Reach and Site Assessment for the SR 109/023 Moclips River Bridge, Moclips, Grays Harbor County, Washington

Work Order MS 5404

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Summary

This report presents the findings from reach and site assessment addressing impacts to bridge number 109-023 over the Moclips River at Milepost 31.50 in Grays Harbor County, Washington

Problem

The assessment was undertaken to look at causes and solutions to debris and sediment accumulations and bank erosion problems that are threatening the structural integrity of bridge number 109-023 over the Moclips River.

Site Assessment Findings

The site assessment showed that:

- The bridge sits on top of a tight, low-gradient meander bend in the tidal and channel migration zones.
- The bridge is supported by 48 creosote wood piles that capture large woody debris.
- A combination of high tides with significant precipitation has the potential to mobilize large wood.
- Regular removal of debris and sediment from the bridge has been needed on an annual basis.

Reach Assessment Findings

The reach assessment showed that:

- The entire Moclips watershed has a very low gradient, approximately 0.7 percent, and very high precipitation, more than 100 inches per year.
- The segment of SR 109 just upstream of the Moclips River bridge acts as a levee, confining the lateral movement of the river.
- An avulsion of the meander bend directly upstream of the bridge occurred between 1955 and 1971; future avulsion risks must be considered significant.
- At times during high flows very large trees are transported down the Moclips to the bridge.

Recommended Alternative

We recommend using bridge replacement with directional wall pier(s), a left bank riprap revetment with spur dikes and a regraded right bank to reduce the angle of attack through the bridge opening. This option appears to have the highest net transportation and environmental benefits and the lowest risk-to-cost option for this project. Mitigation should be unnecessary and costs other than for bridge construction and bank stabilization should be minimal.

Introduction

This report presents site and reach assessments to help identify solutions to debris accumulations and bank erosion. These problems are threatening the structural integrity of the SR 109/023 bridge that crosses the Moclips River at milepost 31.50 in Grays Harbor County, Washington (see figures 1 and 2). The site assessment describes conditions in the immediate vicinity of the bridge, including debris accumulations and streambank erosion. The reach assessment describes river processes upstream and downstream of the project site that could influence the long-term stability of the southern embankment.

The site and reach assessments are prepared following guidance provided by Chapters 2-5 of Integrated Streambank Protection Guidelines (ISPG). The Washington State Aquatic Habitat Guidelines Program published the ISPG in 2003. The ISPG site/reach assessment is consistent with the Level 1 geomorphic assessment described in FHWA's HEC 20: Stream Stability at Highway Structures, 3rd edition.

ISPG is primarily a methodology for problem identification and alternatives analysis. It has no legal or regulatory standing in itself. It is used in this analysis to provide a standardized methodology and set of terminology for the analysis.

Project Objectives and Design Criteria

The objective of the project is to analyze alternatives that will prevent further erosion of the left riverbank underneath and adjacent to the SR 109/023 Moclips River bridge and to prevent the pervasive debris accumulations that build up beneath the structure. Continued erosion of the bank could expose the footings of the adjacent left bank pier, which would compromise the integrity of the structure and affect public safety. The 45 wood piles used to support the piers also routinely capture large woody debris that could affect the structural integrity of the bridge.

The specific objectives of the project are:

- Stabilize the left (south) bank under and immediately downstream of the SR 109/023 bridge to protect the existing or future bridge structure.
- Redirect the primary flow pathway (thalweg) of the Moclips River away from the left bank and into the center of the channel to minimize the risk of toe slope erosion.
- Reconfigure the new SR 109/023 bridge structure so that woody debris will not be captured upstream of the bridge, and so that the accumulation of sediment beneath the bridge will be reduced.
- Construct a replacement bridge to existing design standards. Ideally the new span should be long enough to pass a 80 foot-long, 5 foot diameter Sitka spruce, being that many large, mature spruces exist within the Moclips' channel migration zone that will occasionally be transported downriver during high flows.
- Explore options to improve fish habitat and refugia for the reach within the hydrologic, environmental, and engineering constraints at the site.

Based on information developed in the site and reach assessment, the following design criteria are required:

- Bank stabilization measures and flow redirection structures should be stable and have the ability to withstand scour during flows up to the 100 year (1 percentile annual probability) flood.
- Bank stabilization methods should not result in additional confinement of the river channel, to avoid increasing flow velocities, bed scour, or bank erosion within the reach.
- Bank stabilization measures should minimize additional adverse impacts to aquatic habitat and refugia.
- Bank and bridge treatments should not increase the 100-year floodplain elevations either upstream or downstream of the project site.
- Bank protection structures and bridge alterations should not exacerbate potential loading of debris and drift against downstream piers.
- Treatments should minimize and avoid impacts to riparian function, cover, spawning, complexity, diversity, and flood refugia to the greatest extent feasible. Where practicable, techniques that enhance riparian function should be considered.

Site and Reach Map for the Area in the Vicinity
of the Moclips River SR 109/023 bridge

Base: Georeferenced 2005 Color Aerial Photograph

Figure 1. SR 109/023 Site and Reach Map.

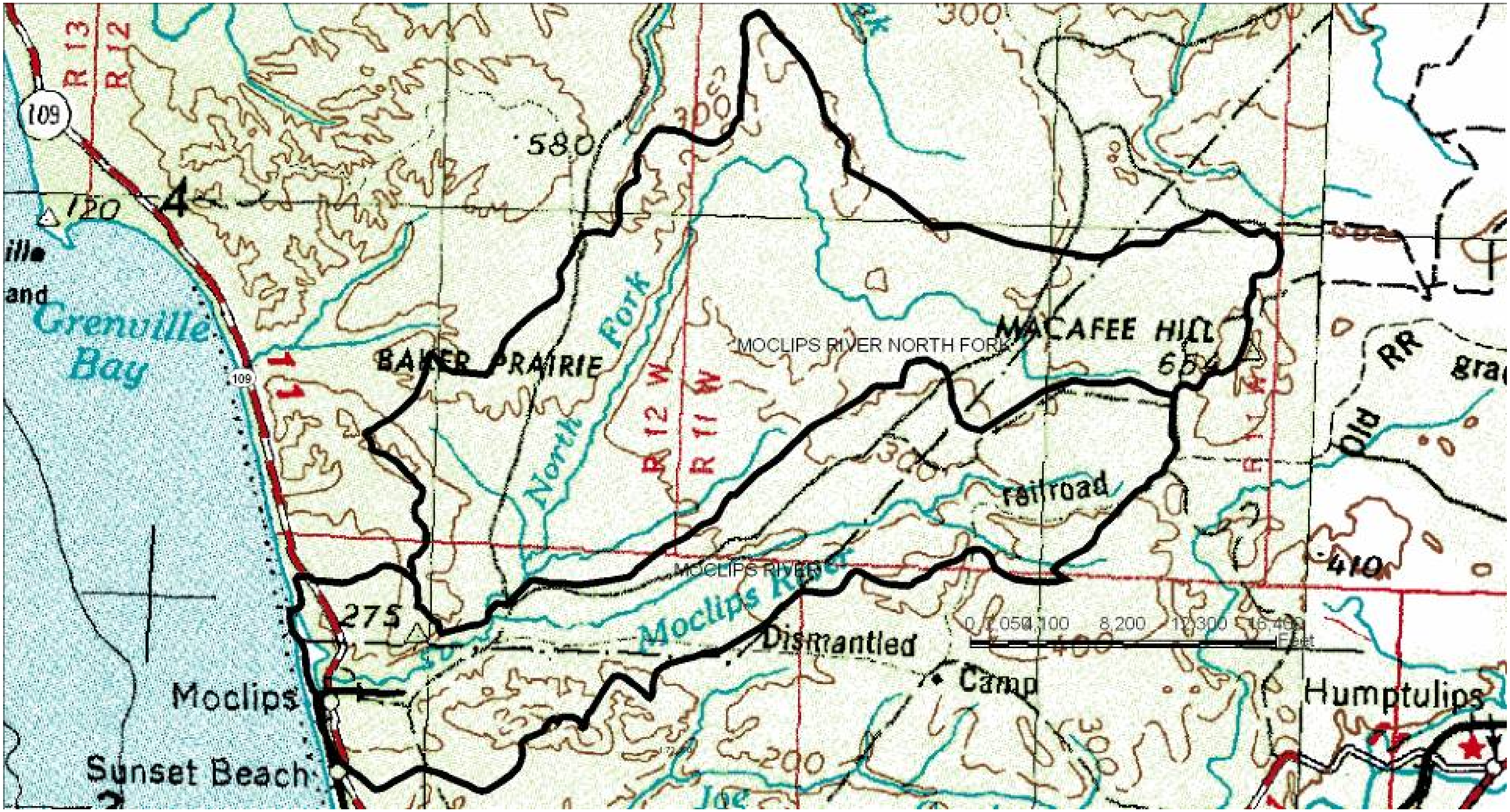

Figure 2. Vicinity Map, Moclips River Watershed.

