100-Year Flood Analysis – Burke Creek Rabe Meadow Riparian Restoration Project

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INTRODUCTION

The purpose of this report is to analyze the effects of a 100-year recurrence flood event under existing and proposed conditions for the Burke Creek Rabe Meadow Riparian Restoration Project between the end of Kahle Drive and Lake Tahoe. This project proposes significant changes to Burke Creek and its floodplain in the vicinity of Nevada Beach Campground, the Tahoe Beach Club and a Douglas County Lake Tahoe Sewer Authority (DCLTSA) pump station and this report examines whether proposed conditions will have any adverse impacts to infrastructure at these locations. As well, a project goal is to improve riparian health and increase the area of stream environment zone (SEZ) along Burke Creek and in Rabe Meadow, and this report examines whether proposed conditions meet this goal, by increasing fluvial space through an increased flood inundation extent in these areas. Finally, this analysis looks to examine whether the proposed project's impact to Lake Tahoe's health and clarity. While this analysis only examines a 100-year flood event, results can be used as a proxy for lesser hydrologic events which will likely result in similar effects at a lesser magnitude.

BACKGROUND

Burke Creek and Rabe Meadow are located on the southeast portion of the Lake Tahoe Basin watershed. The headwaters of the Burke Creek watershed start in the Carson Range in Nevada and flows southwest to west through Rabe Meadow into Lake Tahoe. The proposed project includes portions of Rabe Meadow and the lower reaches of Burke Creek and is located in Section 22 of T 13 N R 18 E. (See Figure 1). Rabe meadow is a complex of wet meadow habitats, springs and riverine systems that is bordered by Jeffrey Pine and Mixed Conifer Forest.

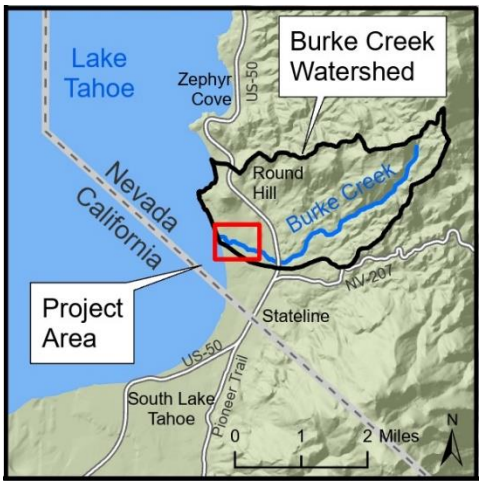


Figure 1: Project location

Burke Creek and Rabe Meadow have been impacted by significant disturbances over the past 150 years that were marked by the European-American colonization and development of the Tahoe Basin. The watershed of Burke Creek was logged extensively during the Comstock Era of the late 1800s and Rabe Meadow was used for livestock grazing from the late 1800s until the 1970s. The 20th century brought development to Rabe Meadow and the historic route of Burke Creek through it, first with the development of Sky Harbor Airport and then with the subsequent redevelopment of the airport into Tahoe Shores Mobile Home Park and the Oliver Park Subdivision in the middle of the century. More recently, the Tahoe Shores Mobile Home Park has been redeveloped and replaced by the Tahoe Beach Club, which is located at the location of the historic outlet of Burke Creek into Lake Tahoe as seen in aerial photos from 1940.

While there are few known records of the condition of Burke Creek 150 years ago at the onset of this period of activity, several significant changes to the creek and meadow are known to have occurred due to anthropogenic activities during this time. First, a significant area of meadow and SEZ has been eliminated due to development. Second, the alignment of Burke Creek through the meadow was changed significantly and has been pushed to the north due to the developments that took over the southern side of the meadow. Third, the Kahle Ditch, which at one point in the 20th century Burke Creek was routed through, creates a secondary channel that collects and conveys water to a secondary outlet to Lake Tahoe. Fourth, numerous historic remnant ditches exist on the USFS lands surrounding Rabe Meadow, some which likely disrupt hydrologic function within meadows and encourage conifer encroachment.

In 1978 the US Forest Service acquired most of the land encompassing Rabe Meadow and the lower Burke Creek watershed. Since this acquisition, several restoration projects have been implemented in Rabe Meadow and Burke Creek. These restorations have also led to significant changes in the creek and meadow. First, in conjunction with the 1978 acquisition, a 1981 restoration created Jennings Pond at the location where construction on a casino had begun, and routed Burke Creek through the pond and through a channel originating at Folsom Spring. Second, a restoration in 1992 re-routed 2,000 feet of Burke Creek at the outlet of Lake Tahoe from the Kahle ditch and through a series of box culverts in Nevada Beach Campground and into a new outlet to Lake Tahoe to the north of the historic outlet. Finally, a multi-year restoration completed in 2018 restored a portion of Burke Creek on the upstream side of Highway 50 and route the creek through a new culvert and channel to Jennings Pond.

EXISTING CONDITIONS

The activities outlined in the previous section have resulted in a significantly altered creek alignment and geomorphology. Figure 2 shows the existing conditions of Burke Creek at its outlet to Lake Tahoe overlayed on a 1940 and a 2018 aerial image and shows the significant loss in riparian area and floodplain extent over the past 80 years. As well, the current routing and outlet of Burke Creek is to the north of the Creek's historic outlet and well outside the area the Creek would be expected to flow under fluvial conditions free from intensive anthropogenic influences.

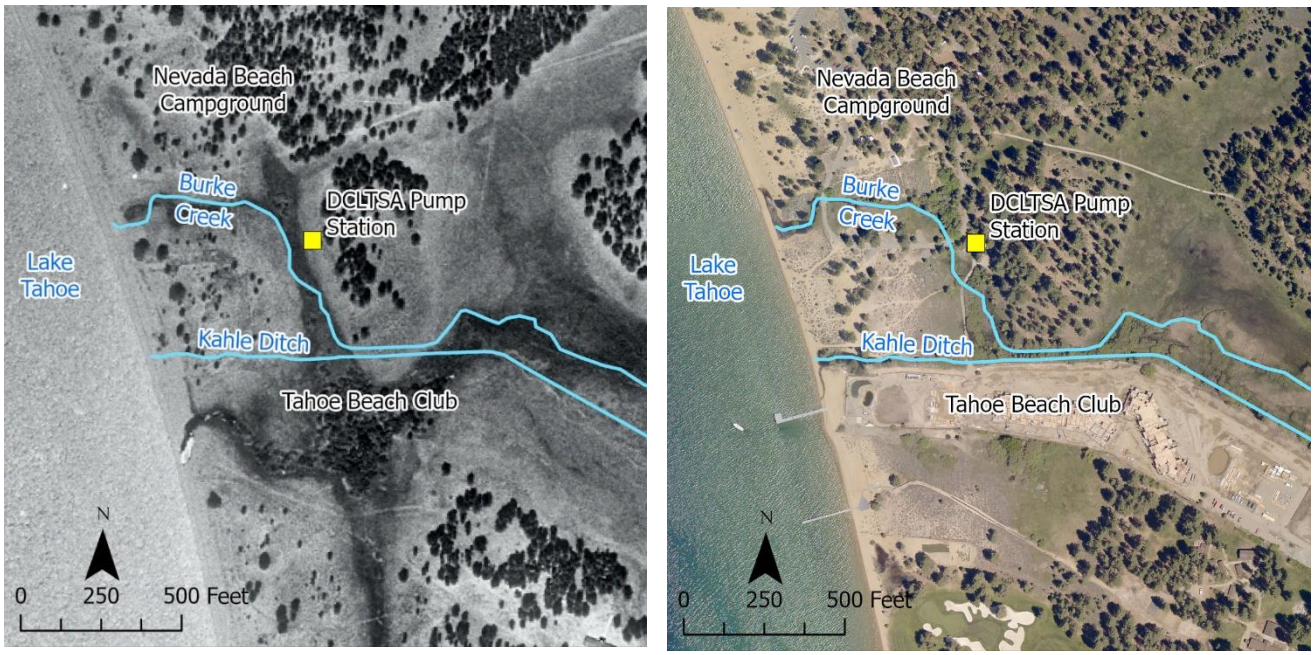


Figure 2: Existing conditions at the Burke Creek outlet overlayed on a 1940 aerial image (left) and a 2018 aerial image (right) (Source: TRPA and Douglas County)

