# Fleish Flume, Overflow, and Tailpiece Replacement

## Historical Restoration / Preeservation under $5 million

TRUCKEE MEADOWS WATER AUTHORITY

Q&D CONSTRUCTION

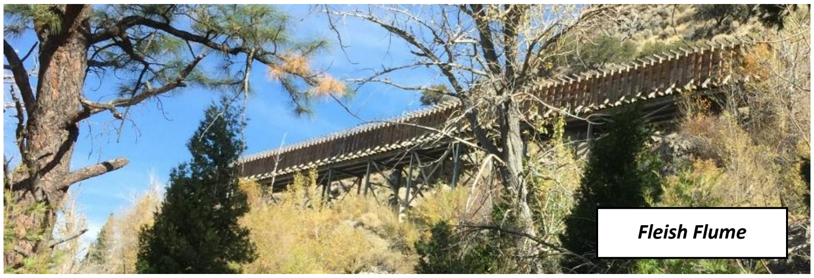
CME CONSTRUCTION MATERIALS ENGINEERS, INC.

HARTMAN STRUCTURAL ENGINEERING

## 2020 APWA Project of the Year Nomination – Historical Restoration / Preservation *under $5M*

### *Fleish Flume, Overflow and Tailpiece Replacement*

If you've ever driven from California to Reno, you've probably seen them – those wooden boxes on stilts running along the Truckee River. In the wintertime they become beautiful ice sculptures. You probably wondered what they were, what purpose they served, and if they are still in use. Yes, they are still in operation and are used to generate electrical power for the Truckee Meadows Water Authority (TMWA).



*Fleish Flume*

This unique and challenging project included removal and replacement of several key components of the historic Fleish Flume, overflow and turbine tailpiece structures. The challenging site included rugged, 30+ degree slopes preventing the use of traditional exploration, construction methods and equipment. Proximity to the highly regulated Truckee River heightened concerns for environmental protection, while working under water in the high flow of the Spring runoff heightened concerns for safety. Inaccessibility along the canyon slopes and within the river itself presented challenges during design to predict anticipated field conditions. Constant field adjustments by the design and construction teams were made to achieve TMWA's performance expectations. Constant communication, creativity and flexibility were imperative to the success of this project.

*Frozen icicles under flume*

### *Historical Significance*

At the end of the 19th century, the Reno area was still the wild, wild west. It was a time when mining on the Comstock (Virginia City) was in full swing. It was a time when Sierra timber was harvested in huge amounts for lumber and pulp. It was also a time before the widespread use of electricity, especially in Nevada.

Back then, the Fleishaker brothers of San Francisco were in the paper and cardboard business. They needed pulp for their Fleishaker Paper Box Company (later becoming Crown-Zellerbach). In 1899, they began building a new company-owned town called Floriston to support a new pulp mill. They also financed the construction of a new hydroelectric flume and electrical generator at Farad to produce power for the new town and to support one of the largest paper mills in the country. A railroad station and siding were built at a nearby place called Fleish.

After completion, excess electrical power from Farad was sold to nearby Reno. At this same time, Comstock gold mining was in its heyday. The Cornish pumps used to remove water from the deep mines were driven by coal-fired steam which added a great amount of heat in the already sweltering underground mines. In addition, coal was expensive in the remote West. These conditions made the lower cost of hydroelectric power very attractive. The electrical distribution system was quickly expanded and electricity was delivered from Farad to Virginia City on September 12, 1900. Seeing the growing need for electrical power, the brothers constructed two additional plants – Fleish (built in 1904 and commissioned in 1905) and Washoe (1905) - forming the Truckee River Power and Electric Company. Although the town and pulp mill are long gone, the Fleishakers' legacy lives on with this hydroelectric system, still in operation after 115 years.


