ENVIRONMENTALLY SENSITIVE GRAVEL BAR SCALPING

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INTRODUCTION

This paper evaluates and summarizes previous studies and presents the results of four years of evaluation of scalping along the Wilson and Kilchis Rivers in Tillamook Co. OR. Data concerning the Donaldson, Barker, Dill and Gomes Bars will be shown. These are two of the four rivers in the basin that have been periodically scalped for many years. Bar scalping does not exceed the annual recruitment rate, consistent with Oregon Department of Fish and Wildlife policy. To reduce any potential impact on salmonids, particularly chum salmon, the scalping is done under a state-county-private coordinated agreement that scalping is only allowed if there is active erosion on the opposite streambank. This agreement was signed in 1992 and had some minor word amendments in 1999

SETTING

Landscape Conditions: Sea level occupied the lowlands of the Tillamook Basin as late as about 6,000 years ago. Stratigraphic sections can be characterized as a mixed sequence of marine gravels and gravely clay, overlaid by a thick sequence of marine sand, possibly volcanic ash and some organic rich zones, overlaid by sandy gravel, overlain by sand, silt and clay estuary deposits. Various units, but in particular the estuary deposits have thin sand layers that are likely to be tsunami deposits from subduction zone earthquakes. A recent published (Reckendorf and Peterson, 2003) list of coseismic events shows subduction zone earthquake events in radio carbon years before present as 3,200; 2,800; 2,500; 1,700; 1,300; 1,100; and 1700AD. With each event would have been subsidence and additions of tsunami sands of various thickness, Once sea level started to drop, alluvial fans and landsides developed around the margin of the basin. Over time the streams developed that meandered and deposited gravelly lateral accretion deposits. During floods some of the lateral accretion deposits were overlain by sandy and silty vertical accretion deposits. As the river downcut to present sea level, the rivers developed new food plains, leaving older flood plains as terraces along the stream banks. This results today in a stepped sequence of low flood plains flooded in ordinary high water (also called bankfull flow); flood plains a few feet higher called intermediate flood plains that are only flooded occasionally, and high flood plains that are only flooded in rare flood events. All of these flood plains, as well as un-flooded terrace, and alluvial fans, which are a combination of stratified sandy, silty, and gravel deposits, are encountered by the Wilson, and Kilchis Rivers at any given location. Of critical importance is that the lateral accretion flood plain gravel deposits that are overlain by vertical accretion finer textured deposits are incised within the fan and terrace deposits. Fines and sand are frequently washed out of the gravel matrix causing the gravel to slough and de-stabilize the overlying material. The tsunami sand layers are also easily washed out causing failure above.

In the 1800's, the Wilson River was much narrower than today such as shown in Figures 10 and 29 in Coulton et al (1996) and in Figure 6-3 in Coulton, (1998). It is estimated that the Wilson River and its bars had a width of roughly 70 feet in the early 1900's. The channel width, including the bar, in 1939 at the Donaldson, and Barker Bars on the Wilson River and Middle Gomes, Lower Gomes, and Dill Bars on the Kilchis River are about 147 ft, 107 ft., 67 ft., 53 ft. and 80 ft., respectively. In 2000 the width measured is 280 ft., 180 ft., 178 ft., 290 ft., and 290 ft., respectively. Widening along the Wilson, and Kilchis Rivers has occurred primarily from lateral erosion of the sandy and silty vertical accretion deposits of the low flood plain, apparent on old (1939) aerial photographs. Once the vertical accretion deposits are eroded off the underlying lateral accretion deposits are exposed as gravel bar. These new gravels have than been taken as gravel scalping in gravel removal operation. In other words, much of the gravel being taken in scalping is from areas that were historically low flood plains, rather than natural bars.

Stream Hydrology and Sediment in Gravel Bars: The Wilson River has had a recording stream gage at RM 11.4 since 1937. This 74 years of record allows for the development of an excellent discharge frequency curve for the Wilson stream gage. A frequency curve (Reckendorf, 2004a) for the Wilson River Gage was developed based on the data in USGS Open File Report 93-63 (Wellman et al, 1993). This frequency curve was extended at the low flows between the 80% chance (2 year average recurrence interval) and 99% chance (1.0 year average recurrence interval), using unpublished data provided by the US Geological Survey.