Today, Burke Creek and its floodplain have several environmental and hydrological issues that have likely arisen due to the alterations to the creek. First, significant flooding occurs in the vicinity of the creek in Nevada Beach Campground, especially at the DCLTSA pump station and access road. This flooding often inundates asphalt roads, and poses a threat to the pump station, whose failure could lead to the spillage of raw sewage less than 600 feet from Lake Tahoe. Second, the inundation and conveyance of stormwater through the Burke Creek from roads and urban areas with minimal treatment has adverse effects on Lake Tahoe's health and clarity. Finally, significant sagebrush and conifer encroachment has occurred in the meadows and floodplain surrounding the creek, indicating an additional loss in riparian ecosystems beyond the areas already lost due to development.

Figure 3: Flooding at the DCLTSA sewer pump station, March 2023 (Photo: NTCD)

The sources of these environmental and hydrological issues are identified as primarily coming from six issues with existing conditions in the project area, summarized as followed:

1. Floodplain area

The significant loss in floodplain in the Burke Creek watershed has resulted in a loss in area where creek flows can be dispersed during high flows. Though there has been a significant loss in floodplain in the entire Burke Creek watershed below Highway 50, this becomes especially pronounced in the area downstream of Rabe Meadow, where the creek becomes confined, first in a narrow area adjacent to the Tahoe Beach Club, and then in areas between roads in Nevada Beach Campground. Thus, flows quickly begin to exceed channel and floodplain capacity in Nevada Beach Campground and then threaten the DCLTSA pump station and campground infrastructure. This loss in floodplain has also led to a significant loss in habitat for riparian plants and animals.

2. Burke Creek Incision

The 1993 US Forest Service Burke Creek project designed an incised channel where the creek now runs parallel to the Tahoe Beach Club property boundary to limit flooding at the time in the Tahoe Sands Mobile Home Park. An examination of design notes and the post-project monitoring report (Norman, 1999) shows that geomorphologists identified a small capacity Rosgen E1 channel as the ideal design in that area for hydrology and ecosystem purposes, however due to flooding concerns, a larger Rosgen C channel was constructed. Flood concerns in this area no longer exist as the adjacent grade in the area was raised for the construction of the Tahoe Beach Club. Today, incision in this area continues to increase, and significant conifer encroachment has occurred adjacent to the creek since the 1993 project. This incision likely contributes to flooding downstream at the DCLTSA access road and pump station, as medium to high flows

are not dispersed to an adjacent floodplain. This incision may also cause the creek to gain groundwater from Rabe Meadow, causing a loss in riparian habitat in that area.

3. Burke Creek Channel Slope

The Burke Creek reach in the vicinity of the upstream two box culverts in Nevada Beach Campground has no gradient according to field topographic surveys. These box culverts were installed as part of the 1993 project and likely have a low gradient due to the design requirements to allow the creek to route to its present-day northern outlet to Lake Tahoe. Significant aggradation has occurred in these culverts, decreasing their capacities, and increasing flooding at the DCLTSA access road and pump station.

Figure 4: Concrete box culvert in Nevada Beach Campground at capacity during spring runoff, April 2019 (Photo: NTCD)

4. The Kahle Ditch

The Kahle Ditch has a negative impact on the quality of Lake Tahoe by conveying untreated stormwater from Kahle Drive towards Lake Tahoe. As well, remnant utilities from the Tahoe Sands Mobile Home Park still exist in the ground along the ditch, and overtime may erode into the ditch. The size of the ditch limits overbanking and dispersion of flows from the ditch into the adjacent meadow. Therefore, the ditch also increases conveyance of flows to the areas downstream with flooding issues. The ditch also gains groundwater from Rabe Meadow thereby degrading adjacent meadow and riparian ecosystems. The outlet of Kahle Ditch to Lake Tahoe today is the high-flow outlet of the Burke Creek watershed to Lake Tahoe. However, only one small, degraded culvert conveys stormwater in the ditch below the DCLTSA access road, and therefore much of the flow volume overtops the road on its way to the Lake, collecting fine sediment pollutants when doing so.

5. DCLTSA Access road

Access to the DCLTSA pump station is along an asphalt road adjacent to Burke Creek that runs from the Tahoe Beach Club property to the pump station. This road must be maintained to provide access to the plant at all times for both routine maintenance and emergencies. As mentioned previously, this road often becomes inundated during high flows as water in Burke Creek attempts to find the most hydraulicly efficient route to Lake Tahoe. Inundation of this road creates a fine sediment pollution source and threatens the critical infrastructure at the DCLTSA pump station. A failure at this station would cause significant environmental issues both at the plant and in the entire casino corridor of Stateline which the plant serves. The road must be plowed during winter to maintain access to the station which can cause additional issues, as large snow berms combined with the plowed road can make the bare asphalt of the road become the most efficient conduit of Burke Creek's flows. An example of this problem arose in March 2023, when emergency actions had to be taken to build dirt berms and excavate drainage routes to Lake Tahoe after the plant became threatened when flows from the creek overtook the road.

Figure 5: Top left, Flooding on the DCLTSA access road, March 2023 (Photo: NTCD). Top right, aerial image of flooding on the DCLTSA access road, June 2018 (Photo: Google Earth). Bottom: Flooding adjacent to pump station and on road, April 2019 (NTCD)

6. Upper meadow ditching

Numerous ditches exist in the meadows of the Burke Creek watershed below Highway 50. Significant sagebrush and conifer encroachment has occurred in meadows along these ditches, indicating a loss in riparian habitat. As well, these ditches increase the conveyance of flows to locations lower in the watershed, thereby contributing to downstream flooding issues.

