HARTMAN
STRUCTURAL ENGINEERING

May 30, 2014
Job #1614

Brent Eisert, P.E.
Truckee Meadows Water Authority
1355 Capital Blvd.
Reno, NV 89520

RE: TMWA Flume Structural Evaluation

Dear Brent,

This letter presents the results of our Structural Evaluation of the wood flume along a portion of the Truckee River. The location of the flume that we evaluated is roughly between Box 49 to Box 134. Photographs 1 through 3 in the Appendix represent the overall appearance of the flume. Our scope of services was to review the As-Built flume condition and offer an opinion as to its structural adequacy. Our evaluation and comments are somewhat general in nature since we did not conduct a detailed analysis of the structural systems associated with the flume.

On May 5, 2014, we walked the flume along the river and conducted a visual inspection of the structural systems. It is our understanding that this portion of the flume was constructed around 1970. For the purposes of our evaluation, the flume can be separated into two parts, the Water Conveying System and the Primary Structural Support System. The Water Conveying System is generally comprised of the upper portion of the flume which holds and conveys water. This structural system utilizes wooden planks supported by a series of vertical wood posts tied together with notched struts. The posts are connected to the struts with metal straps. This construction can be seen in the Appendix and Photographs 4 through 9. Water depth varies, but can be as high as eight feet. This system remains stable as the water exerts equal pressure on each side of the flume.

The Primary Structural Support System supports the upper Water Conveying System and consists of timber post and beams forming a bent in the transverse direction. These bents are spaced between six and ten feet apart and vary between five to over twenty feet in height. Photographs 10 through 14 are indicative of this structural system. For the purpose of this report, our discussion will focus on the Primary Structural Support System since we believe this system is the most susceptible to failure.

The bents comprise the main structural system that supports the weight of the water. Typically these bents are comprised of four vertical posts supporting a horizontal cap beam. Timber stringers supporting the Water Conveying System above connect the bents in the longitudinal direction. Both the timber stringers and cap beams are toe nailed to each other as well as the cap beams to the vertical posts as can be seen in Photographs 15 through 21. These nailed connections only marginally hold the members together. There are some areas where the members are only partially if at all connected. Photographs 22 through 29 show twisted members and connections held together with only wedges. The bents are sporadically cross braced by boards in both the transverse and longitudinal directions.

In general terms the bent connections can be thought of as hinges. Hinges allow the members to rotate about the connection point. As long as the forces and loads remain vertical and are applied symmetrically to the structure, it will remain stable. Since the toe nailed connection does not contribute to the rigidity of the structure, the bent is a structure with movable parts (hinged connections) that have the ability to rotate. In Engineering terms this type of structure is referred to as a Mechanism and is geometrically unstable. Obviously, the supporting flume structure is still standing and the connections exhibit some rigidity. The cross braced boards also contribute

6180 Mae Anne Avenue
Suite 5
Reno, Nevada
89523

Telephone:
(775) 786-4717
Facsimile:
(775) 786-4733
www.hartman-se.com
mail@hartman-se.com

to the present stability of the structure. However, speaking from a strictly analytical point of view, the Primary Supporting Structure is geometrically unstable. In fact, the current configuration cannot even be modeled in a computer program due to its geometric instability. Even though the timbers and posts are large and substantial, geometric instability is independent of the individual strength and rigidity of a structure's members and more a function of its connections.

Although, at the present time the flume system is stable, if a significant lateral load such as a force due to a seismic event is induced on the structure, the stability of this type of structure would be greatly reduced and from an analytical perspective non-existent. Currently the structures lateral force resisting system can only be loosely defined as a partially rigid frame and partially braced system with woefully substandard connections. In a seismic event the lateral forces are distributed relative to the structure's mass distribution. In simple terms the greater the mass of an object, the greater the lateral force it will exhibit in a seismic event. Since the water is contained at the top of the bents and is relatively heavy compared to the supporting members, the flume will experience large horizontal forces and displacements in a seismic event that will be magnified through the structure's connections. The taller the structure the greater the displacements. The connections observed during our site visit do not provide a positive restraint to resist a significant horizontal force. All of the connections are inadequate; however, of particular concern are the connections shimmed with wedges. These connections can again be reviewed in Photographs 25 through 29. Again as previously stated, as long as the loads remain vertical and are symmetrically applied to the bents, the structure will remain relatively stable. Because of the structure's geometric instability, the introduction of a significant lateral force will most likely lead to a total collapse of the system.

