



Basis of Design – Martis Wildlife Area Restoration Project

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Prepared for:



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DRAWING SET

Final Design Drawing Set – 100% Martis Wildlife Area Restoration Project

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1. PROJECT BACKGROUND

The Martis Wildlife Area Restoration Project is located near Truckee, CA, in the Sierra Nevada Mountains, just north of Lake Tahoe on Martis Creek. There are three separate project site locations within the drainage area on separate smaller tributaries; 1) the Culvert Replacement Site, 2) the Middle Martis Headcut Site, and 3) the Lookout Mountain Tributary Incision Site. The Truckee River Watershed Council has identified these three locations as candidates for creek and habitat restoration, as shown in Figure 1.

The project sites are directly upstream from an earthen dam on Martis Creek that is owned and operated by the U.S. Army Corps of Engineers (USACE). The dam was constructed in 1972 and can hold a capacity greater than 20,000 acre-feet. The reservoir originally covered 770 acres; however normal operations keep the pool at approximately 70 acres (USACE). Both the culvert replacement and headcut sites are within the maximum gross pool elevation of the Martis Reservoir, however, the reservoir water surface has never been raised to an elevation that would inundate the sites. Downstream of the dam, Martis Creek flows into the Truckee River. These three projects will be constructed concurrently with the Mainstem Martis Creek Restoration project, also under design and direction through the Truckee River Watershed Council.

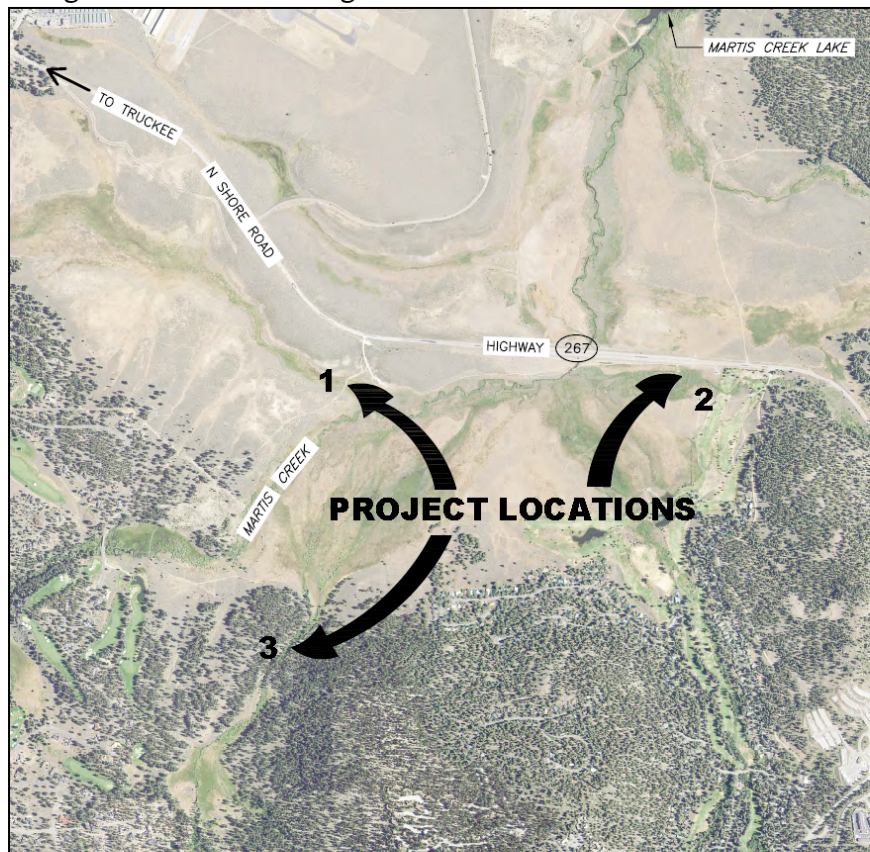


Figure 1. Martis Wildlife Area Restoration Project Area

There is an endangered species present in the Martis Basin, the Lahontan Cutthroat Trout, in addition to other fish species including Rainbow and Brown Trout. An unidentified species of fish was recently observed at the Lookout Mountain Tributary site and is known to be present throughout the reach. Measures to avoid impacts to the all fish species are included in the designs throughout the basin.

There is a long record of human presence in the Martis Valley area. All three sites are impacted by human land uses, mainly due to recreational trails for hiking, biking and dog walking. Direct impacts include channelization, increased incision and stream down cutting, and reduced floodplain cross-sectional area associated creek crossings. These impacts have lowered groundwater levels which has led to a loss of the natural water storage and floodplain connectivity which in turn has degraded aquatic and riparian habitat throughout the project area.

2. GEOMORPHIC CONDITION

All of the project sites are located in Quaternary alluvium and alluvial fan deposits underlying the Martis Valley (Saucedo, 2005). Historic disturbances in the valley include agriculture and grazing, road construction and adjacent development, resulting in channel incision and conversion of historically wet meadows to uplands (Balance Hydrologics, Valley Mountain Consulting 2012). The project sites are located on the lower portion of tributaries to Maris Creek, where the channel planform is meandering; exhibiting pool-riffle morphology. The Culvert Replacement and Middle Martis Headcut Sites are both located in the wet meadows that have formed over time on the distal portion of alluvial fans emanating from the high peaks to the south. The Lookout Mountain Site is located further up the alluvial fan where soils are less developed and the gradient is higher (2%).

The Culvert Replacement Site is located on an un-named tributary, approximately 0.16-mi upstream of the confluence with Martis Creek. The sinuous, single thread channel has experienced historic incision, as evident from the encroachment of sagebrush into the wetted meadow adjacent to the creek. Relic oxbow channel features are 0.5 – 1-ft higher than the current channel thalweg, further indicating the channel has incised into the floodplain. Alterations to the flow regime due to upstream development, and migration of headcuts originating from the main stem channel, have likely contributed to the current degraded condition. The raised road prism currently traverses the entire floodplain, creating a significant obstruction to flow. The 2 culverts installed to convey flows have failed and the road adjacent is eroding. The road and culverts have limited channel migration processes, impacted the transport of sediment and water through the site, and may have contributed to the propagation of headcuts by accelerating flow at the downstream end of the culverts. Restoration of the site should focus on eliminating the impediments to natural processes and delivery of water and sediment downstream resulting from the road and failed culverts.

