Site and Reach Assessment
Yakima River at SR 224 (Van Giesen Road)

Work Order MT0100

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Scope

This report presents the findings for a site and reach assessment addressing channel migration, active left bank erosion, and their impacts on the operations of State Route (SR) 224 between milepost (MP) 8.94 and 9.05 in Benton County, Washington. Continuing left bank erosion and associated eastward channel migration of the Yakima River has been threatening the operations of SR 224. SR 224 (Van Giesen Road) is a four-lane unlimited access highway that at the project site has four 11-foot-wide lanes with two eight-foot-wide outside shoulders, combining for a total roadway width of 60 feet. It connects West Richland with Richland.

Problem

The assessment was undertaken to look at causes and solutions for problems related to channel migration of the Yakima River. This channel migration has the potential to affect the structural stability and operational capacity of SR 224. The channel of the Yakima River is migrating eastward into the SR 224 highway prism, which could affect its future operations.

Site Assessment Findings

The site assessment showed that:

- Left bank scour caused by meander migration of the Yakima River potentially could impact highway operations by undermining the east-bound lanes of SR 224.
- The site lacks riparian cover and habitat complexity.
- The in-stream water quality in the lower Yakima is generally poor with pervasively high temperatures and alkaline (high pH) conditions in late spring through mid fall.
- Highly managed hydrology is unlikely to change in the near future.

Reach Assessment Findings

The reach assessment showed that:

- Dams, water withdrawals, and industrial-scale agriculture affect the upstream reach.
- A COE levee restricts channel migration exclusively to the left bank near the eastbound shoulder of SR 224.
- A rock barb structure directly downstream of the project area on the left bank protects adjacent private property.

Recommended Alternative

We recommend that the problem be addressed using:

- Place a series of four rock barbs upstream of the currently existing barb to deflect and diffuse flow energy away from the left bank and the SR 224 highway prism.
- Incorporate large woody debris into the hydraulic shadow of each barb to provide roughness and fish habitat.
- Establish riparian vegetation (black cottonwoods, alders, etc.) where space is available.

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Introduction

This report presents a site and reach assessment of SR 224 at Van Giesen Road at MP 8.94 through 9.04, where the Yakima River channel is migrating into the SR 224 right-of-way. This has been an ongoing maintenance concern and will eventually affect the operation of SR 224 if corrective actions are not taken.

Site Assessment

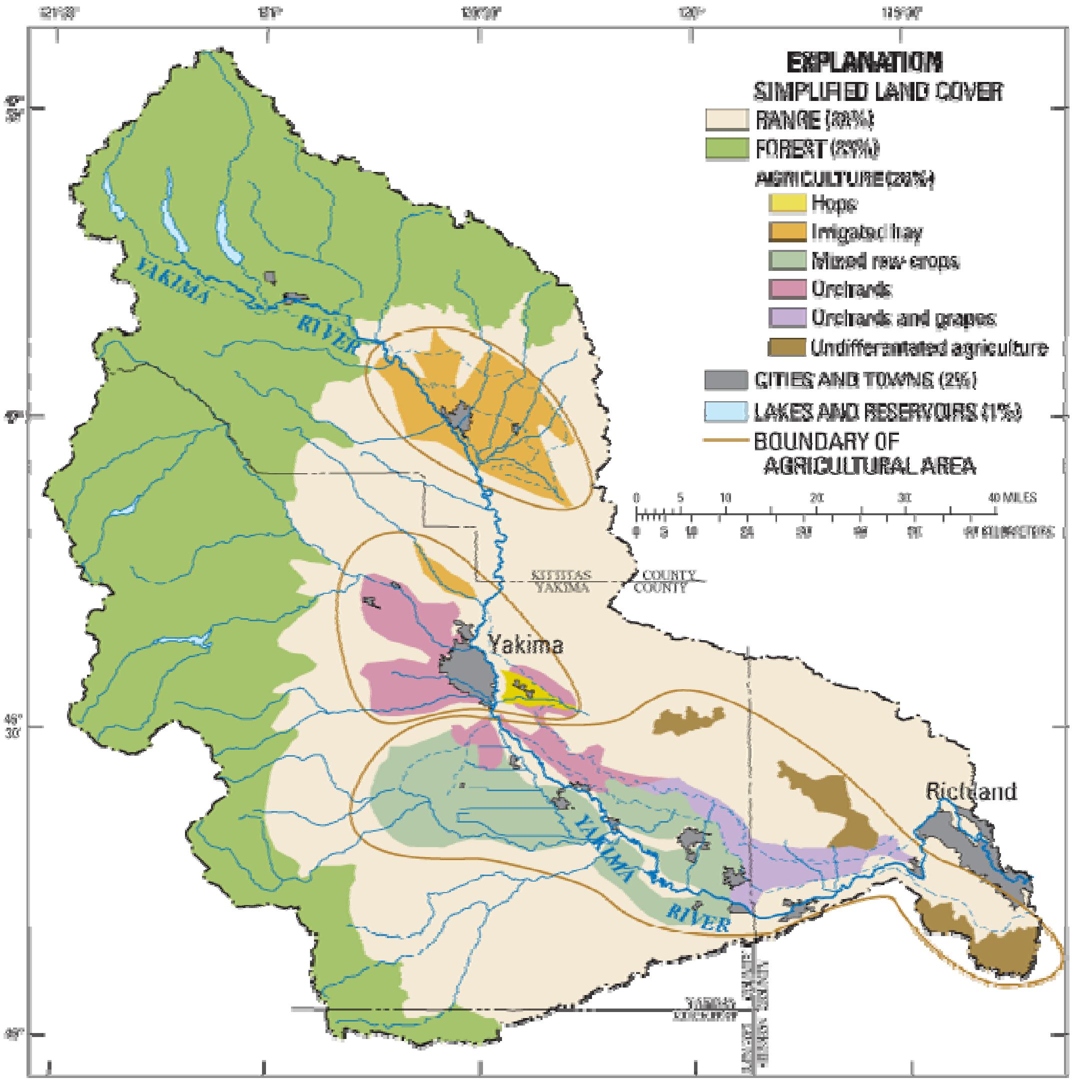
The problem is concentrated on the left bank of the Yakima River near Milepost 9 on SR 224 in West Richland, Benton County Washington. The Yakima River at the project reach has a gradient of 0.1 percent and has a meandering planiform with a tortuosity of 1.8. The reach is an alluvial floodplain; however, the right bank is protected by a certified Army Corps of Engineers (COE) levee that diverts the river's thalweg to the left bank, where SR 224 is located.

Figure 1. Left bank erosion on the Yakima River at SR 224/Van Giesen Road.

Reach Assessment

Watershed Conditions and Land Cover

The Yakima River resides in the second-largest watershed that lies entirely within the state of Washington. The Yakima watershed drains the eastern slopes of the Cascade Mountain Range from Snoqualmie, Chinook, Naches, and White Passes. Above the SR 224 Van Giesen project site (Milepost 8.96, River Mile 8) the Yakima River is 207 miles long and covers 6,070 square miles. The entire Yakima River is about 215 miles long and the total Yakima watershed is about 6,155 square miles when it discharges into the Columbia River.



Land cover data from 1999 Landsat Assessment.

Figure 2. Current Land Cover in the Watershed.

Precipitation in the Yakima watershed has both a strong seasonal pattern and spatial gradient. Winters are wet, summers are dry, and peak river discharge under “natural” conditions is due to the late-spring and early-summer snowmelt. Spatially, basin precipitation is a classic example of the rain shadow effect. The crest of the Cascade Mountains to the west normally receives over

120 inches of annual precipitation, mostly as snow, while total annual precipitation averages about seven inches at the Yakima's confluence with the Columbia in Richland.

Six reservoirs, with a total active storage capacity of 1,070,700 acre-feet, hold the spring and summer snowmelt in the mountains for delivery to irrigation districts between April and October. The water storage behind the three major reservoirs on the mainstem Yakima system (Keechelus, Kachess, and Cle Elum) are released primarily in spring and early summer to augment irrigation in the Yakima basin. The storage in the Tieton/Naches system, including Rimrock, Clear and Bumping Lakes, is released into the Yakima system primarily in late summer and early fall. This method of water management has the ability, at least in relatively "normal" precipitation years, to maintain a relatively constant water supply primarily for agriculture but also for urban uses throughout the growing season. In the Yakima basin, senior water rights holders are mostly agricultural interests. In drought years, many junior water-right holders face cutoffs of water supplies, which are mostly for drinking and other domestic uses. Water rights and associated water allocations have historically been politically and economically very contentious issues in the region.

Land cover in the basin is 29 percent forested, mostly in the western mountains; 50 percent non-forested or rangeland, mostly in the east where sagebrush and bunch grass are the dominant vegetation; and 21 percent agricultural, mostly irrigated land along the historic floodplain of the Yakima River. Geographically, the Yakima Basin overlaps with the combined areas of Kittitas and Yakima counties plus about half of Benton County. The basin also contains a very small and unpopulated sliver of Klickitat County, while small and mostly unpopulated sections of Kittitas and Yakima counties lie outside the watershed. The Yakama Nation Reservation, which is the largest Indian reservation in Washington state, occupies 23 percent of the Yakima River watershed in its southwest corner.

Less than one percent of the basin land area is classified as developed and most of this land is located around the city of Yakima, the largest municipality in the watershed (population 72,000). The total basin population is about 294,000, which is split evenly between urban and rural residents. More than 223,000 of the basin population lives in Yakima County; Kittitas County has a total population of only 33,000 residents, while the remaining 38,000 basin residents live in Benton County.