Site Assessment

The project site is located under and directly downstream of the SR 109/023 Moclips River bridge at SW Quarter of the NW Quarter of Section 8, T20N, R12W. The bridge is at river mile 0.43, and milepost 31.5. SR 109 is a two lane rural arterial highway that provides access to several coastal communities in Grays Harbor County and the Quinault Indian Reservation. A recent aerial photograph (Figure 1) shows the SR 109/023 site and its upstream reach. The position and has pier configurations of the SR 109/023 structure spanning the Moclips River promulgate debris and drift blockages as well as left (south) bank toe slope erosion. Routine maintenance was conducted in 2004 to remove drift blockages that were impinging on one or more of the bridge piers to maintain hydraulic conveyance capacity beneath the bridge. Frequent debris removals are required at the site resulting in a maintenance recurrence interval of approximately five occurrences every ten years (5:10).

The SR 109/023 Moclips River bridge, built in 1955, is supported by five sets of piers with eight creosote wood piles supporting each of the piers. The large number of tightly-spaced piles routinely collects large woody drift and sediment from upstream sources, as shown in Figure 3.

Figure 3. Log jam accumulation on the underside of the Moclips River bridge structure (looking south, March 2007).

Figure 4. Flooding on SR 109 north of the Moclips River bridge in March 2007.

The current meander system and upstream bank revetment system acts to entrain the thalweg of the Moclips River to the left bank during low flows, increasing the erosion potential. At high flows and tides, the flow path and thalweg configurations change considerably. During elevated river stages, the pile of drift and debris that accumulated beneath the bridge during low flows causes the main flow path energy to split. One of the main flow paths remained entrained along the left bank while a new flow path paralleling the right (north) bank became established at high flows and tides (see Figure 4).

The left bank underlying the bridge structure is composed of Oyhut silt loam, a cohesive glacial till soil. The floodplain soils are predominately wetland soils derived from tidal deposits. Figure 5 shows the distribution of hydrologic soil groups within the project area.

The SR 109/023 Moclips River bridge is located on a tight, 180 degree meander bed with a radius of curvature of approximately 175 feet. The bridge and project site resides within the tidal zone of the Moclips River estuary. The bridge site and stream reach are both located within the coastal tsunami evacuation zone. Approximately 550 feet upstream of the bridge at the upstream meander, contiguous rock revetments and groins have been installed along the right (north) bank to prevent bank toe slope erosion and scour next to SR 109. The unusually tight meander bend beneath the bridge has likely been controlled by a combination of geology, adjacent infrastructure, and historic instream structures. The left bank erosion is located directly beneath and just downstream of the bridge. Left bank substrate is a cohesive glacial till (Oyhut silt loam) that, according to the Grays Harbor County soil survey, has significant resistance to shear stress. The left bank beneath and directly downstream of the bridge structure is close to vertical but is not significantly undercut.

The floodplain at the project site is covered by early succession forest comprised mostly of alder, cottonwood, vine maple, with scattered mature Sitka spruce. The presence of mature trees on the inside of the upstream meander indicates that channel migration is very gradual close to the bridge. The outer (right) bend of the upstream meander is heavily armored with riprap revetments and several rock groins to divert the thalweg from the revetment and the SR 109 road prism.

Maintenance records indicate that removal of debris (drift and logs) from the piers has been needed on a regular basis, including 1998, 2002, and 2004. At the time of ESO's field investigation (11/22/2005), a large gravel bar was observed deposited underneath the bridge structure on the inside of the meander bed. A large (approximately 30 inch diameter) tree with a substantial root ball was also lodged on the upstream end of pier three. The bridge sits on top of a tight, low-gradient meander bend in the tidal zone. A combination of high tides with a significant precipitation event has the potential to mobilize large drift, if available.

Reach Assessment

Watershed Conditions and Land Cover

The Moclips River watershed is approximately 31.9 square miles, ranging from its headwaters in the Olympic Mountains foothills to its outlet at the Pacific Ocean within the town of Moclips (see Figure 2). Soils in the watershed are a mix of glacial drift and wetlands. GIS analysis indicates that wetlands cover a total of 1.83 square miles within the watershed – 5.7 percent of the total land area. Outside of most wetlands and the Moclips floodplain, the watershed land cover is almost entirely industrial forestland. The incorporated area within the town of Moclips is limited to the area downstream of river mile 1.2. The Moclips is an ungaged watercourse, so estimates of design flow rates have been estimated using USGS regional regression equations.

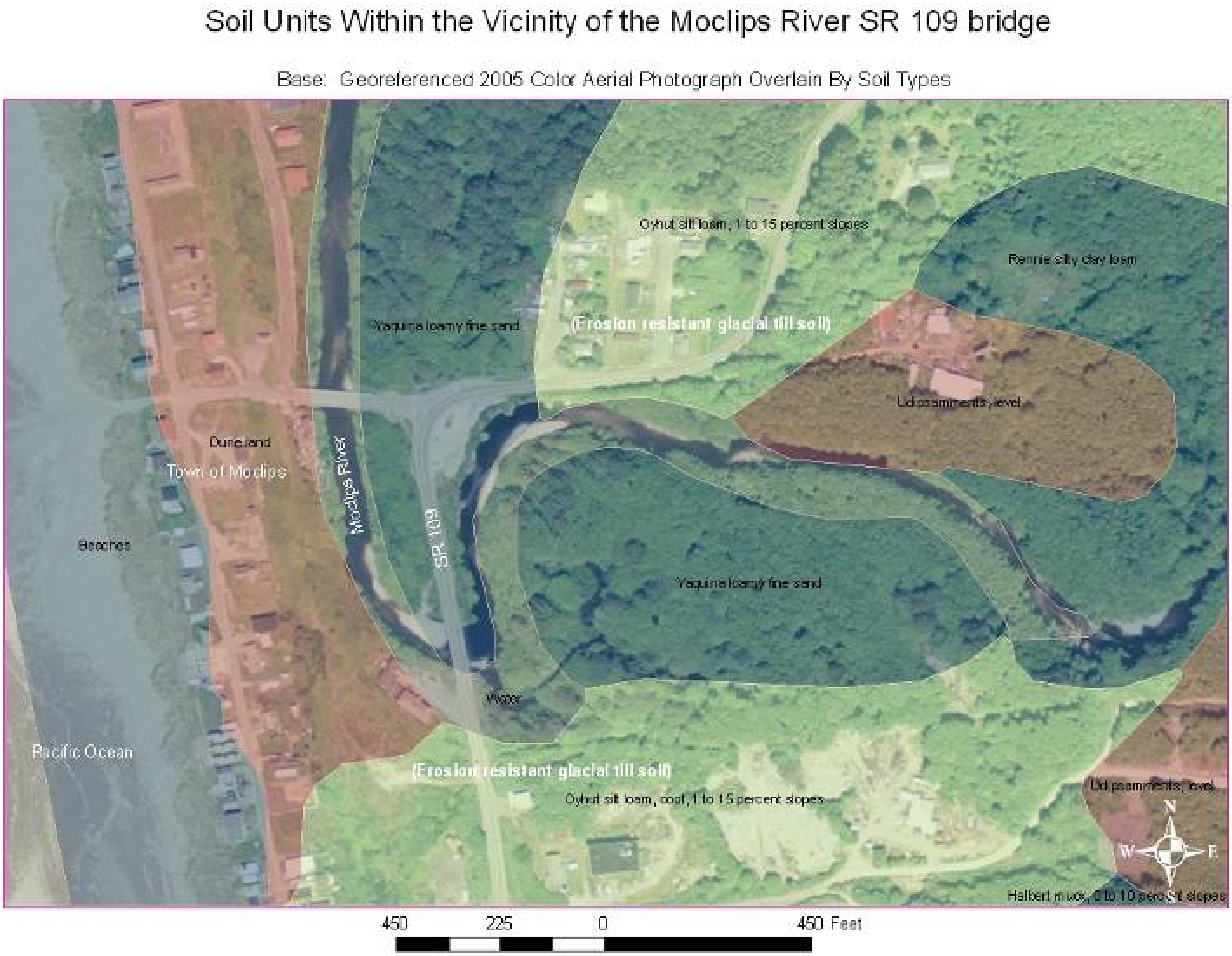

Figure 5. Soils Distributions in the Vicinity of the SR 109/023 bridge.

