ramp

Aerial photo 5: Looking upstream (right) to vicinity of boat ramp, 1971. Photo by John Lilly, Oregon Division of State Lands.

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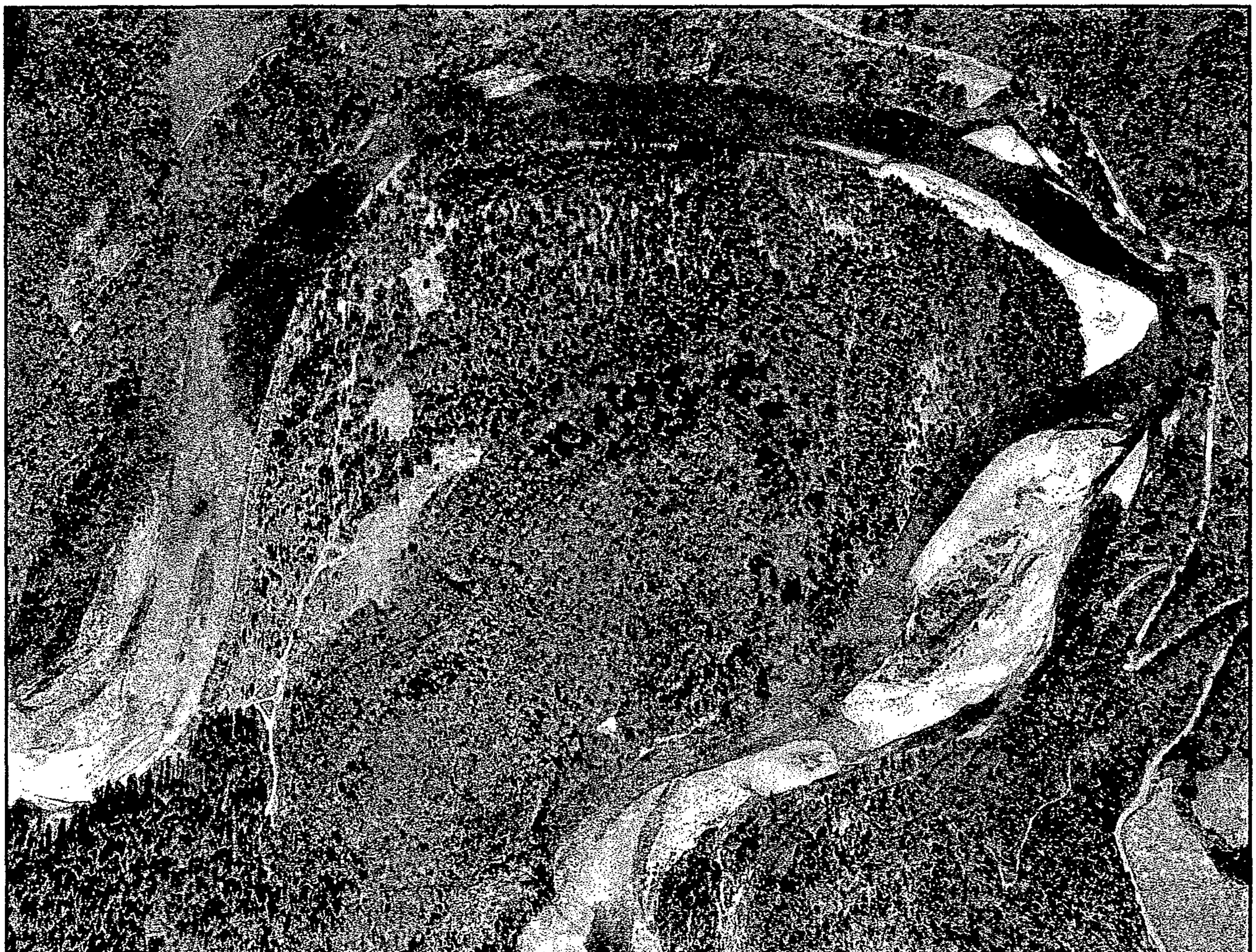

Meander bend of the Sandy River around Alder Ridge, 1972. Month of photo unknown. Flow direction: right to left. No scale.

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Creating livable communities

The Sandy River at Oxbow Park, Oregon

Morphology and dynamics in the vicinity of the boat ramp

Aerial photo 6: Meander bend of the Sandy River around Alder Ridge, 1972. Photo from U..S. Army Corps of Engineers.

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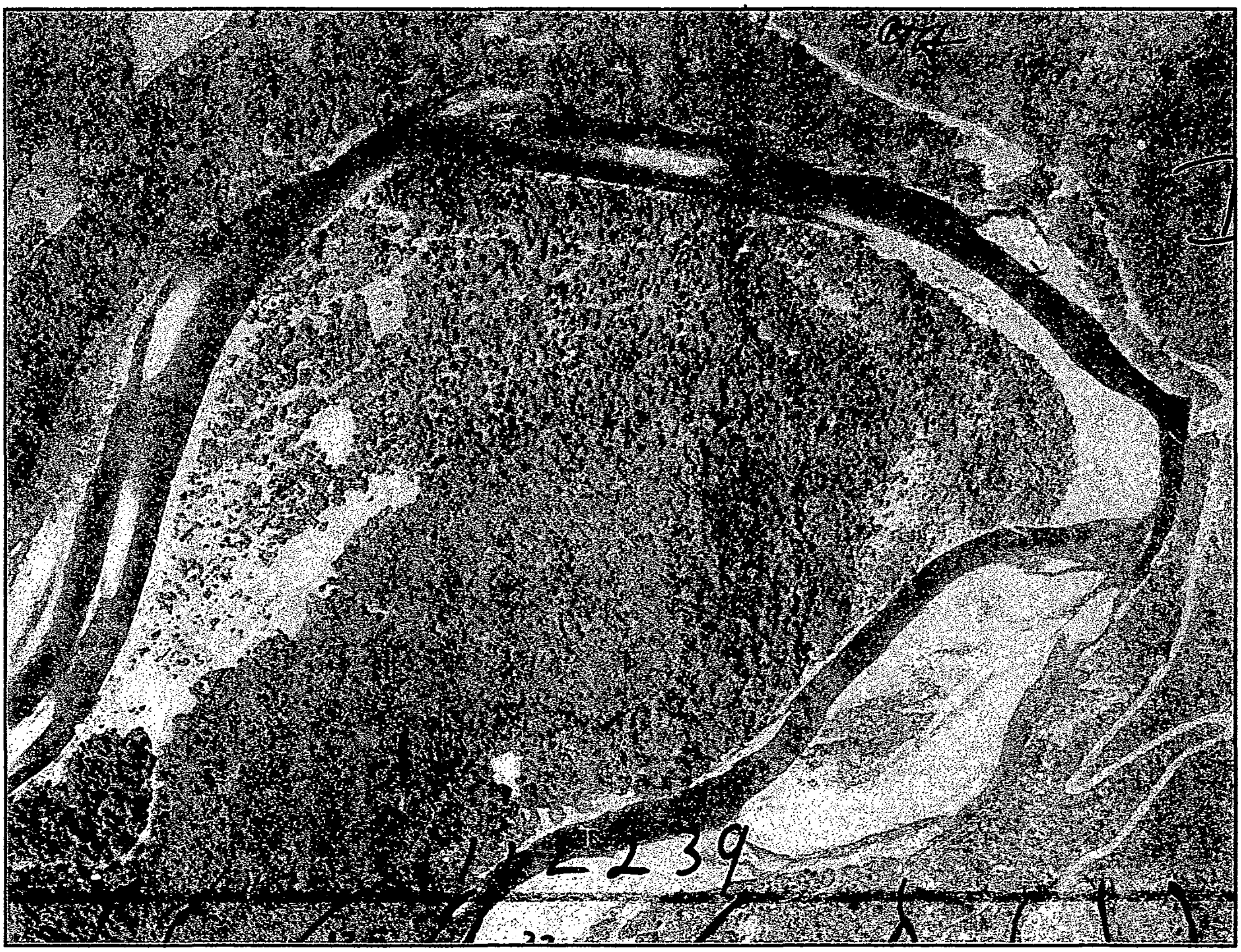

Meander bend of the Sandy River around Alder Ridge, December 1976. Flow direction: right to left. No scale.

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Creating livable communities

The Sandy River at Oxbow Park, Oregon

Morphology and dynamics in the vicinity of the boat ramp

Aerial photo page 7

Aerial photo 7: Meander bend of the Sandy River around Alder Ridge, December 1976. Photo from U.S.D.A. Soil Conservation Service.

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Meander bend of the Sandy River around Alder Ridge, 1989. Month of photo unknown. Flow is from right to left. No Scale.

Aerial photo 8: Meander bend of the Sandy River around Alder Ridge, 1989. Photo from U.S. Army Corps of Engineers.

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Meander bend of the Sandy River around Alder Ridge, September 30, 1991. Flow is from right to left. No Scale.

Aerial photo 9: Meander bend of the Sandy River around Alder Ridge, September 30, 1991. Photo from U.S. Army Corps of Engineers.

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Meander bend of the Sandy River around Alder Ridge, July 8, 1993. Flow is from right to left. No Scale.

Aerial photo 10: Meander bend of the Sandy River around Alder Ridge, July 8, 1993. Photo from U.S.D.A. Bureau of Land Management.

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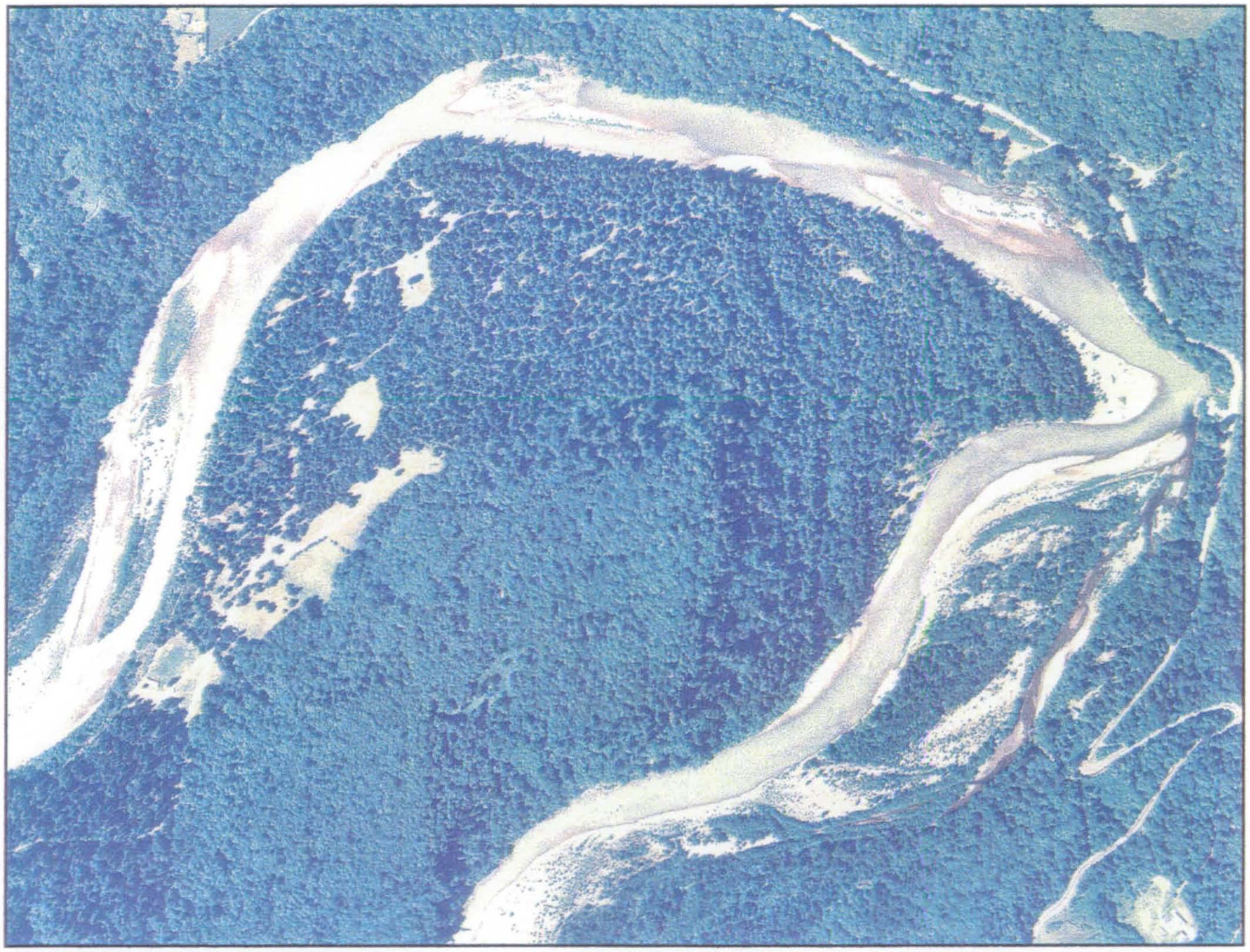

Meander bend of the Sandy River around Alder Ridge, August 24, 1993. Flow is from right to left. No Scale.