Based on field evidence along the Wilson and Kilchis Rivers of the first flat flooded depositional surface, and high water marks of six recent floods, as well as the frequency-discharge curve best break in slope, a bankfull flow at the gage is proposed that has a provisional discharge of 11,500 cfs. This has a stage of 12.5 ft. at the stream gage. Since the gage has a one foot offset, the bankfull depth at the gage is 11.5 ft. The bankfull flood event has an average recurrence interval flood frequency of 1.16 years. However for the Donaldson Bar at RM 5.0 there is an additional 31 sq. mi. of drainage area. The gage has a drainage area of 161 sq. mi. Therefore the additional drainage area represents 19% of the gage drainage area, so all discharges for the Donaldson Bar could be increased for evaluation purposes by as much as 19% as was done in some past studies (Reckendorf, 2005a, 2004) However increasing the bankfull flow by 19% probably overestimates the bankfull flow condition at the Donaldson Bar, because much of the additional watershed comes from lower elevations In addition increasing the bankfull flow by 19% made little difference in the velocity used in the analysis of pre and post scalp incipient motion of particles (Reckendorf 2005a)

The largest flood peak in 2002-2003 was on January 31, 2003 and had a discharge of 17,800 cfs. and a stage of 14.8 feet. That flood has about a 2-year average recurrence interval. A flood occurred on March 22, 2003 that has a provisional discharge of 11,500 cfs and a stage of about 12.5 ft. This flood has an average recurrence of 1.16 years. In the 2003-2004 the largest flood was on January 29, 2004. This flood has a provisional discharge of 12,600 cfs with a stage of 12.8 with an average recurrence interval of 1.23yrs. In the 2004-2005 there was a flood on December 11, 2004 that has a provisional discharge of 11,100 cfs. with a stage of 12.1 ft. This flood has an average recurrence interval of 1.19 yrs. The largest flood of the 2004-2005 occurred on January 18, 2005. It has a provisional discharge of 15,500 cfs. with a stage of 14.0 ft. This flood has and average recurrence interval of 1.6 yrs. Another large flood occurred on March 27, 2005. This flood had a discharge of 12,000 and stage of 12.6 ft. Of the last five floods three of them were between 11,100 and 12,000 cfs. Therefore the bankfull flow of 11,500 cfs. fits the average for the field conditions of ordinary high water. The overall flood history of the Tillamook Basin is reflected in the Wilson River gage or the last 12 years, (and to some degree the debris flow history). has been shown in Reckendorf, 2005a. Almost all of the winter floods shown are close to or above bankfull discharge except the runoff event on December 23, 2000 of 3,750 cfs. and one on 2/24/94 of 8,180 cfs. Several years show three or more floods greater than bankfull in a given year, and it is no surprise the 1996 is one of those years, as a 1% chance event occurred that year.

The Kilchis River Watershed is the adjacent watershed to the Wilson River watershed on its north side. The Kilchis River had at short-term stream gage at approximately river mile 2.5. The Oregon Water Resources Department provided me with a rating curve for the Kilchis River gage (14301450). This rating curve did not extend far enough to include discharges above 8,400 cfs. Therefore for the January 31, 2003, March 23, 2003 or January 29, 2004 floods, I extended the rating curve for these higher observed stages to determine a higher discharges Reckendorf, (2004b), even though there was no field measurement to support these discharges. The January 31, 2003 flood has a discharge of 17,500 cfs. associated with a stage of 14.6 feet. Another flood on March 22, 2003 has a flood discharge of 12,500 cfs. associated with a stage of 12.3 feet. The January 29, 2004 flood has a provisional discharge of 16,700 cfs. associated with a stage of 14.3 feet. Assuming that the Kilchis floods would be operating at about the same flood frequency 1.16 yr., a 11,500 cfs. event on the Wilson River would have a provisional discharge of 11,500 cfs. on the Kilchis River which has a stage of 11.7 (no offset) based on the Kilchis rating curve.