Elevation at the headwaters of the Moclips is approximately 325 feet. The gradient of the Moclips River at the SR 109/023 bridge is very low, approximately 0.25 percent (roughly 14 vertical feet per mile). The entire Moclips watershed from its headwaters to the ocean is similarly low gradient, 0.70 percent or 37 vertical feet per mile on average (see Figure 6).

I. Moclips River valley characteristics:

- Size – 31.9 mi^2.
- Terrain - Coastal lowlands and Olympic mountain foothills.
- Drainage pattern – Dendritic.
- Tributaries - the Moclips has one major named tributary, the North Fork that encompasses 23.6 mi^2 of the watershed.
- Surface geology - Glacio/fluvial unconsolidated. Soils and geology data indicate that the Moclips watershed is comprised of a combination of Holocene glacial till and wetlands/hydric soils.
- Rock type – None, all soils are unconsolidated.
- Land use – Managed forestry and rural residential.
- Vegetation – Temperate conifer forests in various states of re-growth with alder/maples in floodplain areas.

II. Moclips River valley and valley sides:

- Height – 20-40 feet.
- Side slope angle – Less than five degrees.
- Valley shape – Symmetrical.
- Valley side failures – None.
- Failure locations – None.

III. Moclips River floodplain:

- Valley floor type – Continuous.
- Valley floor width – Averages 200-300 feet wide, approximately five river widths, but variable.
- Surface geology – Holocene wetland soils with glacial till on terraces.
- Land use – Industrial forestry with scattered intact riparian areas.
- Vegetation – Mostly (80-90 percent) early-succession deciduous trees with scattered mature Sitka Spruces.
- Riparian buffer – Varies greatly within the floodplain and is in the range between zero/none

IV. Vertical relation of the Moclips channel to valley. Indicators as to whether the relationship between the river and its valley is being aggraded, adjusted, or incised:

- Terraces – None were apparent at the time of the field investigation or is apparent on aerial photos of the reach or watershed.
- Overbank deposits – None were observed during the field inspection, but the dense vegetation and precluded systematic observation.
- Levees – The segment of SR 109 just upstream of the Moclips River bridge acts as a levee since it has been amply reinforced and stabilized using longitudinal riprap revetments with integrated rock groins to prevent right bank erosion and deflect the thalweg of the river away from the bank. The current alignment of SR 109 confines the movement of the Moclips River channel.
- Levee data – None is available.
- Trash lines – None were observed near the bridge or on the nearest upstream reach.

V. Lateral relation of the Moclips channel to valley:

- Plan form – Irregular meanders.
- Bend radius – 175 feet, the average upstream bend radius is 320 feet.
- Meander belt width – Approximately 1/8 mile in reach upstream of the SR 109/023 bridge.
- Location in valley – Variable.
- Lateral activity – An avulsion occurred just upstream of the SR 109/023 bridge between 1955 and 1972.
- Floodplain features – An abandoned right meander bend located just upstream of the bridge exists. Part of the bend now acts as a backwater wetland.

VI. Channel description:

- Flow type – Pool and riffle.
- Bed controls – None currently. Prior to 1982 an in-stream mill pond was located in the channel 1000 feet upstream of the SR 109/023 bridge that cut off bedload to the downstream reach and created “hungry water” conditions that accelerated the eventual avulsion.
- Width controls – The alignment of the SR 109 road prism and associated bank stabilization structure controls the ability of the Moclips to move laterally.

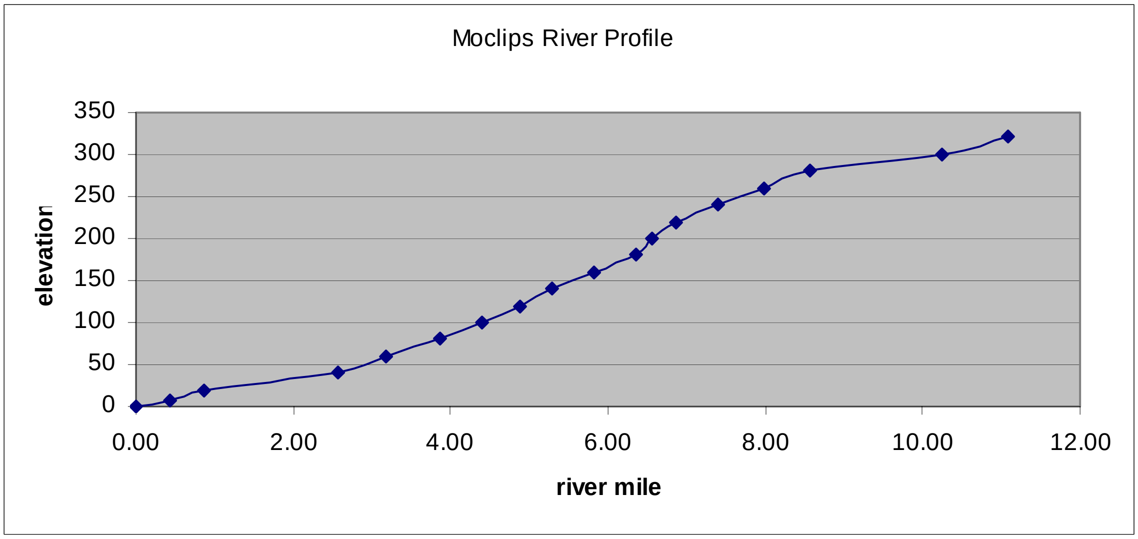

Figure 6: Moclips River Profile

Geology and Soils

The Moclips River flows through a narrow alluvial valley bounded on its north and south sides by terraces of glacial drift. The alluvial valley floor averages less than 1/8 mile wide through the reach directly upstream of the SR 109/023 Moclips River bridge. Some of the uppermost reaches of the Moclips widen out into broad floodplain wetland complexes, some more than 1/3 mile wide. The erosional scarp directly downstream of the SR 109/023 bridge is comprised of Oyhut silt loam, formed from weathered material from glacial outwash. Oyhut soils have very low water erosion potential, a property that probably prevented the ongoing left bank erosion from being more severe than it is presently. The floodplain soils consist of either Group D wetland soils (formed on former tidelands or depression in the drift plain) or Holocene-age alluvium, neither of which provides significant erosion resistance. A map of the soils distribution in the vicinity of the SR 109/023 bridge and its upstream reach is shown in Figure 5.

Hydrology and Flow Conditions

Hydrology and Flow Conditions are summarized in Table 1. Moclips River flow rates and recurrence intervals are shown in Figure 7.

Table 1: Estimated (Modeled) Basin Characteristics at the SR 109/023 Moclips River Bridge

Parameter	Value
Drainage Area (mi^2)	31.9
Mean Annual Precipitation (in/yr)	91.2 (bridge), 103.5 (headwaters)
Channel Substrate (D50)	Gravel, 4 inches – 6inches
Channel Roughness (Manning's n)	0.030
Channel Gradient (%)	0.026
2-year flow (50% ann. probability, cfs)	2580
10-year flow (10% ann. probability, cfs)	4030
25-year flow (4% ann. probability, cfs)	4740
50-year flow (2% ann. probability, cfs)	5350
100-year flow (1% ann. probability, cfs)	6010