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The Sandy River at Oxbow Park, Oregon

Morphology and dynamics in the vicinity of the boat ramp

Aerial photo page 11

Aerial photo 11: Meander bend of the Sandy River around Alder Ridge, August 24, 1993. Photo from U.S.D.A. Bureau of Land Management.

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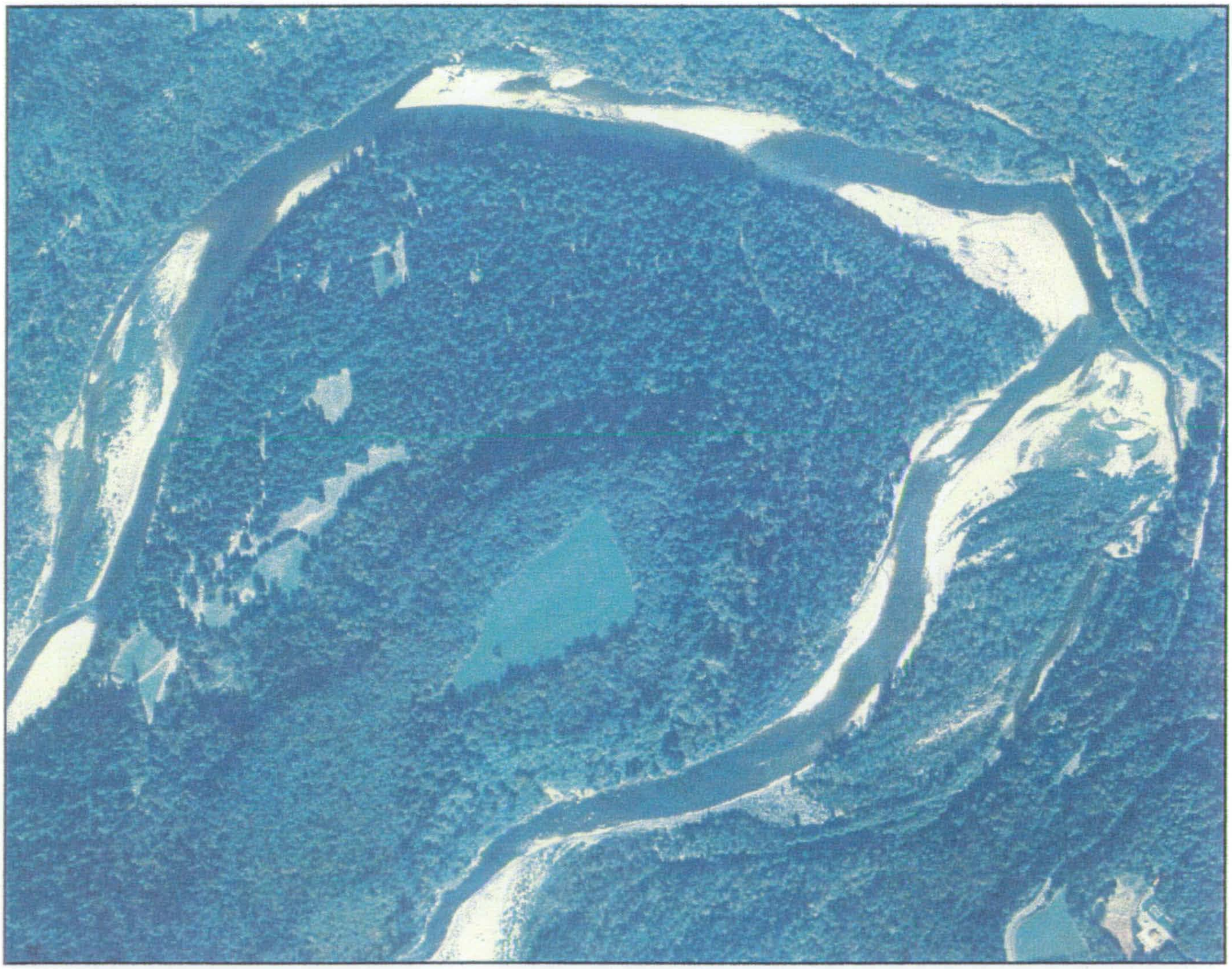

Meander bend of the Sandy River around Alder Ridge, 1997. Month of photo unknown. Flow is from right to left. No scale.

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Creating livable communities

The Sandy River at Oxbow Park, Oregon

Morphology and dynamics in the vicinity of the boat ramp

Aerial photo 12: Meander bend of the Sandy River around Alder Ridge, 1997. Photo from Metro RLIS aerial photography for Multnomah County.

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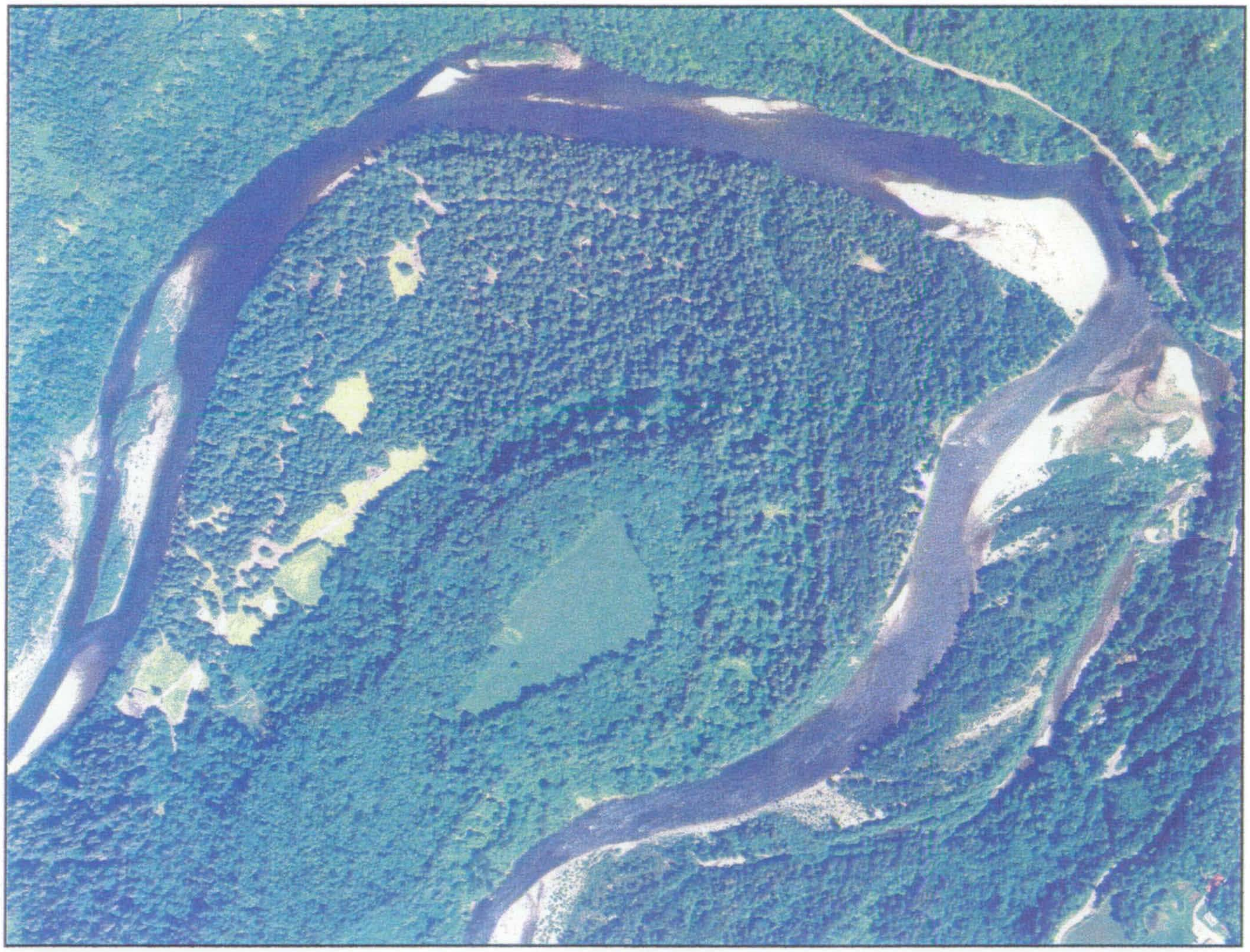

Meander bend of the Sandy River around Alder Ridge, June 31, 1998. Direction of flow is from right to left. No scale.

Aerial photo 13: Meander bend of the Sandy River around Alder Ridge, June 31, 1998. Photo from U.S.D.A. Bureau of Land Management.

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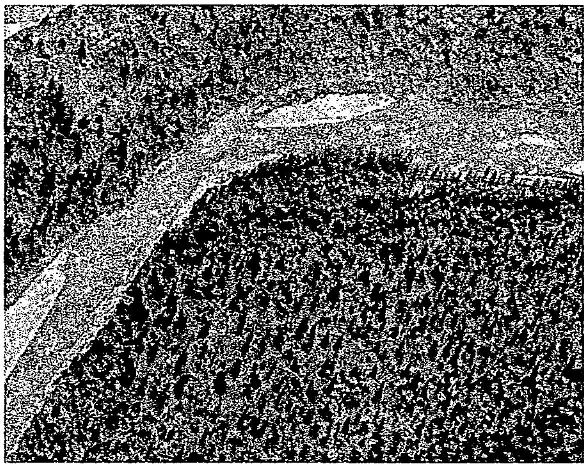
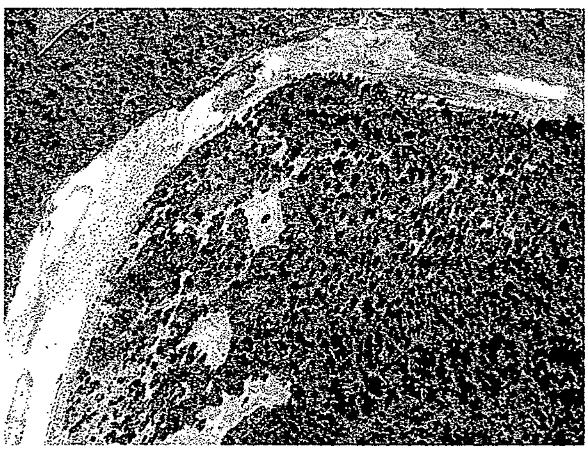
Close-up of vicinity of boat ramp, from aerial photos on previous pages, in chronological order.

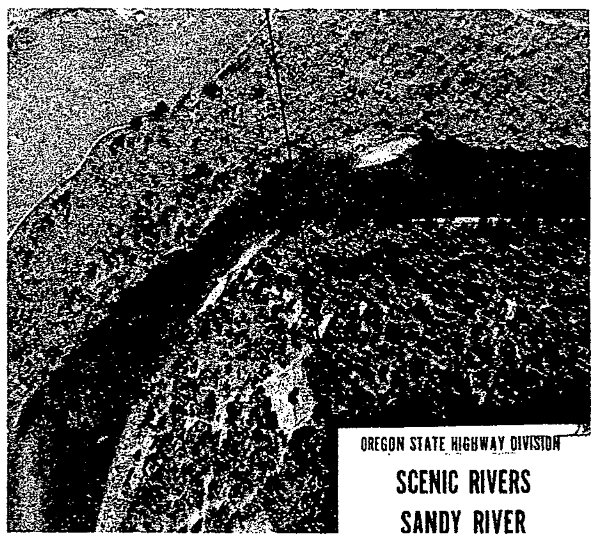


1935

1966

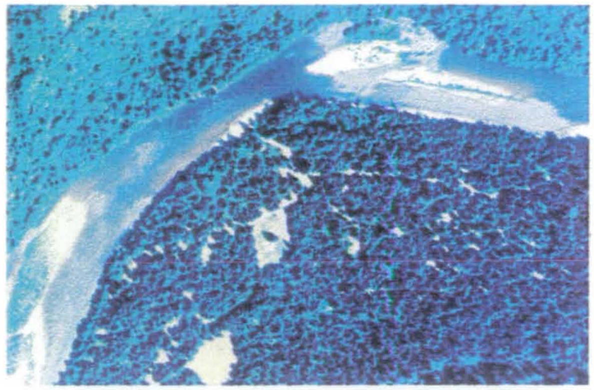


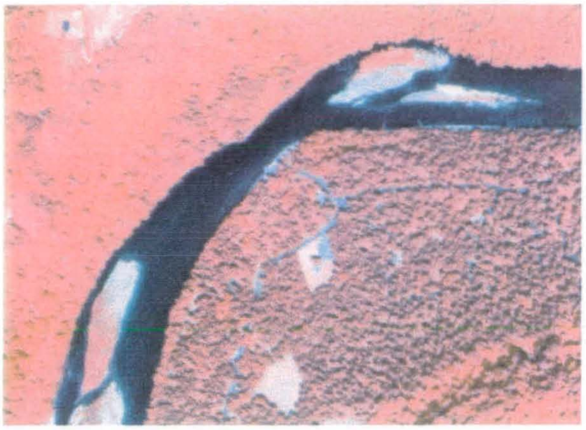
1970

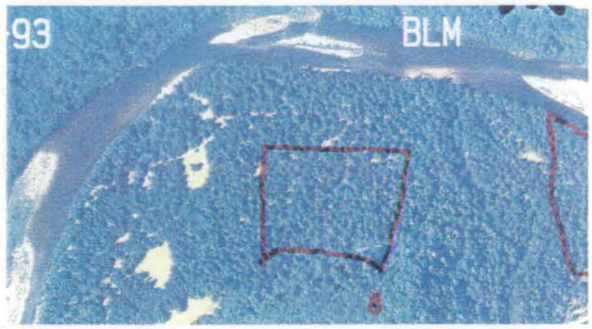


1972


1976


1988


1989



1993


1997


1998

Metro Regional Parks & Greenspaces *Creating livable communities*	The Sandy River at Oxbow Park, Oregon Morphology and dynamics in the vicinity of the boat ramp	Aerial photo page 15