The Middle Martis Headcut Site is located just upstream of Gumba's Crossing on the Tompkins Memorial Trail, approximately 0.4-mi upstream of the confluence with Martis Creek. Currently, there is a multi-thread shallow channel upstream of the headcut connected to the broader vegetated surface of the alluvial fan. Downstream of the headcut, the creek is constrained to a deep single thread disconnected from the vegetated fan surface. Surveys showed that there are numerous relic distributary channels on the fan surface that are now disconnected from the stream. Downstream of the headcut and foot-bridge at Gumba's Crossing, the channel has been straightened historically, potentially leading to the formation of the headcut as the slope of the once meandering channel was dramatically increased (Simon and Rinaldi 2006). Recent diversion of most of Middle Martis channel's flow to the north side of highway 267 has reduced the flows that will come down this reach in turn reducing the channel's sediment transport capacity. The recent diversion, constructed in 2016, passes the majority of discharge directly into the reservoir, avoiding Middle Martis Creek completely (Balance Hydrologics).

The Lookout Mountain Site is located approximately 1.2-mi upstream of the confluence with Martis Creek, upstream of the wet meadow alluvial fans in a confined valley (Saucedo, 2005). The floor of the valley does support wet meadow; however, the soils are less mature and the gradient is greater. The sinuous, single thread channel has experienced historic incision through meander cut-offs and propagation of headcuts

originating downstream through the reach. The primary reach of concern is upstream of Jake's Bridge, where the adjacent floodplain has experienced drying and encroachment of upland vegetation due to incision. The channel is currently undermining adjacent banks, delivering significant amounts of sediment to the channel in an attempt to form an inset floodplain. The lack of instream wood upstream of the bridge, critical to storing sediment in the channel and re-building the thalweg back to pre-incision levels, has delayed the formation of these inset floodplains, as flood flows are sufficient to mobilize the failed bank material (Abbe and Montgomery 1996, Simon and Rinaldi 2006). Downstream of the dam, there are beaver dams and abundant instream wood, and the channel is more connected to the adjacent floodplain. Restoration within the project reach should focus on wood loading upstream of the bridge to partition flood flows, leading to the deposition and retention of sediment in the channel to re-connect the floodplain over time.

3. BASIN CHARACTERISTICS & HYDROLOGY

Basin Characteristics

The full drainage area of Martis Creek is 42.7 square miles. All three project sites are located on smaller tributaries and have much smaller contributing basin areas. The Culvert Replacement site is the largest at 1.6 square miles. The basin area draining to the Middle Martis Headcut site was recently reduced due to a drainage re-routing project that prohibited large flows from crossing Highway 267 and instead routes discharge along the northern side of the highway directly into the Martis Creek Reservoir. This project redirected discharge from 4.5 square miles of the 4.9 square mile basin. A small pipe under the freeway allows for minimal flows into Middle Martis Creek. The Lookout Mountain site has a contributing basin area of 1.2 square miles.

Hydrology

Annual precipitation ranges for the areas are primarily in the low to mid-30-inch range, from 31 inches to 35 inches. The predicted flood events shown in Figure 3 are from the United States Geological Survey (USGS) StreamsStats website and are based on the regional flood-frequency equations for rural ungaged streams in California for Lahontan Region 2 (USGS & USDI). StreamStats calculates floods based on drainage area and precipitation for Lahontan Region 2. For the Culvert Replacement and Lookout Mountain Tributary sites, this is expected to be accurate, however the Middle Martis Headcut site required additional analysis. Because of the construction of the diversion project, a large portion of the basin runoff directly into the reservoir and away from the headcut site. The new drainage area for the Middle Martis site was estimated at approximately 0.4 square miles. Based on the smaller drainage area, the regional flood-frequency equations estimated floods at the Middle Martis site to be 13 cfs, 36 cfs, 70 cfs, and 88 cfs for the Q-2, Q-10, Q50, and Q100 respectively. During the 2-year flood, it is estimated that 1 cubic foot per second (cfs) is contributed from this side of Highway 267; during the 100-year flood, it is estimated that 5 cfs flow into Middle Martis Creek. The interim flows for the 10-year and 50-year were estimated at an additional 2 cfs and 4 cfs respectively. The additional contributions through the pipe are added to each of the estimates from the regional flood-frequency equations.

A full summary of the 2-year through 100-year peak discharges is presented in Figure 3. The higher precipitation in the Lookout Mountain and Middle Martis sites (35 inches) compared to the Culvert Replacement site (31 inches), are a result of the higher elevations of their headwaters.

Percent annual exceedance probability	Hydrologic region (shown in pl. 1)		
	North Coast (Region 1)	Lahontan (Region 2)	Sierra Nevada (Region 3)
50	$1.82(DRNAREA)^{0.904}(PRECIP)^{0.983}$	$0.0865(DRNAREA)^{0.736}(PRECIP)^{1.59}$	$2.43(DRNAREA)^{0.924}(ELEV)^{-0.646}(PRECIP)^{2.06}$
20	$8.11(DRNAREA)^{0.887}(PRECIP)^{0.772}$	$0.182(DRNAREA)^{0.733}(PRECIP)^{1.58}$	$11.6(DRNAREA)^{0.907}(ELEV)^{-0.566}(PRECIP)^{1.70}$
10	$14.8(DRNAREA)^{0.880}(PRECIP)^{0.696}$	$0.260(DRNAREA)^{0.734}(PRECIP)^{1.59}$	$17.2(DRNAREA)^{0.896}(ELEV)^{-0.486}(PRECIP)^{1.54}$
4	$26.0(DRNAREA)^{0.874}(PRECIP)^{0.628}$	$0.394(DRNAREA)^{0.733}(PRECIP)^{1.58}$	$20.7(DRNAREA)^{0.885}(ELEV)^{-0.386}(PRECIP)^{1.39}$
2	$36.3(DRNAREA)^{0.870}(PRECIP)^{0.589}$	$0.532(DRNAREA)^{0.733}(PRECIP)^{1.58}$	$21.1(DRNAREA)^{0.879}(ELEV)^{-0.316}(PRECIP)^{1.31}$
1	$48.5(DRNAREA)^{0.866}(PRECIP)^{0.556}$	$0.713(DRNAREA)^{0.731}(PRECIP)^{1.56}$	$20.6(DRNAREA)^{0.874}(ELEV)^{-0.250}(PRECIP)^{1.24}$
0.5	$61.0(DRNAREA)^{0.863}(PRECIP)^{0.531}$	$0.944(DRNAREA)^{0.729}(PRECIP)^{1.55}$	$19.4(DRNAREA)^{0.870}(ELEV)^{-0.188}(PRECIP)^{1.18}$
0.2	$79.3(DRNAREA)^{0.860}(PRECIP)^{0.503}$	$1.35(DRNAREA)^{0.727}(PRECIP)^{1.52}$	$17.4(DRNAREA)^{0.865}(ELEV)^{-0.110}(PRECIP)^{1.11}$

Note: DRNAREA, drainage area, in mi²; PRECIP, mean annual precipitation, in inches; ELEV, mean basin elevation, in feet.