Many governmental and nongovernmental agencies at multiple levels have land management or water resource responsibilities in the Yakima Basin. At the local level, there are the three counties, 23 incorporated municipalities, and more than two dozen irrigation districts. The U.S. Forest Service (USFS) manages the Wenatchee National Forest in the Cascade Mountains, which includes several USFS Wilderness Areas. In the east, the U.S. Bureau of Land Management manages large areas of rangeland. The eastern part of the basin also includes major portions of the 500 square mile Yakima Training Center, operated by the U.S. Army, and the 586 square mile Hanford Nuclear Reservation, managed by the U.S. Department of Energy. In addition, the Yakama Nation has an active Fish and Wildlife Resource Management Program that operates both on the Reservation and throughout their ceded lands elsewhere in the Yakima Basin.

Agriculture has long been the foundation of the basin's economy and has historically driven water resources management throughout the watershed. The Yakima Valley is one of the richest and most productive agricultural regions in the country, growing more than 60 different crops. Primary agricultural activities include orchards, row crop production, livestock, vineyards, more than 80 dairies, and related food-processing industries. In 1997, there were 5,190 farms in Kittitas, Yakima, and Benton counties (down from over 6,500 in 1982), which collectively had a combined market value for all agricultural products sold exceeding $1,250,000,000 (Washington Agricultural Statistics Service 2003). The U.S. Bureau of Reclamation estimates the value of agricultural products from the Yakima Irrigation Project alone is $700,000,000 for irrigated crops and $250,000,000 for livestock.

The majority of Yakima Basin farms and crop production are in Yakima County, which leads the United States in production of apples, mint, and hops. Yakima County also leads Washington state in the production of pears, cherries, grapes, peaches, plums, asparagus, and sweet corn. Benton County grows many of the same products, and leads the state in grain, corn, and carrots. The principal products of higher-elevation Kittitas County are timothy hay and cattle.

Irrigation use now represents 97.1 percent of total surface water withdrawals in Yakima and Kittitas counties, which is representative of the entire Yakima Basin. The remaining 2.9 percent of surface water withdrawals includes public water supply and independent domestic use, commercial and industrial use, and livestock use. There are currently about 558,000 irrigated acres in the basin, of this total, 465,000 acres are served by the Yakima Irrigation Project. The Project requires an annual diversion of about 2.5 million acre-feet of surface water when supplies permit, and the Bureau delivers this water directly to several dozen irrigation districts in both the upper and lower basins. The Yakima Project includes six major storage reservoirs, 14 irrigation districts, five diversion dams, 416 miles of canals, 144 miles of drains, 1,698 miles of laterals, 30 pumping plants, and nine power plants. This massive irrigation infrastructure is operated as a unified whole, requiring major changes in the timing, quantity, and quality of stream flow patterns in the Yakima River and its largest tributaries. The reservoirs on the upper mainstem Yakima River (Kachess, Keechelus, Cle Elum) contribute most of the supplemented flows in spring through mid-summer). Reservoirs on the Tieton/Naches tributary supply most of the augmented flows in late summer and fall. More detail about irrigation in the Yakima Basin is provided in Figure 3.

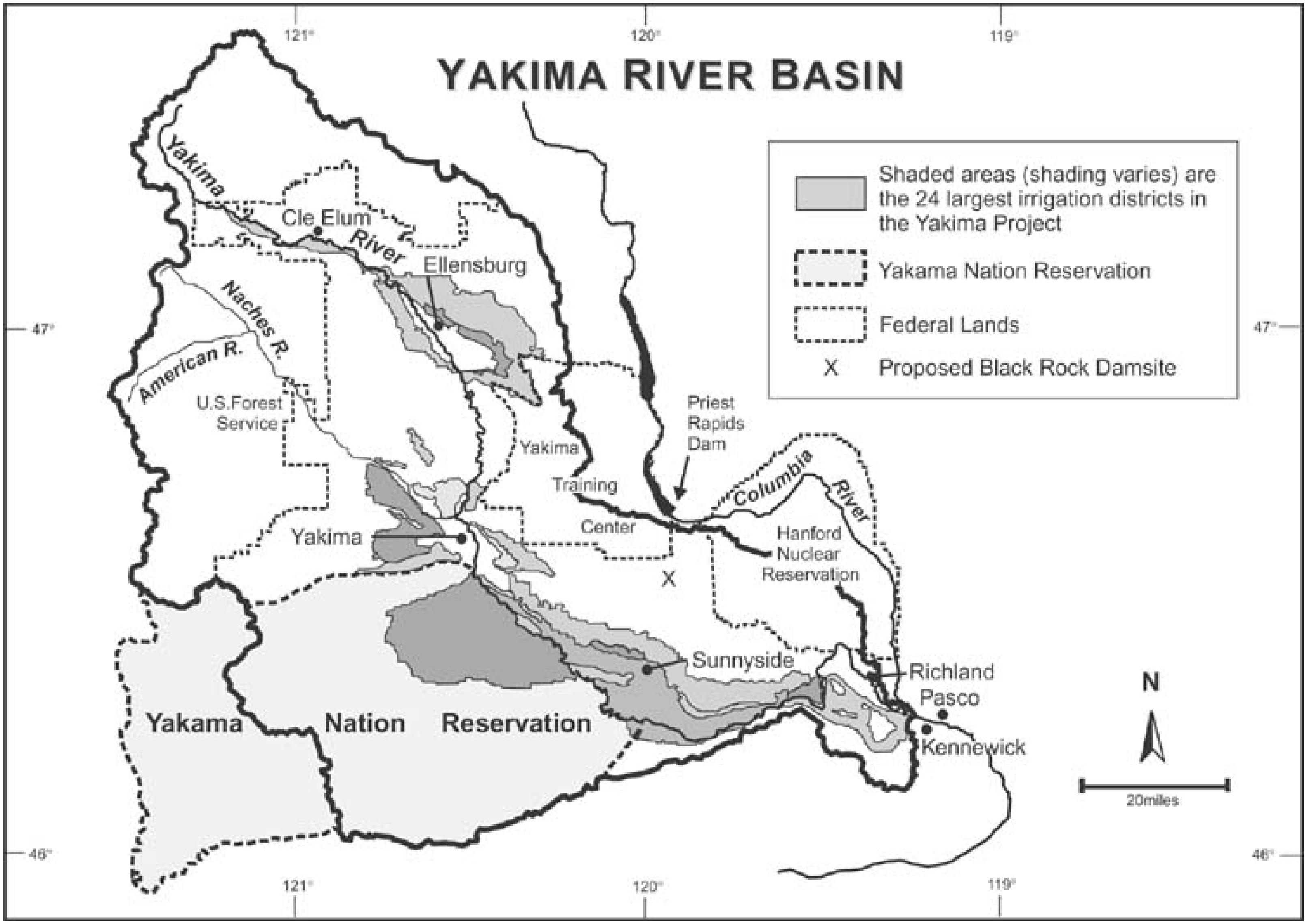


Figure 3. Yakima River Basin Showing Irrigation Districts.

Water rights in the Yakima basin are categorized as "over-appropriated," meaning that more water has been legally allocated than is naturally available in most years. In most years, therefore, there is an inadequate supply to meet the demand of existing water rights holders at current prices. One of the peculiarities of water management in the Yakima Basin derives from the history of the Yakima Project as it affected the local application of the prior appropriation legal doctrine. In 1945, a U.S. court decree set forth a negotiated agreement resolving a 1939 lawsuit between multiple Yakima Basin irrigation districts over water rights to about 90 percent of the diversionary water use in the basin. The 1945 Consent Decree defined the "total water supply available," a concept that, in any given year, combines the unregulated natural flow in the rivers with any return flow and all stored water in the Yakima Project reservoirs. The 1945 decree also established two classes of water entitlements. Senior water rights, which follow the traditional hierarchy based on the date of each user's first beneficial use of water, are those that existed prior to 1905 when the Bureau of Reclamation filed for all unappropriated water in the Yakima and Naches Rivers. These senior rights (49 percent of total project entitlements) are "non-proratable" and to date have always received their full water entitlement. Post-1905 project water rights are "proratable," meaning that in water-short years these rights (51 percent of total project entitlements) are evenly reduced across the board.

Water shortages are not applied sequentially to each most-junior water user, with everyone but the last recipient getting either all or nothing. Instead, shortages are applied proportionally to a group that ordinarily holds almost half the diversionary water rights in the Yakima Basin. Since the 1945 Consent Decree, these junior, proratable rights have been cut back 10 times, in 1973, 1977, 1979, 1987, 1988, 1992, 1993, 1994, 2001, and 2003. Cutbacks have averaged 34 percent, ranging from eight percent (in 2003) to 67 percent (in 1993).

Geology and Soils

At the project site (milepost 8.96 to 9.04), the soils are all classified as unconsolidated Holocene alluvium. These floodplain deposits are typically very friable and have little shear resistance, making it highly erodible during high stream power events. Directly adjacent to the right bank of the Yakima River and downstream of the SR 224/008 bridge (milepost 8.34 to 8.46) for two miles is a certified COE levee that was designed to accommodate the 1933 flood with an additional three-foot freeboard. This levee, which is regularly maintained and has an impervious key, protects residential properties that lie within the historic Yakima floodplain With the right bank being continuously protected by the levee, channel migration can only actively proceed toward the left bank, which is the location of SR 224.

During the Pliocene epoch (two to 12 million years ago) the ancestral Yakima River flowed from the Cascade Mountains across flat-lying Columbia basin flood basalts which had originated from fissures in the earth's surface during the Miocene epoch (12-26 million years ago). In the vicinity of Yakima, north-south compressional forces folded the lava into a series of parallel east-west to southeast-northwest anticlines, synclines, and faults. As the lava beds were pushed up the river cut down through the ridges in a series of narrow gaps. Downcutting more than kept pace with uplift during this period, leaving deep canyons where the river downcut through the uplifted basalt. Yakima Ridge appeared to have risen more quickly than its southern neighbor, Ahtanum Ridge, resulting in a deeper gorge that is still prominent.