Aerial photo

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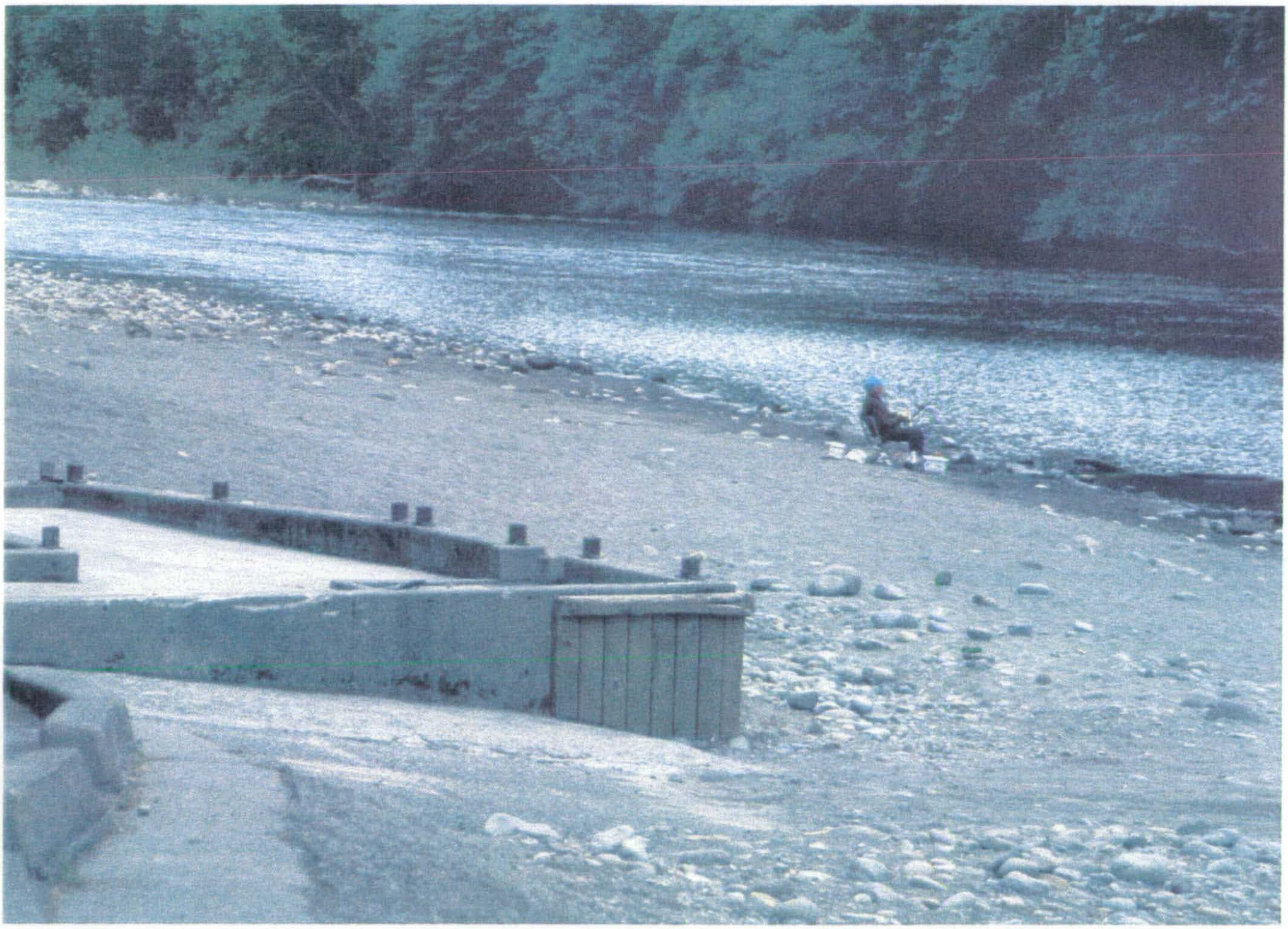
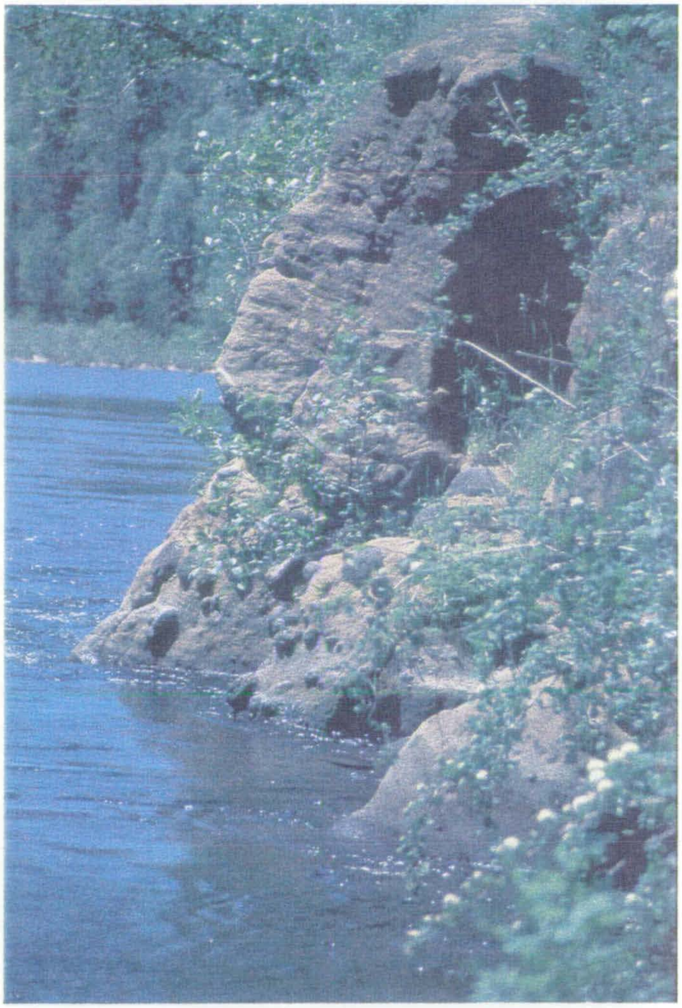
Appendix 4: Project Photos



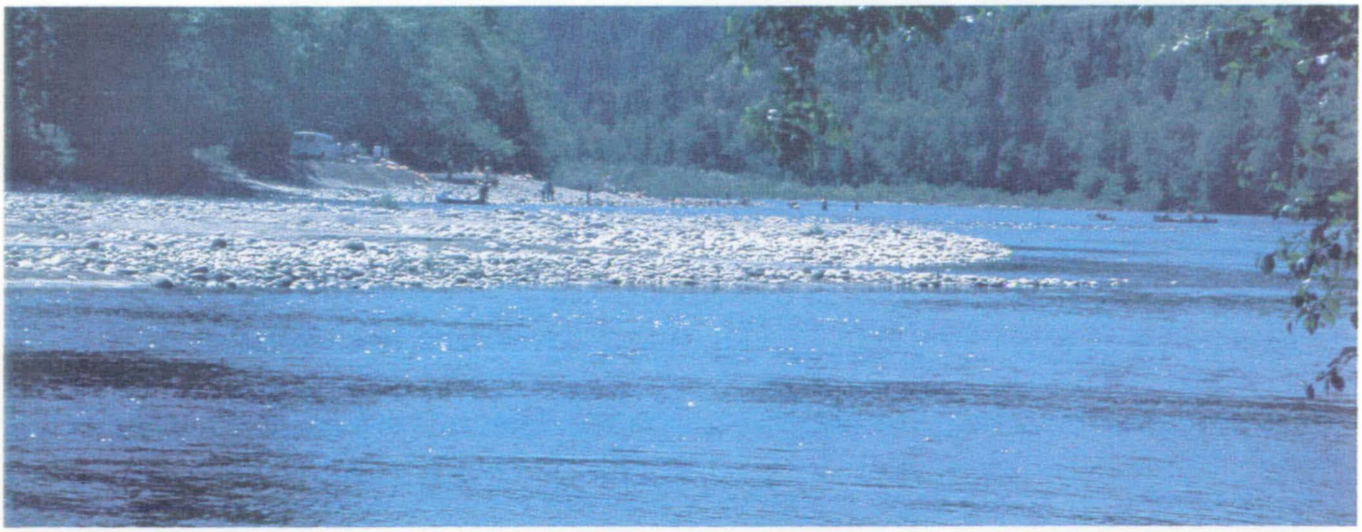
The handicap fishing platform near the boat ramp at Oxbow Regional Park was built in the mid- to late 1980s. Sand that formerly veneered the cobble point bar here has been eroded and has not been replenished by normal beach-building processes. It appears that asphalt and gunnite surfaces at the platform, the boat ramp and in the back beach area are partly responsible for sand starvation here. The large runoff events of 1996 and 1999 probably hastened the erosion of beach sand by focusing flow velocities in the back beach area.

Right: Summer water levels relative to the platform have dropped in recent years, according to park managers. Presently, summer levels reach to the dock only during the late spring freshet or after large runoff events, such as on June 12 after several days of intense rainfall. There is evidence that the channel bottom in this reach is incising.

Left: Sandy River mudstone forms a resistant, vertical bank opposite the point bar on which the boat ramp and fishing platform are located. The thalweg is close to the bank in this location, creating a deep pool. Opposite, the point bar is shallow-shelving, as would be expected.



Below: A mid-channel bar tails out just above the point bar where the boat ramp and fishing platform are located. The channel between this bar and the riverbank immediately upstream of the boat ramp is broad and shallow, and, in summer, lacks a defined thalweg.



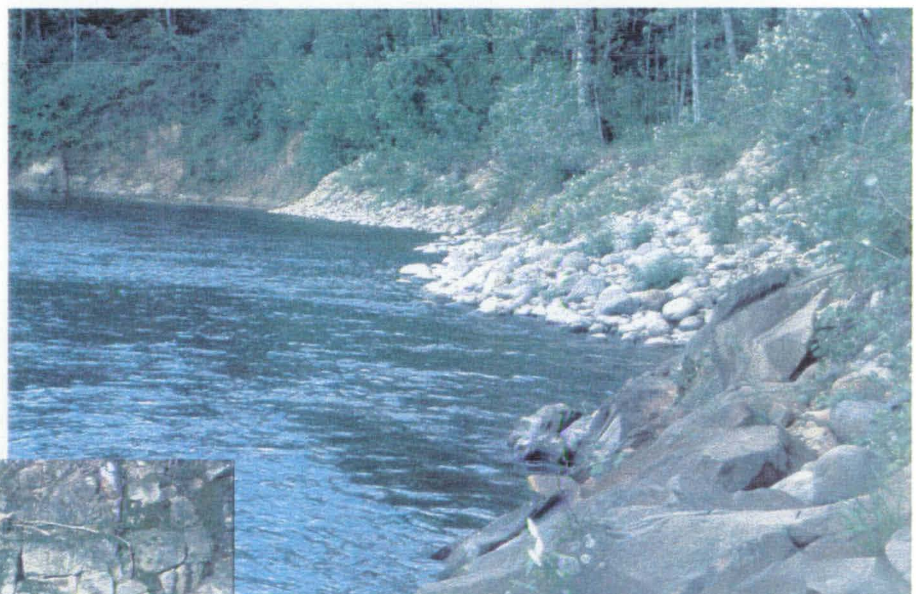
Left: In 63 years of aerial photos, the riverbank immediately upstream of the boat ramp on this straight reach appears to be chronically eroding, resulting in incremental removal of a remnant terrace in this area.