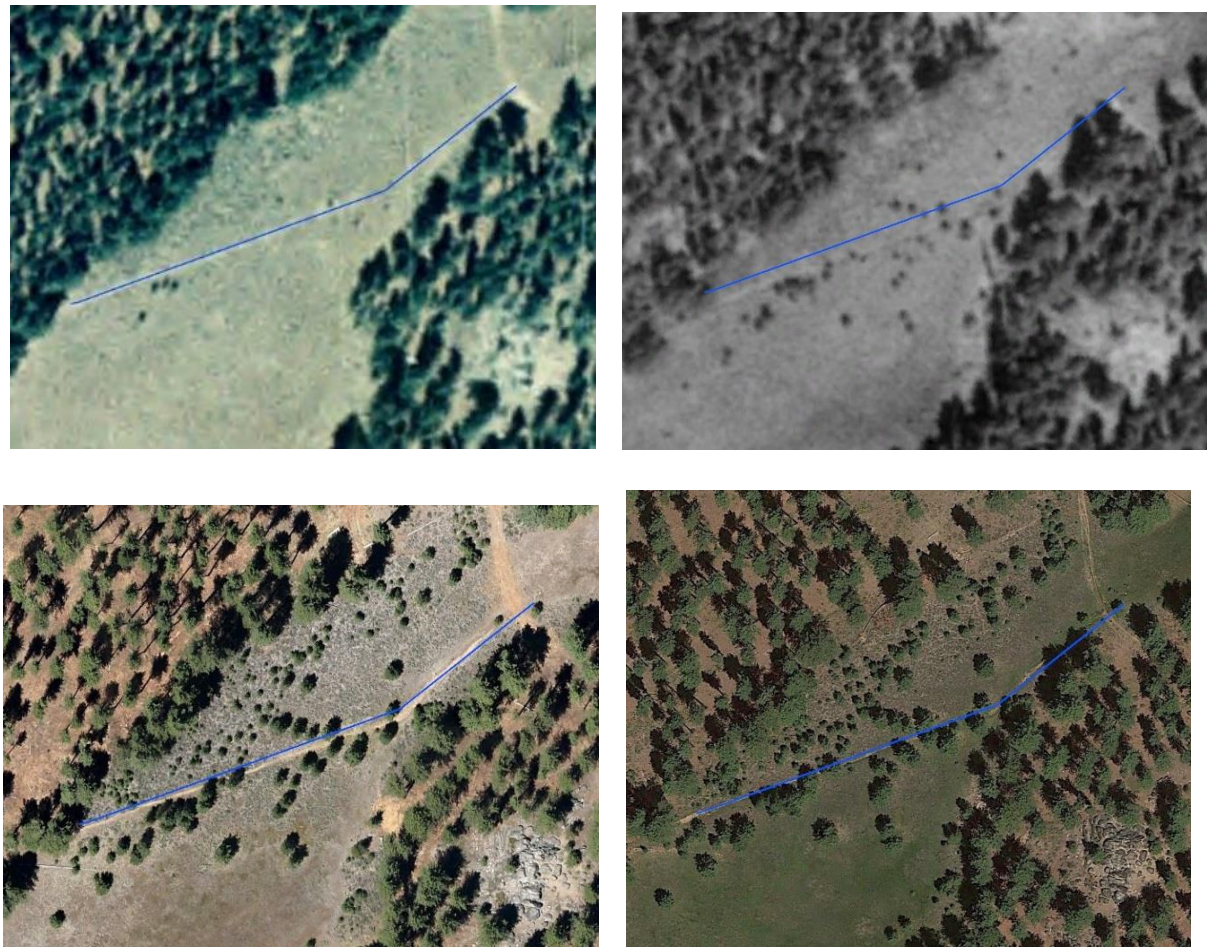


Figure 6: Conifer encroachment along a ditch in Rabe Meadow (Clockwise from top left: 1987, 1998, 2009, 2018). Photos from TRPA and Google Earth.

The FEMA flood map for the project area is covered by map number 32005C0205G (Appendix 1). This map shows the area along Burke Creek in Rabe Meadow and along the Tahoe Beach Club property line classified as Zone A which indicates a special flood hazard area without a base flood elevation. As well, areas to the north, including the DCLTSA pump station and Nevada Beach Campground are shown as "Other Areas Zone D" indicating an area of undetermined flood hazard. The area of Burke Creek from its existing outlet to Lake Tahoe to just upstream of the downstream most box culvert is classified as Zone AE which indicates a special flood hazard area with a base flood elevation. This area is part of the greater flood area that encompasses Lake Tahoe and shows a base flood elevation of 6232.3' NAVD. The FEMA flood zone delineation appears approximate in nature and does not precisely line up with observed flood behaviors in the area.

PROPOSED PROJECT

The project proposes actions to address each of the issues identified in the previous section that currently contribute to environmental and hydrologic issues in the project area. These actions are shown on the map in Appendix 2 and are summarized as following:

1. Floodplain area

The project proposes to restore historic floodplain on the Tahoe Beach Club property adjacent to the Kahle Ditch. This area had fill placed on it during the 20th century, and the project proposes a low gradient (0.25% – 0.5%) floodplain expansion from the Kahle Ditch to the toe of the existing slope on the Beach Club property. As well, the project proposes construction of a new floodplain below the access road to the DCLTSA pump station. A total floodplain area of 200,000 SF (4.6 Ac.) is proposed to be created and/or restored during the project. Existing areas of floodplain are expected to continue to be hydrologically active. The increased floodplain will increase habitat for riparian species and will provide additional space to disperse flows from Burke Creek.

2. Burke Creek Restoration

The project proposes a restoration and realignment of Burke Creek between the end of Rabe Meadow and Lake Tahoe. In the narrow area of fluvial space adjacent to the Tahoe Beach club, the existing incised channel will be realigned and increased in sinuosity with a channel size suitable for annual overbanking under normal hydrologic conditions. At the point where the creek turns to the north towards Nevada Beach Campground, the creek will be routed away from the campground and the DCLTSA sewer station and into the proposed floodplain mentioned in the previous action. This alignment will provide the creek a route to Lake Tahoe that is more like its historic route prior to development of the watershed. The existing outfall of Burke Creek to Lake Tahoe will be maintained, as it is anticipated to continue to receive flows from the meadows to the northeast of the campground. The existing channel will be partially filled in this area, but a gradient will be maintained allowing flows to be directed towards Lake Tahoe. The upper two box culverts will be removed, and the existing creek in this area will be partially filled and regraded to allow the existing riparian areas to be sloped towards and connected to the proposed outlet floodplain to the south.

3. Burke Creek Channel Slope

The proposed restored channel will have a low gradient (<1%) but more consistent slope than the current routing through Nevada Beach Campground. As well, channel sizing will allow overbanking into the floodplain, dispersing high-flows and reducing flooding in undesirable areas.

4. Kahle Ditch Removal

Kahle Ditch is proposed to be filled and regraded as part of the floodplain expansion mentioned in the first action. At the end of Kahle Drive where the ditch currently begins, a stormwater basin will be installed and connected to the storm drain system from Kahle Drive that will treat urban sourced stormwater. Remnant utilities from the Tahoe Sands Mobile Home Park will be removed and disposed of.

5. DCLTSA Access road

The existing DCLTSA access road will be removed and a new access driveway to the pump station will be constructed from Nevada Beach Campground. This new access driveway will be located primarily in upland areas that will be less prone to flooding. The existing road from the Tahoe Beach Club will be part of the

floodplain expansion mentioned in action 1. The Floodplain will have positive drainage towards the proposed Burke Creek alignment to the south to reduce flooding potential at the pump station.

6. Meadow ditch restoration

Ditches in the upper meadows will be restored using fill sourced from other parts of the project and will eliminate channels from these meadows that are currently increasing the conveyance of high flows and contributing to groundwater loss and conifer/sagebrush encroachment.

Additional proposed project actions will include the installation of BDAs (Beaver Dam Analogs) in Burke Creek, and the restoration of Jennings Pond into a meadow floodplain. The Jennings Pond restoration is not examined in this analysis, as finish grade at the pond is planned to be at or lower than the high-water level of the pond and not contribute to increased flood-risk in that area based on topography. Currently Jennings Pond causes seasonal flooding onto the Stateline to Stateline Bike Path and Kahle Drive, and the pond may also be contributing to flooding on Kahle Drive due to groundwater seepage, as the pond is higher in elevation than the road and adjacent neighborhood. Removal of the pond will likely reduce these impacts.

As part of project design, the Tahoe Beach Club BMP plans were examined to ensure that proposed actions do not adversely affect the Beach Club's existing infrastructure. Grading in the floodplain restoration areas was adjusted to ensure adequate coverage is maintained over underground infiltration systems, and grading in all areas upstream of the DCLTSA access road is below all storm drain outfalls. Downstream of the DCLTSA access road, the high flow BMP overflow for the Beach Club is proposed to be relocated to the west through a storm drain manhole and 30" pipe to allow for the proposed floodplain restoration. Pipe sizing for this storm drain extension is based on flows provided by the Tahoe Beach Club BMP plan. The storm drain will outfall at a flared-end section, and a rock channel will be constructed in the floodplain to allow a high-flow conveyance route to be maintained.