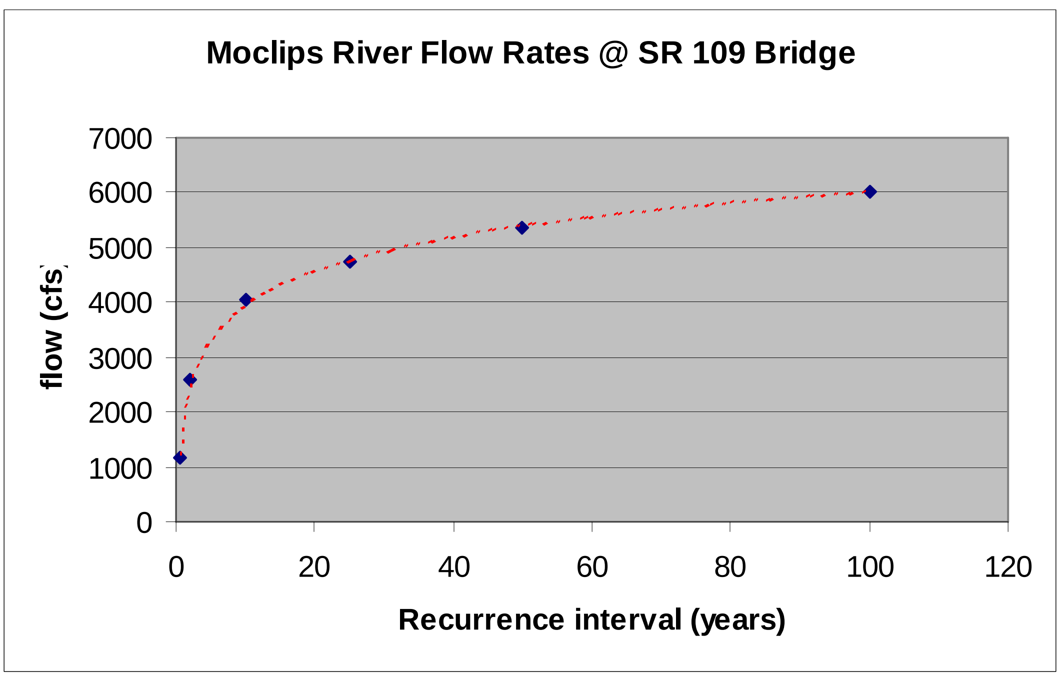

Figure 7. Moclips River Flow Rates.

Sediment Transport and Scour

Mass wasting has not been observed in the Moclips basin due to the relatively mild valley slopes flanking the floodplain. An avulsion of the meander directly upstream of the SR 109/023 bridge occurred between 1955, the construction date, and 1971 (see Figure 8). The 1952 aerial photo (Figure 9) shows several significant features that accounts for the current bridge and river configurations. Directly upstream of the bridge there previously existed a tight left (clockwise) meander which resulted in the thalweg being positioned at an approximate 45 degree angle to the bridge opening.

The 1952 aerial also shows an in-stream mill pond next to a fairly large shake/lumber mill at RM 1.6, 1000 feet upstream of the SR 109/023 bridge structure. The pond was likely used to temporarily hold logs for milling. In the 1971 aerial photo (Figure 10) shows the avulsion of the nearest upstream left meander, changing the approach flow direction from 45 degrees to the bridge opening to nearly directly at the left bank and the southern bridge abutment. The 1971 aerial photo also illustrates the instream mill pond being seriously aggraded with sediment, indicating that a long-term cutoff of bedload to the downstream reach had occurred over time. The cutoff of bedload to the downstream reach likely created a "hungry water" scenario, where the entrapment of bedload and suspended sediment in the millpond increases the carrying capacity of flows moving downstream. The kinetic energy of the system below the pond is shifted such that the downstream flow velocities and shear stresses increased due to the lack of suspended sediment, and the lack of energy dissipation from bedload movement. This likely increased the erosion rate at the meander just upstream of the SR 109/023 bridge that eventually resulted in the avulsion and the dramatic shift of the river's attack angle to the bridge structure. Figures 11 through 13 show the aerial photos of the site and reach for 1982, 1992 and 2005 respectively. Figure 8 shows each of the river's alignments for the aerial photos described above.

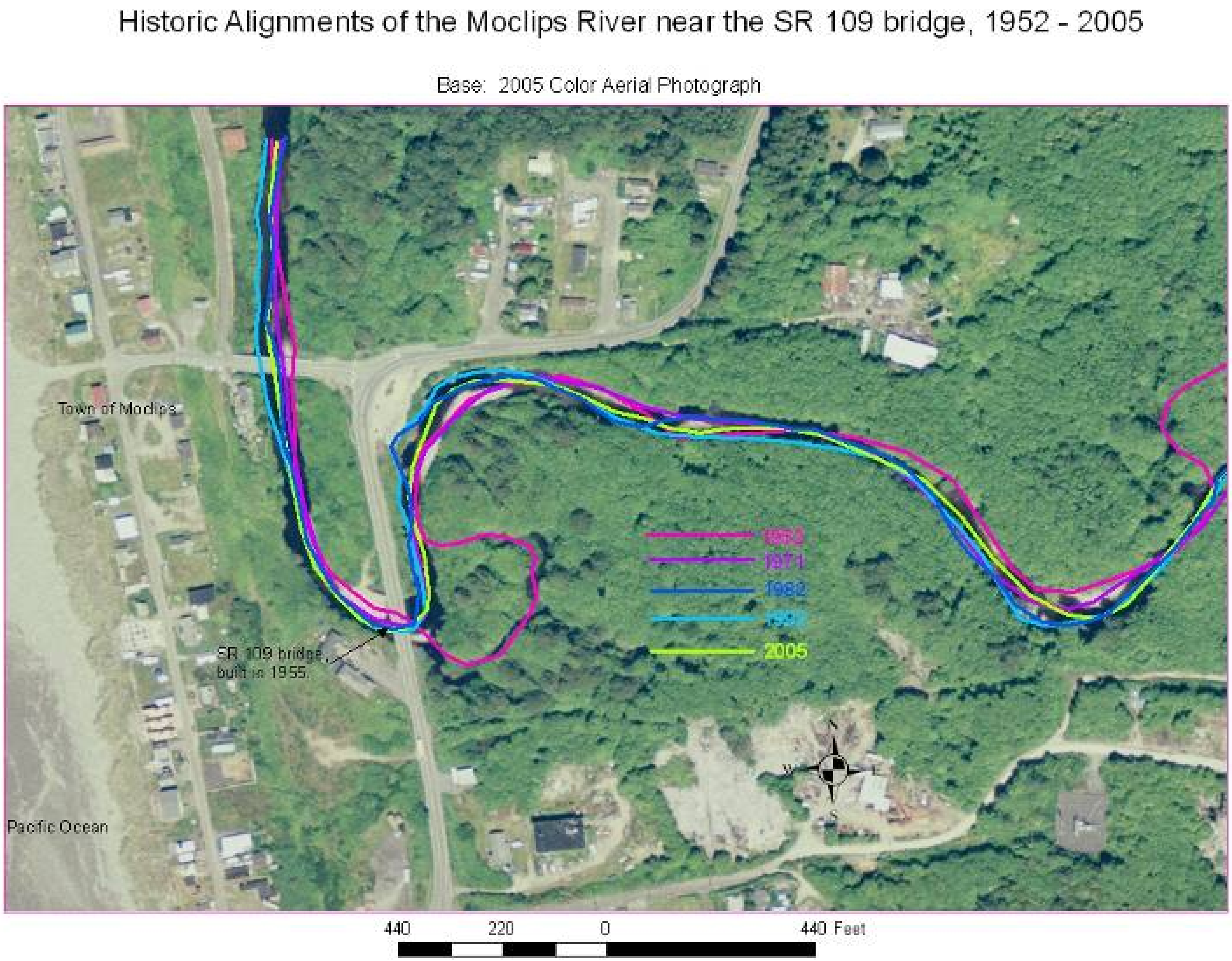

Figure 8. Historic Alignments of the Moclips River near the SR 109/023 bridge, 1952 to 2005.