Figure 2. Regional Flood-Frequency Equations for Rural Ungaged Streams in California (USGS & USDI)

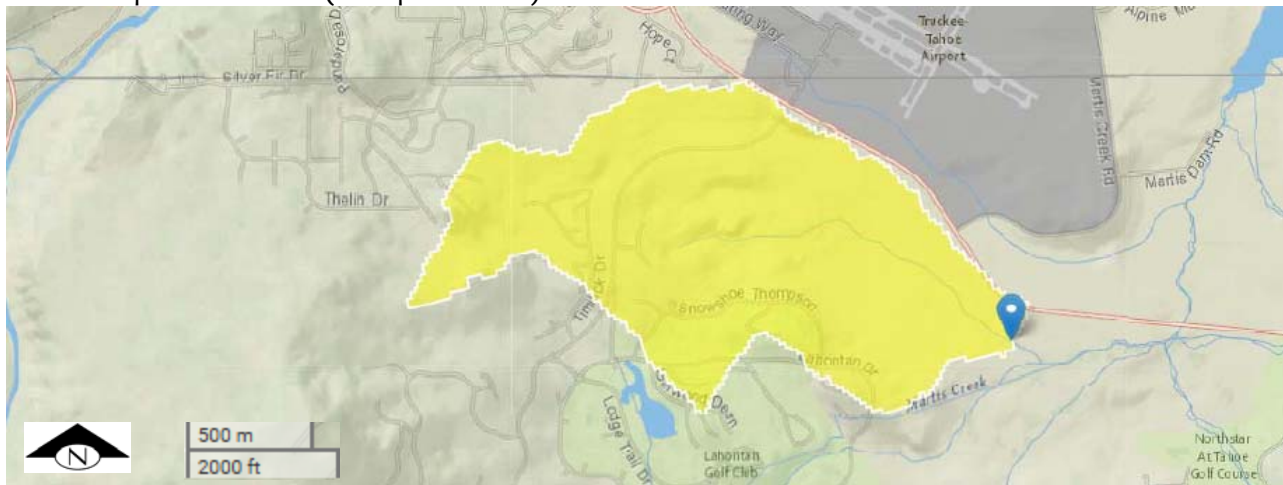
HYDROLOGIC ANALYSIS SUMMARY TABLE						
Site	Basin Area (square miles)	Precipitation (Inches)	Q-2 Discharge (CFS)	Q-10 Discharge (CFS)	Q-50 Discharge (CFS)	Q-100 Discharge (CFS)
Culvert Replacement Site	1.6	31	30	85	169	221
Lookout Mountain Tributary Site	1.2	35	28	84	167	208
Middle Martis Headcut Site – Regression-based	0.4	35	13	36	70	88
Middle Martis Headcut Site – Project Area*	0.4	35	14	38	74	93

* Includes additional discharge through pipe under Hwy 267. The map in Figure 4 shows the full drainage basin, including areas now routed directly into the Martis Reservoir. Note precipitation estimate is for the full catchment that no longer entirely drains to the site.

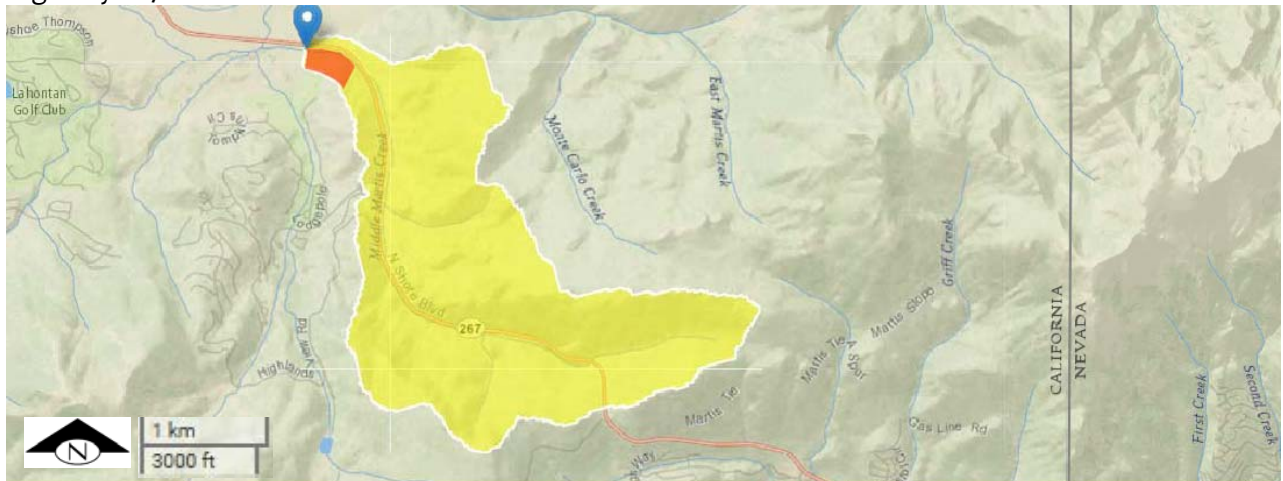
Figure 3. Hydrologic Characteristics Summary Table

The basin areas upstream of each of the project sites are depicted in the following maps (from USGS StreamStats).

Culvert Replacement Site (1.6 square miles).



Middle Martis Creek Site (0.4 square miles). Note the original drainage was 4.9 square miles. Only areas highlighted in orange drain to project site after a 2016 project was completed to divert flow to north side of Highway 267.