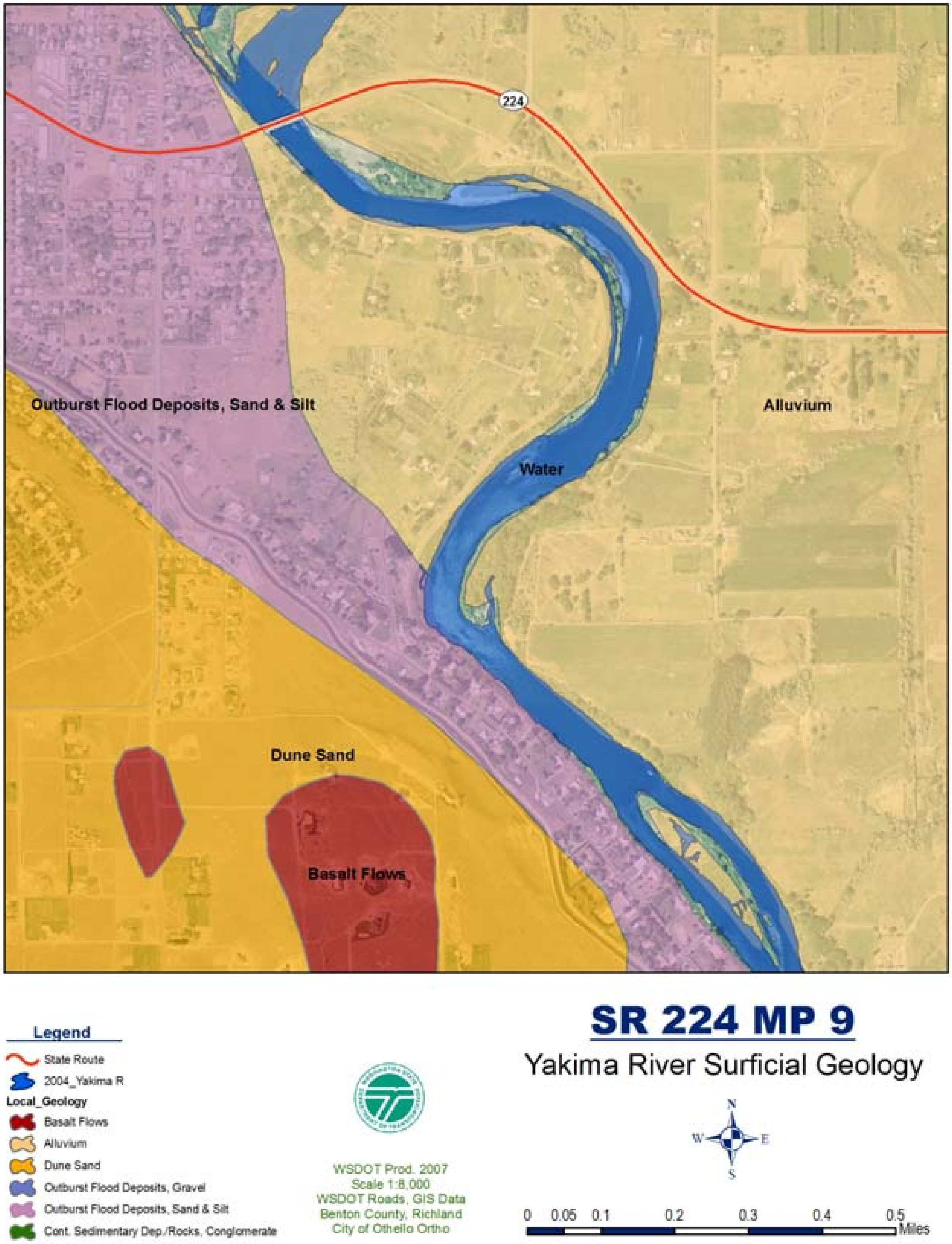


Figure 4. Yakima River Surficial Geology.

The lower Yakima River in the vicinity of the project site has historically been a broad, low gradient alluvial valley (see Figure 4). Flows in the lower Yakima at SR 224 are highly seasonal and are driven by Cascade mountain snowmelt and dam operations. The river is highly managed primarily for agricultural use, with secondary allocations for municipal water supply and fisheries.

Geomorphology

The dominant landforms in the project reach have been defined by three major geologic events, the Miocene Columbia Basin flood basalt deposits, the Miocene Yakima Fold Belt, and the Pleistocene Lake Missoula glacial breach floods (Orr and Orr, 2002). In the project reach, the broad, low gradient Yakima floodplain is the dominant feature. The floodplain in the project area has been truncated by a large COE levee, which eliminates the possibility of channel migration, side-channel formation, and other geomorphic / floodplain functions (see Figure 5).

Under pre-settlement conditions the Yakima River was characterized by multiple channels, complex aquifers and extensive riparian cottonwood forests. Subsequent implementation of headwater dams to supply irrigation water has altered river and floodplain processes critical to the cottonwoods and associated riparian vegetation. In contrast to earlier conditions, flow patterns after the 1960s have generally been unfavorable for cottonwood recruitment although some cottonwood colonization has occurred in association with physical disturbance from gravel mining. With recent flow regimes, regulated flows along upper reaches maintain the river near bank-full throughout the growing season, thus inundating suitable seedling recruitment sites. Downstream, irrigation withdrawals reduce the river stage, resulting in seedling establishment at low elevations that are lethally scoured by subsequent high flows. These regulated flow regimes have not hindered growth of established trees, but have reduced the recruitment of cottonwoods, and has particularly disfavored females, thus altering sex ratios and producing skewed cottonwood population age and gender structures. The decline of cottonwood riparian areas has likely led to a reduction of anabranching decline has also been associated with other changes in riparian plant community composition, including the encroachment of invasive weeds.

Streamflow in the Yakima River Subbasin is mostly generated by the melting of a copious snowpack that accumulates from fall through spring in the Cascade Range. Precipitation falls off dramatically as one moves east from the Cascade crest into the rain shadow, and much of the basin area generates little or no runoff except during low frequency rain or rain-on-snow events. Summer is dry in the basin, so most of the water budget of the basin is delivered to the mountains during the winter months. The Cascades accumulate the largest snow-water content in the continental United States, which, along with the relatively mild climate, causes natural peak runoff to be sustained into the summer months. Remnant glaciers in two tributaries (Cle Elum and Tieton rivers) generate some meltwater throughout the summer. Delivery of this runoff to the river system has been affected by road building and forest practices which have generally caused higher, earlier peak flows and lower summer flows. Where appropriate, the effects of these activities will be assessed in this project.

Two major influences moderated streamflow in the lowland reaches of the Yakima River. Natural lake storage and ground storage accounted for much of the flow in the river system during the typical late summer period of little precipitation or snow melt. Several large and many small natural lakes remained at the time of development of the basin as a legacy of the history of ice-age glaciation in the Upper main stem and Naches arms of the Yakima River system. During late summer, outflow typically exceeded inflow and contributed to the base flow of the river. Sockeye inhabited several of these lakes. Four of the five major irrigation storage reservoirs in the basin were built by placing dams atop moraine plugs to increase the size of the lakes and allow outlet works to be constructed. Fish passage was not included in any of the dams, and sockeye are now extinct in the basin. The dams blocked anadromous fish access to a vast amount of habitat in the basin and dampened the effects of upstream watershed modifications on downstream habitat. Until such time as fish passage can be restored, assessing conditions above the dams will not likely provide much benefit and will not be emphasized in this project (Washington State Conservation Commission. 2001).

Folding of the basaltic lava flow underlying the lower Yakima Valley created large structural basins separated by ridges. Glaciation in the upper watershed along with erosion on the ridges delivered a large volume of gravel to the river system creating a system of alluvial floodplains stretching from the mountains to the mouth of the river that is probably the most extensive alluvial floodplain system in the interior Columbia River Basin. This floodplain system is segmented into discrete reaches separated by ridges, with the Yakima River flowing from one sub-basin to another through short water gaps in the ridges. Such alluvial floodplain reaches are central to the ecology of gravel bed river systems. Hydrologically, a properly functioning floodplain aquifer system captures peak flows and releases base flows, thereby sustaining stream flows through times of low precipitation and runoff. This floodplain interaction helped maintain high base flows in the lower Yakima River, with late summer flow rarely dropping much below 1000 cfs at Union Gap (Parker and Storey, 1915). The surface water/groundwater interaction in these reaches also moderated water quality, especially temperature, by capturing cold freshet flows and discharging them through the summer as cooling baseflows, as well as preventing icing in winter. These floodplain dynamics have largely been eliminated by water management activities devoted to preserving large-scale agriculture in the basin.

The role of alluvial floodplain reaches as the centers of biophysical organization and productivity is documented in “Return to the River” (Independent Scientific Group, 1996) and elsewhere. The extent of such reaches in the Yakima River combined with the substantial water budget accounted for the enormous productivity of the anadromous fish runs in Yakima River Subbasin. All major floodplain reaches in the basin have been modified by physical structures such as highways, railroads, dikes, drainage, and impermeable surfaces, as well as by flow modification and water quality degradation both in the river and in the associated groundwater system. In addition, most of the abundant side channels that characterized these reaches are routinely subjected to dewatering or physical barriers to fish passage. Assessing opportunities to restore, protect, re-water and reconnect these critical off-channel habitats will be a secondary objective of this project.