1952 alignment of the Moclips River near the SR 109 bridge

Base: Georeferenced 1952 Black and White Aerial Photograph

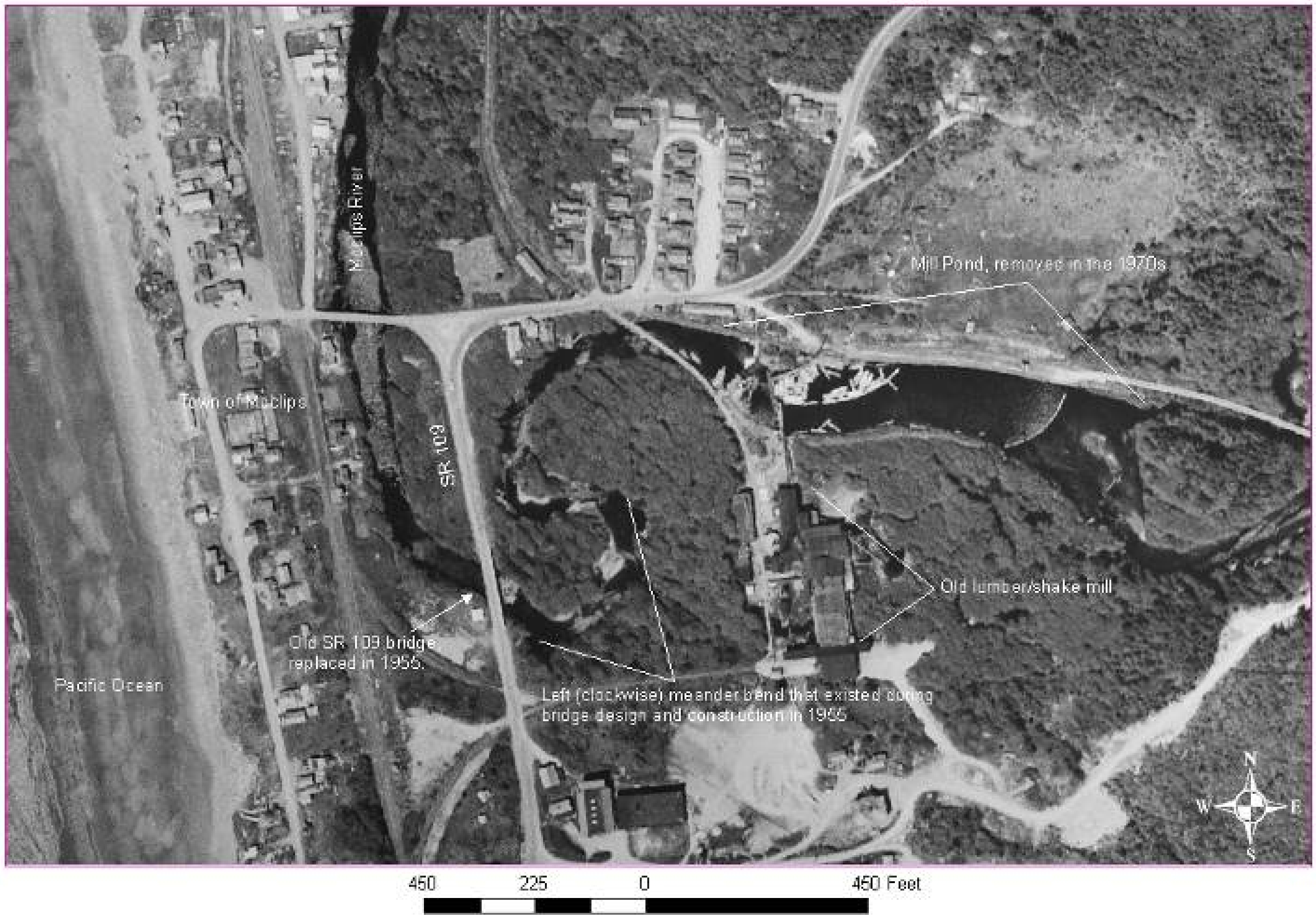

Figure 9. 1952 Aerial Photo in the Vicinity of the SR 109/023 bridge.

Figure 10. 1971 Aerial Photo in the Vicinity of the SR 109/023 bridge.

1982 alignment of the Moclips River near the SR 109 bridge

Base: Georeferenced 1982 Black and White Aerial Photograph

Figure 11. 1982 Aerial Photo in the Vicinity of the SR 109/023 bridge.

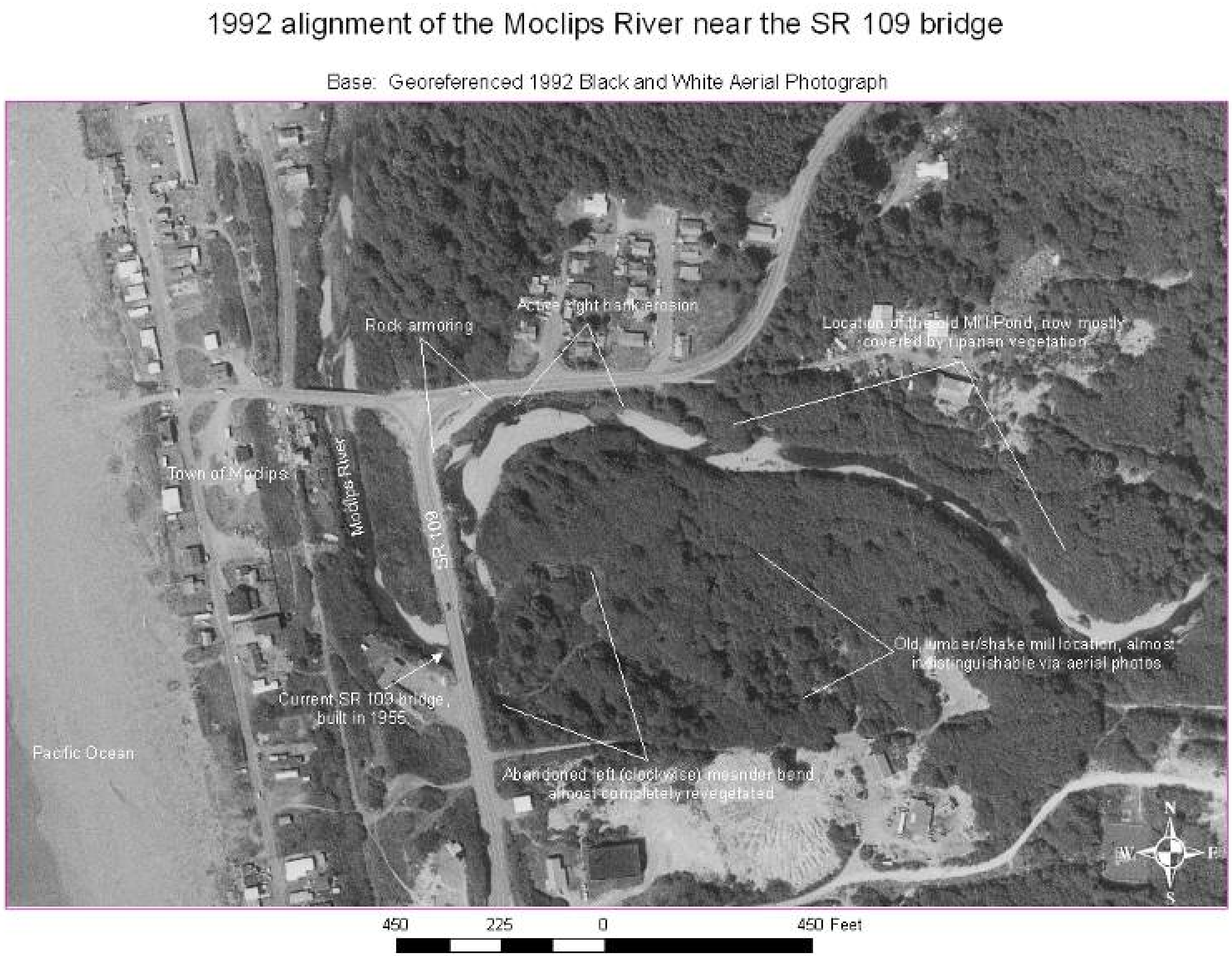

Figure 12. 1992 Aerial Photo in the Vicinity of the SR 109/023 bridge.

2005 alignment of the Moclips River near the SR 109 bridge

Base: Georeferenced 2005 Color Aerial Photograph

Figure 13. 2005 Aerial Photo in the Vicinity of the SR 109/023 bridge.

Channel Migration and Avulsion Risk

Since an avulsion occurred upstream of SR 109/023 bridge within its recent lifespan, avulsion risks must be considered significant. Fortunately, since the old mill pond was removed, the "hungry water" conditions that cut off bedload movement and increased downstream shear stresses no longer exist. While an avulsion was a likely eventuality due to geomorphic conditions such as low gradient and a tightly meandering channel planiform, it is clear that the mill pond accelerated the process considerably.

Riparian Condition and Large Woody Debris

Aerial photographs of the Moclips watershed shows a narrow riparian corridor, rarely more than one tree length (~100 feet) wide, that parallels the Moclips up to approximately RM 5.0. The riparian floodplain is inhabited mostly by deciduous alder, willow, and cottonwood trees, although many mature 24-36 inch caliper Sitka spruces exist within the floodplain. The presence of mature Sitka spruce within the active upstream floodplain suggests that channel and meander migration in the adjacent upstream reach is relatively slow. These Sitka spruces can routinely reach 100 feet tall and can potentially grow much larger in upstream reaches where the localized channel migration patterns have been stable enough to promote long-term tree growth. The largest Sitka spruce in the world (http://www.guidesign.com/olympic/rfsitka.htm) is located on the eastern shore of Lake Quinault, approximately 23 miles northeast of the SR 109/023 bridge project site. This tree has a circumference of more than 58 feet, and towers 191 feet above the rain forest floor. At times during high stages very large trees will be transported down the Moclips to the SR 109/023 bridge. As these trees approach the SR 109/023 bridge opening, they will also need to rotate to navigate around the 180 degree meander. Depending on the orientation of the tree trunk to the in-water pier(s), it may be transported through the structure, or rack on the upside of the pier(s). If a significant root wad is attached to the trunk, racking is more than likely. A single large caliper tree racked on the bridge pier(s) it has the potential to act as a "strainer", recruiting most if not all of the woody debris that is transported downstream.