Lookout Mountain Tributary Site (1.2 square miles):



Figure 4. Project Site Drainage Basin Areas

4. RESTORATION GOALS AND DESIGN

The restoration goals and design components for the Martis Wildlife Area Restoration project sites include the following:

- Restore floodplain connectivity throughout project reaches,
- Reactivate former floodplain surfaces and side channels that have been vertically isolated through incision,
- Provide diverse instream habitat,
- Slow instream velocities to reduce bed scour and incision,
- Collect and store incoming sediment to prevent future bed degradation and trigger aggradation to raise the channel bed,
- Enhance lateral connectivity and water storage in the adjacent soil prism to increase flows during low flow conditions and support expansion of the wetland and riparian corridors,
- Provide stable large wood accumulations where the existing beavers can build larger, stable dams, further increasing instream and lateral water storage for fish rearing areas and recovery of the riparian community.

The restoration designs are fully shown along with the associated specifications in the attached Final Design Drawing Set. The main components are summarized in the following sections.

Site Access and Staging

Access to the Culvert Replacement and Headcut sites is provided from Highway 267 and both sites are relatively easy to access. Construction access to the Culvert Replacement site will require a closure of the Tompkins Memorial Trail system at the project site. Construction access to the Headcut site will not impact the trail system as greatly; minimal impacts require the presence of safety measures for passage through the site during construction. The installation of meadow protection mats to reduce impacts to the floodplain wetland in sensitive areas will be required at the Middle Martis site. Construction vehicles will not be allowed to utilize the pedestrian bridge at the Middle Martis site and the trail will remain open throughout construction with a safety management in place. The Lookout Mountain site will be accessed from Basque Road, to the east of the project site. There is an existing trail that will require some preparation for construction vehicles. The access trail will also require restoration following construction and disturbed areas will be replanted with the Upland Seed mix. Within the floodplain wetland at the Lookout Mountain site, meadow protection mats will also be required, and restorative measures for wetland replanting will be required. All construction access roads will have a quarry spall construction access entrance installed to reduce impacts and sediment transport to the existing roads and infrastructure.

Staging at the Culvert Replacement site will be from the lower parking lot and trailhead for the Tompkins Memorial Trail, just south of Highway 267. This parking lot will not be available for public use during construction, however, there is an upper lot that will stay open. Safety measures for public access through or around the staging area and into the trail system from this trailhead will be managed and provided by the contractor. Public access over the existing culverts on the Tompkins Memorial Trail will not be maintained during construction and this portion of the trail will be marked and closed to the public.

Staging at the Middle Martis Headcut site will also be south of Highway 267, on a portion of higher ground, outside of the wetland, east of the project site. There is a drainage ditch running parallel to Highway 267 that requires a 50-foot clearance.

There are two staging areas identified at the Lookout Mountain site; one along the access road and the other down at the project site on the east bank. The staging areas will require restoration to previous existing conditions, replanting with either; the upland or wetland replanting seed mix.

Stream Bypass and Fish Removal

A stream bypass will be required at all three of the project sites for the duration of construction. The stream bypass is composed of a fish screen and gravel bag coffer dams at both the upstream and downstream ends of the project extents. The bypass pipe can be gravity run or with a pump system, at the discretion of the contractor. Dry working conditions must be provided. Fish removal procedures must meet requirements as stated in the permit documents and shall be performed prior to construction. Maintenance of the fish screen and bypass pumping will be maintained throughout construction to ensure no fish kills occur. Upon construction completion, the full stream bypass will be removed and any disturbance areas will be restored.

Unnamed Tributary Culvert Replacement Site

Unnamed Tributary Culvert Replacement Alternatives Analysis

An alternatives analysis was performed for the Culvert Replacement Site to evaluate all appropriate options available for the culvert replacement. Three alternatives were analyzed with the design goal of passing the 500-year flood of 363 cfs. The average channel slope at the site ranges from 0.5% to 1.5% and channel width ranges from approximately 2 to 5 feet. Both culverts under the Tompkins Memorial Trail require replacement due to failure and an inadequate hydraulic capacity during flood events. All cross sections in Figures 5 through 7 are facing downstream.

Culvert Replacement Alternative 1 – Large Culverts (2)

The first restoration alternative was to replace the two existing 24-inch culverts with two larger culverts that could pass the 500-year flood. Based on the site hydrology, topography, and hydraulics, two 77-inch by 52-inch pipe-arch culverts were determined to be the minimum size required, if only two culverts were to be installed. The two culverts would have a combined capacity greater than 375 cfs. A cross section of the proposed alternative is shown below. The road fill is the larger aggregate hatch over the culverts. The maximum allowable approach slope is 10% grade.

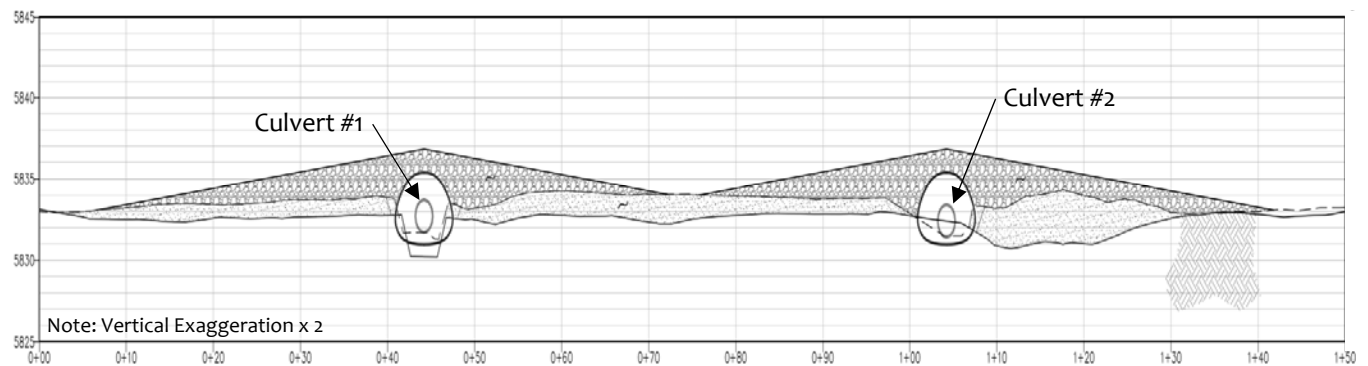


Figure 5. Culvert Replacement Alternative 1 – Large Culverts (2)

In order to provide adequate cover to the culverts, a minimum of 18 inches of roadway fill cover would be necessary to ensure that truck loading would not compromise the structural integrity of the culverts. This required a large amount of fill laterally adjacent to the two existing channels; abutment fill that would negatively impact adjacent floodplain habitat. This alternative would require the greatest amount of net fill in the wetland and would have the largest impact to the wetlands.