Major modifications to the flow regime of the Yakima River Subbasin have accompanied the development of irrigation in the basin (YRBWEP Programmatic Environmental Impact Statement). The spring freshet is greatly depressed in most of the basin. In the upper Yakima, where most of the storage capacity is located, the spring freshet has been largely eliminated, but low spring and early summer flows give way to anomalously high flows as the river is used to “wheel” irrigation water to downstream users. The Naches arm contains two main tributaries, the Naches and Tieton Rivers. The Tieton is entirely regulated by Rimrock Dam and has no spring freshet and a scheduled annual peak in September. The upper Naches watershed and that of its tributary, the American River, generate the largest unregulated runoff in the basin and are accessible to anadromous fish. The lower Yakima River (below Sunnyside Dam) at SR 224/Van Giesen Road is a hybrid of these upstream hydrographs. Flows here are always below natural levels, and the freshet is depressed (most of what remains is generated by the Naches River). Low flows begin early and maintain levels of less that one-third of natural runoff. Flows in several areas of the basin fluctuate more rapidly and frequently than pre-development conditions. Assessing the effects of flow modifications and fluctuations is a major focus of ongoing work in the basin.

Hydrology and Flow Conditions

The lower Yakima River's hydrology is heavily influenced by dams, diversions, and industrial-scale agricultural practices. All of the high flow, high stage events that are found at the project site occur during late fall, winter, and early spring, generally as a result of the annual melt-off of the Cascade snowpack and rain-on-snow . The USGS river gage at Kiona (see Figure 5) .is located 5.4 river miles upstream of the SR 224 project site. Kiona flow data will be used to analyze hydrology at the SR 224 project since there are no significant inflows from tributaries or irrigation withdrawals between the Kiona gage and the project site.

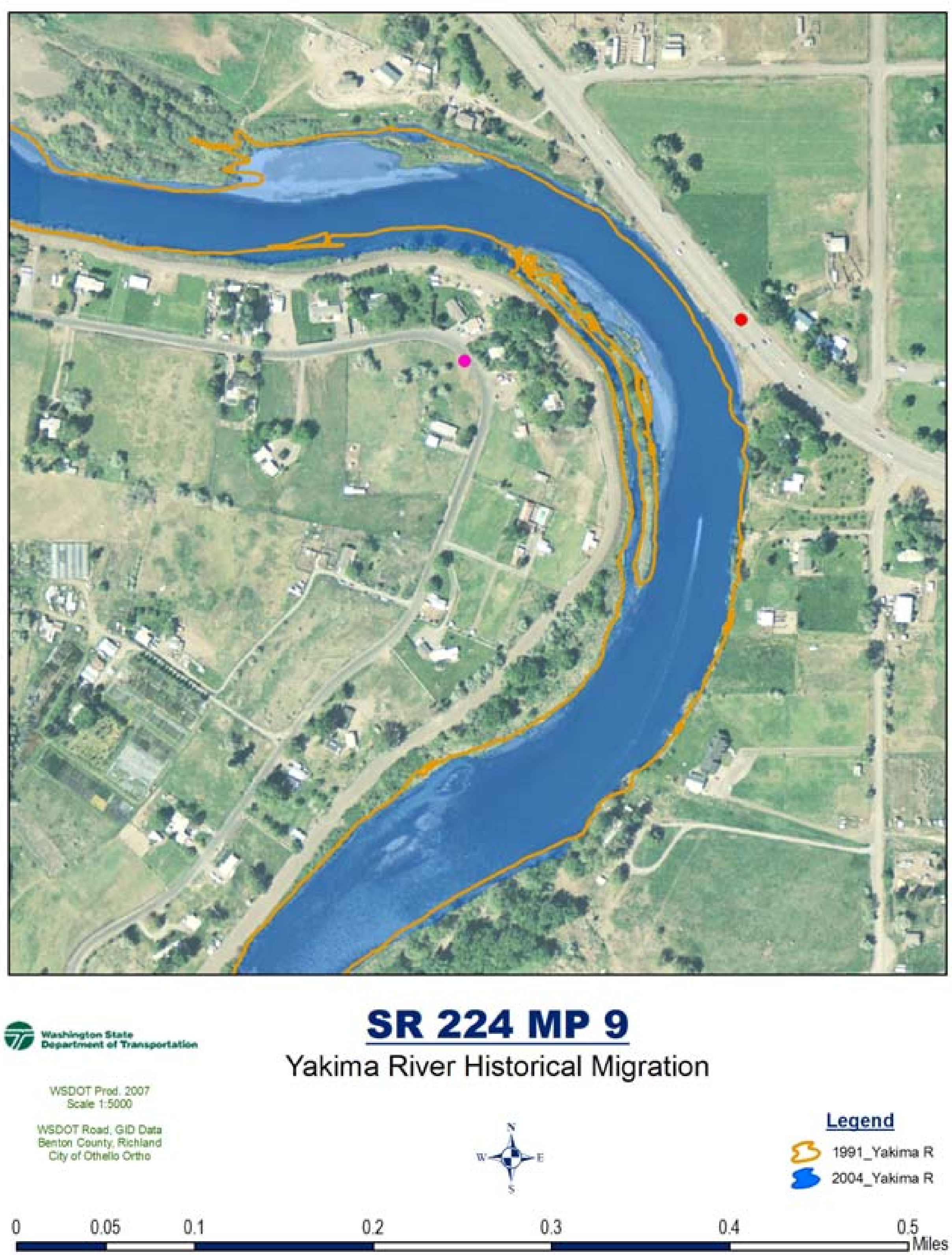


Figure 5. Yakima River Migration.

Channel Conditions

Channel geometry and flow characteristics: Table 1 and Figure 6 show peak flood flow and ranked annual high flows at the Kiona gage. The 2-year flow is 3,400 cubic feet per second (cfs) and the 100-year flow is 7,300 cfs. Annual peak flows have ranged from a low of about 1,100 cfs to a high of about 7,100 cfs.

Table 1. Peak Flood Flow Statistics for Yakima River at Kiona Gage (12510500).

Statistic	**Flow (ft^3/s)**
Q2	3,400
Q10	4,300
Q25	5,800
Q50	6,700
Q100	7,300
Q500	8,100

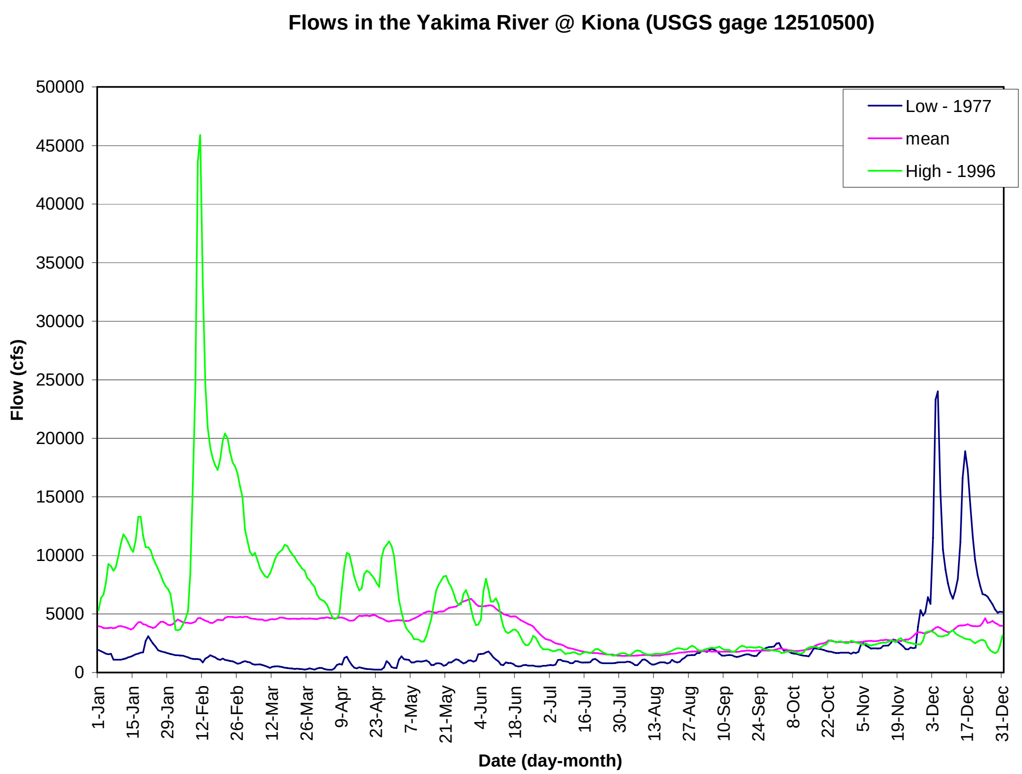


Figure 6. Historic High, Low, and Mean Yakima River Flows at Kiona.