The willows submerged in the foreground are growing on a long mid-channel bar that tails out just above the point bar and boat ramp. The bar is covered on this date by high water following a storm of several days' duration. The channel here is broad and shallow, lacking a defined thalweg.

Left: The riverbank upstream of the boat ramp is chronically eroding due to shear stresses on the non-cohesive bank materials during high flow events. Incremental erosion is slowly reducing the extent of a remnant lahar outwash terrace in this area. Segments of trail along the river in this location have been undermined, washed out or abandoned. The mid-channel bar can be seen in the upper left.

Right: This extensive bar opposite the mouth of Gordon and Trout creeks was laid in the 1996 flood event. A 1966 aerial photo shows a former extensive bar in this general location after 4 ***the 1966 flood. The lower river is a dynamic zone of sediment transport and deposition.***

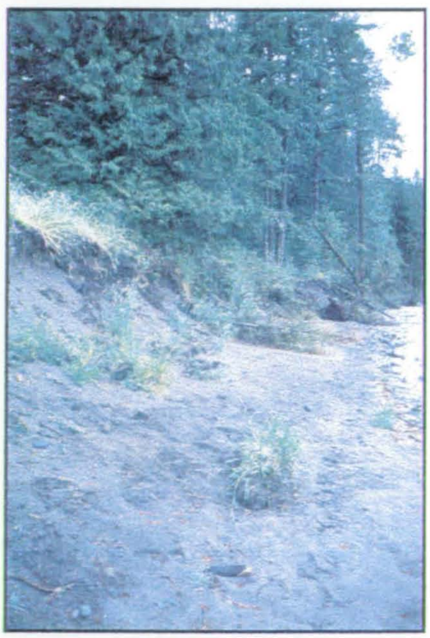
Right and below: Resistant materials outcrop on the bank opposite the new bar, forcing the river to make an abrupt bend to the west. The bar above was deposited in a zone of decreased flow energy just downstream of this constrained reach.



Boring lava, Troutdale formation and Sandy River mudstone confine the channel on the outside bend starting below the mouth of Gordon and Trout creeks.

Above: A different view of the same bar, located just downstream of "The Point," shows it bulging high above the river (note the person standing at the water's edge at the right, for scale). This bar squeezes the channel against the opposite bank and increases velocity in the long straight reach just above the boat ramp.

In the flood of 1996, erosion of the lahar terrace near Group Camp 2, and deposition on the downstream portion of the bar at the mouth of Gordon and Trout creeks, resulted in the channel shifting west. Prior to the 1996 flood, the rock circled in the photo to the left had been on a point bar at the tip of Alder Ridge. The rock today is on a bar across the channel (east) from its prior location, as this photo shows. The rock itself has not moved, but dynamic erosion and deposition have shifted the location of the channel where it rounds the point of Alder Ridge.



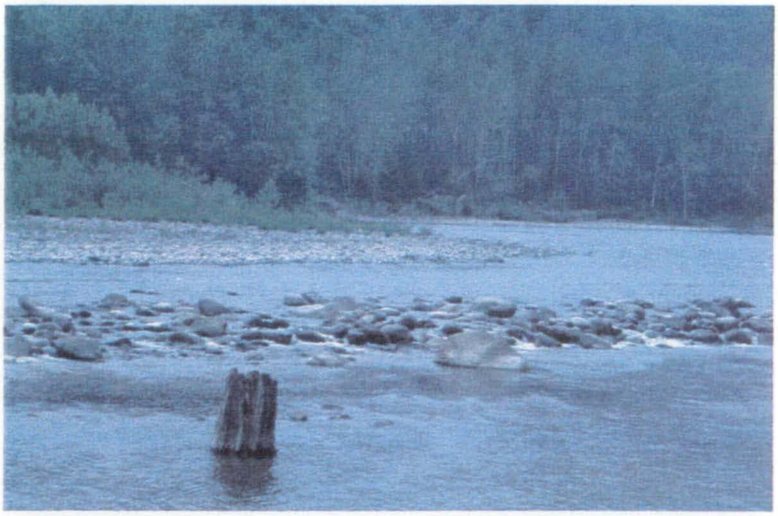
Erosion of the streambank near Group Camp 2 proceeds as follows: Ordinary bankfull events exert shear stresses on the highly erodible lahar sands comprising the riverbank. Materials at the toe of the bank are swept away and the top of the bank is undercut. The bank is not stable at such a steep angle, and begins to ravel. Unsupported vegetation falls from the top. Shear stresses are intensified during events of magnitude, resulting in greater bank erosion during these events. Thus, there is a repeated cycle of chronic erosion during both ordinary bankfull events and events of greater magnitude.

Left: The root zone of annual grasses in coarse, gray lahar sands can be seen in the riverbank near Group Camp 2. Finer, lighter alluvial sands that were deposited in the '96 and '99 events overlie the lahar sands in this location. Below: Overbank flow during these events left fresh deposits in the woods and created new high flow channels across the terrace.

Thus, both lateral erosion and deposition are occurring at the point of Alder Ridge, where, over time, the river is removing the lahar terrace here. Left: Gravel lag deposits temporarily armor the toe of the eroding bank. However, these materials will also be moved by shear stresses in subsequent high flow events and the bank will continue to retreat.

According to park managers, the Thanksgiving Day storm of 1999 exposed this stump in the channel near Group Camp 2. This tree is thought to have been buried by sediment-laden runoff from lahar activity during the Old Maid eruptive period, about 200 years ago. This tree is rooted below the bed of the present-day channel, suggesting that incision through the lahar materials is still taking place in this reach. This is consistent with findings that incision is taking place at several nearby locations downstream. The lahar terrace level eroded in the vicinity of Group Camp 2 by the high flow events of '96 and '99 has already been removed in downstream locations where greater channel incision has taken place. This photo was taken from the bank near Group Camp 2, looking obliquely upstream across the channel toward the upstream end of the bar at the mouths of Gordon and Trout creeks also shown on the next page.

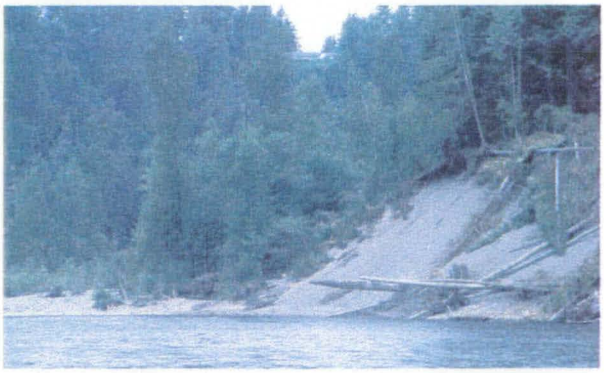
The bar at the mouths of Gordon and Trout creeks enlarged in the downstream direction as a result of sediment deposition during the '96 and '99 events. It is interesting to note that the older vegetation of the bar (shown above) was not disturbed by these high water events, as was the case on "The Floodplain" bar in the vicinity of Camp Collins, downstream. This further suggests that channel incision is taking place in this reach of river.



Left: The 1999 Thanksgiving Day flood exhumed a tree in growth position in the channel in the vicinity of Group Camp 2.

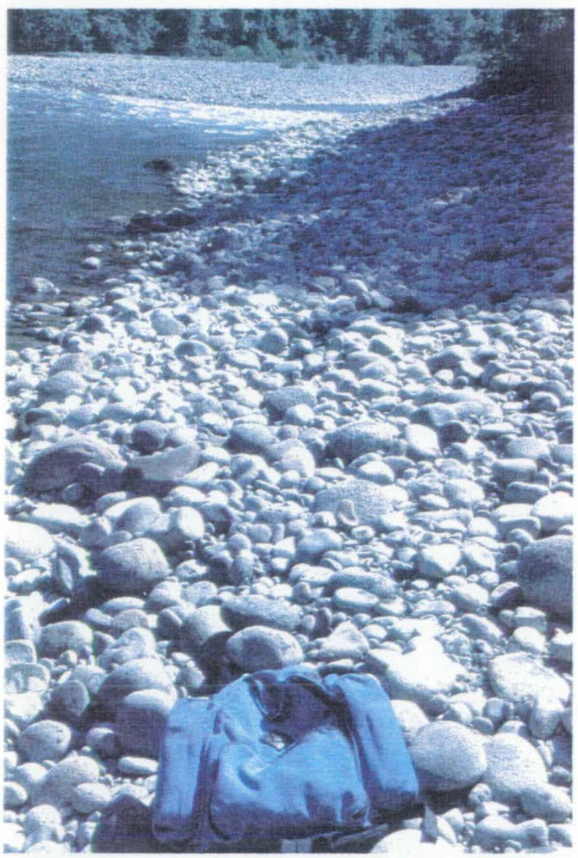
The 1964 flood exhumed forests that had been buried during rapid aggradation after the Old Maid eruptive period on Mount Hood, about 200 years ago. The area pictured is the long bank downstream of the present-day boat ramp. This bank was subsequently armored with a concrete bag revetment built by the Youth Conservation Corps in the late 1960s.

Photos by J. Wunner, Jan 12, 1965.



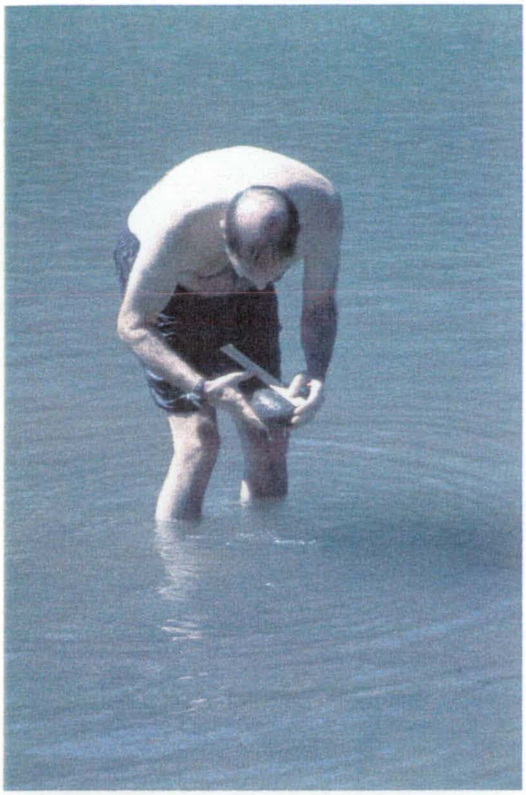
Another striking exposure of trees buried by lahar outwash is located approximately opposite Picnic Area B in the park. In the photo above, the tree in horizontal position is being exhumed. The others have fallen from above, having succumbed to bank failure caused by undercutting and oversteepening. In the photo to the left, note the elevation of the active floodplain on the left (downstream is to the left). The bottom photo shows the floodplain just upstream of this remnant lahar terrace. Thus, the terrace is being eroded both vertically and laterally by bankfull flows as well as flows of greater magnitude.

left: The downstream end of the mid-channel bar that tails out near Group Picinc Area A has high, vertical banks, in which an oxidized layer and imbricated cobbles are exposed, suggesting incision in this part of the channel.

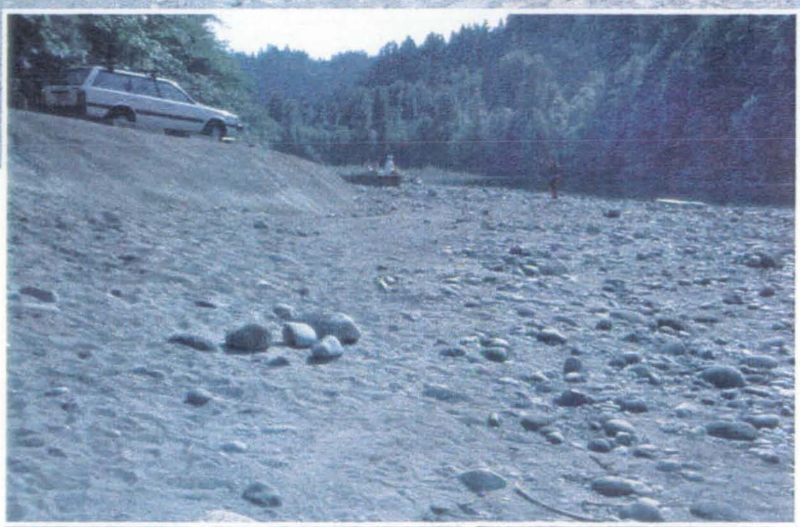


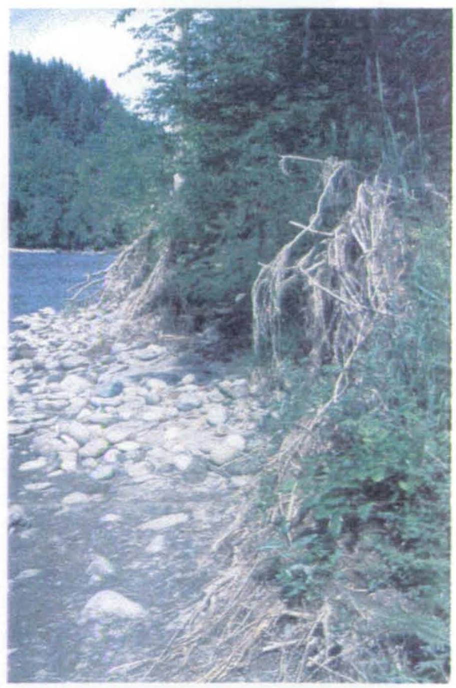
Left: Downstream view of the same mid-channel bar. The vertical bank shown above is just out of sight in the upper right corner of the photograph to the left. The cobbles in the fore-ground armor the channel and are under water under bankfull discharges.