Water Quality

Water quality in the Moclips River is excellent overall and is classified as a Class AA waterbody, the highest water quality ranking given in Washington state. The river is not listed as being impaired for any pollutant in the Washington State Department of Ecology's 303(d) listing (Washington State Department of Ecology, 2004). The only observable deficiency in the water quality of the Moclips is coloration due to tannins, which is typical of smaller Olympic coast streams. These tannins are natural and have no known toxicity to humans or aquatic organisms nor do they affect dissolved oxygen levels.

Fish Utilization in the Moclips Watershed

The project site and the upstream reach are both within the tidal zone. No species are listed as candidate, threatened, or endangered under the Endangered Species Act with the possible exception of Bull trout. Based on current or historic habitat conditions, bull trout use is documented for systems located between Goodman Creek and Grays Harbor, including the Moclips. These systems are not believed to support spawning populations but may provide foraging and over-wintering opportunities for bull trout.

Table 2. Salmonid Stock Status in the Moclips River Basin.

Stock	**Utilization**	**ESA Status**	**ESU**
Coho (*Oncorhynchus kisutch*)	migration	Candidate	N/A
Winter steelhead (*O. mykiss*)	migration	N/A	N/A
Bull Trout/Dolly Varden (*Salvelinus confluentus*)	Migration/foraging/overwintering	Threatened	N/A
Chum (*O. keta*)	none	Extirpated	N/A
Cutthroat trout (*O. Clarki*)	migration	N/A	N/A
Sockeye (*O. nerka*)	migration	N/A	N/A
Fall and Spring chinook (*O. tshawytscha*)	migration	N/A	N/A

(StreamNet 2000; Phinney et al. 1975; WDFW and WWTIT 1993; WDFW 2005)

Mechanisms and Causes of Geomorphic Failure

Primary Mechanisms of Failure:

There are four major elements which result in streambank erosion and debris accumulations at the SR 109/023 Moclips River bridge.

The primary cause for the repeated maintenance actions needed to remove drift from the bridge's understructure is the presence of 48 (5 piers with 8 piles each) in-water wood pile structures supporting the current bridge deck. These piles do not allow passage of much of the larger floating debris downstream of the bridge and accentuated the low velocity areas on the inside of the meander that promotes deposition of gravel and sediment deposition in a large river bar. The accumulated woody debris underneath the bridge also causes localized flow path alterations which also promotes left bank erosion beneath and downstream of the southern bridge abutment. A secondary, but still major, cause for the concurrent left bank/southern bridge buttress erosion and right bank aggradation directly downstream from the bridge/road location at the maximum curvature of a 180 degree, 175 foot radius meander.

The bridge structure is near the end of its functional life. Bridge inspection reports from 1996, 1998, 2000, 2002, and 2004 all reported leaching and leaching cracks in the construction joints, full-length cracks in many of the pilings, and repeated scour holes next to piers two and 4. Any comprehensive and permanent repair of the current conditions that require ongoing maintenance would necessarily include a full bridge replacement spanning the current width of the Moclips at bank full conditions. A fully-spanning bridge would likely be "self mitigating", as it would restore natural hydrologic, sediment, and woody debris transport through the structure and reach. If a fully-spanning bridge is found to be not feasible, minimizing the number of piers would minimize any compensatory mitigation that may be needed for permit acquisition by reducing the projects in-water footprint. In addition reduction of the number of piers is central to reducing the need for in-water maintenance work to remove debris—a key project objective.

The second major element which results in streambank erosion and debris accumulations is the very tight radius of curvature at the meander bend (approximately 175 feet) at the project site beneath and adjacent to the bridge is largely responsible for current left bank erosion problems. The current meander configuration is the result of an avulsion of an upstream left (clockwise) meander that occurred between 1952 and 1971. Once the avulsion occurred, the river's angle of attack to the bridge structure changed from west-northwest to due south, directly into the left bank and southern bridge abutment. This current meander pattern, which hasn't changed significantly since the avulsion, created the existing conditions which promote erosional and depositional subareas within the project site. When the bridge was constructed, the Moclips was aligned flowing west-northwest (azimuth 310^{o}) through the structure, adequate and appropriate for smoothly transitioning the flow pattern to the downstream right meander. After the avulsion, the main flow became focused directly on the abutment and left bank, creating the current situation.

The third major element which results in streambank erosion and debris accumulations is the presence of a rock longitudinal stone toe with barbs located at the upstream meander bend concentrates the thalweg directly at the south bank bridge buttress and the left bank erosional scarp just downstream and adjacent to the bridge.

The fourth contributor to debris and sediment accumulations at the bridge site has to do with the site's proximity to the Pacific Ocean. This reach of the Moclips river is under tidal influence. The backwater effect resulting from high tides reduces stream velocities, thus interrupting normal sediment transport processes twice daily. Because this is a natural function of tidal fluctuation Nothing can be done to reverse the effect of tides on bed-load transport.

Another minor factor which results in streambank erosion and debris accumulations is extensive historical logging within the entire Moclips River watershed. This has historically increased affected peak flood flows and stage/duration relationships. The Moclips basin has not incurred significant urbanization but has been logged repeatedly since the late 19th century. It is likely that baseline hydrology and some channel degradation occurred in the Moclips at the onset of large-scale logging. Being that these initial landscape alterations happened more than a century ago and logging has continued on a regular basis, it is likely that hydrologic and geomorphic stability has been attained.

One other minor factor which results in streambank erosion and debris accumulations is the fact that the existing alignment of SR 109 largely determines the meander configuration of the Moclips within the upstream reach . The transition of SR 109 from a north-south to an east-west alignment north of the SR 109/023 bridge plays a considerable role in determining the current river configuration of the upstream reach.

Abating the Primary Failure Mechanisms:

Three types of action can help to abate the primary failure mechanisms. These are:

1. Bridge replacement, preferably spanning the entire Moclips River channel. Removal of the 48 piers that support the existing bridge structure is critical to stopping the regular accumulations of drift beneath the structure and the associated downstream aggradation. It appears likely that due to federally-mandated freeboard requirements at least one pier will be necessary to support the new structure. If so, bridge openings should be at least 80 feet and preferably 100 feet to allow passage of the large woody debris that routinely gets transported to the SR 109/023 bridge from the upstream floodplain.
2. Flow deflection to divert the river's thalweg away from the point where the curvature of the meander bend starts to increase and the thalweg diverts from the center of the channel and starts to entrain along the left bank. Deflection structures could be groins or barbs constructed of large rock or a combination of rock and large woody debris. Designs need to consider the daily tidal fluctuations that can, in conjunction with high river flows, increase the daily stage by more than 10 feet.
3. Construction of a continuous riprap left bank revetment to reduce the amount and extent of erosion at the meander's cut bank. Spur dikes, barbs, or hard points should be incorporated into the revetment design to divert the thalweg from the cut bank and increase the life span of the revetment.

Alternatives Considered

No-action.

No-action alternative: The bridge structure will continue to degrade. Ongoing funding to conduct routine and regular maintenance or emergency actions will be needed to clear drift and debris accumulations, grout voids and leaching cracks in the bridge deck and support structure, fill in scour holes downstream of the piers, and armor the south buttress and the left bank erosion scarp. Extreme weather or geologic events such as a flood event combined with very high tides, tsunamis, earthquakes, etc. could eventually result in failure of the bridge structure.

Advantages: No construction costs would be incurred. Permits would be needed for in channel debris removal activities.

Disadvantages: Significant and ongoing inspection schedules and maintenance actions would be needed on a continuous basis. The structural integrity of the bridge deck and support structure would continue to deteriorate.

Bridge replacement alone.

Bridge replacement without flow deflection, diffusion, bank armoring, or stream relocation: This option assumes that the new bridge would either span the entire bank-full width of the Moclips River at its current length or, if mid-span piers are included in the design, provide openings long enough to pass large woody debris through the structure.