Culvert Replacement Alternative 2 – Small Culverts (15)

The second alternative to be analyzed was to replace the existing culverts with multiple 35-inch by 24-inch pipe-arch culverts. With a maximum of 25 cfs each, a total of fifteen culverts were required to pass the 500-year flood. The 35-inch by 24-inch pipe-arch culverts only require a 12-inch roadway fill cover, thereby reducing the required fill in comparison with the Large Culvert alternative. Seven of the culverts would be installed parallel to the existing alignment of Culvert #1 and the remaining eight culverts would be installed parallel to Culvert #2, as shown in Figure 6.

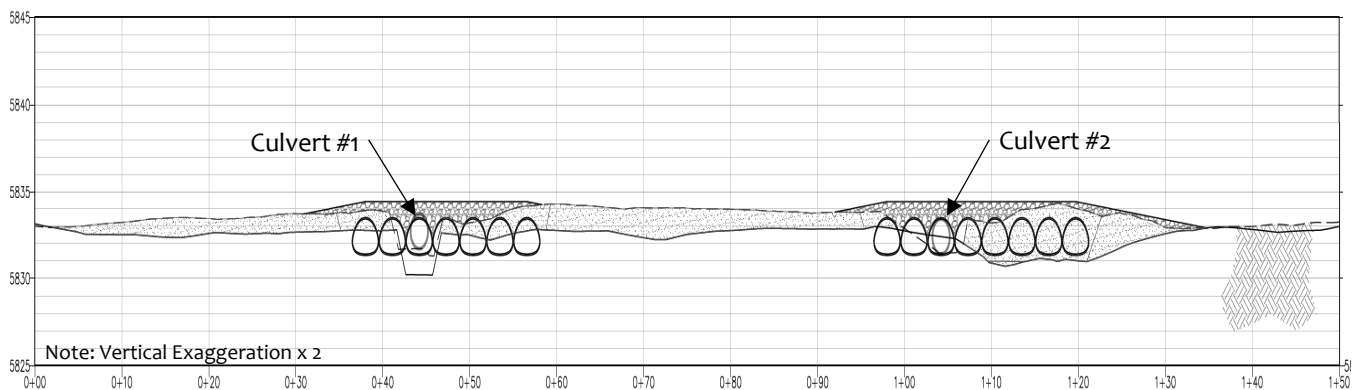


Figure 6. Culvert Replacement Alternative 2 – Small Culverts (15)

Together, these fifteen culverts would provide enough capacity and hydraulic connectivity to preserve the road integrity during flood events and allow for improved resilience in the event of channel migration. However, debris passage, especially during larger events when larger material is mobilized would be problematic and plugging is more of a risk. This alternative reduces amount of fill required for the road profile in comparison with the Large Culvert alternative, however, there is a large project footprint and overall disturbance to wetland areas.

Culvert Replacement Alternative 3 – Full Span Bridge

The third alternative for the Culvert Replacement site was the full-spanning bridge replacement option. This option is the preferred alternative that has been progressed into final design. Figure 7 below (along with the Final Design Drawing Set) shows the cross section of the proposed railcar bridge.

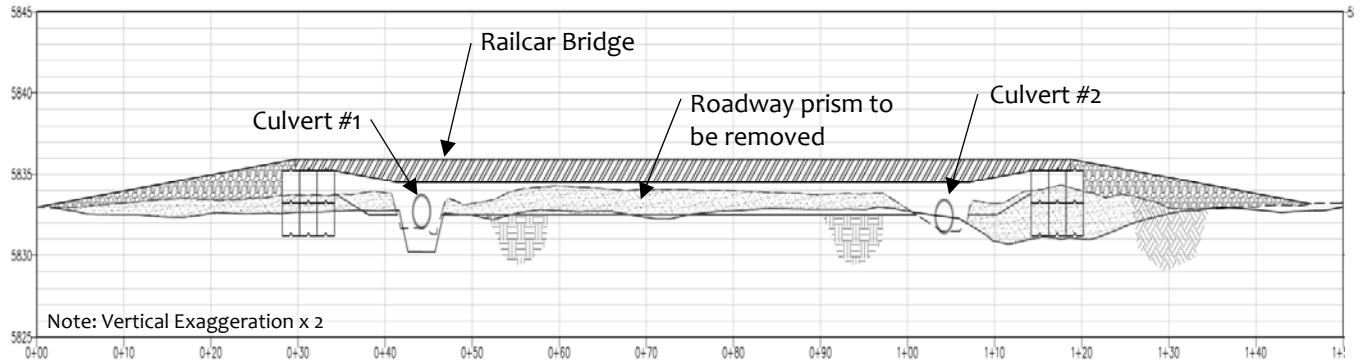


Figure 7. Culvert Replacement Alternative 3 – Full Span Bridge

The full-span bridge allows for an 80-ft clear span that will provide the greatest amount of floodplain connectivity while restoring natural processes and allowing for channel migration, passage of large woody debris and sediment. The span will pass the 500-year flood without endangering the abutments or road.

There will be a large amount of excavation as part of the bridge installation. The majority of this will be the road prism removal. There will also be minimal fill within the wetland due to the construction of the abutments. Additional specifics of the full-span bridge design are described in the following sections.

The Alternatives Analysis Matrix in Figure 8 provides a comparison of all three alternatives, outlining their individual restoration opportunities, risks and associated costs. The excavation and fill quantities are also provided. Though the full-span bridge has the highest material cost, it was agreed upon by the project team that this alternative would provide the maximum restoration opportunity, while minimizing risk, and would be the best long-term solution to the crossing of the Tompkins Memorial Trail of the Unnamed Tributary.

