RJH CONSULTANTS, INC.

MEMORANDUM

Project 14107

TO: **Craig Roepke – Bureau Manager**

FROM: **Michael L. Graber, P.E.(1) – Project Manager**
Robert J. Huzjak, P.E. – President RJH

DATE: **May 30, 2014**

RE: **Technical Review of BHI Draft Final Preliminary Engineering Report Gila River Diversion, Conveyance, and Storage Alternatives Report**

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1.0 Introduction

1.1 Purpose

The purpose of this memorandum is to present the results of our technical review of *Preliminary Engineering Report (PER) Gila River Diversion, Conveyance and Storage Alternatives*, January 2014 prepared by Bohannan Huston, Inc. (BHI) for the New Mexico Interstate Stream Commission (ISC). RJH Consultants, Inc. (RJH) was tasked with identifying significant issues that may significantly impact the technical and financial results and conclusions presented in the PER. This work was performed in general accordance with Work Order ISCGR-14-1 dated April 1, 2014.

1.2 Preliminary Engineering Report Objective

We understand that the objective of the PER was to identify options for diverting, conveying, and storing a minimum of 10,000 acre-feet (ac-ft) per year from the Gila River between Turkey Creek and Cherokee Canyon, near the towns of Gila and Cliff, New Mexico. Six potential off-stream dam and reservoir sites and three new river diversion locations were identified. The new river diversions could be used to divert water to the new storage reservoirs. The PER recommended an alternative that diverted water at Elevation (El.) 4695 from the Gila River, downstream of the confluence of the Gila River and Turkey Creek. Diverted water would initially be conveyed into a tunnel and then into a series of closed conduits that would deliver water to four off-stream dam and reservoir sites. The dam and reservoir sites were located in Winn, Pope, Sycamore, and Dix Canyons and provided a total storage capacity of approximately 70,000 ac-ft.

1.3 Technical Review Summary

In our opinion, an appropriate level of investigation, data collection, and analyses was used in the PER to develop conceptual-level project planning and costs for the following project components:

1. River diversion locations and diversion types.
2. Conveyance conduits and locations.
3. Development and selection of a recommended alternative.

In our opinion, several project components were not adequately addressed in the PER and it is currently unknown if these components represent significant technical challenges or potential fatal flaws. These include:

1. Storage reservoirs and dams.
2. Project water availability.
3. Gila River sediment.

Although all of the above items are important, the dams and reservoirs are complex, dominant, and expensive project features and appropriate evaluation of these components require a specialized level of experience and expertise to evaluate and develop feasible concepts, especially with limited data. The PER conclusions and recommendations would benefit from input by personnel having extensive experience in design and construction of dams and reservoirs.

2.0 Identified Significant Project Issues

This section provides our opinion of significant issues we identified. Our opinions are based on our review of the information in the PER, discussions with BHI, and our experience.

2.1 Dam Site Geology

The *Preliminary Geology and Geotechnical Services Report* dated December 17, 2013, compiled by Geo-Test identified significant geological and geotechnical issues associated with constructing dams and reservoirs at the selected dam sites. These issues include highly permeable reservoir basin soils for use as dam embankment borrow, highly permeable abutment and foundation soils, and bedrock that is estimated to be an average of 50 or more feet below existing ground surface. The closest identified source of suitable dam core material was approximately 15 miles from the dam sites and the possible quantity of the core borrow source was not estimated. All of these issues represent significant technical challenges and project costs related to constructing safe and reliable dams and reservoirs. Additional risks are identified below:

- The highly permeable soils in the reservoir basins could result in significant seepage losses that could exceed evaporation losses. The PER tabulated a total of 6,140 ac-ft of evaporation per year at full reservoir storage for the four recommended Alternative 2B Reservoir sites. Based on information on Page 10 of a report dated August 2013 for the New Mexico Interstate Stream Commission titled *Review of Aquifer Characteristics in Gila Group Aquifer & Preliminary Design of Wells and Evaluation of Well Performance in Grant County, New Mexico* the hydraulic conductivity of the upper Gila Conglomerate ranges from about 1 to 10 feet per day. The Upper Gila Conglomerate appears to be the predominate material at the selected reservoir sites according to the Geo-Test Geology and Geotechnical Services Report dated December 17, 2013. Based on this conductivity data and an assumption that the entire reservoir basin consists of this Upper Gila Conglomerate, seepage losses for the four reservoirs could be tens of thousands to hundreds of thousands of ac-ft per year. If the Gila Conglomerate at the selected reservoir sites is the well cemented unit, the hydraulic conductivity is anticipated to be between 0.0013 and 0.7 feet/day, and the corresponding combined seepage losses for the four reservoirs could be in the range of 600 to tens of thousands of ac-ft per year. The broad range of potential seepage losses highlights the importance of evaluating the hydraulic conductivity of the reservoir basin soils. The expected seepage losses, when combined with the evaporation losses, could easily equal or exceed the planned minimum annual diversion yield of 10,000 ac-ft, which would result in no available usable water from the project.