Below: When one layer of cobbles is removed, fine gravels and sand are revealed beneath the armoring layer.



Left: Measuring sediment grain size along a cross-channel transect.
Above: Fine sediments beneath the armoring layer on the bar at the launching area.
Below: "Skeletal" point bar at the launch area, with eroding bank directly upstream.





Above: A vehicle maneuvering area, a picnic area and a handicap fishing dock extend into the floodway on this point bar at the boat lauch area.

Right: The bank upstream of the lauch area shows chronic erosion due to the confined nature of the channel in this reach. Despite the availability of sand in the the transport system, it appears that velocities are now too high in the launch area for the deposition of sand. The structures in the floodway contribute to this problem.

Appendix 5: Technical Notes for Stream Barbs and Rock Weirs, NRCS

TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE
PORTLAND, OREGON January 1, 2000

ENGINEERING – NO. 23

DESIGN OF STREAM BARBS

DESCRIPTION

Stream barbs are rock structures that extend into the stream flow to modify flow patterns and bed topography. They are very low structures that should be completely overtopped during channel-forming flow events (approximately a 1.5-year flow event). Channel-forming flow or bankfull is defined as the flow that transports the greatest amount of sediment over a long period of time and controls the channel geometry. Bankfull flow DOES NOT mean flow to the top of the channel bank.

Each stream channel and project site is unique. Geomorphic characteristics, such as meander pattern, width/depth ratio, radius of curvature, particle size distribution, channel gradient, and pool/riffle spacing, all impact the effectiveness of stream barbs. Onsite evaluation of the appropriateness and utility of stream barbs is necessary. They are most effective in gravel and cobble bedded streams with slopes less than three percent.

Stream barbs redirect stream flow with a very low weir and disrupt the velocity gradient in the near-bank region. The low weir section is pointed upstream and forces the water flowing over the weir into a hydraulic jump. Flowing water turns to an angle perpendicular to the downstream weir face causing the flow to be directed away from the streambank. The weir effect continues to influence the bottom currents even when the barb is submerged by flows greater than the channel-forming flow. The disruption of the velocity gradient reduces channel bed shear stress and interrupts sediment transport -- this results in sediment deposition adjacent to the barb. The local flattening of water slope upstream of the barb causes an eddy and sediment deposition. The flow separation caused by the hydraulic jump and flow redirection downstream of the barb creates an eddy, which also promotes deposition.

Stream barbs are used for bank protection measures, to increase scour of point and lateral bars, to direct stream flow towards instream diversions, and to change bedload transport and deposition patterns. Other benefits of stream barbs include reducing the width to depth ratio of a stream channel and providing pool habitat for fish. Trees with rootwads can be added to these structures to improve fish habitat value.

Using stream barbs in conjunction with bioengineering methods is the most favorable combination. The barbs relieve direct streambank pressure from flow and vegetation provides for energy dissipation and sediment deposition. The vegetation is the long-term stabilizing factor.

Prepared by Janine Castro, Geomorphologist, USDA NRCS

GENERAL MATERIAL SPECIFICATIONS

Rock for barbs shall be durable and of suitable quality to assure permanence in the climate in which it is to be used. The rock shall be sound and dense, free from cracks, seams, and other defects that would tend to increase deterioration from weathering, freezing and thawing, or other natural causes. The rock fragments shall be angular to subrounded in shape. The least dimension of an individual rock fragment shall not be less than one-third the greatest dimension of the fragment. Rock will have a minimum specific gravity of 2.5.

Depending on availability, large rock (generally greater than 3-feet in diameter) can be less expensive by weight and can take less time to install. If large rock is not available or is not preferred, follow the rock sizing criteria listed below.

Material sizing should follow standard riprap sizing criteria for turbulent flow (Far West States-Lane Method) for the design flow and be modified with the following formulas (Chapter 16, Engineering Handbook):

$$D_{50\text{-barb}} = 2 \times D_{50\text{-riprap}}$$

$$D_{100\text{-barb}} = 2 \times D_{50\text{-barb}}$$

$$D_{minimum} = 0.75 \times D_{50\text{-riprap}}$$

Note that the Far West States-Lane method gives the riprap D_{75} and not the D_{50} -- a gradation is required to obtain the riprap D_{50}. Once the riprap D_{50} is obtained, use the gradation listed above. When the ratio of curve radius to channel width is less than six, rock sizes become extremely large, and result in a very conservative design.

Rock in the weir should be well graded in the D_{50} to D_{100} range for the weir section (the smaller material may be incorporated into the bank key). The largest rocks should be used in the exposed weir section of the barb. DO NOT use the Isbash Curve when sizing rock for stream barbs as it results in sizes too small for this application.

Rock sizing depends on the size of the stream, maximum depth of flow, planform, entrenchment, and ice and debris loading. Adjustments may be necessary for your local area.

GENERAL DESIGN GUIDANCE

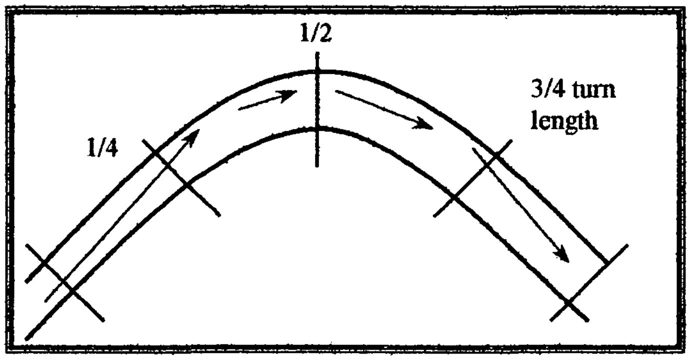
see attached figures for reference

(1) **Location and Number of Barbs** - Stream barbs are typically placed along the outside of a bend where the thalweg is near the streambank. If the thalweg (deepest part of the channel) is in the center of the channel, other bank protection measures should be considered. Stream barbs will not protect banks that are eroding due to rapid drawdown or mass slope failure.

The number of barbs required at any given site will be determined by (1) barb spacing, (2) the length of the eroding meander bend, (3) channel geometry, (4) bedload, and (5) desired effect for overall watershed management.

The furthest upstream barb should be located just upstream of the area that is first impacted by flood flow erosion. This is often above the actively eroding bank and the location can be difficult to determine during low flows. Often barbs do not need to extend to the downstream extent of the eroding bank, as upstream barbs will modify the angle and distribution of velocity, stopping the erosion. In general, in a stream with moderately regular meander patterns, barbs should not be placed downstream of 3/4 of the turn length (Figure 1).

Figure 1.



(2) **Height** - The height of the stream barb (H) is generally determined by the elevation of channel-forming flow discharge (approximately a 1.5-year event). For ungaged streams, channel-forming discharge can be determined using field indicators such as bed features and the presence or absence of vegetation. The channel-forming or "bankfull" elevation is not necessarily the top of the bank; for most streams, "bankfull" is equal to or slightly above ordinary high water.

The structure is intended to function as a weir and is therefore nearly flat (slope should not exceed 1V: 5H) but MUST always have a positive slope. Barbs constructed with flat weir sections may lose a few rocks from the center of the barb resulting in a negative slope and essentially force water closer to the bank.

$$H_{max} = 1/3\ D_{avg} \text{ to } 1/2\ D_{avg}$$

$$D_{avg} = \text{average channel-forming flow depth}$$

The relative height between successive barbs is very important. The difference in height between barbs should approximate the energy grade line of the stream regardless of local variations in bed topography.

To reduce scour depths, decrease the barb height. Higher barbs, up to the channel forming flow elevation, cause greater flow convergence, and thus greater scour depths.

(3) **Spacing** – Proper spacing of barbs is necessary to prevent the stream flow from cutting between two barbs and eroding the bank. A vector analysis (plotting the proposed barbs with vectors projecting at right angles to the downstream side of the barb) can give some indication of flow lines and flow interception by subsequent barbs. Given that the flow will leave the barb in a direction perpendicular to the downstream weir face, the subsequent barb should be placed so that the flow will be captured in the center portion of the barb before the stream flow intersects the bank.

Typically, barbs influence the flow patterns for a distance downstream equal to 5 to 10 times the barbs perpendicular projection into the stream, although there is much local variation.

(4) **Angle** – The structure should project upstream such that the flow is directed away from the streambank. The angle can vary from 20 to 45 degrees from the tangent to the bank depending upon the curvature of the bend and the intended realignment of the thalweg. If the purpose is to maintain a deep thalweg near the streambank, then a tight angle (20 degrees) is required. A vector analysis can be used to estimate the angle required to turn the flow. The downstream side of the barb should be a straight, uniform line because it controls the flow direction.

(5) **Length** – For most barbs, the effective length (L_{eff}) should not exceed 1/4 the channel-forming flow width (W). Barbs that extend beyond this length tend to alter the meander pattern of the stream and the stream flow that may affect the opposite bank. Stream barbs should not be used to change the meander pattern of an entire stream system or to "channelize" the stream flow. Caution should be used anytime a stream barb is installed, especially if the barb is longer than 1/4 the channel width, because they are very powerful hydraulic structures. For bank protection, the barb generally can be less than ¼ the channel-forming flow width of the channel.

Maximum $L_{eff} = W/4$

Barb Length for Bank Protection $W/10 < L_{eff} < W/4$

For the barbs to affect the dominant flow pattern, they must cross the thalweg. Shorter barbs will affect only secondary, near-bank currents. If the calculated effective length results in barbs that do not influence the dominant flow path, then adjustments should be made to the barb length and subsequently the key length and barb spacing. If this is not feasible, other techniques should be considered.

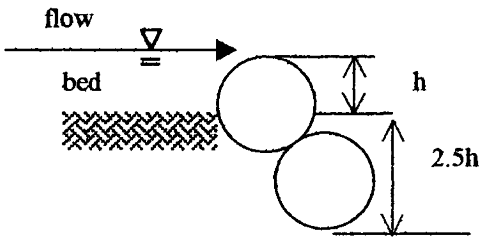
(6) **Profile** – The barb transitions from the exposed barb section to the bank key on a slope of 1V: 1.5H to 1V: 2H. The weir section at the streambank should not exceed the channel-forming flow level (1.5-year flow) as this results in a jetty rather than a barb. The top of the key must be high enough to prevent water from flowing around and eroding behind the structure. Banks that are frequently overtopped will require a more extensive key that extends further back into the bank. Bank material will also need to be considered when designing the dimensions of the key.

(7) **Width** - The width of a barb generally ranges from one to three-times the D_{100}. The width does not need to be more than two rock diameters and can even be the width of a single large rock at the tip of the barb. The barb width may need to be increased (10 to 15 feet total width) to accommodate construction equipment in large rivers or where necessary. Wider structures will result in a more uniform, stronger hydraulic jump. Wider structures should be used if a deep scour hole downstream of the barb is expected.

(8) **Length of Bank Key** - The purpose of the bank key is to protect the structure from flanking due to erosion in the near bank region. The length of the bank key is generally about half of the length of a short barb to 1/5th the length of a long barb or 4 times the D_{100}. Bank key length should not be less than 1.5 times the bank height or eight feet (whichever is greater). Buried cut-off logs or rocks can be used in conjunction with the bank key. The buried log or rock should be oriented perpendicular to the direction of FLOOD FLOWS.

(9) **Depth of the Bed Key** -- The bed key depth should be determined by calculating expected scour depth around the tip of the structure. If a bed key is not incorporated, or if the bed key is too shallow, scour may erode the bed material downstream, causing the rock to fall into the scour hole. The bed key is typically placed to a depth of D_{100}. Note that scour depth will likely exceed the depth of the thalweg (deepest part of the channel).

In lieu of a scour analysis, scour depth can be estimated using the following:



Expected scour depth for gravel or cobble bed streams can be estimated by:

Scour = 2.5*h

Where h = height of exposed rock relative to bed elevation.

For sand, use 3 to 3.5*h

To reduce scour depths, decrease the barb height. Higher barbs cause greater flow convergence, and thus greater scour depths.