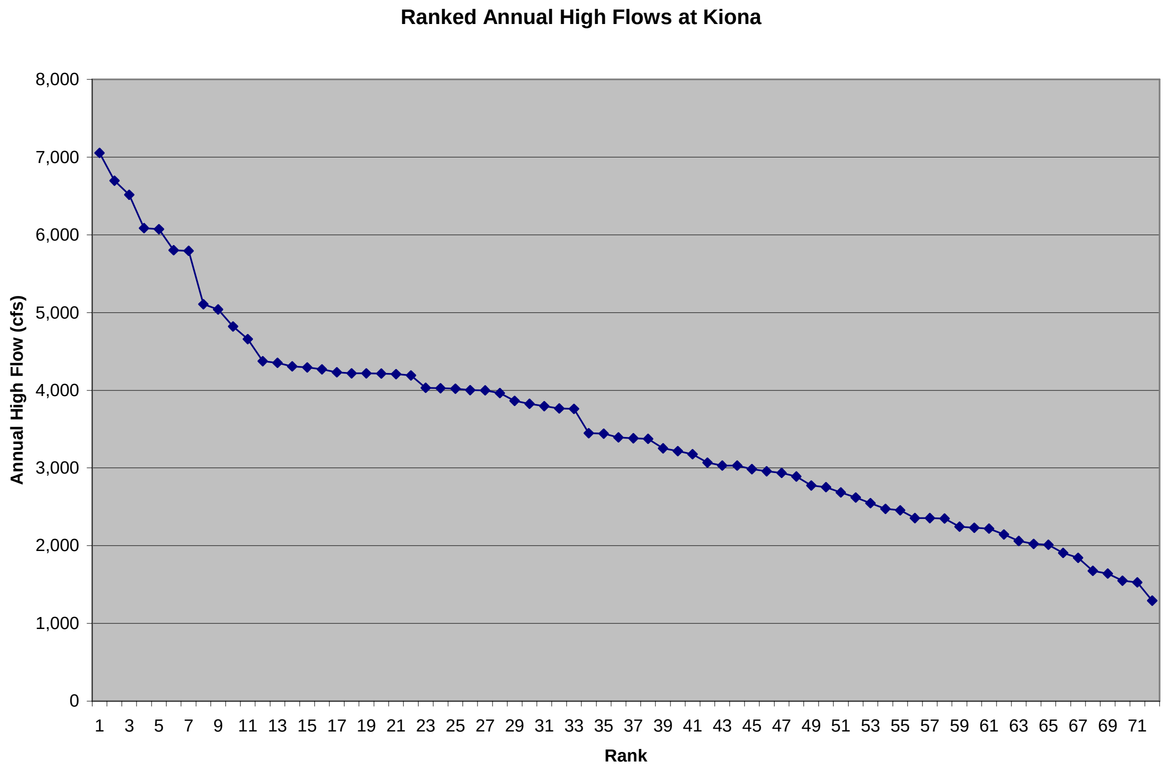


Figure 7. Ranked Annual High Flows at Kiona.

Channel alignment and profile: The Yakima River at SR 224/Van Giesen Road has a very low gradient and has a meandering planiform at the project site and in the upstream and downstream reaches. Lateral bars, point bars, and a few mid-channel islands are present. Channel gradient in the upstream reach is 0.8 percent. The ordinary high water mark at the project site is about 365 feet, as estimated from the Kiona stage data and the energy grade line between the Kiona gage and SR 224/Van Giesen (estimate from DEM).

Channel migration and avulsion risk: Channel migration at the project site is currently rotating clockwise through the meander and is moving east and southeast through the alluvial floodplain that extends well to the east of the current position of the Yakima and SR 224. Historic aerial photos (see Figure 5) do not show rapid migration, but due to the close proximity of the Yakima River to SR 224 (in places, less than eight feet), any future eastward migration may affect SR 224 operations. Any chance of an avulsion occurring is precluded by the COE levee that protects the right bank.

Local scour: As the thalweg has increasingly shifted to bear on the left bank entrainment, a large cut bank has formed. This cut bank exposes between eight and 15 feet of alluvial sediment, depending on the season, with winter flows providing the higher stages and correspondingly higher stream power and shear stresses on the bank. Local scour is severe and may be very deep. The channel of the Yakima adjacent to SR 224 will need to be surveyed before design of the structures needed to protect the left bank and SR 224. Any type of deflection or diffusion structure, such as barbs, groins, J-hooks, vanes, etc., will undoubtedly need large quantities of stable fill material such as heavy loose riprap or jetty stone for structural stability in such a large river.

Preferential flow pathway: The upstream reach approaching SR 224 is quite straight, flows due east, and directs flow energy directly into the left bank at the onset of the clockwise meander. After exiting the meander, the flows are rotated by 110 degrees and exit the reach heading south-southwest. Throughout the project area, the Yakima River's thalweg is entrained against the prominent left cut bank.

Back eddies: As the thalweg has moved into the left bank along SR 224, localized near-bank obstructions have developed from sloughing at the meander's cut bank. This results in localized near-bank back eddies that result in strong downwelling and upwelling currents, high boundary stress, and high velocity gradients in the near-bank region (see Figure 7).

Figure 8. Near-bank Back Eddies and Resulting Scallop-Shaped Erosion Features.

Riparian Conditions

Trees that once covered the islands on the valley floor are sparse and their decline is an expected function of flood reduction strategies in the Yakima Basin. The mid-river islands and lateral bars that have historically been locations for riparian tree stands and vegetation are lacking and declining because of reduction of flood flows and reduced sediment loads. As in many arid or semi-arid environments, the transition from riparian vegetation to upland vegetation such as sage and cheat grass is very abrupt. An elevation difference of three feet or less could transition vegetation from riparian to upland.

Large Woody Debris

The project reach is starved for in-stream large woody debris due to the lack of significant riparian cover and lack of upstream recruitment due to development, agriculture, and levees. Historic riparian vegetation was likely limited to deciduous species such as black cottonwood and alder. It is unlikely that conifer species were ever established at the project site or in the lower Yakima basin.

Water Quality

Water quality in the lower Yakima basin is highly impaired by high seasonal temperatures, alkaline conditions, and turbidity as indicated by water quality data collected at the USGS gage at Kiona. Mid-summer temperatures are high enough to impair all fish species that may inhabit the river.

Tables 2 and 3, below, show the aquatic life temperature and dissolved oxygen criteria in fresh water from Chapter 173-201A of the Washington Administrative Code (WAC), “Water quality standards for surface waters of the state of Washington.”

Table 2. Aquatic Life Temperature Criteria in Fresh Water.

Chapter 173-201A WAC, Table 200 (1)(c).

Category	**Highest 7-DADMax**
Char Spawning	9°C (48.2°F)
Char Spawning and Rearing	12°C (53.6°F)
Salmon and Trout Spawning	13°C (55.4°F)
Core Summer Salmonid Habitat	16°C (60.8°F)
Salmonid Spawning, Rearing, and Migration	17.5°C (63.5°F)
Salmonid Rearing and Migration Only	17.5°C (63.5°F)
Non-anadromous Interior Redband Trout	18°C (64.4°F)
Indigenous Warm Water Species	20°C (68°F)

Table 3. Aquatic Life Dissolved Oxygen Criteria in Fresh Water.

Chapter 173-201A WAC, Table 200 (1)(d).

Category	Lowest 1-Day Minimum
Char Spawning and Rearing	9.5 mg/L
Core Summer Salmonid Habitat	9.5 mg/L
Salmonid Spawning, Rearing, and Migration	8.0 mg/L
Salmonid Rearing and Migration Only	6.5 mg/L
Non-anadromous Interior Redband Trout	8.0 mg/L
Indigenous Warm Water Species	6.5 mg/L

Fish Utilization and Habitat Availability

The Yakima River system supports coho, spring Chinook, fall Chinook, summer steelhead, and bull trout/Dolly Varden (presumed present), as well as several non-salmonid species. Both steelhead and bull trout in the Yakima River are listed as threatened under the federal Endangered Species Act. Survey notes indicate species potential for steelhead, Chinook, and various char species in the project site and reach are dependent on the highly-variable water quality in the Lower Yakima River. Water temperatures in the lower Yakima are seasonally variable and tend to be very high from late spring to early fall (see figures 8 and 9). This is mostly a natural phenomena, being that the river is located in a near-desert climate, but temperature excursions are more-than-likely exacerbated by dams, diversions, and agricultural return flows that tend to increase water temperatures. Mechanisms that can lower temperatures in the reach, such as phreatic recharge or hyporheic flows, are weak to nonexistent due to low localized precipitation and channel simplification. Spawning and rearing habitat in the reach is sparse to nonexistent. Various fish species do migrate through the reach to access habitat features upstream in the Upper Yakima and its major tributaries. Water quality data collected at Kiona (six river miles upstream of the project site) suggests that fish survivability is highly seasonal due to severe temperature fluctuations and all species are impaired during high temperature windows that generally exist between mid June through mid-September.

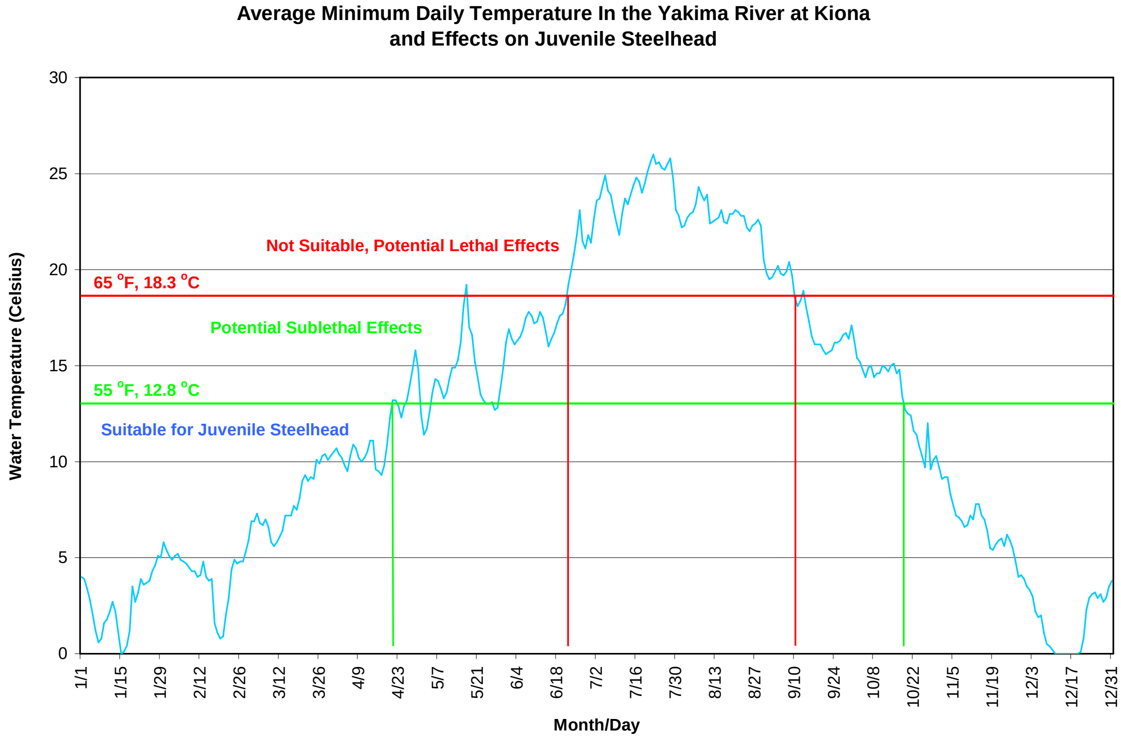


Figure 9. Effects of Mean Lower Yakima Water Temperatures on Juvenile Steelhead.