A study by Stinson and Stinson, (1998) looked (1993-1997) at the effects of gravel bar scalping on the morphology of gravel bars and particle size distribution of the bar gravel and gravel armor layer in four watersheds in Tillamook County.. The study, which took repeated samples at the same location for particle size distribution, showed no consistent downstream decrease in particle size for either the Wilson, or the Kilchis River. The Stinson's (1998) concluded that there was no correlation between gravel bar harvesting and the variability in particle size. They found no trend in any particle size class increasing or decreasing consistently over the course of the study. There was no correlation between the particle size distributions and gravel bars in the same watershed. They found no correlation between the flows in the watershed and the particle size distributions as shown in the lack of a corresponding shift in the particle size distributions between 1994 and 1996 to match the flow pattern shift. The variability encountered in particle size is consistent with a landslide-debris flow-debris torrent dominated system. It depends on the variability in size of source material, and on debris flow occurrence and movement for local storms conditions on where any given sediment debris has moved and distributed downstream.

Dynamic Equilibrium: The natural dynamic equilibrium condition along the Wilson, and Kilchis, Rivers in the Tillamook Bay Watershed, has been severely altered over the years by alteration of sediment load and size as well as the channel slope, and probably the discharges. These alterations have come about because of initial logging and log drives down the rivers, forest fires, roads and railroads built for salvage logging, woody debris accumulations and blowouts of woody debris accumulations, removing channel large woody debris, and channel straightening and alterations by the Corps of Engineers and local landowners, especially after floods. These changed conditions along with a landslide-debris flow-debris torrent driven system, have resulted in over-widened streams with mixed bed material load that is not in equilibrium with flow conditions. The over widen width with a bed material load that did not increase with flow or decrease with distance downstream (Stinson and Stinson 1998) is evidence that the Wilson and Kilchis Rivers are operating in a “chaos condition” and are not in a dynamic equilibrium condition. There have been gravel operations along the Wilson, Trask, Kilchis, and Miami River in the Tllamook Bay Basin that have removed some gravel sediment from some channels and bars for over 50 years. however, in about the last 10 years there has only been bar scalping. The over widen condition existed 70 ft. to 147 ft. by 1939, and 200 ft. by 1953) prior to most of the gravel removal operations. The gravel removal does not appear to be the cause that created the dis-equilibrium condition. It is the excess sediment supply (Reckendorf, 2005a, 2004, 1995) from landslide-debris flows-debris torrents along with the over-widen channel and bar area that prevents the discharge and slope from re-establishing a dynamic equilibrium condition. Part of the over widened channel may have been caused because of past large and repetitive log debris jams moved down the channels (Coulton et al 1996), and by disturbances along the channel for salvage logging after the Tillamook Burn fires. The excess sediment supply in the watersheds of rivers keeps bars replenished and growing. Un-scalped bars through sedimentation keep growing in width and height. However, it takes a flood larger than a bankfull event to add much sediment height once the bars grow in height up to the level of the low flood plain.

Landslides, Debris Flows, and Debris Torrents: The term landslides denotes “the movement of a mass of rock, debris, or earth down a slope” (Cruden, 1991). One study (USDA, 1978) stated that there were 1,870 human caused landslides in the Wilson Watershed verses 86 natural landslide. On the Kilchis they (USDA, 1978) stated that there were 828 human caused landslides verses 28 natural landslides. Sometimes landslides are converted to debris flows, which are landslides where, “considerable amounts of loose material are suddenly moved by an excessive amount of water and transported in an extremely fast and destructive flow through a valley.” (TRB, NRS, 1996). Debris torrents are likely the most important means of sediment transport in the upper watersheds in the Tillamook Bay Watershed (TBNEP, Chapter 6 Sedimentation, Charland and Reckendorf, 1998). Debris torrents are rapid movements of water-charged debris confined to steep headwater channels. They begin as landslides and debris flows and can transport up to 100 times more than the initiated slide when fully developed (Mills, 1997a, and 1997b). The most common triggering mechanism for debris torrents are extreme water discharge, either heavy rainfall or temporary damming of a channel (Van Dine, 1985). Debris flows and torrents tend to deposit there material where channel gradients decline. Once the debris flow or debris torrent reaches a stream they can stop and develop a local sediment debris jam in a channel, or at a tributary junction. Once they have formed a plug in the channel they cause the stream to severely erode the streambank to get around the plug of sediment. The plug of sediment debris does not move all at once but moves downstream as a pulse only under high runoff conditions. Therefore the streambanks are progressively eroded out in a downstream direction, as the stream finds more easily eroded material in the streambanks than the coarse material in the sediment debris in the channel. One statewide study (Hofmeister, 2000) associated severe storms, that cause flood peaks, with landslides (all forms of upland slope failure were included). The severe storms were February 1996, November 1996, and December 1996/January 1997 which generated 9,582 landslides in Oregon that were reported in the inventory. Tillamook County accounted for 836 landslides, of which 212 landslides were inventoried in the Wilson Watershed, and 159 in the Kilchis Watershed.