- Deep dam foundation cutoffs in highly permeable soils are challenging to construct and normally very expensive. Understanding the nature of the foundation bedrock is also very important in developing an effective strategy to manage seepage losses and seepage safety. No information was provided on the general properties of the bedrock so it is unknown at this point if the hydraulic conductivity of the bedrock is low or high. Some minimal understanding of the bedrock based on general geologic mapping should be used to develop an understanding of bedrock properties and how these properties will impact the feasibility, design concept, and cost of dam construction.
- If not properly addressed, the identified highly permeable dam abutment soils at the selected Alternate 2B dam and reservoir sites represent not only a significant source of reservoir seepage but a significant dam safety risk.
- The lack of suitable onsite material for construction of the low permeable core represents a significant technical challenge and project cost. While a single borrow source of potential core material was identified 15 miles from the dam site, the potential quantity of material available at this borrow source was not identified. Without some initial understanding of the available volume of this core borrow source, no evaluation could be made as to the adequacy of the borrow source for constructing the proposed dams. Also, the cost to haul suitable core material from a distant source is significant and if the borrow source lacks sufficient volume to construct the dam cores, additional and potentially more distant borrow sites would have to be identified.

All of the listed conditions represent potential fatal project flaws either from a technical or financial standpoint. Although the PER is a conceptual-level planning document, potential fatal flaws that are known should be identified in the PER and the technical and financial challenges to address these potential fatal flaws should be identified and quantified. The Draft Final PER does not adequately address the potential fatal project flaws in regards to the selected dam site geology.

2.2 Project Water Availability and Yield

The PER stated the 2004 "Arizona Water Settlements Act" (AWSA) allocated an annual average 14,000 ac-ft of water from the Gila River and the project objective was to supply an annual "safe" yield of 10,000 ac-ft per year. The term "safe" is assumed to indicate minimum yield. Constraints were placed in the AWSA on when the project could divert and store. These constraints included no diversions when the Gila River flow was less than 150 cfs and the maximum diverted flow could not exceed 350 cfs. No discussion or analysis is presented in the PER that addressed timeframes when these constraint conditions would be met and when the project would be allowed to divert and store based on historical stream flow records and required deliveries to senior water rights and downstream states.

The PER did not contain a discussion or quantification of the projected annual diversion yield available to the project based on historical flow records and deliveries other than stating the assumed safe yield would be 10,000 ac-ft. This information is needed to support sizing of the reservoirs and conveyance facilities and the opinion of safe yield.

The PER did not discuss or quantify the projected annual net yield from the project taking into account evaporation, seepage losses, and transit losses associated with diverting, storing, and delivering project water. Projected annual reservoir evaporation losses were tabulated but not expressed as a percentage of the project annual gross yield.

The projected net project yield is the foundation for justifying the project. When estimating the net project yield, Gila River historical flow and diversion records, past and projected future hydrologic cycles of drought and higher than average precipitation should be compared to computed system losses to evaluate long-term project viability.

2.3 Project Cost Estimate

The cost estimate for the recommended Alternative 2B and other alternatives did not include costs for major elements required to safely design and construct zoned embankment dams. The costs for some of the tabulated cost items were substantially understated and the uncertainty in the costs for foundation treatment (seepage control) were not identified. Additional information is provided below:

- The dam embankments were treated as homogenous dams when developing quantities and associated costs. The dams were conceptualized in the Geotechnical Report to be zoned earthfill, which is appropriate and would be required to meet dam safety criteria. Considering the dams to be homogeneous resulted in severely underestimating the cost for higher priced zones in the embankment.
- Quantities and the associated cost for the dam core were not included in the cost estimate. The cost to transport, condition, place, and compact core material could be from 10 to 20 times more expensive per unit volume than shell (general) embankment material.
- Quantities and associated costs for drain and filter material were not included in the cost estimate. While the Geotechnical Report indicated that it may be possible to process these materials from onsite borrow sources, the cost to process and place these materials in a zoned earthfill dam could be 10 to 20 times more expensive per unit volume than general embankment material.
- Quantities and the associated costs for embankment upstream slope protection were not included. The cost to develop and place upstream slope erosion protection would likely be in the range of a million dollars.
- A unit cost of $2.00/cubic yard was used as a basis for placing general dam embankment fill material. Gradation, lift thickness and moisture-density requirements for embankment dams are held to a higher standard than roadway embankments and are on average significantly higher in cost. In our opinion, a unit cost in the range of $3.00 to $3.50/cubic yard would be a more appropriate value to use for a conceptual level cost estimate.
- There was a cost estimate item for gate house and control, which was generally $50,000 for each dam. We are not sure what this includes, but this could not have included the outlet works intake structures, conduits, gates or valves, or discharge and energy dissipation structures. The hydraulic control units for the gates or valves alone would be more than $50,000. It appears that the costs for the outlet works may not be included. These costs for the outlet works would be significant for high hazard dams over 100 feet in height.
- There was not a cost item for foundation and abutment seepage management. The geotechnical report indicated deep seepage cutoffs would be required and that dam abutment seepage is expected to be significant. The expense of providing seepage cutoffs in the dam foundation and abutments will be significant. Based on depths of

at least 50 feet to bedrock and experience on other projects, costs for foundation and abutment seepage management will likely be millions of dollars.

- There was a cost for a concrete spillway but it appears to only include a channel. No concept was provided, but it did not appear to include a control structure, energy dissipation structure, drainage facilities, or earthwork. The cost of these other spillway components for a large spillway to safely route the Probable Maximum Flood (PMF) are expected to be millions of dollars.
- A permitting cost of $120,000 per dam was used but, based on recent experience with dams of comparable size requiring an environmental impact study, a permitting cost more on the order of $500,000 to $1,000,000 per dam would be more appropriate.
- There were no costs for dam instrumentation tabulated. Although these would not be significant, they could approach $100,000 for a high hazard dam that is over 100 feet in height.
- A value of 5 percent of the estimated construction total was used to estimate the design costs for each dam. It is assumed the 5 percent was to include the geotechnical investigation and analyses because these required design items were not tabulated in the cost estimate. This is low for dams, especially for dams with challenging geotechnical and geological conditions.
- A value of 20 percent of the estimated construction cost total was used to account for contingencies. A value of 20 percent of the construction total to account for contingencies is more appropriate once there is site-specific geotechnical data and some design work is complete. It is our opinion that the contingency should be more in the range of 30 percent at this level of project development, especially when the geological conditions are uncertain.

It is our opinion that the total cost for the project may be significantly low. There is considerable uncertainty in many geologic and design concepts for the dam and some of the required elements of the dams were not included. In addition, some of the unit costs are unrealistically low. When all of these elements are considered it is our opinion that the cost of the dams could be underestimated by more than 100 percent. Therefore, it is our opinion that the overall project costs may be 25 to 50 percent higher than the current estimate.

3.0 Technical Comments

This section contains technical comments concerning details presented in the PER that, in the opinion of RJH, should be more completely evaluated and further refined. In our opinion these issues probably do not represent potential fatal flaws, but additional analyses or data is needed to confirm project feasibility.

3.1 Stated Project Tasks

Project Objectives, Section 1, Page 2 of 55 – One of the listed project tasks is to develop 30 percent conceptual designs for planned project diversions. While important, the development of the diversions is a relatively minor project component when compared to the requirements, risks, and cost of constructing the proposed large dams and storage reservoirs and confirming water availability and yield. It is unclear in the PER why the scope of work required these components to be advanced to a higher level of design than the dams.

3.2 River Crossings

River Crossings, Section V, Page 17 of 56, identifies underground conveyance piping as being drilled or jacked under the river flowline. The presence of previously identified river alluvium at crossing locations that could contain larger materials or variable subsurface conditions may make this construction approach difficult and risky. Without specific geotechnical data, we would recommend development of the project cost using a more conventional method (shored excavation) to evaluate feasibility. This would account for the risk and uncertainty at this level of study. The two costs could be used to develop a cost range for planning purposes.