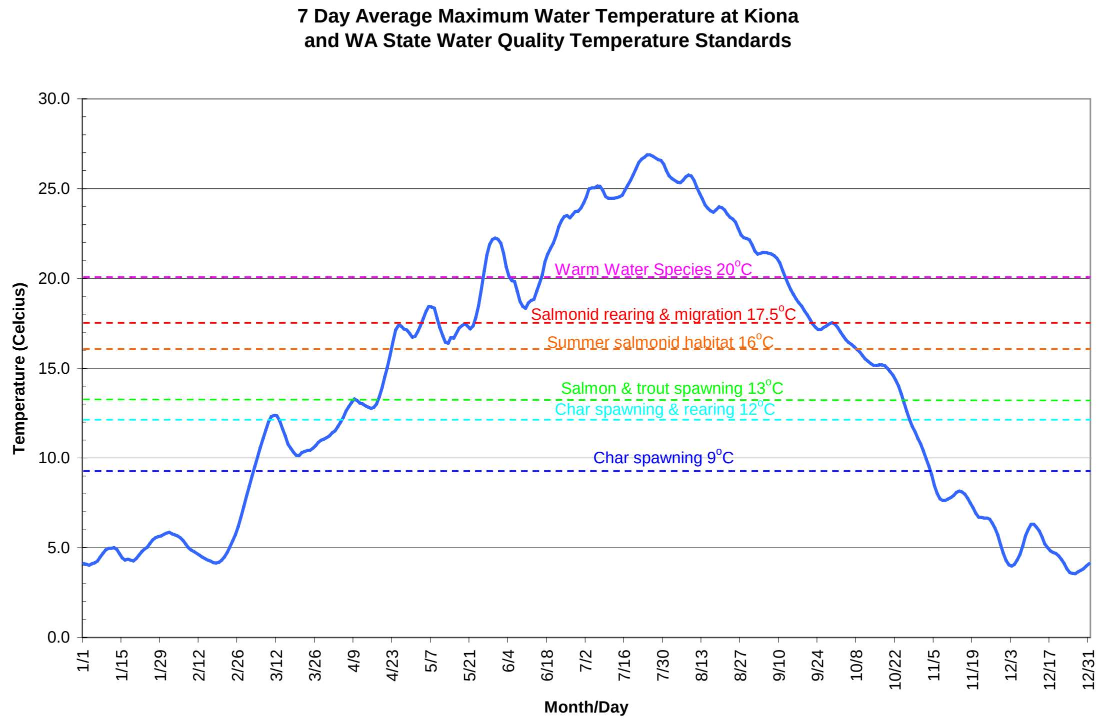


Figure 10. Lower Yakima water temperatures water quality standards.

Mechanisms of Failure

Mechanisms and Causes of Geomorphic Failure

The thalweg alignment is directed at the vulnerable eastbound shoulder on the left bank. This imparts significant shear stresses at the actively eroding cut bank and promotes channel migration to the east and south, rotating clockwise. This trend is reinforced by the placement of the large levee on the right bank, which precludes channel migration on the right bank.

Site-Reach Based Failure Mechanism Interaction

The channel at the SR 224/Van Giesen Road project site has a tortuosity (meander curvature/channel top width) of approximately 1.6, as determined from aerial photos. When tortuosity ratios are three or less, the primary components of longitudinal velocity impact the outer river bank at a very abrupt angle, resulting in significant cross-stream flow. The resulting momentum transfer of the fluid mass directly into the streambank and the work that the bank performs in turning the flow (in this case from due east to south-southwest) results in significant bank erosion. Hydraulic forces are highest on the outside/left bank and have resulted in a significant erosional scarp located very close to the eastbound shoulder of SR 224. Across the channel along the right bank a point bar has formed with sediment and bed material being supplied by both primary longitudinal and helicoidal currents (Natural Resources Conservation Service 2005).

Primary Mechanisms of Failure

The primary mechanism for failure at this site is toe erosion along a bend in a smoothed channel with reduced vegetative structure. This is exacerbated by the presence of the levee on the right bank which forces any channel migration of erosive response into the road prism.

The site-based conditions have deteriorated to the extent that a abrupt failure of the left bank may be possible during a significant flood event. A combination of cross-flow currents and helicoidal currents in the near vicinity of the left bank (next to SR 224) are the mechanisms that influence the active erosions along the 580-foot length of river bank. Due to the relatively low tortuosity of the lower Yakima at the project site, cross-current flows are the primary mechanism for erosion at the northern end of the erosional scarp. At the southern end, it is likely dominated by helicoidal flows. In helicoidal flows, centrifugal acceleration acts outwardly on water as it flows through a meander bend and leads to a differential surface water elevation ("superelevation"). This results in a downward acting pressure gradient that is magnified by the degree of curvature and tortuosity. The superelevation-induced pressure gradient and the primary downstream velocity component result in spiraling circulation that induces additional shear stresses to the outer bank.

Abating the Primary Mechanisms of Failure

The bank is eroding rapidly and must be protected in the near future. It appears that road relocation is not be feasible here because it involves multiple, significant real estate purchases that must be acquired from willing sellers, and would significantly increase the costs of any proposed project. Near-bank velocities and shear stresses must by attenuated through alteration of helicoidal flows and interception of cross-stream flows. Controlling these hydraulic forces can result in the redistribution of energy from the near-bank region toward the center of the channel (USGS, 2005). Standard ISPG-approved structures that are suitable to accomplish these goals can include barbs, groins, and vanes. The Yakima River at SR 224 is probably too deep to construct vanes, which must extend across the majority of the stream channel. Regardless of the treatment selection chosen, a channel survey will be needed to calculate volumes of fill and associated mitigation requirements.

Treatment Alternatives

Site-Based Alternatives Considered

The 2003 Integrated Streambank Protection Guidelines (ISPG) and FHWA publication HEC 20 (Stream Stability at Highway Structures) were used to address the overall project objectives and to evaluate treatment alternatives. Each guideline and treatment alternative in the ISPG was based on the current best science and technical practices for river restoration and aquatic habitat protection.

The following site-based alternatives were considered:

No action alternative: Eastward channel migration would continue as would left bank erosion. Because the channel is already in close proximity to the Yakima River's active cut bank, eastward channel migration would eventually undermine the eastbound shoulder and compromise the safety of the highway.

Continuous riprap revetment: WSDOT right of way does not cover the upstream and downstream termini of the active cut bank at the project site. One typical mechanism of failure for riprap revetments designed to protect the toe of a slope is the propensity of a river to make an "end run" on the revetment, resulting in exacerbation of the existing problems for the road by simply moving the problem from one place to another. This could have the possible outcome of actually making the erosion site larger due to translation of the problem to adjacent bank areas.

J-Hook Vanes: The J-hook structure is basically a combination of a vane in the center portion of the channel with a barb-like section adjacent to the eroding bank. J-hooks can include a combination of heavy, loose rip-rap, logs and root wads. They are located on the outside of stream bends where strong downwelling and upwelling currents, high boundary stress, and high velocity gradients generate high stress in the near-bank region. The structure is designed to reduce bank erosion by reducing near-bank slope, velocity, velocity gradient, stream power and shear stress. Redirection of the secondary cells from the near-bank region does not cause erosion due to back-eddy re-circulation. The vane portion of the structure occupies one-third of the bankfull width of the channel, while the "hook" occupies the center 1/3. The design criteria requires rock being extended over two-thirds of the bankfull width. Given that, the river's mean width is a critical design flaw for application at the SR 224 Van Giesen project site. The Yakima River at the riffle section just upstream of the project site has a bankfull width of approximately 180 feet, implying that a properly-designed series of J-hook vanes would have to be each 120 feet long. This would require a huge amount of heavy, loose riprap and some underlying jetty stone. While J-hooks could potentially be a good alternative to prevent left bank erosion, they would need to be significantly enlarged relative to barb structures and would require much larger volumes of heavy loose riprap (see below).

Highway Relocation Without Other Treatment Alternatives: Currently the left bank of the Yakima River is too close to the eastbound shoulder of SR 224 to construct buried groins or an avulsion sill with excavation of the eastbound shoulder. Road relocation to the east or northeast would provide space to allow the channel to migrate. This could have the potential to provide some, albeit marginal quality, aquatic habitat. Road relocation alone (without other treatment) has several factors (other than cost) that make this option not conventionally feasible as a long-term solution at Van Giessen:

- Just moving SR 224 to the east would not abate the site based mechanism of failure (cross-current and helicoidal flow-induced shear stresses due to meandering) and would just delay the inevitable, but slow, channel migration to the east.
- A significant dislocation of SR 224 would involve significant and multiple real estate purchases that generally must be acquired from willing sellers in non-emergency conditions.
- Any major relocation of SR 224 to the east would likely have an adverse affect on driving safety, since it would involve converting a straight segment of highway into one with at least two significant curves.
- Allowing continued channel migration and downstream translation of the left bank would eventually displace the erosional energy to downstream private properties. The relocation of the road has been suggested as a measure that would allow channel migration floodplain inundation, and other floodplain functions to occur. Unfortunately other reach based conditions and constraints interfere with these benefits being realized.