HYDRAULIC MODEL

A HEC-RAS 2D model was developed to examine the hydraulics of a 100-year flood in the project area between Kahle Drive and Lake Tahoe. A 2009 study by Winzler Kelly (Allen and Kincaid, 2009) examined flows in Burke Creek upstream of Highway 50 and determined a 100-year peak flow of 120 CFS at that location. The report used a calculated value of 44 CFS per square mile in the watershed for determining catchment flows based on a comparison to gauged streams on the east and southeast side of the Tahoe Basin.

Using GIS, contributing catchments were determined for the study area. Using the Winzler Kelly numbers and adding an additional increase for the amount of development in a catchment, peak flows for each of these catchments was determined. As well the BMP plan and as-builts for the BMP system at the Tahoe Beach Club was examined, and the outfall of that system was modeled based on locations and flows determined by that report.

Thus, four locations were identified as contributing significant flows to the study area (see Appendix 2 for locations):

1. 150 CFS at Burke Creek, which drains most of the watershed.

2. 8 CFS at Kahle Drive, which conveys flows from the Oliver Park neighborhood during large storms.
3. 60 CFS from the meadows to the northeast of Nevada Beach Campground, which receive runoff from upland forests and the highly developed Round Hill neighborhood.
4. 16 CFS from the Tahoe Beach Club BMP overflow outfall, which currently discharges to Kahle Ditch downstream of the sewer plant access road.

Lake Tahoe was used as the downstream boundary of the model, with the lake modeled at its high-water line to account for conditions that may cause the most upstream flooding.

Existing terrain used in the model was based on topographic field surveys conducted between 2020 and 2022 by Welsh Hagan and Associates and the Nevada Tahoe Conservation District. This data was then combined with the 2011 Lake Tahoe LiDAR dataset for areas without field survey. Proposed terrain was based on these same sources and updated with the proposed project grading plan. Beaver dam analogs that may be installed as part of this project were assumed to fail and therefore excluded from the model based on their NRCS expected lifespan, their limited resistance to high flows and due to the small proportion of water volume they would retain compared to 100-year peak flows. Culverts were modeled as an internal 2D flow structure in HEC-RAS with dimensions and slopes based on survey data. A Manning N-Value of 0.016 was used for all paved areas in the model. To account for future riparian vegetation, a N-Value of 0.05 was used in the channel and a value of 0.075 was used in the floodplain. These higher roughness values also represent the likely temporary effect of any constructed BDAs.

A 24-hour unsteady flow simulation was run with coincident peak flows from the contributing catchments. Time step of the model varied and was based on the Courant number.

RESULTS

Appendices 3 and 4 show the modeled inundation and flood elevations under existing and proposed conditions. Inundation is increased within the proposed floodplain areas and in the upper meadows, and significantly reduced in Nevada Beach Campground and adjacent to the DCLTSA pump station. Under proposed conditions, nearly all inundation of existing roads and infrastructure is eliminated in the project area, except for a small area of road in Nevada Beach Campground. This area receives flows from the meadow to the northeast, and the existing culvert at this location appears to be degraded and could perhaps be slated for replacement by the Forest Service. Appendix 3 also shows that modeled flood elevations are still several feet below Beach Club Drive, providing a significant factor of safety, and unchanged in elevation except within the Forest Service boundary and at the area identified for SEZ restoration on Tahoe Beach Club lands.

Appendix 5 shows the existing FEMA flood boundaries overlayed on the existing and proposed modeled inundation boundaries. The FEMA Zone A boundary appears to not fully reflect flood risk under existing conditions, which is not surprising since it currently shows the boundary of this zone along the Kahle Ditch, an area that is often inundated. Flood risk under proposed conditions stays within the proposed floodplain restoration area, which is several feet below Beach Club Drive. Appendix 6 shows modeled water surface elevation changes between existing and proposed conditions and proposed cross-sections with the modeled water surface elevation under proposed conditions. This again shows that there is a significant

decrease in flooding in Nevada Beach Campground under proposed conditions, while a small increase in water surface elevation occurs in two areas where Kahle Ditch is restored and existing channelized flows are dispersed to a floodplain. The flood elevation in these areas are still four to five feet below Beach Club Drive. The cross-sections in Appendix 5 also show that a much a larger flow would be required to inundate the cross-sectional area that would be needed to overtop upland areas on Tahoe Beach Club property.

HEC-RAS also allows users to examine modeled stream power as a function of water velocity and shear stress. Areas with higher stream power indicate areas with a higher erosion and scour potential. During high flows, this erosion could potentially unearth underground utilities or cause bank erosion that could affect adjacent roads. Model results showed higher levels of stream power under existing conditions (Figure 3) throughout Kahle Ditch and in straight sections of Burke Creek, including the section adjacent to the Tahoe Beach Club. Stream power in both of these areas was reduced under proposed conditions (Figure 4). Therefore, not only does the proposed project reduce flooding in Nevada Beach Campground and adjacent to the DCLTSA pump station, it also reduce risks from scour and erosion to infrastructure in these locations and at the Tahoe Beach Club.