Martis Valley Unnamed Tributary Culvert Replacement Alternatives Analysis											
Description	Quantities	Rough Material Cost	Restoration Opportunity: Improve floodplain connectivity and conveyance	Risk	Permitting challenges	Disturbances	Excavation (CY)	Gravel Base and Abutment Material ⁵ (CY)	Culvert Volume (CY)	Road Prism Volume ⁴ (CY)	Asphalt Wetland Impact Area Outside Existing Road (SF)
Large Culverts: Replace existing culverts¹	(2) 77x52" Pipe Arch Culverts, 35-ft length each	\$21,000	Provides conveyance of flows and some sediment, lacks natural process restoration (channel migration, side channels, LWD transport, sediment transport)	Potential for culvert plugging with sediment and/or wood during a large event, obstructing flow and overtopping conditions on the road. Somewhat less risk than under current conditions as culvert size would be larger.	Increasing the size of the culverts requires the most amount of earthwork in the wetland area, including a net of 60 CY of fill. There is still no connectivity through the maintenance road with the exception of the two culverts.	Excavation removing existing culverts and installing 2 new culverts (approx. 20 CY), road fill over new culverts (approx. 86 CY); install sub grade > D100 to prevent incision through culvert	20	86	57	122	1,530
Small Culverts: Replace existing culverts with series of culverts¹	(15) 35"x24" Pipe Arch Culverts, 25-ft length each	\$26,000	Provides conveyance of flows and sediment, potential for main stem channel migration and/or side channel development through multiple openings, improved sediment conveyance over range of grain sizes, lacking LWD transport	Low potential for culvert plugging with sediment and/or wood during a large event due to multiple culverts. Significantly less risk than under current conditions.	Installing additional similarly sized culverts (a total of 15) allows for a minimal raise of the existing maintenance access road and requires the least amount of fill. Overall, there is a net excavation of 18 CY in the floodplain. Major channel movement cannot be accommodated by this option.	Excavation removing existing culverts and installing 15 new culverts (approx. 72 CY), road fill over new culverts (approx. 48 CY); install sub grade > D100 to prevent incision through culvert	72	48	63	38	1,020
Full span bridge² 24 Ecology Blocks	(1) 89' Bridge ³	\$54,000	Provides conveyance of flows and all sediment, maximum restoration of natural processes including channel migration, side channel development, natural LWD transport	Restoration of natural flows, sediment and wood transport. Impacts downstream may pass as a result of the passage of flood flows, sediment, and wood.	There will be a large amount of initial disturbance removing the existing road prism. This is a long term benefit, allowing for reconnection of a large amount of the floodplain. There is still some fill associated with the approach design for the bridge.	Removal of existing road grade and culverts (approx. 88 CY), excavate new channel and final grade floodplain surface (approx. 47 CY fill for abutments), planting; install sub grade > D100 to prevent incision through new channel.	88	47	-	-41	-170
Existing Roadway										100	0

¹ Excavation is primarily into the wetland
² Excavation is primarily of the existing roadway prism
³ Fill to rebuild road prism and abutments. Includes ecology blocks for the bridge option
⁴ The Road Prism Volume Calculation: [Gravel Base and Abutment Material - Excavation + Culvert Volume]. The existing roadway prism within the project extents is included for reference.

Figure 8. Culvert Replacement Alternative Analysis Matrix

Unnamed Tributary Culvert Replacement Preferred Design

The design for restoration at the Culvert Replacement site includes the removal of two failed culverts and approximately 75 feet of road prism fill. An 89-foot railcar bridge was selected as the preferred alternative at the Culvert Replacement site and will be installed with a clear span of 80 feet. This provides a larger cross-sectional channel area and allows for conveyance of the 100-year flood and the 500-year flood under the bridge. Currently, the existing condition of the culvert does not provide adequate conveyance during the 100-year flood and the road is over-topped. The northern channel requires minimal excavation for approximately 100 feet downstream of the culvert in order to reconnect with the upstream elevations. The southern channel does not require any additional excavation or grading.

The bridge will be placed on ecology-block abutments that require a minimal amount of fill to raise the road profile. The bridge will be bolted to the abutments and secured to mitigate any shifting due to potential settlement. Because the soils at the site are mainly clays and silts, some settlement of the bridge may occur over time and maintenance to re-level the bridge may be necessary.

The disturbance area is mainly due to the road prism removal, and any disturbed floodplain areas will be re-seeded with a wetland seed mix. The Culvert Replacement site restores the Unnamed Tributary by reconnecting the two channels upstream and downstream of the access road/Tompkins Memorial Trail crossing and allows for greater hydraulic conveyance and increased available areas for future channel migration under the bridge.

Middle Martis Headcut Site

The Middle Martis Headcut site is a 4-foot headcut just upstream of a pedestrian bridge crossing on Middle Martis Creek. The drop of the headcut significantly restricts the floodplain connectivity with the Middle Martis Creek in this location, lowering the groundwater level and reducing the amount of true wetland plant species and increasing the prevalence of plant species associated with dryer areas throughout the basin. The corrective measures to restore this site include regrading the local area of the headcut to a 4:1 maximum slope and reinforcing the channel and drop location with rootwads and racking bundles. The rootwads and bundles will be mostly buried and will help mitigate the risk of further incision and the potential of the headcut to re-develop by holding the channel grade. Additionally, seven bio-engineered check dams (type 2) will be installed at approximately 50-foot increments downstream of the headcut. The check dams will be built from two racking bundles that will be channel spanning, and installed perpendicular to flow. The bundles will be mostly buried in the channel and will only block the lower 3-6 inches of the channel. They will be secured with log posts embedded in the banks and will work to hold sediment and slow water velocities to help reduce the risk of additional incision.

Upon completion of the restorative measures at the headcut and downstream reach, the disturbed areas will be planted with the wetland seed mix. The Middle Martis Headcut site actions aim to address the immediate headcut problem, reconnect the floodplain with the channel, and decrease the risk of further headcuts developing in the reach by promoting bed aggradation and stability with the bioengineered check dams.

Lookout Mountain Tributary Site

The Lookout Mountain Tributary site is a 260-foot reach of the tributary in the vicinity of Jake's Bridge. The reach has become significantly incised and disconnected from the adjacent side channels and wetland areas. There is a large amount of downed wood and trees that can be used to construct incision treatment

structures in the creek to help raise the channel bed and water surface elevation. The incision structures will be primarily installed with hand crews and will block the channel area and work to slow water velocities. Over time, this will promote bed aggradation and a reversion back to the historical channel cross-section and greater connectivity to the adjacent floodplain.

The incision treatment structures will be constructed with multiple larger key logs/rootwads that will be embedded in the bank and channel. Smaller logs, branches, and slash will be bound into racking bundles (similar to the Middle Martis Headcut site) and placed securely between the key logs.