The recommended bridge openings should be at least 80 feet and preferably more than 100 feet Construction of any new bridge would include removal of the existing 48 wood piles and would be self-mitigating by removal of the obstructions that prevented natural sediment and woody drift transport, and removal of the potentially toxic creosote piles. The very tight right/clockwise meander configuration that currently exists would remain. If the left bank is left unarmored and the thalweg undeflected, the left bank erosion and right bank aggradation would continue and continued maintenance actions would need to continue on a regular basis. This would likely create a situation where routine inspections beyond the standard two-year bridge inspection cycle and recurring maintenance would be needed.

Advantages: Replaces the existing bridge with a new bridge built to current structural standards. Removal of the existing 48 wood piles from the river bed would allow natural transport of sediment and wood to the downstream reach and greatly reduce the need for repeated cleanout underneath the bridge structure.

Disadvantages: Flow energy would remain entrained on the southern bridge buttress and left bank which will continue the ongoing erosion pattern. This would facilitate an expanded inspection schedule for the new SR 109/023 bridge and probably continued repeated maintenance actions to armor the left bank.

Bridge replacement with piers, rip-rap revetment, regraded right wall.

Bridge replacement with directional wall pier(s), a left bank riprap revetment with spur dikes and a regraded right bank to reduce the angle of attack through the bridge opening: In this alternative, a bridge replacement would incorporate wall piers directed in an east-west orientation to help deflect the river's main flow energy through the center of the bridge opening, allow it to transition smoothly to the reach downstream of the bridge, and deliver flow towards the aggraded gravel bar that has been the cause of repeated maintenance actions. One significant factor is the daily stage variations on the Moclips that can regularly exceed 10 feet in a given day because of a combination of tidal fluctuations and storm flows.

Piers, if incorporated into the design, should preferentially be elliptical wall piers that have the ability to deflect part of the river flows perpendicular to the bridge opening, which would be in a east-west orientation. This feature would also help prevent aggradation at the downstream right bank that has been the cause of repeated maintenance actions in the recent past.

With an expanded bridge span, the right bank directly adjacent to the northern bridge abutment should be regarded to help transition the thalweg through the bridge structure. This would involve removal of part of the riprap revetment installed prior to 1971 to protect the existing bridge's northern abutment after the Moclips avulsed, abruptly changing the entry angle of the river's thalweg relative to the bridge opening.

In addition to the wall piers and regarded upstream right bank, a left bank riprap revetment would be needed directly downstream of the new bridge to provide additional stability to the eroding left bank. To prevent continuing erosion of the downstream left bank, the revetment should have a 2:1 grade and should cover the length of the existing erosional scarp. This revetment should ideally incorporate small spur dikes or hard points extending into the river channel to assist in directing the thalweg and associated shear forces away from the left bank and into the downstream meander. This revetment/spur dike configuration nearly identical to the systems installed upstream of the existing SR 109/023 bridge structure to prevent upstream erosion next to SR 109.

Using bend correction factors from ISPG, shear stresses on the outside of the river bend could range from 0.2 pounds/ft^2 at bankfull flow to 0.5 pounds/ft^2 during major floods. Nomographs from FHWA (1988) indicate that unvegetated banks for the Oyhut silt loam, the native material at the eroding left bank at the SR 109/023 bridge, would be eroded by shear stresses greater than 0.1 lbs/ft^2.

To further protect the left bank and bridge buttress from erosion, a revetment system should be constructed.

A schematic example of the spatial configuration of the groins and revetment is illustrated in Figure 14.

Advantages: In addition to a new bridge designed to current structural standards, flow re-direction, and bank erosion prevention would be accomplished. Ongoing maintenance needs would likely be significantly reduced. The removal of the existing creosote in-stream wood piles from the Moclips River channel would result in a large net benefit to environmental and hydrologic function and should not require any compensatory mitigation.

Disadvantages:. Large trees may occasionally become lodged against the any in-stream piers and may redirect the river’s thalweg in unintended directions. In those cases, the trees may have to be removed.

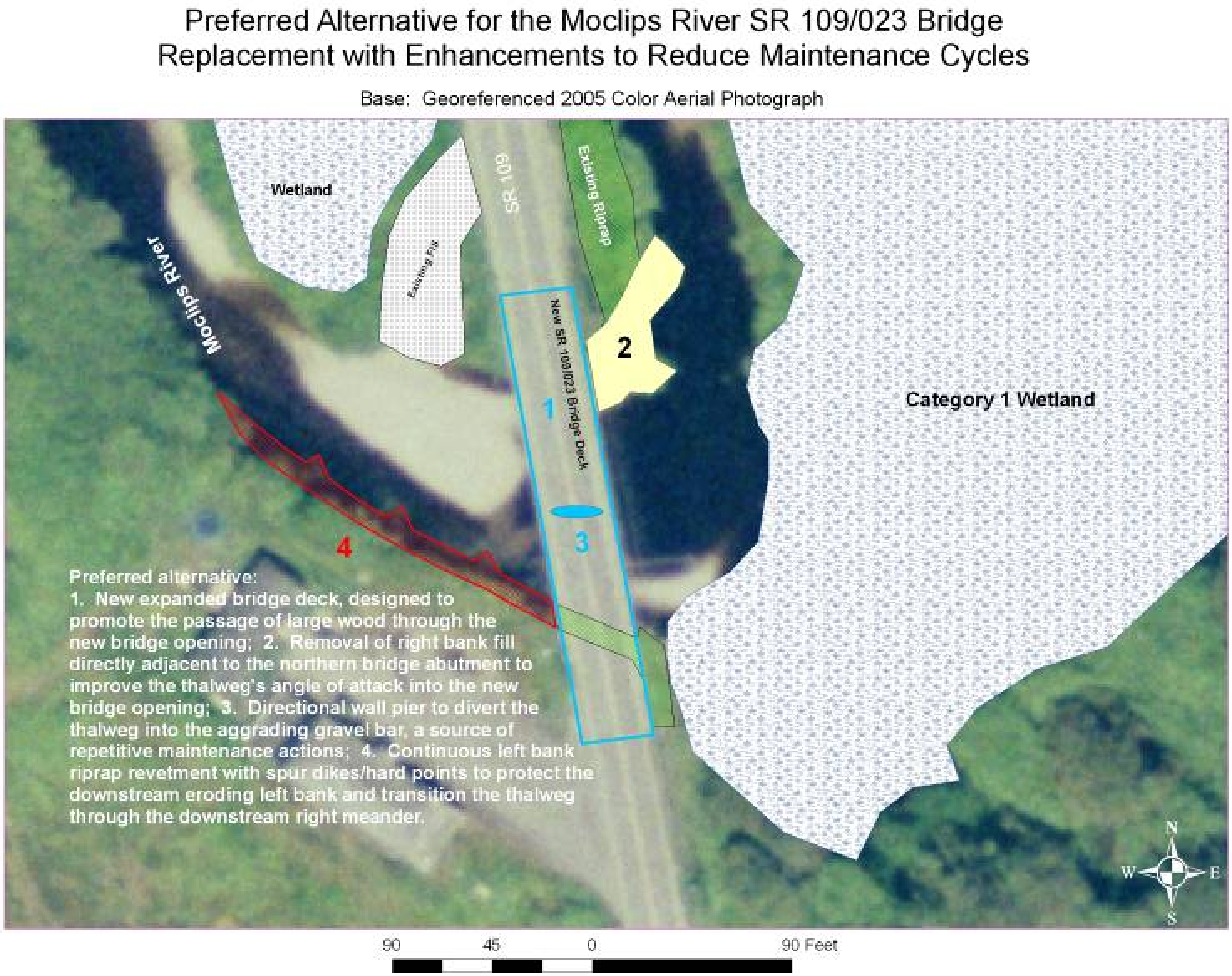

Figure 14. Preferred Alternative for the Moclips River SR 109/023 bridge.

Bridge replacement with armoring.

Bridge replacement with a rock bendway weir or barb system with rock revetment armoring: This is identical to the right bank repair used on the upstream meander to protect the SR 109 road prism just north of the SR 109/023 bridge. This configuration may be problematic for the site near the bridge structure and adjacent left bank because a continuous rock revetment would likely shut off river flows into an existing forested backwater wetland, a remnant of the historic meander that avulsed sometime between 1955 and 1972. This wetland most likely provides decent aquatic habitat and refugia. Cutting off diurnal river flows into the wetland would alter the wetland's hydroperiod significantly, and likely require significant compensatory mitigation to recover losses in wetland function and habitat losses.