Ditches were determined to be the most cost-effective means to transport large volumes of water to the power penstocks. However, the terrain along the Truckee River was not conducive to continuous earthen channels. Across depressions, over ravines, and around rocky cliffs, the water was transported using flumes. Because wood was strong, inexpensive and plentiful in the area, carpenters used great skill to assemble elevated boxes to transport a moving column of water eight feet wide and up to six feet deep and as high as 36 feet above the ground. The system was frozen solid in the winter and baked in the dry Nevada summers. It was understood at the time that the system would require regular maintenance and would also be prone to damage from rockslides, flooding, and old age. Typically, the upper structure would require replacement every 20 years with structural supports replaced every 40 years or so. Zooming ahead 100 years, this original life-cycle concept remains consistent today. Thus, maintenance and replacement are regular duties.

*Project Scope*

In 2018, TMWA anticipated replacing several sections of the Fleish Flume and the wooden chute that dumped overflow water from the penstock back into the Truckee River. The overflow support system and turbine outflow had very little-known history of replacement. Because of this, transitioning an archaic structure to meet the needs of current seismic codes presented a daunting challenge. Unexpectedly, before the 2017 flume reconstruction season began, one of the two iron turbine outlet pipes broke off into the Truckee River causing a loss of 15% of the generating power and creating an imbalance in the two parallel Francis turbines. Believed to have been part of plant modernizations made in the 1930s, the riveted pipe simply rusted away.

As a result, in 2018 TMWA released three contracts - one to replace sections of the wooden flume, one to replace the wooden overflow and one to replace the two tailpiece pipes. Q&D Construction was awarded all three contracts. Even though they were separate contracts, they were essentially one project in three separate parts.

*Unusual accomplishments under adverse conditions including, but not limited to age or condition of the facility, adverse weather, soil or other site conditions over which there is no control.*

Challenges began during design in the geotechnical phase. Early in the spring of 2018, the steep slopes in the shaded canyon containing the flumes remained snowy and frozen. The structures were precariously balanced on wooden legs with no foundations, including one section more than 24 feet in height. A majority of the alignment was inaccessible for exploration equipment and was barely accessible for hiking. Because the structures were aged and ready to be replaced, many areas were simply not safe to access. The geotechnical team found highly unstable slopes, large boulders perched above the structures, exposed bedrock, and active drainage ravines. It was decided to keep the existing alignment intact as much as possible and use best judgment practices from site observations and limited borings and adjust the design to field conditions during construction.

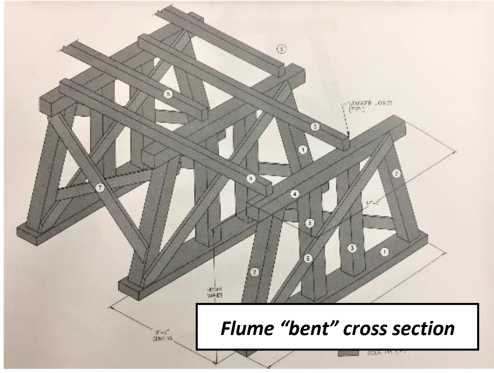
**Powerhouse "doghouse"**

The overflow structure was balanced on wooden legs with no foundations and was perched on a 30-degree slope above an 80' cliff. Seismic requirements dictated that the new support system be constructed of structural steel. The steel supports required modern concrete footings constructed on an inaccessible rocky slope. Assumptions of bedrock conditions were made from visual inspection with the design to be finalized after the bedrock footings were excavated.

Replacing the broken tailpiece pipe presented a daunting challenge. The outlet broke off when the river flow was high. The structural engineer had to wait until after the spring runoff had subsided to conduct an inspection. The only access was by rowboat in the swift current. Access was further complicated because the outlets were located in a recessed archway submerged in the river underneath the building with a cantilevered concrete doghouse perched above. Again, several conditions regarding the pipe connection and rubble building construction had to be assumed because of the nearly impossible access.