Active Erosion: Gravel scalping has been allowed in the Tillamook Basin since 1992, based on a state-county-private coordinated agreement. According to that agreements scalping is only allowed if there is active erosion. Active erosion over the years has caused stream widening as reflected in Tables 1 and 2. Table 2 is based on average conditions between aerial photo dates, except for the year 2000 which is based on cross section width. As shown in Table 2 rates are very high in some time periods for some time periods or locations. For example high erosion rates between 1939-1953 likely reflect the impact of the Tillamook Burn, salvage logging operations, log drives and breached log jams. Between 1994-200 rates are quite high likely reflecting the 1996-1997 flood runoff and related debris flows and torrents. Local conditions of very high erosion rates are shown for Tannler Bar on the Wilson River., between 1939 and 1953. These high rates are attributed to debris flow deposition and associated log jams causing local dams in the river that were flanked by the Wilson River by eroding its streambanks. The immediately upstream Barker Bar erosion rates are also high but not nearly as high as the Tannler Bar rates, and the Barker Bar would lie in the backwater of any debris flow plug along the downstream Tannler Bar. Erosion rates were also quite high along the Kilchis River between 1939 and 1953, also reflecting salvage logging as well as excess sediment supply from debris flows. The length of active streambank erosion is shown in Table 1, for the streambanks across from the bar stated. All areas of active erosion have weak stratigraphic layers, sloughing of gravels as fines and sand are washed out effectively decreasing matrix material, overhanging layers, and slump blocks at the base of the streambanks. All of these areas have essentially no effective vegetative cover, but have overhanging vegetative cover from above of Japanese Knapweed, Himalaya Blackberry, and Morning Glory. These vegetative materials provide essentially no erosion control protection, or a rooting system that binds the soil together, and hang out as much as 9 feet from the bank.

Stream Bar, Bed, and Bank Scour Conditions: At the Donaldson bar along the Wilson river, the competent average erosive velocity (Simon and Senturk, 1977, Figure 9.8) for pre and post-scalped conditions are reflected in Table 3. Using the gage discharge of 11,500 cfs., and a bankfull of 11.5 ft., the average velocity is 11.7 ft./sec. for pre-scalped conditions, and 7.9 ft./sec. for post-scalped conditions. The median bar size is 12.5 mm. and the median streambed size is 13 mm. The leave armour area (105 ft.) has an armour d50 of 27 mm. and the leave side of the upper bar has a d50 of 35 mm. As shown the average velocity for the pre-scalped conditions can cause incipient movement of particles up to 90 mm. at the 11 ft./sec. velocity, but only up to 30 mm. in the post-scalped condition. Therefore for the post scalped condition the average velocity will not cause particle movement of the buffer at the upped end or side of the bar. Although the post-scalped condition is shown to be high enough to move the median bar d50 there is no field evidence during floods or in post flood evaluation that scour, especially a scoured back channel, has developed. In contrast re-deposition is occurring with each runoff event with the amount varying with discharge and debris flow activity. As shown in Table 3, the results are little different if adjusted for a drainage area correction of 19%. The discharge is 13,385 cfs. and the average velocity 11.3 ft./sec. The incipient motion of particles is essential the same. The gravel basal stratigraphy along the right streambank that is undermining the right streambank, has an estimated d100 of less than 90 mm. with a sand and silt matrix material that is much smaller. This means that the pre-scalp velocity can readily scour out all of the gravel material, to undermine the overlying materials. This does not happen uniformly along the 575 feet of active eroded streambank, but instead results in an overhanging or vertical streambank along some areas and sloughed gravels. Under both conditions there are failed slump blocks at the base of the slope that are slowly reworked during flood runoff conditions. For the Barker Bar the 15.6 ft./sec pre-scalp velocity can cause significant d50 bed material movement, or streambed scour of material smaller than 200 mm. It is significant that there are many slump blocks along the 250 feet of 10 foot high eroding streambank. The Barker Bar was not scalped for three years (2001-2003), and the vertical streambanks with slump blocks may reflect the lack scalping in those years. For the Barker Bar post-scalping average velocity is shown to be high enough to cause significant movement of median d50 of 9.7 mm. However there are no scour areas or back channel scour channels developed after scalping in 2004. The upstream buffer leave area has a d50 of 42 mm., which is likely preventing downstream scour from occurring. For the Dill Bar on the Kilchis River the leave buffer armour is 53 mm. which is substantially above the bar median d50 of 17 mm. Post scalping average velocity will only cause incipient motion of particles with a d50 of less than 6 mm., which indicates essentially little incipient motion of particles on the post-scalped bar. For the Lower Gomes the leave area buffer armour is 26 mm. In addition the average size of the pebbles in the basal sloughing along the opposite streambank is less than 20 mm. Therefore the average velocity conditions for pre-scalped conditions, which can cause significant bed movement of particles with a d50 of up to 37 mm. is more erosive in the pre-scalp than post-scalp conditions where significant movement of particles will only occur for particles smaller than 7 mm.