Advantages: This alternative would be very similar to the upstream barb/revetment system, which has been effective in protecting the upstream right bank and was previously subject to continuing erosion along the outside meander. There presently is a staging area north of the current bridge that could be used to stockpile rip rap for continuing barb and revetment reinforcements.

Disadvantages: Significant compensatory mitigation would likely be needed to construct a continuous rock revetment, as explained above. Permit negotiations and consultations with the federal services and tribes may prove to be problematic.

This alternative presents several difficult issues involving constructability and permitting. Most of these involve access to and impacts to the large type 1 wetland complex located on the left (west) bank upstream of the bridge. Because of these difficulties this alternative was eliminated from further consideration.

Bridge replacement with realignment and reshaping.

Bridge replacement with Moclips River realignment and left bank reshaping: This alternative is probably the most comprehensive semi-permanent fix that could be realized for this project. It is also the most complex and probably the most expensive option due to the need for land acquisitions, extensive excavation, fill, and haul requirements. Environmental permitting and consultations with tribes and federal services would likely involve intensive and time-consuming negotiations. While realigning the channel would improve the angle-of attack over current conditions it would lengthen the channel in the upstream reach considerably, and would adversely affect what is currently excellent off channel habitat Conversely, the river realignment option would have several benefits to SR 109, the SR 109/023 bridge, and aquatic habitat within the upstream reach. The re-aligned river would be placed far away from the SR 109 road prism until it approaches the new bridge at an angle that is close to perpendicular to the bridge structure and directing the river's thalweg through the center of the opening . The abandoned reach may then eventually evolve into a forested backwater wetland area that could provide substantial aquatic habitat and other wetland functions. However it would remain shorter that the re-aligned channel and thus always susceptible to re-occupation through river avulsion unless extensive measures were taken to thwart channel migration. With the river's angle of attack no longer directed at the left bank scarp, it could then be reshaped to assume a more natural angle of repose at a 3:1 slope and then revegetated with willows, cottonwoods, herbaceous shrubs, and other suitable riparian vegetation. Left bank reshaping would likely require increasing the span of the new SR 109/023 bridge to accommodate the extended slope.

Design objectives for realigning the Moclips River should necessarily include:

- Avoidance of the old mill site (located approximately 500 feet due east of the current 023 bridge; see Figure 9) is essential. As an older industrial site, the risk of finding hazardous materials or contaminated soils at the site would be significant and should be avoided at all costs. The old mill site is not listed as a MCTA, RCRA, or CERCLA site, but the mill was decommissioned long before these laws were enacted in the early 1970s.
- Realignment of the Moclips should avoid as many of the mature large caliper Sitka spruce trees located within the floodplain as possible.
- The geometry of the realigned meander system should be reconfigured such that the same stream length and gradient are maintained.
- The section of the realigned Moclips River just east/upstream of the new SR 109/023 bridge should be configured to transition smoothly into center of the bridge opening and into the downstream reach.

An example of a Moclips River realignment scenario that accomplishes these objective is depicted in Figure 15.

Advantages: Bank armoring, flow deflection, or compensatory mitigation would not be needed. The abandoned backwater reach would provide new aquatic habitat and would eventually become a fully functioning forested wetland. The land needed to realign the river is undeveloped, is located within the 100-year floodplain, has very low development potential, and could be relatively cheaper than most available land in the area. Maintenance needs for SR 109 and the SR 109/023 bridge would be reduced. Structural inspections for the bridge could proceed on a standard schedule.

Disadvantages: Land acquisition needs would be substantial and may not be available. This alternative would impact a category 1 wetland that would require substantial mitigation. Nearby mitigation opportunities do not exist at this time. Construction of 1000 feet of new Moclips river channel would require a significant amount of excavation and hauling, which would complicate permitting. If no nearby areas for stockpiling excavated soils can be located, haul and disposal costs could become extreme. In addition, the existing channel would remain shorter that the re-aligned channel and thus would always be susceptible to re-occupation through river avulsion unless extensive measures were taken to thwart channel migration.

Realignment of river channels are usually a contentious subject, regardless of the net benefits accrued. Permit negotiations could then become contentious and affect project delivery.

Because this alternative is plagued by issues involving constructability, wetland and rearing habitat impacts, avulsion potential, channel lengthening (and potential impacts to sediment transport capability) it was eliminated from further consideration.

Preferred Alternative

The SR 109/023 bridge replacement with directional wall pier(s), a left bank riprap revetment with spur dikes and a regraded right bank to reduce the angle of attack through the bridge opening appears to be the option with the highest net transportation and environmental benefits and the lowest risk-to-cost option for this project. Mitigation should not be necessary and costs other than for bridge construction should be minimal.

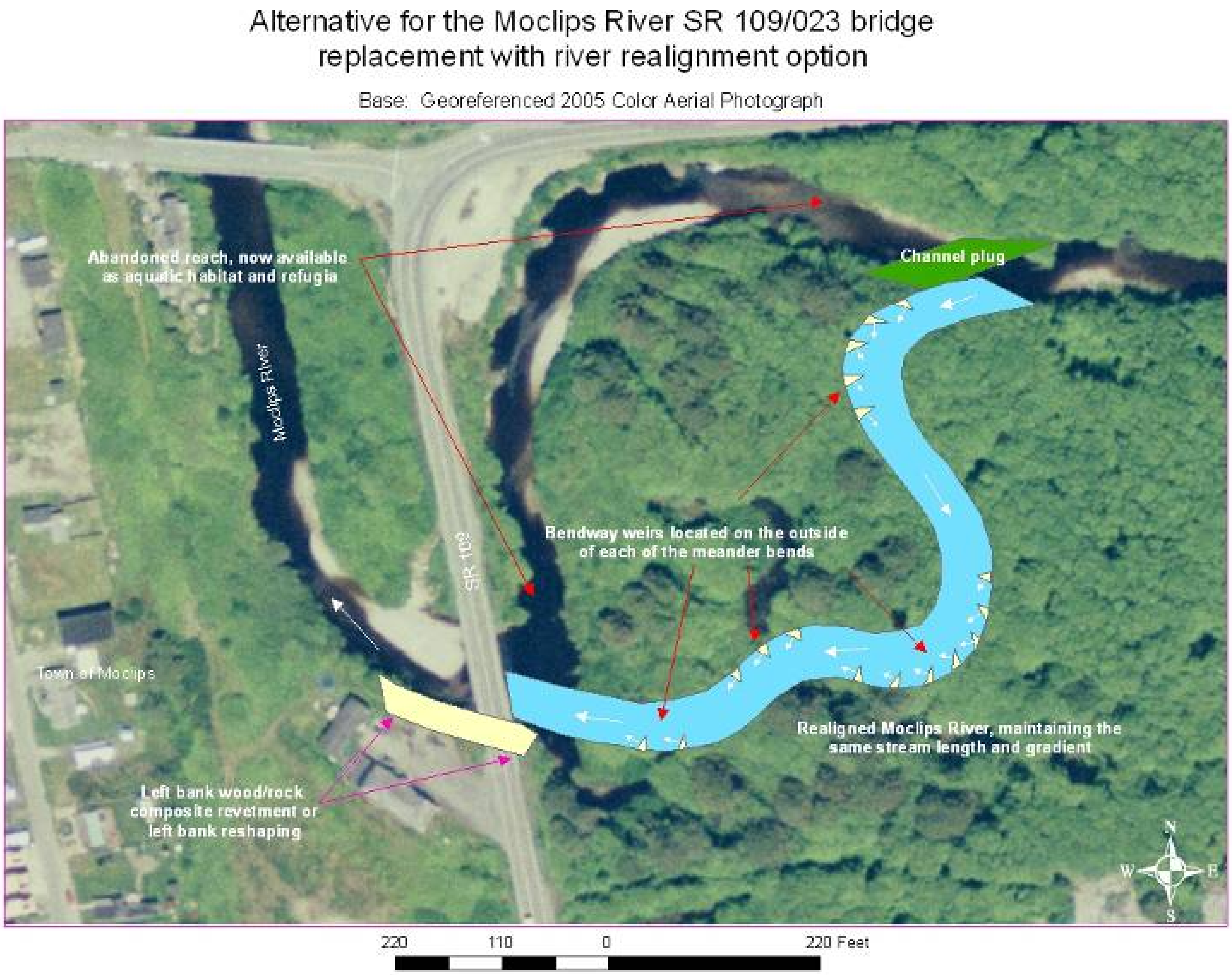

Figure 15. Alternative for the Moclips River SR 109/023 bridge.

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