*Design*

The flume was to be rebuilt with no foundations. Evolution in design over the past 100 years showed that the structure was most stable on wooden cross beams notched to support upright posts with notched cross beams above forming what are known as "bents." Longitudinal beams spanned between the "bents" with a wooden box constructed on top to contain the water. Design for the soils supporting the frame was reasonably straightforward. The contractor was to construct access roadways and level the alignment using modern earthmoving equipment. Subgrade was stabilized and flattened using coarse aggregates to allow free drainage of surface runoff and flume leakage.

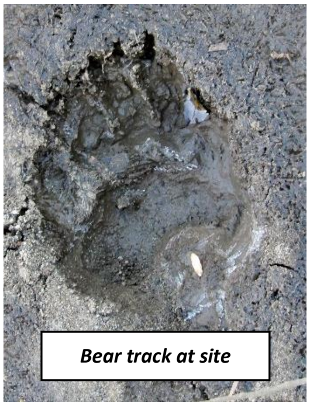


**Flume "bent" cross section**

Steel subframe

The overflow structure was to be entirely replaced with modern steel framing. Concrete footings were to be excavated into bedrock incorporating prestressed rock anchors. The challenge in design was not knowing a precise elevation of stable bedrock due to the presence of underbrush, surface soils, and boulders. Even walking the steep slope above the sheer drop-off was not safe. Complicating matters further, the overflow structure also spanned the historic but operational Steamboat Irrigation Ditch owned by others, which could not be excavated for geotechnical exploration.

### Flume Construction



Bear track at site

Construction on all three segments commenced in the fall of 2018. Access roadways were pioneered to allow removal of the flume lumber. The terrain on certain portions of the site was so rugged that helicopters were used to remove the waste materials. As the fall progressed to winter, the sun hit the frozen canyon site for only a few brief hours each day. Earthwork was further complicated by one of the wettest winters on record. Paw prints frozen into the newly placed soils indicated the regular presence of bears, mountain lions, racoons and coyotes.

During construction, the contractor proposed that it was more efficient to level the subgrade as much as possible to make the bents more consistent in height instead of custom fitting each frame. It was decided that constructing and maintaining 24' tall bents did not make good economic sense. As a result, the contractor provided a more level subgrade than originally designed, filling the depression to shorten the wooden legs. Top-ground concrete piers were added to prevent runoff erosion in the ravine. Field adjustments such as these occurred regularly, requiring a collaborative effort of the design team, the contractor, and TMWA, adapting to field conditions while still meeting the intent of the design.

Spider excavator

### Overflow Construction

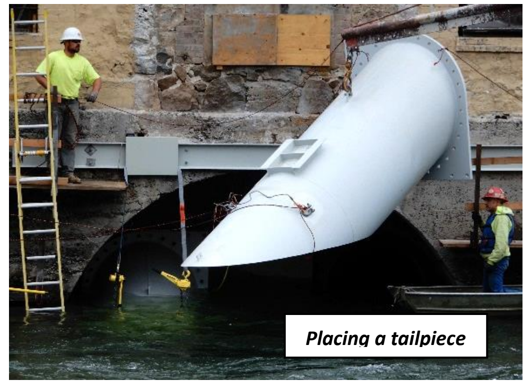
The steep slope at the overflow necessitated the use of a specialized "spider" excavator capable of clinging to the 30+ degree slope and hammering footings into the bedrock. The excavator was also fitted with a drill head to bore holes for the prestressed rock anchors. During excavation of a footing near the Steamboat Ditch, a concealed schist in the bedrock necessitated the immediate redesign of the footing adjacent to the channel from a bearing condition to a cantilever design integrating additional rock anchors. For this part of the project, constantly changing subgrade conditions, clarifications for footing elevations, and challenging weather required weekly (sometimes daily) meetings with the design team who often worked overnight to provide solutions and minimize impact on project schedule.