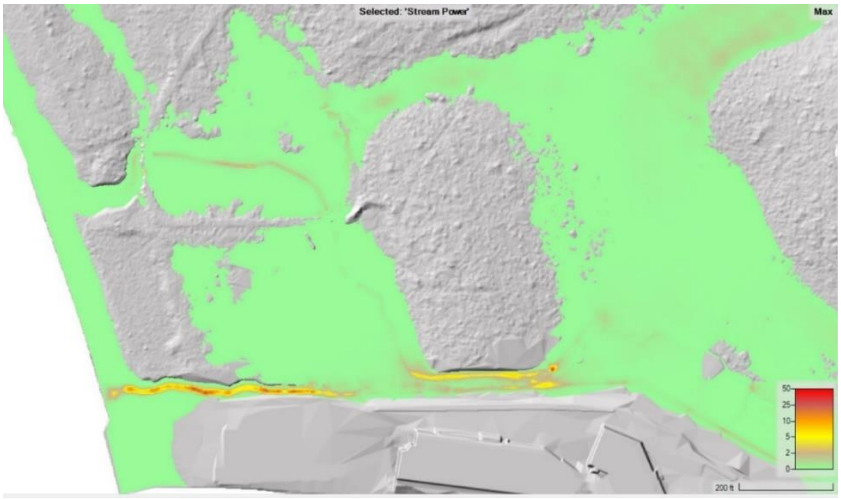


Figure 7: Stream Power, Existing Conditions

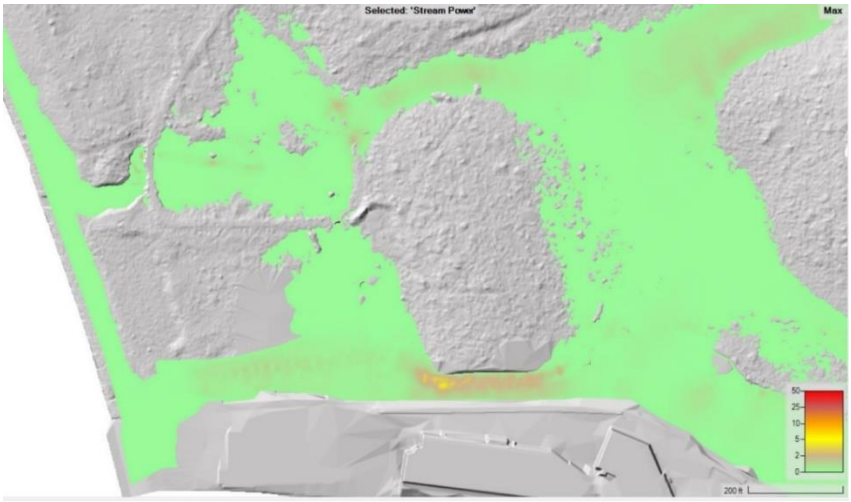


Figure 8: Stream Power, Proposed Conditions

High flow flood events in Lake Tahoe generally occur during winter months when a large snowpack exists and melts during a storm. While the model flows consider the potential for the snowpack contributing to creek flows, this analysis does not specifically examine how topography may change due to snow berms. However, flood issues are more likely to occur where human actions create hydraulically conductive paths for creek flows, and therefore the best way to mitigate the risk is to move infrastructure that may require the creation of snow berms away from flow paths. There is less uncertainty about how snow berms may affect the results of this model when infrastructure is further away from the creek. Consequently, there is less uncertainty with how snow berms may affect results in the proposed conditions model compared to the existing conditions model, as the DCLTSA access road increases uncertainty over flood extents under existing conditions.

CONCLUSION

The proposed Burke Creek Rabe Meadow Riparian Restoration Project will not cause flooding that adversely affects infrastructure and fixed works at the Tahoe Beach Club, the DCLTSA Pump Station or in Nevada Beach Campground. Instead, the project will reduce flooding, scour and erosion, all of which pose a risk to infrastructure in these areas. As well, the project significantly increases riparian areas and will hydrologically reactivate degraded historic meadow areas. Finally, the project decreases conveyance of stormwater from developed areas to Lake Tahoe, thereby helping protect the Lake's clarity.

APPENDICES

1. Ex. FEMA Panel
2. Proposed Actions
3. Existing Inundation and WSE
4. Proposed Inundation and WSE
5. Proposed Inundation and FEMA Boundaries
6. WSE Change and Cross-Sections
7. Project Civil Plans

REFERENCES

Allen, Steve and Kincaid, Michael. June 2009. Burke Creek Restoration Project Alternatives Analysis Report, Burke Creek At Highway 50, Stateline, Nevada. Winzler & Kelly, Michael Love & Associates and McBain & Trush Inc, prepared for the Tahoe Regional Planning Agency.

Amoros C, Bornette G. 2002. Connectivity and biocomplexity in waterbodies of riverine floodplains. Freshwater Biology 47: 761.

Cooper and Merritt. 2012. Assessing the Water Needs of Riparian and Wetland Vegetation in the Western United States. USDA Forest Service Rocky Mountain Research Station. General Technical Report RMRS-GTR-282. September 2012. https://www.fs.fed.us/rm/pubs/rmrs_gtr282.pdf

Hagan, David. June 23, 2020. Tahoe Beach Club Phase 1 Record Drawings, Storm Drain, Sewer Plan and Profile. Welsh Hagan Associates.

Nevada Tahoe Conservation District and Wood Rodgers. June 2014. Final Burke Creek-Rabe Meadow Complex Master Plan Existing Conditions Report.

Nevada Tahoe Conservation District and Wood Rodgers. November 2014. Final Burke Creek-Rabe Meadow Complex Master Plan, Development of Capital Improvement Projects and Alternatives Evaluation Report.

Norman, Susan. August 1999. Burke Creek Stream Channel Restoration Monitoring Report, 1990-1998. USDA Forest Service Lake Tahoe Basin Management Unit.

Pease and Herzog, 2019. Updated Groundwater Investigation Tahoe Beach Club Buildings 3 and 4. Letter to Patrick Rhamey dated January 18, 2019.

Poff, R.J. and Associates, 2003. Soils Report prepared for Tom Castenada, Tahoe Beach Club, May 28, 2003.

Federal Emergency Management Agency. National Flood Insurance Program Flood Insurance Rate Map, Douglas County, Nevada and Incorporated Areas. Panel 40 of 600, Map No. 32005C0040G. Effective January 20, 2010, revised March 24, 2016.

Thorp JH, Thoms MC, Delong MD. 2006. The riverine ecosystem synthesis: biocomplextity in river networks across space and time. River Research and Applications 22: 123–147.

Watershed Sciences, Inc. August 2010. Lake Tahoe Basin Lidar. US Department of Interior Bureau of Land Management in partnership with the Tahoe Regional Planning Agency and the US Geological Survey. Available at Open Topography: https://portal.opentopography.org/lidarDataset?opentopoID=OTLAS.032011.26910.1

Welsh Hagen Associates. 2016. Geotechnical Investigation Report The Beach Club on Lake Tahoe. Stamped by Edward Phariss, July 21, 2016.

Welsh Hagen Associates. 2018. Technical Drainage Report for Tahoe Beach Club.

Wheaton, Joseph & Bennett, Stephen & Bouwes, Nick & Maestas, Jeremy & Shahverdian, Scott. 2019. Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Version 1.0. 10.13140/RG.2.2.19590.63049/2.

APPENDIX 1:

Existing FEMA Flood Panel

National Flood Hazard Layer FIRMette

APPENDIX 1

FEMA

119°57'17"W 38°58'48"N

119°56'40"W 38°58'20"N

Feet

0 250 500 1,000 1,500 2,000

1:6,000

Basemap: USGS National Map: Orthoimagery: Data refreshed October, 2020

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN — Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 — Cross Sections with 1% Annual Chance
- 17.5 — Water Surface Elevation
- Coastal Transect
- 513 — Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 3/16/2023 at 1:57 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

APPENDIX 2:

Proposed Actions

Appendix 2: Proposed Restoration Conveyance Modifications

Burke Creek Rabe Meadow Riparian Restoration Project
Douglas County, Nevada

Legend

- Flood Modeling Extent (Callouts Indicate Input Model Flows)
- Ex. Road to be removed
- Proposed paved access

Drainage Structures & Actions

- Ex. Box Culvert (To Remain)
- Remove Ex. Box Culvert
- Remove Ex. CMP
- Install FES BMP Overflow
- Remove Ex. FES BMP Overflow
- Install 24" HDPE Storm Drain

Channel Modifications

- Ex. Channel (Unchanged)
- Proposed Channel
- Fill Ex. Channel

Floodplain Modifications

- Stormwater Basin
- Fill Ditch in Meadow
- Floodplain / SEZ Expansion

N

0 125 250 375 500 Feet

Scale: 1:3,200
Coordinate System:
NAD83 State Plane
Projection: Nevada West
Aerial Imagery Source:
EagleView, 4/14/22
Preparation Date: 3/16/2023

Nevada Tahoe Conservation District

Upper meadow flows from Round Hill
60 CFS

Nevada Beach Campground

Ex. Burke Creek

DCLTSA Pump Station

Lake Tahoe

(P) Burke Creek

Kahle Ditch

Tahoe Beach Club BMP Overflow 17 CFS

Burke Creek

Kahle Ditch

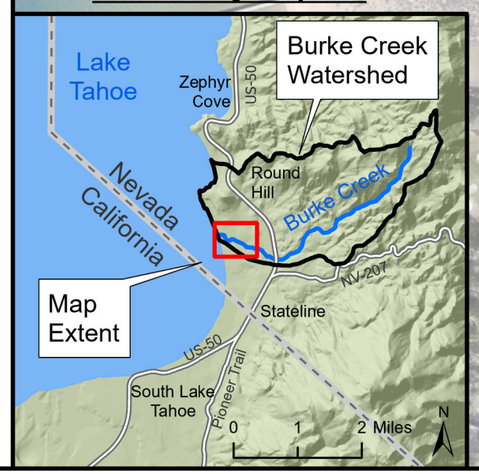
Tahoe Beach Club

Burke Creek
150 CFS

Kahle Drive

Kahle Drive & Oliver Park Neighborhood
8 CFS

Vicinity Map



APPENDIX 3:

Existing Inundation and WSE

Appendix 3
Existing 100-Year Flood Elevations & Inundation

Burke Creek Rabe Meadow Riparian Restoration Project
Douglas County, Nevada

Legend

- Flood Modeling Extent
- *100-Year Flood WSE Contour (Lake Tahoe Datum)*
- Existing WSE Contour
- *100-Year Flood Inundation*
- Existing Conditions

N

0 125 250 375 500 Feet

Scale: 1:3,200
Coordinate System:
NAD83 State Plane
Projection: Nevada West
Aerial Imagery Source:
EagleView, 4/14/22
Preparation Date: 4/6/2023

Nevada Tahoe Conservation District

Nevada Beach Campground

Lake Tahoe

DCLTSA Pump Station

Tahoe Beach Club

Kahle Drive

Ex. Road El.=6233

Ex. Road El.=6235

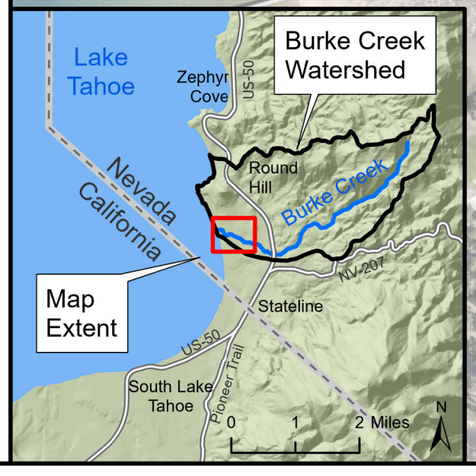
Ex. Road El.=6237

Ex. Road El.=6239

Ex. Road El.=6243

Ex. Road El.=6243.7

Vicinity Map



APPENDIX 4:

Proposed Inundation and WSE

Appendix 4
Proposed 100-Year Flood Elevations & Inundation

Burke Creek Rabe Meadow Riparian Restoration Project
Douglas County, Nevada

Legend

- Flood Modeling Extent
- *100-Year Flood WSE Contour (Lake Tahoe Datum)*
- Proposed WSE Contour
- *100-Year Flood Inundation*
- Proposed Conditions
- *Innundation Change*
- Proposed Decrease
- Proposed Increase

N

0 125 250 375 500 Feet

Scale: 1:3,200
Coordinate System:
NAD83 State Plane
Projection: Nevada West
Aerial Imagery Source:
EagleView, 4/14/22
Preparation Date: 4/6/2023

Nevada Tahoe Conservation District

Nevada Beach Campground

Lake Tahoe

DCLTSA Pump Station

Ex. Road El.=6233

Ex. Road El.=6235

Ex. Road El.=6237

Ex. Road El.=6239

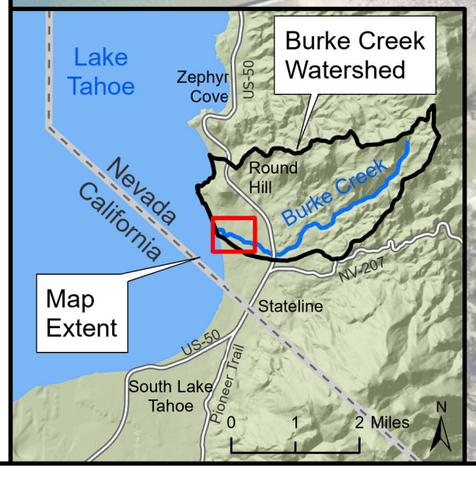
Ex. Road El.=6243

Ex. Road El.=6243.7

Tahoe Beach Club

Kahle Drive

Vicinity Map



APPENDIX 5:

Proposed Inundation and FEMA Boundaries

Appendix 5
Ex. FEMA Zones & Modeled Proposed Conditions Inundation

Burke Creek Rabe Meadow Riparian Restoration Project
Douglas County, Nevada

Legend

- Flood Modeling Extent

Ex. FEMA Flood Risk Zone

- A - Flood Hazard Zone Without Base Flood Elevation (BFE)
- AE - Flood Hazard Zone With BFE
- D - Area of Undetermined Flood Hazard
- X - Area of Minimal Flood Hazard

100-Year Inundation >4"

- EG & FG
- EG
- FG

N

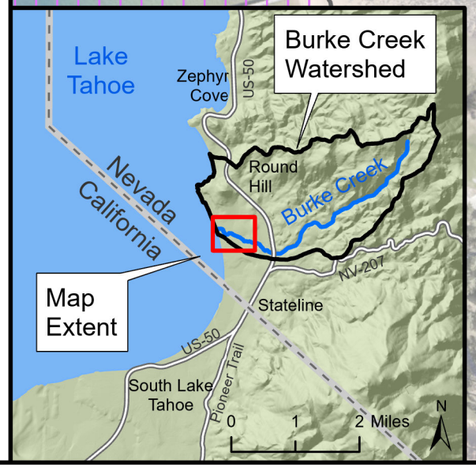
0 125 250 375 500 Feet

Scale: 1:3,200
Coordinate System: NAD83 State Plane
Projection: Nevada West
Aerial Imagery Source: EagleView, 4/14/22
Preparation Date: 4/6/2023

Nevada Tahoe Conservation District

Nevada Beach Campground
ZONE D
DCLTSA Pump Station
Lake Tahoe
ZONE AE
ZONE A
ZONE X
Tahoe Beach Club
Kahle Drive

Vicinity Map



APPENDIX 6:

WSE Change and Cross-Sections

Appendix 6
Proposed Conditions Cross Sections & 100-Year Flood Water Surface Elevation Change

Burke Creek Rabe Meadow Riparian Restoration Project
Douglas County, Nevada

Legend

- Flood Modeling Extent
- *WSE Change*
- EG Inundation Only
- Decline >12"
- Decline 4" - 12"
- Change less than 4"
- Increase 4" - 12"
- Increase > 12"
- FG Inundation Only
- Cross Section

N

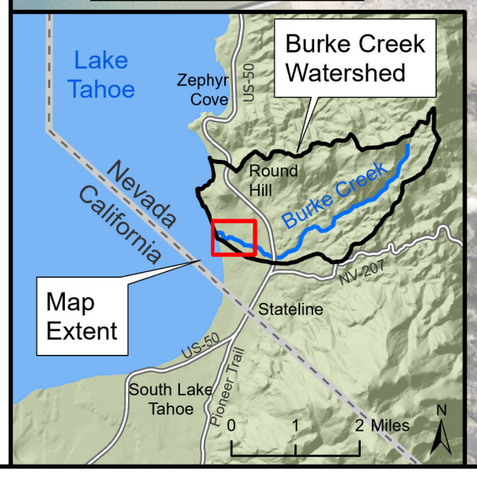
0 125 250 375 500 Feet

Scale: 1:3,200
Coordinate System: NAD83 State Plane
Projection: Nevada West
Aerial Imagery Source: EagleView, 4/14/22
Preparation Date: 4/6/2023

Nevada Tahoe Conservation District

Nevada Beach Campground
Lake Tahoe
DCLTSA Pump Station
Tahoe Beach Club
Kahle Drive
A B C D E F G H I J K