Wood Loading

Wood loading calculations were based primarily on the Fox and Bolton paper (Fox & Bolton, 2007). Additional resources were used to corroborate this wood loading reference (Abbe & Montgomery). Distributions of large woody debris, measured in the number of pieces per 100 meters of channel were studied for a range of regions and bankfull width (BFW) class. Their findings were for Alpine regions with a bankfull width from 0 to 3 meters, the median number of pieces per 100 meters was 22 pieces, with a 25 to 75 percentile range of 15 to 28 pieces. The table summarizing the different regions and associated number of pieces per 100 meters of reach is shown in Figure 9 below (Fox & Bolton, 2007).

The study is based on the trend analysis with wood volumes with increasing basin size and the correlation of bankfull width to basin size and cross sectional area.

Region	BFW class	75th percentile	Median	25th percentile
Number of pieces				
Western Washington	0–6 m	>38	29	<26
	>6–30 m	>63	52	<29
	>30–100 m	>208	106	<57
Alpine	>0–3 m	>28	22	<15
	>3–30 m	>56	35	<25
	>30–50 m	>63	34	<22
DF–PP forest zone	0–6 m	>29	15	<5
	>6–30 m	>35	17	<5
Volume				
Western Washington	0–30 m	>99	51	<28
	>30–100 m	>317	93	<44
Alpine	>0–3 m	>10	8	<3
	>3–50 m	>30	18	<11
DF–PP forest zone	0–30 m	>15	7	<2
Number of key pieces				
Western Washington	0–10 m	>11	6	<4
	>10–100 m	>4	1.3	<1
Alpine	>0–15 m	>4	2	<0.5
	>15–50 m	>1	0.3	<0.5
DF–PP forest zone	0–30 m	>2	0.4	<0.5

Figure 9. Fox & Bolton, 2007: Distributions of large woody debris and number of key pieces per 100 m of channel by region and bankfull width (BFW) class.

The design at the Lookout Mountain Tributary site is showing 5 logs or rootwads (as available) per incision treatment structure. For the full reach length of approximately 275 feet (slightly less than 100 meters), the design includes a total of 5 incision treatment structures, or 25 wood pieces. This design is meant to closely align with wood loading that would have been present before human disturbances to the basin.

The incision treatment structures will raise the water surface elevation during floods. Both the 2-year and the 100-year flood were modeled at the site. The 100-year flood, in both the existing and proposed conditions fully inundates the reach and overtops Jake's bridge. Because of this, it was decided that it is prohibitively expensive and impactful to raise Jake's bridge to be able to pass the 100-year flood. The 2-year flood model output shows that with a 1-foot raise, the bridge will be able to clear the 2-year flood inundation level. Ecology blocks will be brought to the site and installed on native materials (unless the base materials are deemed insufficient during construction) to provide for the bridge raise. A handrail will also be required with the increased drop height. Native materials at the site will be placed to accommodate the trails' raised profile and provide a continuous crossing at Jake's bridge.

These treatment actions will help reduce incision, raise water surface elevations and lessen the risk of any damage to the existing infrastructure.

5. HYDRAULIC ANALYSIS

Hydraulic Modelling

All three sites were modeled in Riverflow 2D, a 2-dimensional hydraulic model, and provide the basis of design for these project locations. The peak discharge for the 100-year flood for both the Culvert Replacement site and the Middle Martis Headcut site were the selected flood events that were modeled. At the Lookout Mountain Tributary site, Jake's Bridge was found to be fully inundated at the 100-year flood and it was determined that the 2-year flood would be the basis of design.

The primary objective of Natural Systems Design's (NSD) hydraulic analysis was to evaluate flow patterns, hydraulic parameters, and inundation extents to characterize current riverine conditions within the localized project area. Establishing baseline hydraulic conditions also enables quantitative comparison with the proposed condition modeling to be completed in future project phases. The hydraulic analysis was conducted for the 2-year and 100-year peak flow discharges described in the hydrologic analysis. All model runs were performed in steady state (discharge does not vary with time) with a non-deformable bed (no adjustments for scour, sediment transport or deposition).

Hydraulic models were created representative of existing conditions using Hydronia's RiverFlow-2D Plus GPU and Aquaveo's Surface-water Modeling System (SMS) v12.2 computer software. RiverFlow-2D is a two-dimensional finite volume computer model that provides depth-averaged hydraulic parameters at nodes within a triangular model mesh domain by solving the shallow water equations resulting from integration of the Navier-Stokes equation. The Navier Stokes equation is derived from applying Newton's Second Law (Force = mass*acceleration) to fluid motion, and is generally expressed as:

$$\rho \left(\underbrace{\frac{\partial \mathbf{v}}{\partial t}}_{\text{Unsteady acceleration}} + \underbrace{\mathbf{v} \cdot \nabla \mathbf{v}}_{\text{Convective acceleration}} \right) = \underbrace{-\nabla p}_{\text{Pressure gradient}} + \underbrace{\mu \nabla^2 \mathbf{v}}_{\text{Viscosity}} + \underbrace{\mathbf{f}}_{\text{Other body forces}}$$

Inertia (per volume)
Divergence of stress

Where ρ = fluid density

μ = dynamic viscosities

p = pressure

∇ = *del operator* (abbreviation for derivative (gradient) of 3D vector field)

f = term representing body forces acting on the fluid (per unit volume)

SMS is a GIS-based program that creates the triangular model mesh, model input files, and displays model results. The following sections provide more in-depth information on specific components of our hydraulic analysis, data development, and results. Actual model results of the inundation extents for the Q-100 at the Culvert Replacement and Middle Martis sites and Q-2 at the Lookout Mountain Tributary sites for both the existing and proposed conditions are shown in the Final Design Drawing Set.

Model topography

The hydraulic analysis utilized a composite surface developed in AutoCAD Civil3D from a topographic and bathymetric survey of the channel bottom and adjacent floodplain areas performed by NSD staff on September 18th to 20th, 2017, and bare earth Light Detection and Ranging (LiDAR) acquired from the United States Forest Service (USFS), 2014 USFS Tahoe National Forest LiDAR. The LiDAR was collected by the National Center for Airborne Laser Mapping (NCALM) in 2013 and 2014. The original collection method used NAD 83 (horizontal datum), UTM Zone 10 N and NAVD 88 (vertical datum) in meters. For the hydraulic modeling software, everything was projected into US feet and State Plane, California Zone II. Survey data for this project generally consisted of centerline or thalweg information and periodic cross sections spanning the bankfull channel.