  With the exception of the segment of the left bank adjacent to SR 224 the entire river reach has been constrained by flood control and bank stabilization structures. Upstream on the left bank, a large concrete bulkhead protects riverfront mansions. Downstream on the left bank a series of river barbs protects additional riverfront homes. The entire right bank is heavily controlled with rip rap and a flood control levee. The presence of such extensive control structures has a profound effect on geomorphic process the effects on these processes is discussed below.

- Meander translation. This process occurs as the channel planiform shifts downstream. As mentioned above, existing houses, flood control and bank stabilization structures prevent downstream movement of the channel. Meander translation forces the erosive power of the river mainly into the descending limb of the meander as it advances down the river gradient. This transfer of erosive energy results in considerable downstream stability and potential liability problems.
- Meander rotation. Under this process the meander rotates (in this case clockwise) around the radius of the meander curve. This forces the erosive power of the stream into the descending limb of the meander as with meander translation, however it also results in a downstream rotation of the meander apex. Again, this forces the river into adjacent private property. This scenario can have a more profound effect on downstream properties as the rotation of the meander apex increases the likelihood of flanking downstream structures.
- Meander extension this process results in lateral movement of the meander apex away from the existing channel center line, lengthening the meander. While this may slow down velocities, this process also expands the erosion zone both upstream and downstream as the meander lengthens. It is here where the relationship between the channel width and the potential meander wavelength becomes important. The Yakima River at this location is approximately 120 feet wide the channel segment length is 580 feet long. If the meander were to extend through this bank segment, over 40 percent of the segment length would be taken up by the cross sections of the rising and descending limbs of the meander channel. This leaves a remaining segment of only 340 feet to accomplish

the meander bend itself. The result would be a meander bend that is too sharp to be stable. The likely eventual outcome of this would be a neck cutoff avulsion at the base of the meander that would effectively shorten the overall reach significantly, thus increasing downstream velocities and erosive power.

- Floodplain inundation The flood control structures located in this reach and those upstream have resulted in baseline conditions that have decoupled the river from its floodplain. As with channel migration floodplain inundation functions are inherently reach based process and thus cannot be rectified on a simple site basis. WSDOT maintenance records indicate that the left bank floodplain is only inundated during the largest flood events. Moving the highway would not change this and the result is that little if any additional floodplain inundation would occur by merely moving the road.
- Channel migration and floodplain functions are inherently reach scale geomorphic processes. The presence of extensive flood control works throughout this reach precludes the normal mechanisms for channel migration. The unfortunate conclusion here is that because of the severe extent of flood control structures the perceived geomorphic and habitat benefits suggested by moving the road cannot be realized in this reach.

While the benefits of moving the highway would be marginal at best given the other reach constraints, the cost of moving the highway would be astronomical real estate oprices in the Richland area range from $295,000.00 to 521,00.00 per acre for land that includes buildings. Moving SR 224 would require purchase of several homes and farms along with hundreds of acres of land, Some of these properties are literally riverfront mansions. For example, the property that is immediately downstream and east of SR 224 is on a 10-acre parcel. This infers a cost of between 3.1 million and 54. million dollars to acquire. Given the high cost and low benefit derived form the effort, this option cannot be considered to be a viable alternative.

The conclusion from this analysis is that a major relocation of SR 224 would have significant engineering, permitting, fiscal, and legal implications that would likely delay project delivery for several years.

<u>Highway Setback Realignment With Buried Groins and Riparian Plantings</u>: This site-based treatment alternative involves a minor realignment of SR 224 to the east and northeast to facilitate the construction of buried groins in the newly-created margin between the realigned SR 224 pavement and the eroding cut bank. The realignment of SR 224 proposed in the alternative would move the highway 30 to 35 feet to the northeast, providing enough room to construct buried groins, establish a riparian buffer, and move the highway away from the active cut bank of the Yakima River. A minor realignment should not affect any existing neighboring buildings or structures, would minimize real estate purchases, and shouldn’t have a major effect on driving safety. In addition to the buried groins, the realignment would provide additional space for riparian plantings in the same margin created by the setback. Riparian plantings, when established, would provide root structure to the soil that would likely reduce the rate of bank erosion at the cut bank and would provide organic detritus and associated surface roughness to the eroding cut bank. With a bankfull width of approximately 300 feet, ISPG and HEC 20 recommends that the length of the buried groin not exceed 15 percent of the bankfull width, which yields a maximum length of 45 feet. With a launchable toe, buried groins that are constructed to be 30 feet long would end up with a maximum length of 36 to 40 feet, which would be an adequate size for the Van Giessen site. ISPG and HEC 20 recommend that the spacing between buried groins be be-

tween two and five times the groin length. With these criteria, the buried groins should be spaced 75 to 90 feet apart, resulting in seven buried groins throughout the project site.

It may be difficult to establish a riparian zone between the realigned SR 224 pavement and the left bank of the Yakima River due to the very arid climate. Mature trees do exist in several locations on the east side of SR 224. Very drought-tolerant arid zone tree and shrub species (http://www.aridzonetrees.com, http://plant-materials.nrcs.usda.gov/wapmc/releases.html) such as Acacia, Idaho Locust, Mackenzie's Willow, Desert Willow, Mock Orange, Canyon or Desert Hackberry, Black Cottonwood, Siberian Dogwood, Western Redbud, or Rocky Mountain Juniper should be considered to minimize drought-induced mortality and to ensure development of the riparian zone between SR 224 and the Yakima River. Consideration should be given to constructing a guardrail parallel to SR 224's eastbound lane to deal with roadside clear zone restrictions.

This alternative has distinct advantages and disadvantages. The main disadvantage is the fact that road realignment and relocation will likely require acquisition of segments of adjacent properties on the east side of SR 224, which can be a significant cost element, many times costing in the millions of dollars depending on local real estate values and demand. The advantages of this alternative, however, are several. By not placing any structures within the Yakima River itself, the project would not require several permits and would avoid significant mitigation actions. More significantly, placing the structures within the bank avoids impacts to the regulatory floodway, and base flood elevations and would allow additional active channel and proto-floodplain areas to be created between the groins as the bank is allowed to recede.

Since no fill would be needed inside the ordinary high water mark in this alternative, a COE Section 404 permit, the associated Section 401 Water Quality Certification, a Hydraulic Project Approval, Endangered Species consultations, or mitigation to comply with Benton County's zero rise floodplain ordinance would not be needed. With a combination of the setback realignment, riparian buffer establishment, and buried groins, significant channel migration and bank erosion toward the SR 224 pavement over the long term will likely be halted. As a whole, the setback alignment with buried groins and riparian buffer will likely abate the site-based mechanism of failure over a very long period of time. Figure 11 shows a schematic of the locations of the setback alignment, buried groin locations, and riparian buffer.

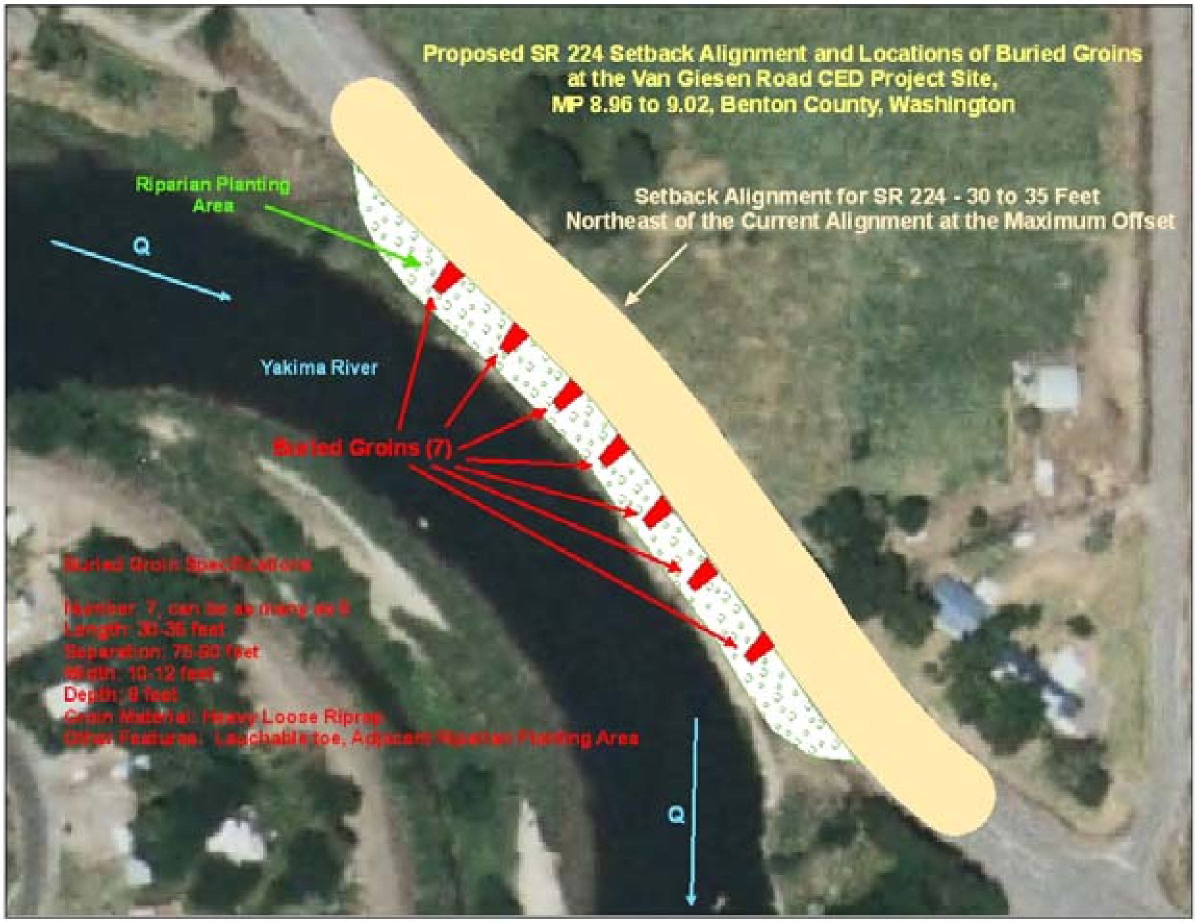


Figure 11. Proposed configuration for a setback alignment of SR 224 with buried groins and riparian plantings.