(10) **Construction** - Stream barbs should be constructed during low flow conditions to minimize instream disturbances. Short barbs can be constructed from the bank while long barbs may require the use of the barb surface as a platform during construction. The barb width can be reduced as the equipment works back from the tip of the barb towards the bank. The rock should never be end dumped.

Construction should always start at the upstream end of the project site. Alterations to the design during construction are sometimes necessary -- be sure to have someone on site to insure proper installation and get concurrence from the designer.

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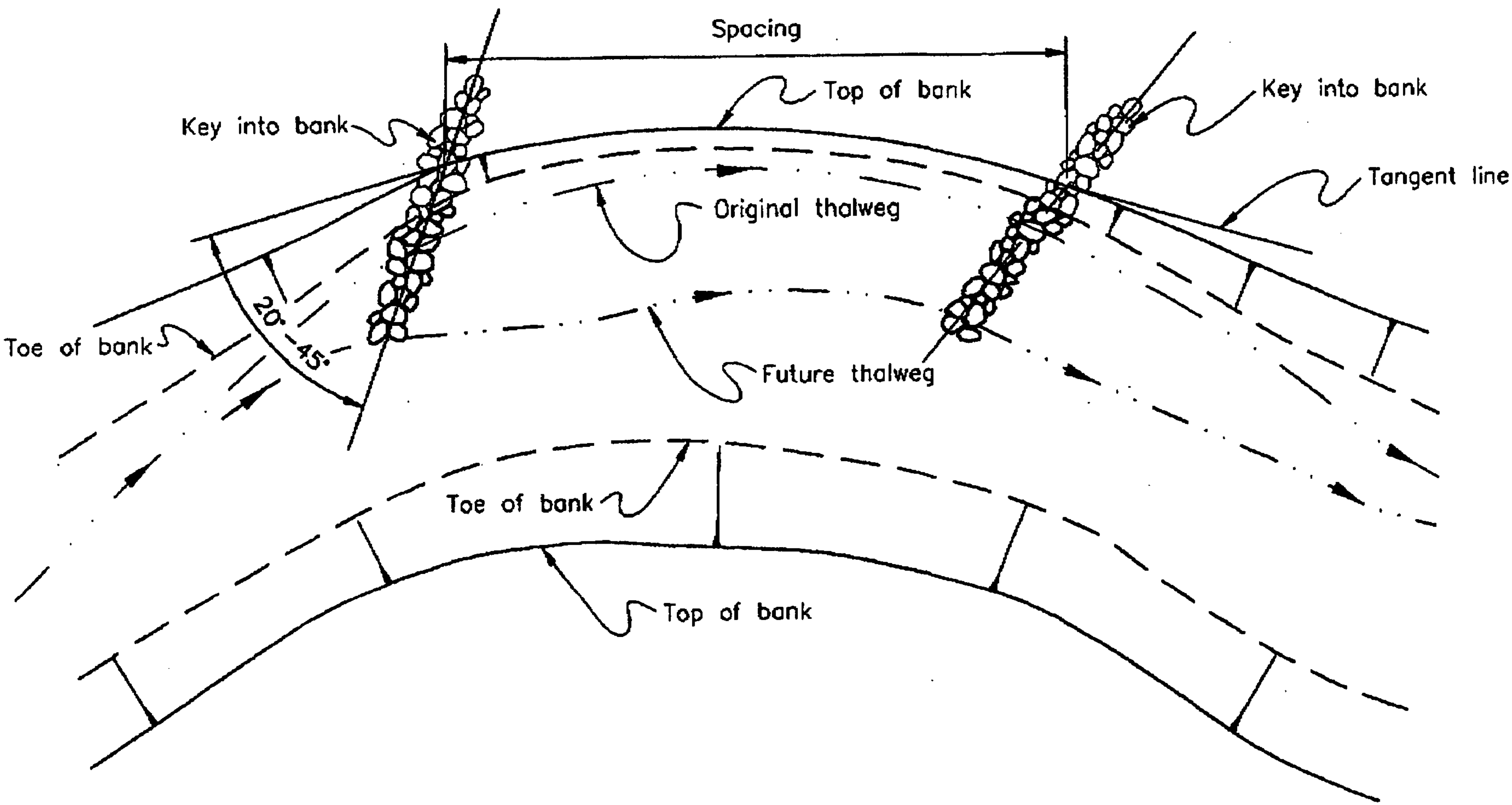
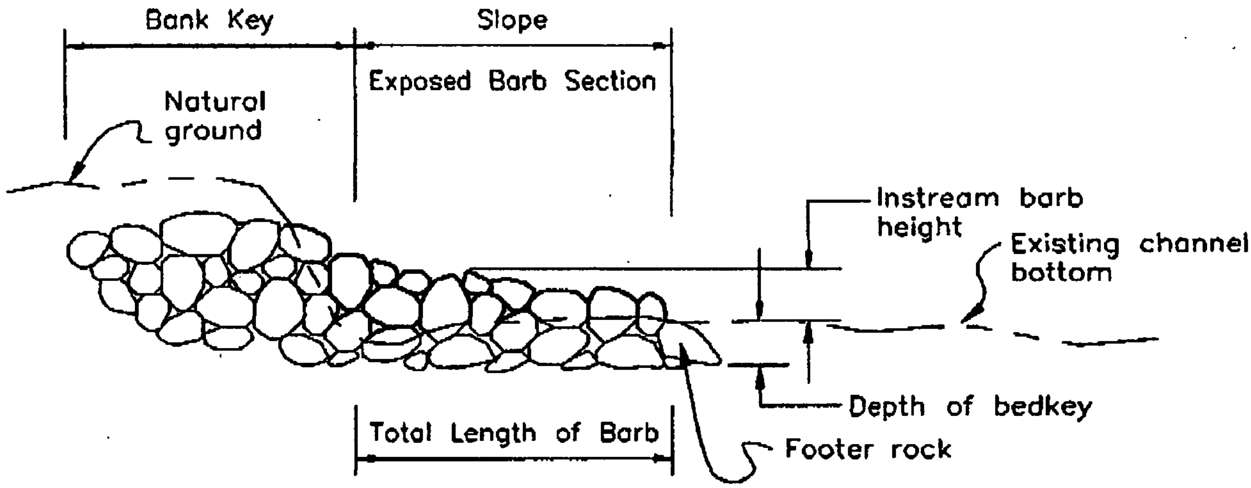


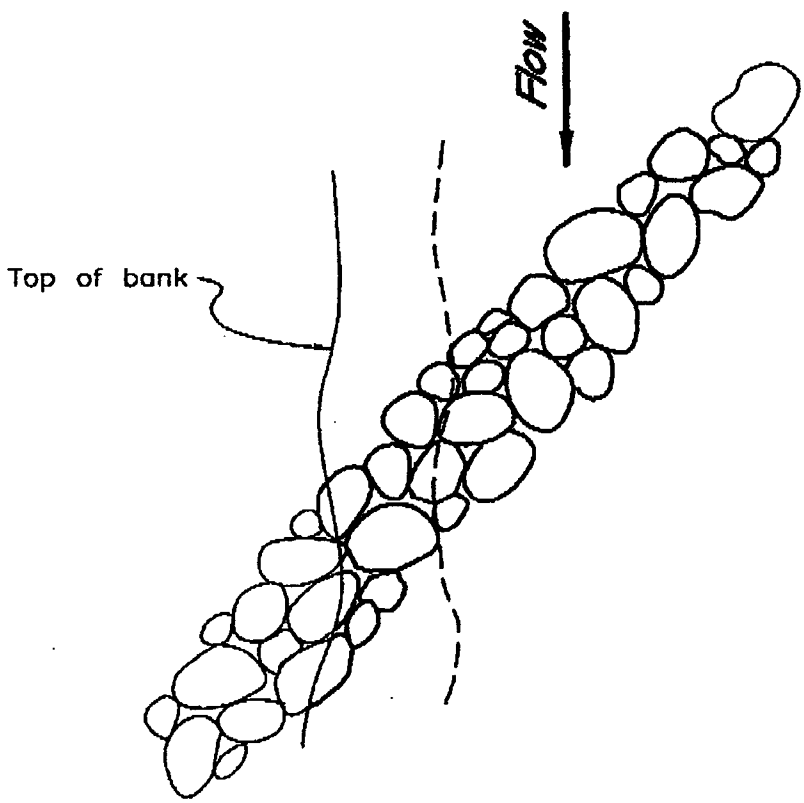
STREAM BARB

Not to Scale

barbplan1-2.dwg



SIDE VIEW



PLAN

STREAM BARB

barbdetail1-2.dwg

TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE
PORTLAND, OREGON January 1, 2000

ENGINEERING – NO. 24

DESIGN OF ROCK WEIRS

DESCRIPTION

Porous and solid rock weirs are channel spanning rock structures that are installed to (1) center, and sometimes create, a stream thalweg; (2) protect streambanks by redirecting stream flow; (3) establish and maintain a lower width to depth ratio; (4) provide fish passage by concentrating low flows in flat-bottomed channels into narrower, deeper channels; (5) increase sedimentation along streambanks; (6) control flow direction and therefore minimize meandering; (7) raise water surface elevations to provide water to diversions and channel alcoves; (8) stabilize stream gradient; (9) provide energy dissipation; (10) create pool habitat; and (11) buttress the bole of a rootwad for aquatic habitat cover.

Rock weirs are very low structures that should be completely overtopped during channel-forming flow events (approximately a 1.5-year flow event). Channel-forming flow, or bankfull discharge, is defined as the flow that transports the greatest amount of sediment over a long period of time and controls the channel geometry. Porous weirs have spaces between the exposed rock near the middle of the channel to further accommodate fish passage for some species, while solid weirs are continuous across the channel. Both porous and solid rock weirs are designed in a 'V' or 'U' shape with the trough oriented upstream (see attached figures).

Each stream channel and project site is unique. Geomorphic characteristics, such as meander pattern, width/depth ratio, radius of curvature, particle size distribution, channel gradient, and pool/riffle spacing, all impact the effectiveness of rock weirs. Onsite evaluation of the appropriateness and utility of rock weirs is necessary. They are most effective in gravel- and cobble-bed streams with slopes less than three percent. These structures should NOT be used in sand-bed streams. For streams with a channel-forming flow width greater than 100-feet, 'V' or 'U' shaped weirs are not recommended; 'W' shaped weirs are more effective in very wide streams but are more complex to design and build and are not covered in this technical note.

Rock weirs redirect stream flow to the center of the stream channel and disrupt the velocity gradient in the near-bank region. They utilize a low weir section pointed upstream to force water flowing over the weir into a hydraulic jump. Flowing water turns to an angle perpendicular to the downstream weir face causing the flow to be directed away from the streambank. The weir effect continues to influence the bottom currents even when submerged by flows greater than the channel-forming discharge. The length of the thalweg created downstream varies with slope and radius of curvature, but is typically 100 to 200-

Prepared by Janine Castro, Geomorphologist, USDA NRCS

feet. The disruption of the velocity gradient reduces channel bed shear stress and interrupts sediment transport in the near bank region.

Using rock weirs in conjunction with bioengineering methods is the most favorable combination. The weirs provide direct streambank protection from flow and vegetation provides for energy dissipation and sediment deposition.

GENERAL MATERIAL SPECIFICATIONS

Rock for weirs shall be durable and of suitable quality to assure permanence in the climate in which it is to be used. The rock shall be sound and dense, free from cracks, seams, and other defects that would tend to increase deterioration from weathering, freezing and thawing, or other natural causes. The rock fragments shall be angular to subrounded in shape. The least dimension of an individual rock fragment shall not be less than one-third the greatest dimension of the fragment. Rock will have a minimum specific gravity of 2.5.

Depending on availability, large rock (generally greater than 3-feet in diameter) can be less expensive by weight and can take less time to install. If large rock is not available or is not preferred, follow the rock sizing criteria listed below.

Material sizing should follow standard riprap sizing criteria for turbulent flow (Far West States-Lane Method) for the design flow and be modified with the following formulas (Chapter 16, Engineering Handbook):

$$D_{50\text{-barb}} = 2 \times D_{50\text{-riprap}}$$

$$D_{100\text{-barb}} = 2 \times D_{50\text{-barb}}$$

$$D_{minimum} = 0.75 \times D_{50\text{-riprap}}$$

Note that the Far West States-Lane method gives the riprap D_{75} and not the D_{50} -- a gradation is required to obtain the riprap D_{50}. Once the riprap D_{50} is obtained, use the gradation listed above. When the ratio of curve radius to channel width is less than six, rock sizes become extremely large, and result in a very conservative design.

Rock in the weir should be well graded in the D_{50} to D_{100} range for the weir section (the smaller material may be incorporated into the bank key). The largest rocks should be used in the exposed weir section. DO NOT use the Isbash Curve when sizing rock for rock weirs as it results in sizes too small for this application.