Mesh

The mesh is developed from the topographic data and is a key component of the 2D hydraulic model. The model computes a depth-averaged flow velocity and depth at each node in the 2D (x-y) mesh. Each of the elements comprising the mesh is assigned an elevation and a roughness value needed to run the computation routine. RiverFlow-2D utilizes a flexible tri-angular mesh to solve for volume conservation and momentum in the x and y directions at each node (representing depth average). The governing equations are applied at each node in an iterative routine until converging on a solution that achieves conservation of mass and energy to within an acceptable error.

Boundary Conditions

Each of the three project sites had its own surface mesh and inflow/outflow boundaries. All three models were run as a free inflow set at the flood discharge specific to each site as determined by the USGS StreamStats analysis. Downstream boundary extent allowed for a free outflow of water. The models were run at a steady state until a volumetric balance was obtained between the inflow and outflow.

Roughness Values

Within each of the models, different roughness areas were delineated to better define the channel, floodplain, side channels, upland shrub regions, and willow clumps. Figure 10 (Chow) (Barnes) shows the roughnesses that were used for all three models:

ROUGHNESS TYPES	MANNING'S N VALUE
Channel -main	0.032
Channel – side	0.034
Floodplain Grasses	0.03
Floodplain Grasses - Long	0.06
Floodplain Shrubs	0.05
Floodplain Willow	0.07
Riprap	0.28
Road - gravel	0.024
Logjam	0.15

Figure 10. Manning's n Values used in hydraulic model

Each of the models had an existing conditions (EC) and proposed conditions (PC) surface topography and roughness mesh. The same discharges were run for both models at each of the sites. The spacing of nodes along each boundary/delineation was adjusted to increase node density in areas of interest to between 5- and 10-ft (main channel, side channels, etc.) and reduced in other regions to between 20- to 40-ft (outer edge of floodplain, upland shrub regions, etc.). In this way, the model mesh was optimized to provide detailed information in areas of interest, while also balanced with reduced computational times.

Results Summary

The existing and proposed condition model results are summarized in the Results Summary in Figure 11, with key results for the 2-year and 100-year flood simulations described below. The Culvert Replacement site observation location is at the existing location of Culvert #1, or the north culvert. The observation location for the Middle Martis Headcut site is located at the downstream end of the project, at the lowest bioengineered check dam, at approximately station 0+10. The observations at the Lookout Mountain site is at the thalweg location under Jake's Bridge.

CHANNEL	DESCRIPTION	EXISTING CONDITIONS				PROPOSED CONDITIONS			
		2 year		100 year		2 year		100 year	
		Depth	Velocity	Depth	Velocity	Depth	Velocity	Depth	Velocity
		feet	fps	feet	fps	feet	fps	feet	fps
Culvert Site	At the center of Culvert #1	0.9	4.6	1.6	4.0	0.9	2.8	1.4	3.4
Headcut Site	At Sta. 0+10	0.9	4.4	2.8	5.3	1.0	4.4	3.0	4.7
Lookout Mt	Existing thalweg, Jake's Bridge	1.0	5.5	2.7	5.7	1.1	4.2	3.2	4.9

Figure 11. Existing and Proposed Conditions, Hydraulic Model Results Summary

These locations were chosen because the changes in depths and velocities (in feet per second, fps) were a determining factor in each of the designs and represent the maximum values at that point; they are not averages across a cross-section.

The main feature or hydraulic change at the Culvert Replacement site is the removal of two culverts and the associated road prism (approximately 70 feet) between the two culverts. Removing these features allowed for the floodplain upstream and downstream of the road to be reconnected and for flows to be more evenly distributed between the bridge abutments instead of overtopping and washing out the existing road prism. This increase in conveyance allows for lower water surface elevations locally through the channels and under the bridge during the modeled flood events, lowering the predicted depth from 1.6 feet to 1.4 feet. Due to road prism removal and the larger cross-sectional area, the velocities are reduced in the proposed condition, down from 4.0 feet per second to 3.4 feet per second. The lower velocities will reduce the risk for future incision of the channels and reduce the potential for additional sediment transport (beyond the natural sediment budget) and disconnection from the floodplain.

At both the Middle Martis Headcut site and the Lookout Mountain Tributary site, additional roughness, or the installation of large woody debris and bioengineered check dams, is a large component of each of the site designs. This raises the water surface elevation throughout the reach and inundates a larger area in the proposed conditions model runs, concurrently slowing discharge velocities.

At the Middle Martis Headcut site, during the 100-year flood, water surface elevations were raised 0.2 feet at the downstream end of the project extents (station 0+10). Depth changes varied throughout the site due to the flat topography and dispersed flows. The regrading at the headcut allowed for more discharge to remain in the channel and reduced the risk flows running over the Tompkins Memorial Trail to the south, while deepening and slowing flows in the channel itself. The maximum velocity at station 0+10 slowed from 5.3 feet per second to 4.7 feet per second.

The Lookout Mountain site is similar to the Middle Martis Headcut site in the design goal of increasing water surface elevations and reducing velocities. The incision structures at the Lookout site were larger relative to the channel size than the bioengineered check dams at the Headcut site and the larger impact is evident in the hydraulic modeling. At Jake's Bridge, the depths increase almost half a foot during the 100-year flood and velocities slow from 5.7 feet per second to 4.9 feet per second. While there is some interaction with the bridge at this location, the depth changes are consistently between 0.2 and 0.5 feet throughout the reach due to the added roughness of the incision structures.

Summary

The new bridge at the Culvert Replacement site will allow for better floodplain connectivity and conveyance of the Unnamed Tributary floods into the Martis Mainstem. It will better protect the Tompkins Memorial Trail by reducing the potential for overtopping and damage to the roadway. At the Middle Martis Headcut site, the regrading of the headcut drop and construction of bioengineered check dams will help the Middle Martis Creek water surface elevations rise and reconnect with the adjacent floodplain. The restorative actions will also reduce the potential for the continuation of headcut propagation upstream. The incision structures at the Lookout Mountain site will introduce more wood to the system, diversifying aquatic habitat and providing hydraulic benefits of slowing discharge and raising the water surface elevation. The benefits of the structures will grow over time, as sediment and additional woody debris accumulates during higher flood events.

All three of these projects will help to meet the restoration goals for the Martis Wildlife Area. Each site has a need that is addressed by the design and helps to restore floodplain connectivity, increases riparian and aquatic habitat health and diversity, and helps begin to restore the channel hydraulics to historical conditions.

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