Vicinity Map



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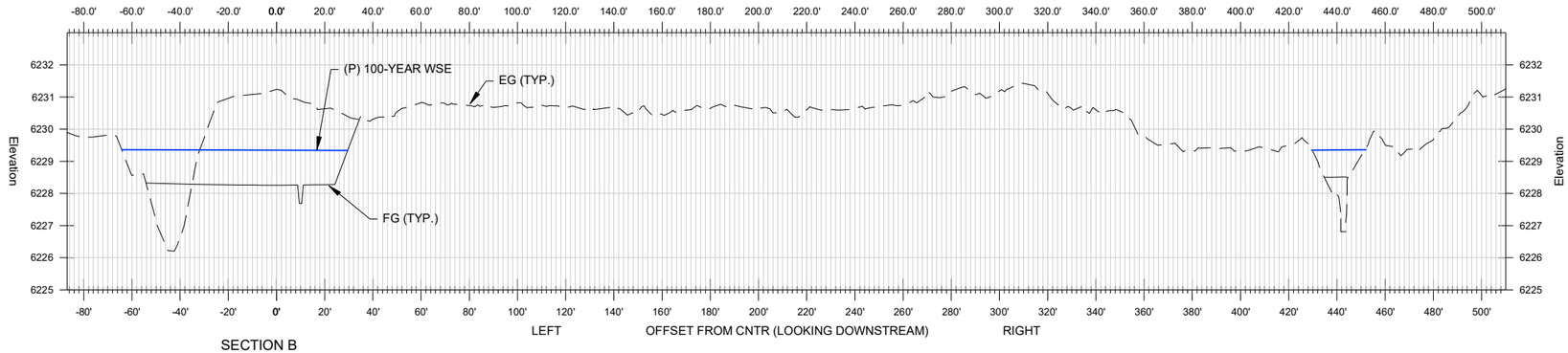
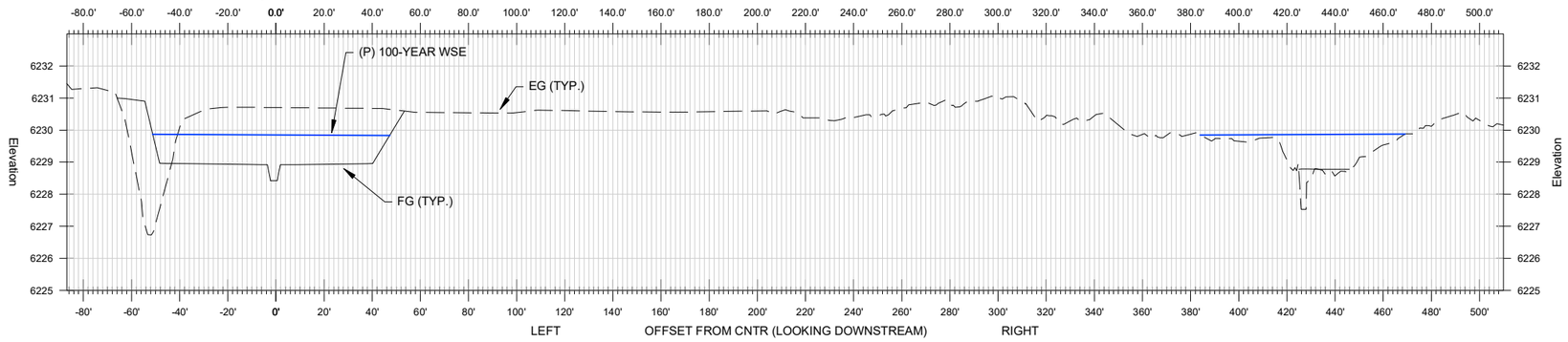
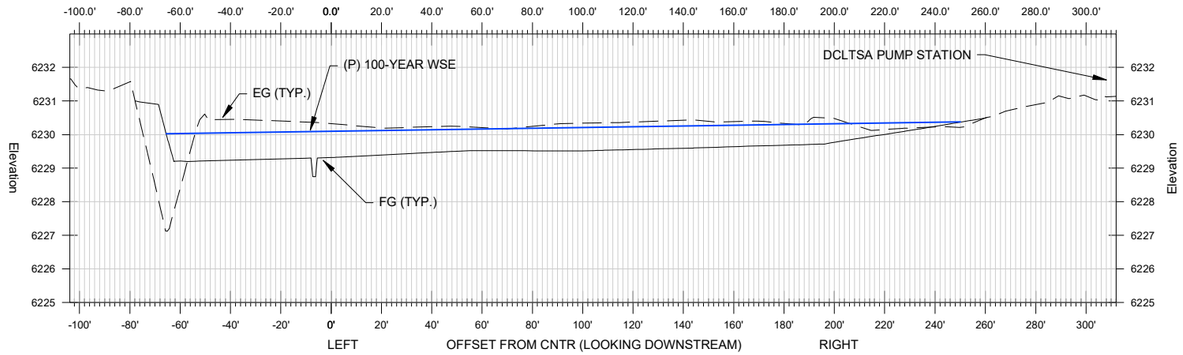


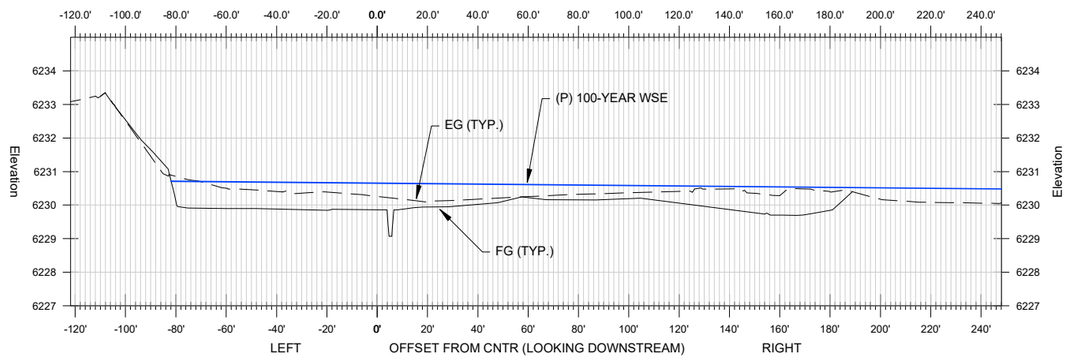
SECTION B

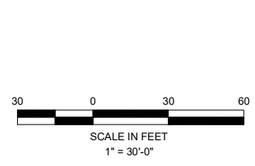


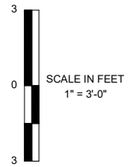
SECTION C, DCLTSA STATION PROPOSED DRAINAGE



SECTION D, AT EX. ACCESS ROAD







PROPOSED CROSS-SECTIONS

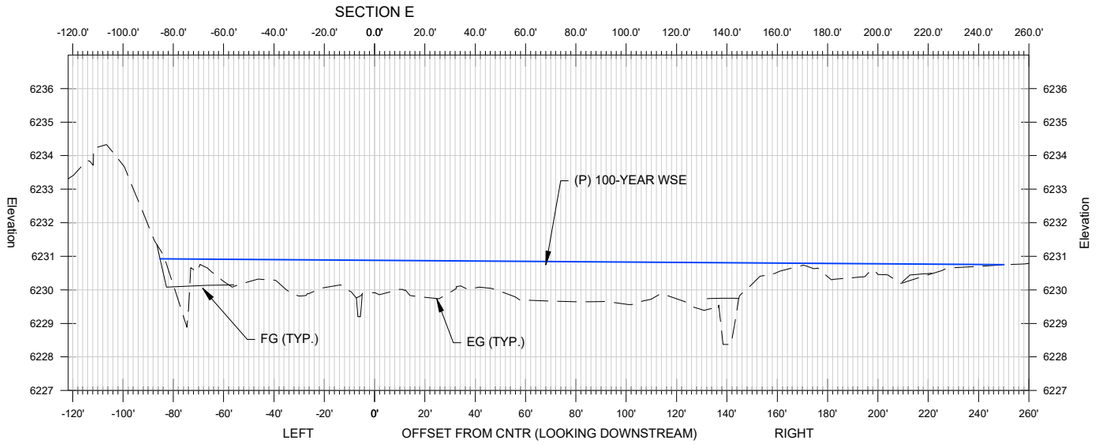
HORIZONTAL SCALE: 1"=30', VERTICAL SCALE: 1"=3', H:V=1:10