Table 1 Channel and bar widths and active erosion length

BAR	RIVER	1939	1944	1953	1994	2000	Length
		ft.	ft.	ft.	ft.	ft.	ft.
DONALD.	WILSON	147		200	260	280	575
BARKER	WILSON	107	136	155	170	180	250
TANNLER	WILSON		136	150	160		
DILL	KILCHIS	80	89	140	180	290	345
L. GOMES	KILCHIS	55	92	120	150	223	385
M. GOMES	KILCHIS	67	91	130	160	178	120

Table 2 Average erosion rates

BAR	RATE	RATE	RATE	RATE	RATE
	1939-1944	1939-1953	1944-1953	1953-1994	1994-2000
	ft./yr.	ft./yr	ft./yr	ft./yr	ft./yr
DONALD.		3.8		1.46	2.2
BARKER	5.8	4.8	2.1	0.37	1.7
TANNLER	16.6	14	1.56	0.2	
DILL	6.3	4.28	5.7	0.98	12.2
L. GOMES	4.3	4.78	3.11	0.61	8.1
M. GOMES	4.8	4.5	4.3	0.73	3

Table 3   Stream bar and bed characteristics.

BAR	Bank full	Bank full	Velocity	Bar d50	Bed d50	Signifi-cant d50 Mov.	Buffer d50	Leave Buffer
	cfs.	ft.	ft./sec.	mm	mm	mm	mm	ft.
Don. Pre.	11500	11.5	11	12.5	13	90	27-35	105
Post Scalp			7.9			30		
Don. Pre.	13385	12	11.3	12.5	13	93	27-35	105
Post Scalp			8			30		
Bark. Pre.	11500	11.5	12	9.7		95	42	20
Post Scalp			8			32		
Dill Pre.	11500	11.7	7.5	17-26	14	25	53	100
Post Scalp			5.2	12		7		
LGom Pre.	11500	11.7	8.4	13-15		37	26	80
Post Scalp			5.3	9		8		