Rock sizing depends on the size of the stream, maximum depth of flow, planform, entrenchment, and ice and debris loading. Adjustments may be necessary for your local area.

GENERAL DESIGN GUIDANCE

see attached figures for reference

(1) **Location** - Rock weirs are typically placed in straight reaches of a stream channel near the downstream end of a riffle section. The upstream tip of the weir should be

located at one to two channel widths downstream of the crossover. They should be placed in areas where pools would naturally form. Rock weirs will not protect banks that are eroding due to rapid drawdown or mass slope failure; other techniques should be employed.

(2) **Height** – The height of the weir section near the stream bank (H) is generally determined by the elevation of channel-forming discharge (approximately a 1.5-year event). For ungaged streams, channel-forming discharge can be determined using field indicators such as bed features and the presence or absence of vegetation. The channel-forming elevation is not necessarily the top of the bank; for most streams, the channel-forming elevation is equal to or slightly above average annual peak flow.

To achieve proper weir function the slope is nearly flat (slope should not exceed 1V: 5H) but MUST always have a positive slope towards the center of the channel. Rock weirs that are constructed with flat sections may lose a few rocks in the near bank region resulting in a negative slope essentially forcing water closer to the bank.

Relative height of weirs used in a series is very important. Generally the slope between the weir crests should not be flatter than the pre-project water surface slope at low flows. The center of the weir should be at grade with the channel bed to allow for sediment transport and fish passage. To reduce scour depths, decrease the weir height. Higher weirs cause greater flow convergence, and thus greater scour depths.

(3) **Spacing** – Rock weirs are typically used in a series if the intended purpose is fish passage or grade control with an elevation change (headcut) greater than one-foot. For fish passage, the spacing depends on slope, length of backwater effects created and associated depth, and length of thalweg created downstream. For grade control, the rock weirs should be placed no closer than the net drop divided by the channel slope. As an example, a one-foot high weir in a stream with a two-percent gradient will have a minimum spacing of 50-feet (1/0.02).

(4) **Angle and Offset** – The structure should project upstream such that the flow is directed away from the streambank. The angle from a tangent to the bank can vary from 20 to 60 degrees, although a hydraulic analysis is necessary for weirs with arm angles approaching 60 degrees. Once the arm length reaches 50 to 60-feet, it is necessary to truncate the 'V' and cross the channel in more of a horseshoe shape.

(5) **Profile** – The rock weir transitions from the exposed weir section to the bank key on a slope of 1V:1.5H to 1V:2H. The weir section at the streambank should not exceed the channel-forming flow level (1.5-year flow). The bank key must be long enough and high enough to prevent water from flowing around and eroding behind the structure. Banks that are frequently overtopped will require a more extensive key that extends further back into the bank. Bank material will also need to be considered when designing the dimensions of the key.

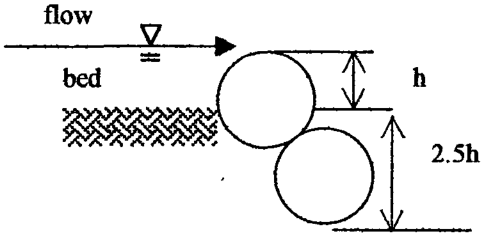
The exposed weir section slopes from the channel-forming flow level at the banks down towards the center of the channel. The center of the weir should be at grade. The legs of the weir can be maintained at the channel-forming level into the stream channel if the purpose is to reduce channel width and concentrate stream flow. This may be advantageous in streams where fish passage is a concern during low flow periods.

(6) **Width** – The top width of a rock weir generally ranges from one to three-times the $D_{100\text{-weir}}$. The weir width may need to be increased to accommodate construction equipment in large rivers because of the rock weight and track hoe reach. Wider structures will result in a more uniform, stronger hydraulic jump. Wider structures should be used if a deep scour hole downstream of the weir is expected.

(7) **Length of Bank Key** – The purpose of the bank key is to protect the structure from flanking due to near bank erosion. The length of the bank key is 4 times the $D_{100\text{-weir}}$ and should not be less than 1.5 times the height to the top of the bank or eight feet (whichever is greater). Buried cut-off logs or rocks can be used in conjunction with the bank key. The buried log or rock should be oriented perpendicular to the direction of FLOOD FLOWS. Left over rock, or rock that is too small for the instream portion of the barb can be used in the cut-off trench.

(8) **Depth of the Bed Key** -- The bed key depth should be determined by calculating expected scour hole depth downstream of the weir. The bed key is typically placed to a depth of $D_{100\text{-weir}}$. However, channel excavation depth in a live stream is sometimes limited because of sloughing; a very large rock often works better than trying to place two large rocks on top of one another. Note that scour depth will likely exceed the depth of the thalweg (deepest part of the channel). Scour depths will be greater in streams that are relatively deep or have higher gradients.

In lieu of a scour analysis, scour depth can be estimated using the following:



Expected scour depth for gravel or cobble bed streams can be estimated by:

Scour = 2.5*h

Where h = height of exposed rock relative to bed elevation.

For sand, use 3 to 3.5*h

To reduce scour depths, decrease the weir height. Higher weirs cause greater flow convergence, and thus greater scour depths.

(9) **Construction** – Rock weirs should be constructed during low flow conditions to minimize instream disturbances. It is usually necessary to work in the stream channel while constructing rock weirs. The rock should never be dumped. The rock should be placed with the proper equipment to insure that the rocks are interlocked and stable. It is CRITICAL that the designer or an inspector experienced in these structures be present during installation.

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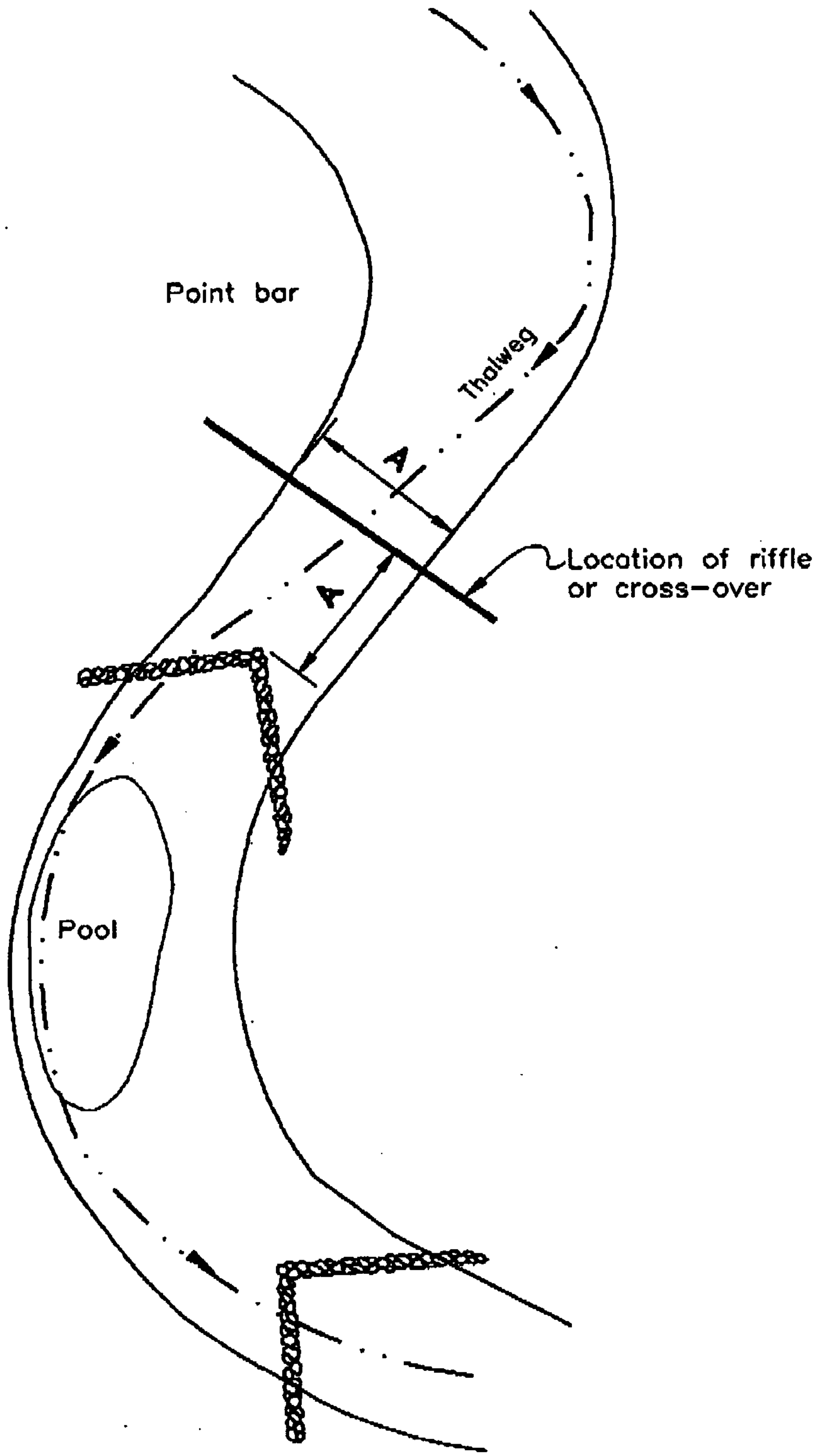
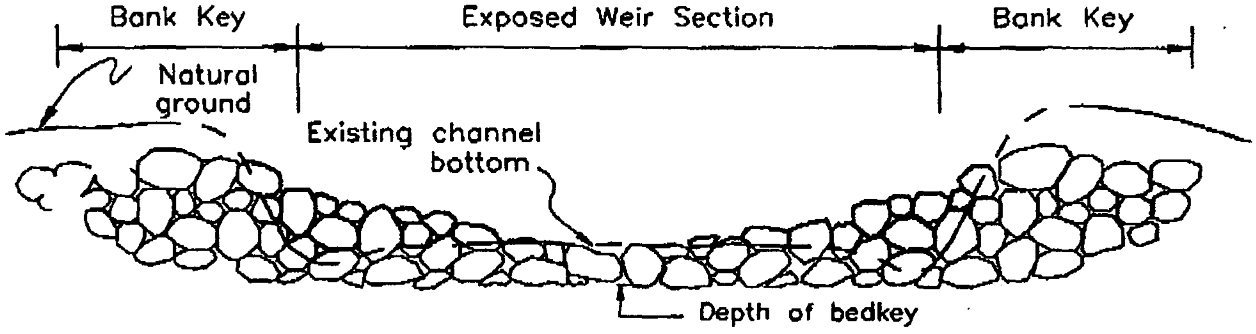
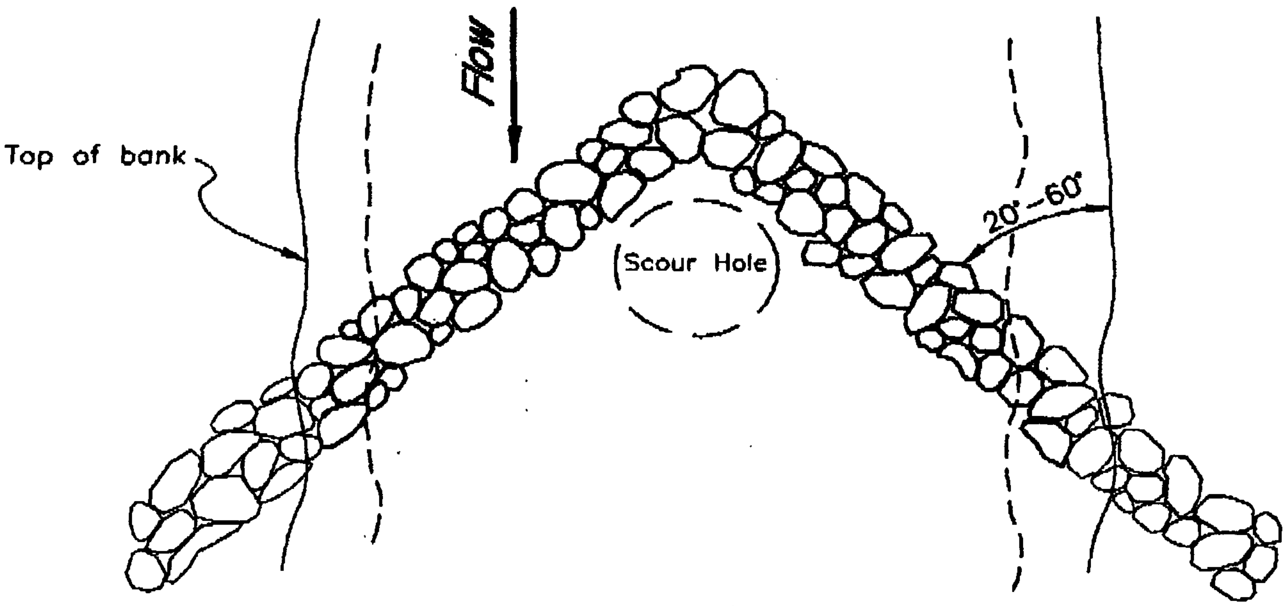