<u>Engineered Log Jams</u>: Engineered log jams (ELJs) are riverine flow deflection and diffusion structures that use natural materials to emulate natural processes that can protect roadways adjacent or parallel to river channels. Use of these structures in large channels to protect roads is a relatively new technology that is currently being developed in the Pacific Northwest west of the Cascades. ELJs typically use multiple agglomerations of large logs with multiple redundant anchoring systems in order to deflect flow energy away from critical structures and diffuse concentrated localized flowpaths. Engineered log jams are usually placed in series and in combinations. The placement of large logs in actively eroding locations creates significant engineering obstacles due to the buoyancy of the wood, their large surface-area-to-volume-ratios, long-term physical degradation of the wood, and high length-to-width geometries that tend to create torque and rotational forces that can compromise stability of the structure. Woody structures tend to be regarded as significant aquatic habitat features and are desirable for that reason alone. ELJ technology is largely in the development stage and long-term stability is largely unknown. ELJ's can be negatively affected by extreme flows, large fluctuation in water surface elevations, and ice flows, all of which occur at this site. In addition one of the chief reasons for using ELJ's is for the important geomorphic functions they provide in facilitating channel migration, and side channel formation. Because this reach is impinged by a large levee system and the highway,

these functions are precluded by baseline conditions. Because of these factors, ELJs were not selected as the preferred alternative for this site. In lieu of ELJs, a alternative recommendation (below) would be to incorporate rock/wood composite deflection diffusion structures that use large woody members into proven engineering structures (barbs) in areas (hydraulic shadows) where rotational forces would be minimal and rock overburden would be available to defeat buoyancy. In addition, this type of structure also provides channel roughness, complexity, cover, and edge habitat functions due to their LWD components. These are all habitat benefits that are sorely lacking in the project reach, and structures of this type would be beneficial from both a habitat and infrastructure standpoint.

<u>Rock barbs with large woody members with root wads incorporated into a expanded mantle/bed key</u>: Rock barbs are sloping, partially submerged rock structures, connected and keyed into the river bank, that act as individual weirs with the ability to translate the thalweg and its associated shear stresses away from the eroding cut bank (see Figure 10). When properly designed and constructed, barbs can be powerful hydraulic structures that can predictably induce localized areas of both sediment scour and deposition. Several criteria need to be met to facilitate construction of a series of barbs to deflect and diffuse Yakima River flows at Van Giesen Road:

1. Extent: All barbs need to be constructed within the current SR 224 right-of-way.
2. The barbs should not extend across more than one-quarter of the bankfull channel width. With a mean bankfull width estimated at 180 feet at the project site using aerial photos, the barbs should extend between 40 and 45 feet from the left bank of the Yakima River.
3. The spacing of the barbs should be less than four times their length and should be determined using a vector analysis. A preliminary vector analysis of the Van Giesen site indicates that a barb spacing no greater than 150 feet should be used.
4. The angle of the barbs relative to the left bank should be determined using a vector analysis, assuming that flows will be directed mostly perpendicular to the barb orientation. A preliminary analysis shows that these angles should be between 55 and 70 degrees, depending on the localized radius of curvature.

While barbs are probably the most historically proven flow redirection and diffusion structures for river restoration, several regulatory and mitigation factors limits its feasibility. Since barb construction would require placing fill into a navigable river, a Corps of Engineers Section 404 permit would be needed and mitigation would be required. The 404 permit would then trigger the requirement of obtaining a Section 401 Water Quality Certification from the Department of Ecology. Performing work within the ordinary high water mark of the Yakima River would require the acquisition of a Hydraulic Project Approval from the state Dept. of Fish and Wildlife, which may facilitate additional mitigation. Finally, and most significant to the project, Benton County's floodplain ordinance requires "zero rise", which has the effect of requiring removal of fill or structures within the floodway to compensate for the volume of fill used to construct the barbs. This is a significant mitigation requirement that would be difficult to comply with since WSDOT owns very little land along the Yakima to remove fill or structures. All of these factors would result in protracted permit negotiations, related time delays, and expanded project costs due to said time delays and additional mitigation requirements.

Figure 12. Proposed River Barb Configurations.

Reach-Based Alternatives Considered

As discussed above, the reach-based mechanism for failure is largely due to the presence of a large certified COE levee flanking the right bank of the Yakima at the project site and its adjacent up and downstream reaches. This levee protects many properties from flood damage and is routinely maintained to pass the 1933 flood levels with a three-foot freeboard. With the right bank being essentially "anchored," channel migration can only proceed toward the east and SR 224. Removing this levee or other reach-based alternatives to allow the river to return to its historic floodplain are not practical options.

Preferred Alternative

The preferred alternative is to set the highway realignment back, with buried groins and riparian plantings. The left bank of the Yakima upstream of the bridge is eroding rapidly and the bank erosion is threatening the continuing operations of SR 224. The best long-term option to abate the migration of the Yakima River into the eastbound lanes of SR 224 would be use a setback alignment of SR 224 to create space for construction of buried groins and riparian plantings. Permit and mitigation requirements would be minimal (clearing and grading permits from the county are most likely) to nonexistent. While property acquisitions could be expensive, the set-back alignment with buried groins would be a long-term solution to the site-based mechanism of failure and would most effective meet the goals of the CED program and the project objectives. River barbs, while being very proven and powerful hydraulic structures to move the thalweg from the active cut bank, would have daunting and expensive permitting and mitigation requirements due to fill and construction activities within the river.

Conclusions

The bank must be protected in order to prevent portions of the SR 224 roadbed from being undermined and swept into the Yakima, with operations of SR 224 being impaired. While a series of rock barbs will likely abate the problem for the next 10 to 20 years, SR 224 may eventually need to be relocated to the east. The channel of the lower Yakima will continue to migrate eastward toward the highway throughout the years/decades. Relocation would require substantial funding and significant purchases of private property in the vicinity.

References

Alt and Hyndman. 1984. Roadside Geology of Washington. Mountain Press,. Missoula, Montana.

Federal Highways Administration. 2001. Hydraulic Engineering Circular No. 20, Stream Stability at Highway Structures, 3rd ed.

Federal Highways Administration. 2001. River Engineering for Highway Encroachments. Hydraulic Design Series Number 6. Publication No. FHWA NHI 01-004.

Independent Scientific Group. 1996. Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem.

Knowles, S.M. and Sumioka, S.S.. 2001, The National Flood-Frequency Program—Methods for Estimating Flood Magnitude and Frequency in Washington, 2001. U.S. Geological Survey Fact Sheet FS-016-01, 4 p.

Natural Resources Conservation Service. 2005. Engineering Technical Note No. 23, Version 2.0, Design of Stream Barbs. Portland, Oregon.

Natural Resources Conservation Service. 2001. Engineering Technical Note – No. 12, Design of Stream Barbs. Boise, Idaho.

Orr and Orr. Geology of the Pacific Northwest. 2002. Waveland Press, Long Grove, Illinois.

Rosgen, D.L., 2006. Cross-Vane, W-Weir, and J-Hook Vane Structures. Wildland Hydrology, Inc.

Sumioka, S.S., D.L. Kresch, and K.D. Kasnick, 1998. Magnitude and Frequency of Floods in Washington. USGS Water Resources Investigation Report 97-4277. Tacoma, Washington.

U.S. Geologic Survey. Real-Time Data for Washington Stream Flow. Gage No. 2510500 - Yakima River at Kiona, WA

U.S. Geologic Survey. StreamStats. http://water.usgs.gov/osw/streamstats

Washington State Department of Ecology. 2006. 2004 Statewide Water Quality Assessment 303(d) Report. http://www.ecy.wa.gov/programs/wq/303d/2002/2002-index.html

Washington State Department of Ecology. On-Line Well Log Database, http://apps.ecy.wa.gov/welllog/

Washington State Conservation Commission. 2001. Salmon and Steelhead Habitat Limiting Factors in WRIAs 37 - 39. Washington State Conservation Commission, Lacey, WA.

Washington State Department of Fish and Wildlife. 2003. Integrated Streambank Protection Guidelines. Aquatic Habitat Guidelines Program.

Washington State Department of Fish and Wildlife. 2004. Stream Habitat Restoration Guidelines. Washington State Aquatic Habitat Guidelines Program.

Washington State Department of Transportation, 2002. Preliminary Draft Biological Assessment – SR 224, Van Giesen Road Bank Stabilization.

Washington State Department of Transportation, 2007. Design Manual.

Washington State Department of Transportation, 2004. Hydraulics Manual.

Washington State Department of Transportation, 2006. State Highway Log.

Washington State Department of Transportation. 2007. Standard Specifications for Road, Bridge, and Municipal Construction, English Units.

Washington State Department of Transportation. Bridge Engineering Information System (BEIST).

Washington State Department of Transportation. WSDOT Photogrammetry Lab. Geo-rectified Aerial Photos of SR 224 at Van Giesen Road, Benton County Washington: 1991 and 2004.