Testing rock anchors

### Tailpiece Construction

The condition of the existing turbine outlet structure was impossible to determine until construction began since the remaining tailpiece remained submerged in the Truckee River. The first order of business was to improve access by removing the obsolete concrete doghouse cantilevered over the recessed tailpiece arch. TMWA had great concerns that no demolition debris would end up in the river. A series of catch nets surrounded the structure as the contractor cut the structure free and lifted it by crane to the shore. The concrete doghouse was demolished and transported to a crushing plant for recycling. Access remained difficult because the outlet pipes were in an arch tunnel recessed six feet inside of the building exterior walls. A preliminary investigation by SCUBA divers concluded that the inverts of both tailpiece pipes had rusted away and large holes cavitated into the concrete encasement. With the removal of the second tailpiece pipe, the structural engineer was able to confirm corrosion and cavitation in both pipes. Not anticipating the cavitation, the structural engineer drafted a revised repair whereby the existing pipes would remain, the cavitation holes would be filled with grout, and a steel invert would then be welded to the existing pipe to protect the grout.

Connections to the turbine were disassembled but the only access to the damage was from the river side. Exterior access was limited because the top of the recessed arch was less than five feet above the water surface during high flow, leaving both pipes three-fourths submerged. Regulators controlling the river mandated that the contractor could not construct a cofferdam or bulkhead to allow work in dry conditions without a multi-year review period. So, divers worked submerged in the 45-degree water to remove all loose materials from the cavitation holes before water blasting the remaining surface. Because the repair area was under the surface of the cold water, special high-strength subaqueous grout was selected and pumped into the voids.



***Placing a tailpiece***

***Diver working in the Truckee River***

The engineer determined that the new tailpieces could be mounted to the original grouted rubble wall using epoxy anchors. Repairs commenced during the winter months when the river was anticipated to be at its lowest height, however placing the new tailpieces would not be completed until the spring runoff had commenced.  The river elevation fluctuated more than 6 feet during construction. The steel invert was welded and held in place using structural anchors. Specialty grout was used with field-cured test samples suspended in the chilly waters to verify in-situ strength.

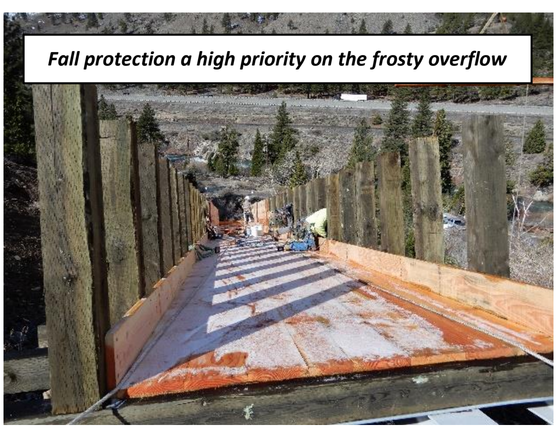
Attaching 2,500 lb. pipes to a 114-year old rubble masonry wall underwater also presented a massive challenge. The divers drilled into the wall utilizing templates that matched the bolt pattern on the new flanges. Underwater epoxy was injected prior to insertion of the new anchor bolts. With no room for error, the bolts had to be straight, level and plumb to match the holes on the flanges. Once completed, the new tailpieces were counterbalanced on a crane and lowered into place. Because of the care taken in preparation, the new pipes were mounted quickly and easily. With daily communication between the owner, designer and contractor during construction, the project was completed successfully and is operating smoothly.

***Divers attach the tailpiece to the rubble wall***

*Use of good construction management techniques and completion of the project on schedule.*

Teamwork was paramount to success on this project. Effective communication between field, office, and design teams was key to getting the job to meet the intent of the design given the constructability challenges. Despite the challenges, the owner, designers, and contractor completed the flume and overflow systems on time. The unexpected high water in the river due to the unusually wet winter complicated completion of the tailpieces.