ROCK WEIR

weirplan1-2.dwg



SIDE VIEW



PLAN

SOLID ROCK WEIR

sweirdetail1-2.dwg

Appendix 6: Project correspondence summarizing selected site visits

ClearWater West ~~~~
7306 SE Main Street ▫ Portland, Oregon 97215
Phone: (503) 257-9359 ▫ Fax: 255-5824
E-Mail: mmitchel@teleport.com

MEMO

TO: Charles Ciecko

FR: Marty Mitchell

RE: Oxbow shoreline / boat ramp / charrette

Today's date: Oct 5, 2000

Charlie:

Here are a few notes from our visit to the boat ramp and environs in Oxbow Park Monday:

<u>Attending</u>
Jim Lind, manager, Oxbow Regional Park
Jim Muck, fisheries biologist, Oregon Department of Fish &Wildlife
Tim Abbe, Ph.D., registered geologist, Philip Williams & Assoc., Seattle
Janine Castro, Ph.D., fluvial morphologist, Natural Resources Conservation Service
Marty Mitchell, C.P.E.S.C, natural resource planner, ClearWater West

- Handicap fishing platforms around the state have developed much the same problems;
- The most enduring boat launch facilities in dynamic river systems are unsurfaced native river rock and gravel; this is sufficient to launch a drift boat;
- It would be very expensive to try to design a feature that would protect the existing facilities during worst-case events such as the storms of Thanksgiving Day 1999, and January 1996;
- Also, it is hard to design for the big events;
- Facilities like this are hard on channels;
- Fall Chinook are spawning in side channels — NMFS probably wouldn't support a project to protect these facilities unless some other amenity were offered;
- Offer to open up a side channel for enhanced habitat;

- Might want to look at a site below Camp Collins for a boat launching facility instead;
- It would be cheaper to move the boat ramp than try to control the river here;
- Restoration costs are extremely high; would need to put in coffer dams, the whole works; very, very expensive; could be millions;
- ODF&W won't allow logs to be put in a channel unless the log is 2X the channel width;
- That is irrelevant in large rivers;
- An analysis can be done to show what it will take to create stability for a created log jam in a setting like this;
- There is a tremendous potential to recruit islands here;
- It is evident that some of the debris jams here are several generations old and therefore stable;
- But there is not a lot of wood here;
- Yes, nothing like you would see in Alaska or undisturbed systems in the PNW;
- Key wood is a necessary component of stability; other wood wraps onto it;
- Rate of decay of logs is a factor in long-term stability (species, size);
- Jams can be principal cause of channel migration, because they deflect flow;
- Logs can bury themselves in rivers, due to the mechanics of scour and fill around them;
- Wood elevates systems through the aggradation they influence, so forested systems can change vertically as well as from side to side;
- In this system, wood may be entering the system, but it does not appear to be staying around;
- The high flows of 1996 and 1999 floated a lot of it out of the ordinarily-flooded channel margin;
- Incision and confinement may be creating a high energy corridor in which there is not much that a log can hang up on;
- In general, wood does not go very far from where it falls into the system;
- Need a reach assessment before making any decision; this could be hundreds of thousands of dollars;
- It is essential to have accountability for design decisions;
- Having "before" and "after" data is important, too. Jim Lind and ODF&W have the presence and the interest to be able to provide on-going monitoring;
- Rearing habitat is the big thing here;
- Need to know what fish surveys are being done, what surveys will continue to be done;
- Need to know whether the incredibly muddy nature of the river the day after the 3" rainfall stems from a slide upstream, or what. It could be important to stabilize these sediment sources;
- Side channels are remarkably stable in nature;
- There are opportunities to open up side channels in the park; this could be an attractive selling point;
- A combination of measures could be "sold" to funding entities for 'buy-in": namely do habitat improvement that also functions as flood control for downstream land uses, in exchange for protecting the boat ramp or putting it somewhere else;
- Funding sources are important: BPA, NWPPC, OWEB, ODF&W, Metro

Greenspaces, PGE, others;

- A boat ramp project would need to be done as part of a large plan;
- Make certain to invite Bud Tollman, Rod Brobeck, Bill Baake to the charrette;
- Remember, PGE has funds;
- NWPPC grant is due mid-November.

Project: Oxbow shoreline charette

Notes: Site visit 11-13-00

This process was suggested:
- Ask NRCS to evaluate whether the debris jam upstream and across the river is causing the problem.
- Develop a few alternative remedies, based on NRCS's findings.
- Have Larry Swenson, a NMFS passage engineer, look at the alternatives.
- Chances are that anything that is done in this reach will result in the loss of some habitat.
- It looks as if impacts on fall Chinook would be the major concern.
- Therefore, suggest some actions that can be undertaken to improve habitat in the area to counterbalance habitat that is lost as a result of the actions taken.
- Offer mitigation under the Section 404 permit from the Corps and DSL.
- Keep in mind the long-term trajectory of properly functioning condition.
- ESA consultation would be required under section 10, but NMFS would probably be open to working something out.
- A biological assessment would be required to support the proposed alternative.
- Make sure to have Jim Myron and Bill Baake on board.
- Bianca Streif of USFWS can give some ideas.
- Have a pre-application meeting with Judy Linnton of the Corps, and all the players: ODF&W, USFWS, NMFS, Metro.

If proposing a barb or series of barbs:
- Watch out that a barb does not takce out or move the mid-channel bar
- Make certain that barb angle is pointing upstream

An alternative was suggested (one that would not require any of the above activities). This is to dig a deep trench in the ground perpendicular to the river, upstream of the boat ramp. Backfull this trench with very large rock and cover. It was suggested that this will prevent the river from eroding into the bank above the boat ramp.

Highlights of NMFS' Final 4(d) Ruling

- Effective dates: September 8, 2000 for steelhead and January 8, 2001 for salmon
- Establishes a prohibition on "take" of any individual fish in one of the 14 salmon and steelhead ESUs covered by the rule.
- Underscores NMFS' interest in working with parties to find conservation solutions to problems of take instead of relying on enforcement actions.
- Establishes 13 programs or activities in which the above prohibition on take is not applied:
  - Habitat restoration activities that are part of an approved watershed conservation plan (guidelines to be established by state governments and approved by NMFS)
  - Water diversion screens certified by NMFS or by the staff of other agencies and tribes that have been authorized by NMFS
  - Routine road maintenance for Oregon's Department of Transportation and other road maintenance programs that are similar to Oregon's
  - Municipal, residential, commercial, and industrial development or redevelopment that meets some or all of 12 criteria identified by NMFS to help achieve "properly functioning condition" for habitat needed by the listed species
  - Certain park maintenance activities of the City of Portland as part of the city's "integrated pest management program"
  - Washington State's forest management activities that meet the state's forest practices criteria
  - Other ESA-permitted activities under Section 7 (consultation) or Section 10 (habitat conservation plans) of the act: ongoing scientific research, rescue and salvage activities, fisheries management activities, some artificial propagation practices, joint tribal and state management plans, and other scientific research on fish

Photo by Joe Cone

NMFS also identified three categories of activities that it believed could result in take of salmon and steelhead: activities that (1) are "very likely" to result in take, (2) "may" result in take, or (3) are "unlikely" to result in take but collectively could present problems for listed fish. The service noted that ultimately any activity identified under the "very likely" category will be assessed on its own merits but cautioned that activities in this category will receive greater attention.

"Very likely" activities include

- Constructing or maintaining barriers that eliminate or impede a listed species' access to habitat or migration
- Discharging pollutants, such as oil, toxics, carcinogens, or other organic nutrient-laden water (including sewage)
- Removing, poisoning, or contaminating plants, fish, wildlife, or other biota required by the listed fish for their life cycle and habitat needs
- Removing or altering rocks, soil, gravel, vegetation, or other physical structures essential for the habitat of listed fish
- Removing water or otherwise altering streamflows that impair essential behavioral patterns or habitat
- Releasing nonindigenous or artificially propagated species in a listed species habitat
- Constructing or operating dams or water diversion structures with inadequate fish screens or passage facilities
- Constructing, maintaining, or using inadequate bridges, roads, or trails on stream banks or unstable hillslopes
- Conducting timber harvest, grazing, mining, earth moving, or other operations that result in substantially increasing sediment into streams
- Conducting land use activities in riparian areas and unstable areas that might increase sediment delivery into streams of listed fish
- Illegal fishing
- Streambed activities that might trample eggs or trap adult fish preparing to spawn
- Interstate and foreign commerce dealing in listed salmonids (including exporting or importing)
- Altering lands or waters in a way that promotes predators in waters with listed fish
- Shoreline or riparian disturbances that might prevent or interrupt habitat characteristics upon which the fish depend
- Filling or isolating side channels, ponds, and intermittent waterways in a way that destroys habitat needed for refuge during high streamflows

Appendix 7: Peak flow data for the Sandy River, 1911-2000
(Sta. #14142500 below Bull Run River)

STATION 14142500 SANDY RIVER BLW BULL RUN RIVER, NR BULL RUN, OR

AGENCY: USGS
STATE: 41
COUNTY: 005
DISTRICT: 41

STATION LOCATOR
LAT. LONG.
452657 1221438

DRAINAGE AREA: 436.00 SQ MI
CONTRIBUTING DRAINAGE AREA: SQ MI
GAGE DATUM: 200.00 (NGVD)
BASE DISCHARGE: 17000.00 CFS

WATER YEAR	DATE	TIME	PEAK DISCHARGE (CFS)	DISCHARGE CODES	GAGE HEIGHT (FT)	GAGE HEIGHT CODES	HIGHEST SINCE	MAX GAGE HEIGHT (FT)	DATE	TIME	GAGE HEIGHT CODES	NUMBER PARTIAL PEAKS
1911	01/19/1911		20700	6								0
1912	01/12/1912		24800	6								0
1913	03/29/1913		21200	6								0
1914	01/05/1914		15600	6								0
1930	02/01/1930		21300	6	12.05							0
1931	03/31/1931		58000	6	20.60							0
1932	03/18/1932		32000	6	14.70							0
1933	06/09/1933		22600	6	12.40							0
1934	12/22/1933		41000	6	16.78							0
1935	12/20/1934		32500	6	14.80							0
1936	01/04/1936		26600	6	13.43							0
1937	04/14/1937		19500	6	11.56							0
1938	12/29/1937		32000	6	14.66							0
1939	02/15/1939		21800	6	12.23							0
1940	02/06/1940		17800	6	11.10							0
1941	11/29/1940		21600	6	12.14							0
1942	12/02/1941		14400	6	10.00							0
1943	11/23/1942		40300	6	16.53							0
1944	02/06/1944		13500	6	9.74							0
1945	02/13/1945		21400	6	11.90							0
1946	12/28/1945		44300	6	17.46							0
1947	12/12/1946		38600	6	16.15							0
1948	01/07/1948		36300	6	15.60							0
1949	05/02/1949		20800	6	12.40							0
1950	02/24/1950		27000	6								0
1951	11/02/1950		15100	6	10.71							0
1952	02/03/1952		17900	6	11.56							0
1953	01/18/1953		34200	6	15.80							0
1954	11/22/1953		26400	6	13.85							0
1955	12/30/1954		26100	6	13.78							0
1956	11/26/1955		42200	6	17.55							0
1957	12/11/1956		32300	6	15.33							0
1958	04/20/1958		32400	6	15.35							0
1959	12/11/1958		21000	6	12.43							0
1960	10/22/1959		21600	6	12.60							0
1961	11/24/1960		35900	6	16.20							0
1962	04/06/1962		20700	6	12.35							0
1963	11/20/1962		30400	6	14.84							0
1964	01/25/1964		22000	6								0
1965	12/22/1964		84400	6	22.30							0
1966	01/14/1966		14000	6	9.26							0
1985	11/03/1984		19600	6	15.93							0
1986	02/23/1986		52700	6	20.89							0
1987	03/01/1987		17000	6	15.37							0
1988	12/10/1987		30500	6	17.57							0
1989	01/10/1989		16200	126								0
1990	04/27/1990		27700	6	17.65							0
1991	01/15/1991		26300	6	17.20							0
1992	12/06/1991		25400	6	17.03							0
1993	11/21/1992		22100	6	16.40							0
1994	02/24/1994		15400	6	14.92							0
1995	10/31/1994		33100	6	18.33							0

1996	02/07/1996 21:30:00	58600	6	22.59	0
1997	12/25/1996 08:30:00	27600	6	17.43	0
1998	10/30/1997 23:00:00	19200	6	15.78	0
1999	12/28/1998 04:00:00	40500	6	19.38	0
2000	11/25/99 22:30	57,600		21.44	

PROVISIONAL DATA