Another significant point to consider relating to the bent connections and members is their reduced capacity due to deterioration. In many places the wood has deteriorated to a point where the members are crushed or the member's section properties have been compromised. This can be seen in Photographs 30 through 33. Many nail diameters have been reduced due to deterioration which will greatly reduce the connection capacities. This deterioration is difficult to detect since much of it is found inside the members rather than on the surface.

Another significant concern is the foundation system supporting the bents. Many of the bent posts are precariously situated on questionable and unreliable foundations. Photographs 34 through 49 depict some of these conditions. In some instances it appears that only friction is keeping the post in place. Many of these conditions not only simulate a hinge, but an even worse roller support condition where the post is prevented from moving in only the vertical direction, but allowed to move in any direction horizontally. Photograph 50 is a good example of this condition. The only restraining elements that keep the post from sliding off the supporting blocks are the toe nails and friction. The presence of water does not help in the connections restraint. Photographs 51 and 53 also show this condition. The stacked blocks in Photograph 51 only exacerbate the roller condition. The diagonal board in the picture appears to be the only restraint that keeps this post from kicking out other than friction and a significant split can be seen in this member. Many support conditions as depicted in Photographs 52 and 53 do not even have a diagonal board brace. These diagonal board braces are essential to hold the posts from kicking out and most of them are randomly placed as can be seen in Photographs 54 through 57.

The taller portion of the flume is located in steep rock outcrops. This necessitates locating the posts in tight niches, many in which there is little bearing capacity. These conditions are shown in Photographs 58 through 69. As the rock becomes weathered, the bearing capacity of these members is further reduced along with the ability of the supporting "foundation" to restrain the bent posts. Not only are these foundation connections substandard as far as resisting forces due to ground motions in a seismic event, they are susceptible to failure due to other conditions such as rockslides or floating debris in the river. Since the post connections to the supporting foundation system is not restrained, the flume may be subject to collapse in the event of a rockslide or flood due to the external forces these events may exist. Photograph 70 is a good example of the potential for a failure due to a rockslide. Photographs 71 and 72 also show areas where falling rocks have impacted the posts, but luckily not to a failure. Photographs 73 and 74 show several other areas that are probable unstable conditions where falling rocks could impact the bent posts.

Inherent in any structural design is a continuous load path with adequate strength and stiffness to transfer forces from their point of application to a final point of resistance. All parts of the structure must be connected to form this continuous load path and provide for a lateral force resisting system that is capable of transferring the forces through its members and connections to the foundation system. The foundation system must be capable of resisting these forces and also accommodate movements imparted to the structure by ground motions during a seismic event. The flume structure has a vertical force resisting system, but a weak lateral force resisting system. The lateral capacity of the flume is limited by a lack of positive member connections, inadequate bracing and unrestrained foundation connections as well as an inherent geometric instability. Deterioration of the members has also weakened the structure and further reduces its capacity both as a vertical and lateral force resisting system.

The construction of this portion of the flume is a tribute to the men who worked on the project as this structure has adequately performed for many years. Due to severe accessibility constraints, it was a very difficult system to construct. The terrain limited the placement of many of the bent posts. The flume was constructed in an era where seismic conditions were less understood than today. As such its structural system does not address lateral forces as we know them today. It has also not been subject to significant ground motions that will induce these lateral forces. This report has noted several deficiencies regarding the lateral force resisting capacity of the flume structure. In our opinion, these deficiencies are significant as to the overall performance of the structural system of the flume.

Please give me a call should you have any questions.

Sincerely,

Hartman Structural Engineering, LLC

Stephen J. Cooper

Stephen J. Cooper, P.E.

SJC/sh