*Safety performance and demonstrated awareness for a good overall safety program during construction.*



***Fall protection a high priority on the frosty overflow***

Despite numerous hazardous conditions presented by inclement weather; icy structures; steep and unstable slopes; construction perched above a cliff; with lions and bears; the project was completed with a very good overall safety record during design and construction.

Project vehicles utilized an uncontrolled crossing of the Union Pacific Railroad main east-west track. Because this track is quite distant from Reno, numerous trains each day were moving down the line at high speeds. The construction activities required dozens of crossings every day with heavy equipment and construction vehicles. Other than several very prolonged waits due to trains stopped across the only crossing, no complications or incidents were reported.

*Community relations as evidenced by efforts to minimize public inconvenience due to construction, safety precautions to protect lives and property, provision of observation areas, guided tours, or other means of improving relations between agency and the public.*

The construction occurred on a very popular hiking and biking trail along the Truckee River. TMWA allows access along this service corridor as a courtesy to the public. Unfortunately, trail access had to be closed for safety reasons due to the presence of large earthmoving equipment. Fortunately, much of the construction occurred during the wet winter months when trail usage is minimal. Fishermen and kayakers were generally uninterrupted in their use of the river during construction. Because of the remote conditions, the general public was not impacted by construction activities.

Several small tours were conducted during construction. TMWA maintains a policy of openness to customers and tours of these historic hydroelectric facilities are available; see *TMWA.com* for details.

*Demonstrated awareness for the need to protect the environment during the project. This includes any special considerations given to particular environmental concerns raised during the course of the project.*

Any project constructed adjacent to the Truckee River is restricted by numerous environmental issues. TMWA has a particular interest in protecting the Truckee River because it is the single largest source of drinking water for their facilities and their customers. During flume and overflow construction, the contractor worked on the slopes above the river. Upslope construction was protected by a full SWPPP program with various runoff measures placed and maintained by the contractor. Final slopes were treated with various methods to protect against runoff velocity and erosion.

During tailpiece construction, the specialty diving subcontractor that worked in the river has regularly provided underwater construction services in the pristine waters of Lake Tahoe and was fully versed in environmental protection. Special measures included lubricating hydraulic equipment with non-hydrocarbon oils certified safe for drinking water. Special floating barriers were positioned in the river to contain and absorb any possible leakage from the construction activities.

The mountain of waste wood generated during demolition was not landfilled. The lumber was pulverized by a subcontractor, removed from the site and used as slope protection or incinerated to produce electrical power.

*Additional conditions deemed of importance to the public works agency, such as exceptional efforts to maintain quality control and, if value engineering is used, construction innovations as evidenced by time and/or money saving techniques developed and/or successfully utilized.*

This project was a model for innovative design and construction solutions to difficult field conditions. It seemed that every day a new challenge presented itself. Many of the changes made during construction increased the construction cost but will result in a reduction of long-term costs for future maintenance and repair. During construction of the flume, a very large and undermined boulder abutted the flume alignment. After several negotiations, all of the solutions proposed were deemed not to be cost-effective. During construction, the void under the boulder was filled with grout. After construction was completion, runoff drainage continued to destabilize the mammoth stone. TMWA innovated again by drilling inclined steel columns below the boulder to prop it up. Now if the boulder settles further, it will stabilize atop the steel columns ensuring a longer-term solution at a reasonable cost.

*Use of alternative materials, practices or funding that demonstrates a commitment to sustainability and/or use of sustainable infrastructure.*

Power costs are one of TMWA's largest operating expenses. These hydroelectric power plants are a significant source of clean, renewable energy, generating on average 50 million kWh per year, depending on river flows. The TMWA hydroelectric plants save 15,000 metric tons of $CO_2$ every year. Since 2007, TMWA's pumping and treatment facilities have consumed an average of 50 million kWh per year, with these plants offsetting 60% of TMWAs energy costs and lowering water rates by 3% to customers. Not bad for 115-year old green energy!