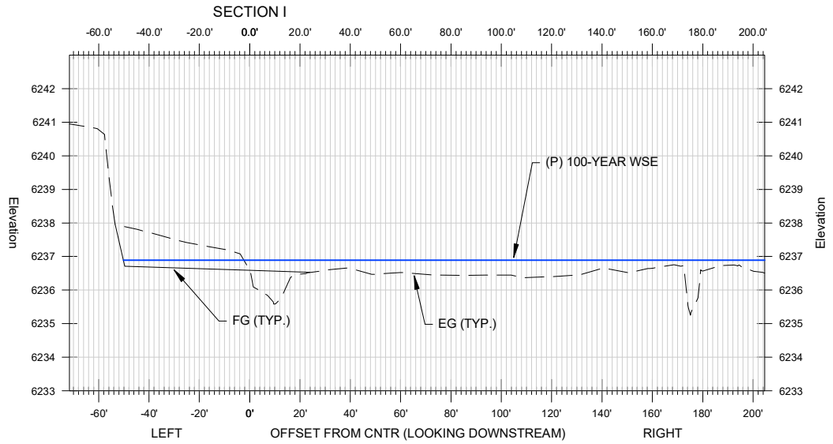
Nevada Tahoe Conservation District

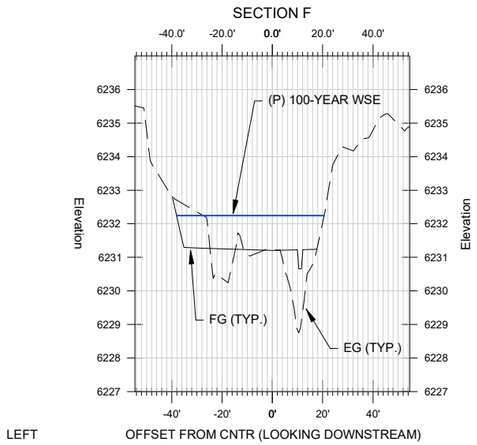
APPENDIX 6 - CROSS-SECTIONS

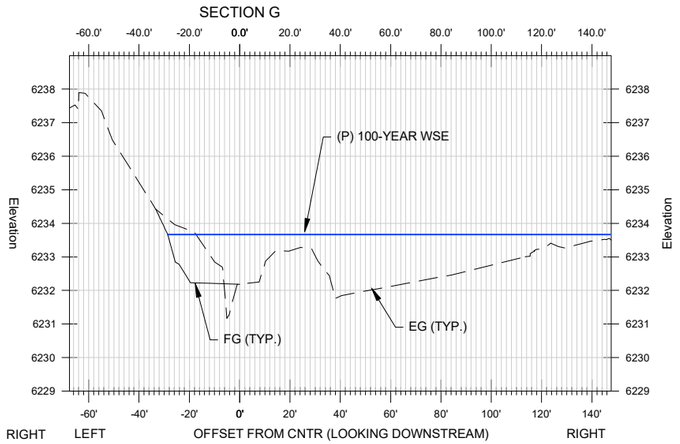
BURKE CREEK - KAHLE DITCH SEZ RESTORATION

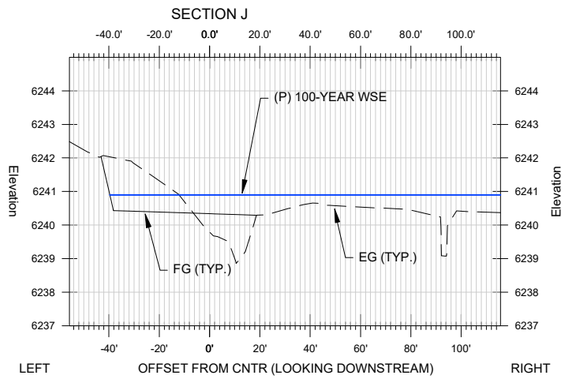
DESIGNED/DRAWN	PJ
CHECKED BY	MK
DATE	3/7/2023
SCALE	AS SHOWN
PROJECT	BCRMRRP - BCKD
SHEET	XS-1

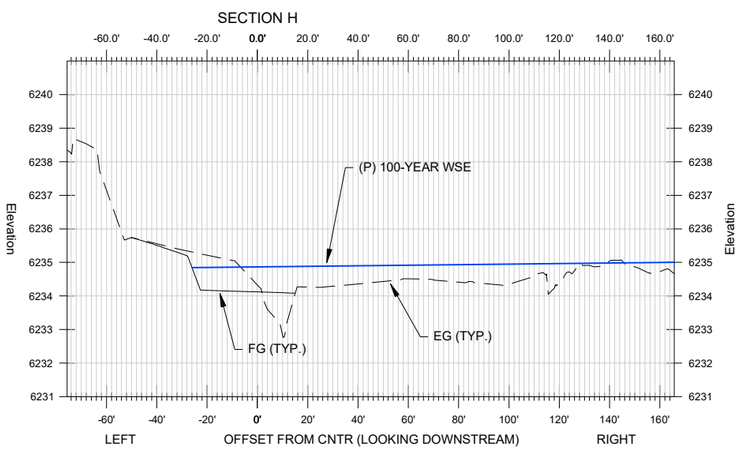


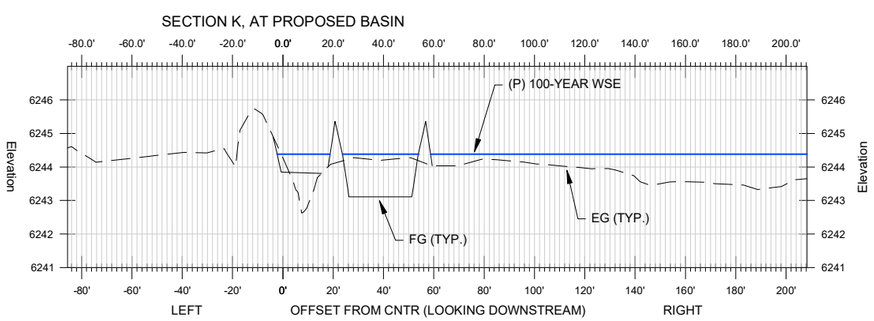


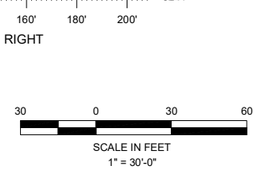


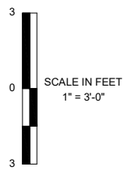












PROPOSED CROSS-SECTIONS

HORIZONTAL SCALE: 1"=30', VERTICAL SCALE: 1"=3', H:V=1:10

Nevada Tahoe Conservation District

APPENDIX 6 - CROSS-SECTIONS

BURKE CREEK - KAHLE DITCH SEZ RESTORATION

DESIGNED/DRAWN	PJ
CHECKED BY	MK
DATE	3/7/2023
SCALE	AS SHOWN
PROJECT	BCRMRRP - BCKD
SHEET	XS-2

3 OF 3

APPENDIX 7:

Project Civil Plans