ENVIRONMENTAL ISSUES AND CONCERNS

A number of environmental issues have been raised concerning gravel scalping Castor and Cluer, (2003); Kondolf et al (2002); and Oregon Water Resources Institute (OWRRI,1995). Castro and Cluer (2003) referenced other authors that streambanks derive their strengthened resistance from vegetation and to a lesser degree from their composition, height and slope. The concept that weak units cause failure by streambank scour, which undermine overlying materials, is ignored. Castro and Cluer (2003) in general ignore the confining condition caused by bars and higher velocities in pre-scalp verses post-scalp. Castro and Cluer (2003) state, “Using shear equations and the flow continuity equation, one can expect that shear stress will increase most in the upper part of the sediment removal areas where the slope increase is most pronounced.. Laboratory experiments by Begin et al (1981) verified the effect.” The difference in slope on the Donaldson Bar is 0.5% down the bar to 0.16% down the channel. No increase in scour has occurred. The Begin et al (1981) flume experiment was for a 1% slope with a base level lowering that allowed a headcut to form and migrate upstream . No such condition occurs for the four bars evaluated. Kondolf et al (2002) state that “bar scalping typically reduces preferred salmonid spawning and rearing habitat by removing riparian vegetation and woody debris, reducing the area of adjacent pools and riffles, and causing channel bed degradation.” No vegetation has been removed by gravel operations in the last four years, no additions of large woody debris (LWD), and any LWD that was present has not been disturbed. The pools and riffles have remained at the same location, there is no change in the depth of the streambed based on comparing 2000 and 2004 cross sections. Kondolf et al (2000) state, “By removing most of the gravel above the water lever, the confinement of the low water channel is reduced or eliminated, changing the patterns of flow and sediment transport through the reach." The channels along the four scalped bars all have thalwegs, and the bars are scalped at a cross slope There is no evidence, in the last 4 years of evaluation, that the thalweg has moved or that there has been any change in flow pattern or sediment transport through the reach because of the scalping. Castro and Cluer (2003) state, "Disturbing or harvesting the armour layer of streambeds and bar deposits provides the stream readily erodible sediment supply because relatively finer grained sediment are now available for transport at a lower discharge. The new supply of sediment derived from the streambed will be moved downstream where it can adversely affect aquatic habitats. " The streambeds are not disturbed along the four bars discussed, and an armour layer is left at the upped end , and side of each bar as discussed and reflected in Table 3. However, even where there is data on post scalp particle size, for the Dill Bar a d50 of 12 mm present, is still higher than the 7 mm size for a velocity of 5.2. ft./sec.. For the Lower Gomes Bar the post scalping size of 9 mm is marginal to have significant incipient motion by the 5.3 ft./sec., and no field evidence of significant movement. The upstream armour is probably a control in preventing scour from starting.

CRITERIA FOR EVALUATION AND RECOMMENDATIONS

The criteria for evaluation are: (1) bankfull discharge; (2) stream slope; (3) bar slope; (4) bed and bar d50 particle size; (5) buffer d50 particle size; (6) bar depositional slope; (7) cross sectional area for pre-and post scalp conditions; (8) documented erosion condition based on average erosion rate from aerial photographs, and documented photographs and or notes of sloughing, and slump blocks; (9) documentation of eroding streambank materials and stratigraphy across from the bar, (11) document growing vegetation on eroding streambank, (11) documentation of overhanging vegetation materials on streambank; (12) documented LWD on bar and along streambank; (13) document rip rap, barbs, and veins; (14) documented woody material and soil bioengineering installations; (15) use cross sections to determine area for bankfull condition, and with bankfull discharge calculate average velocity to cause significant motion of pre and post scalp particles; (16) determine the primary source of sediment and (17) evaluate potential solutions and recommend most viable to reduce streambank erosion with minimal aquatic habitat impact.

The criteria recommended for carrying out environmental sensitive bar scalping are: (1) work in the dry and leave upper and side bar buffer at low flow; (2) scalp bar at approximately the slope of depositional bar; (3) leave the scalped bar with a roughened surface; (4) remove all scalped materials from the bar; (5) do not place or leave upper or side bar berms, (6) do not scalp bars at a higher level than the annual recruitment rate (OWRRI, 1995). Bar berms recommended by fish agencies in the past have caused split flows and development of back channels that have trapped downstream migrating fry when back channels dewater. Bar scalping has not caused the rivers to scour back channels and the bars are scalped with a leave armour area that prevents a scoured back channel from forming. The bars have not caused downstream alterations such as scour or deposition along the Wilson and Kilchis Rivers. and there has been essentially no change in the stream slope or thalweg along the bars in the four years of evaluation. A few downstream migrating fry have been trapped in dewatered back channels created by berms on the Donaldson and Dill Bars in 2000. These back channels continue to fill in by natural depositions. In addition a few chum fry were documented in June 2005 to be tapped in a natural spit channel on the Lower Gomes Bar in the buffer area above the scalping The conclusion for the velocity data is that the pre-scalped velocity can cause significant movement of the bar particle sizes verses the armor protected post-scalped condition where the runoff spreads out over a much broader area. In other words if the bars are allowed to build up to constrict flow between the bar and the opposite streambank than erosion will be much higher along the sides of the un-scalped bar as well as the opposite streambank.

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