3.3 Sediment Control

Sediment Control, Section V, Page 17 of 56 states natural storm runoff is often laden with sediment and should be mitigated by construction of stormwater detention facilities upstream of the storage reservoirs. There is no mention of mitigating the sediment contained in the diverted Gila River flows. A U.S. Geological Survey Study for data collected between 1959 and 1967 indicated a significant concentration of very fine, smaller than 0.0625 mm, suspended sediments contained in the flows measured at the Gila River Gauge near Gila, New Mexico. Sedimentation could have a significant impact on design, sizing, and feasibility of the diversion, conveyance, and storage reservoirs. Management of sediment could be technically challenging and very expensive both in terms of capital cost and operations and maintenance costs. This potentially important issue does not appear to have been addressed. Depending on the results of this evaluation, this could become a significant project feasibility issue.

3.4 Category 2 Diversions

The PER, in Section VI, Page 25 of 55, for the selected category 2 diversion sites recommends concrete weirs with coanda screens. While these types of filtering screens can be effective in removing debris and larger diameter suspended sediment particles from the river surface flow, they do not function well for the very small diameter sediment particles found in the Gila River. Data compiled by the New Mexico Interstate Stream Commission found that much of the Gila River sediment was finer than 0.0625 mm. Based on design data for coanda screens, sediment particles finer than about 0.10 mm are not generally removed by flow through the screens.

As an alternative, a stainless steel cage screen located in the river alluvium would take advantage of the natural filtering action of the alluvium and could be enhanced with a constructed multi-stage sand and gravel filter encompassing the cage screen. The alluvium would function to remove large sediments from the river flow and the constructed sand and gravel filters encompassing the caged screens would progressively filter out the fined grained particles. If the constructed sand and gravel filters are correctly graded to be filter compatible, they generally do not plug, even over long time periods. The graded filters stop the finer grained sediments from being transported through the filter but allow the alluvial flow to pass into the caged screen. No estimate of hydraulic conductivity of the alluvial soils is provided for the selected sites so it is not possible to estimate an approximate size and number of caged screens required to satisfy the project diversion criteria. Performing appropriate testing of the alluvium at the selected diversion locations would be necessary to estimate appropriate values for hydraulic conductivity.

Section VI, page 28 of 55, the PER indicates the elevation of the diversion trough and coanda screen will be set such that once the river flow exceeds 150 cfs, water will begin to flow through the screen and into the trough. The dimension of the screen and trough will be sized to convey a maximum of 350 cfs. In a natural stream channel with ever-changing channel geometry, changing deposited sediment levels, and changes in available head due to variable river stage, we question the ability of the proposed diversion system to operate within the very limited project range and, over time, may either begin to divert too little flow or too much flow.

3.5 Category 1 Diversions

Section VI, Page 32 of 55, the PER states the category 1 diversion structures be designed to withstand high flows up to 30,000 cfs. This statement appears to be based on the recent September 2013 flood event that washed out the existing category 1 diversion structures, but this assumption is not stated or justified. Based on stream flow records at least two recent Gila River high flow events have exceeded the September 2013 high flow event. The basis for the selection of the 30,000 cfs flow is not defined, but it might be lower than appropriate for a project of this magnitude.

3.6 Stormwater Detention Facilities

Section VI, page 37 of 55 details the Storm Water Detention Facilities Sizing. No general details of construction are provided for the planned detention facilities, only that they are planned to detain runoff from a 100-year storm event. To be effective as runoff sediment control, the structures would have to be located on-channel. These facilities would have relatively small outlet discharge pipes that would be designed to route a 100-year inflow design flood through a combination of short term detention storage and outlet capacity. Floods of larger magnitude would certainly overtop the detention dam embankments resulting in an erosional failure of embankment. The downstream storage reservoir would probably be able to route the detention dam failure but the accumulated sediment behind the dam would be deposited in the storage reservoir basin. The impact from this sediment should be considered.

4.0 Recommendations

This section provides our opinion of work that should be performed to address the primary issues we have identified in the PER. In discussing the ISC PER scope and background with BHI, we understand that some of the following may be included in a subsequent ISC work order for the Gila River project. We have identified our recommendations for additional studies in a priority order. After each task is complete the technical and economic feasibility should be evaluated before moving on to other tasks:

1. **DEVELOP TYPICAL CONCEPT PLANS AND SECTIONS FOR THE ALTERNATE 2B DAMS** - Develop a general concept for each dam and ancillary facility (outlet works, spillway) including a plan view, and typical transverse and longitudinal sections for each of the four dams listed in the recommended Alternate 2B dams. Utilize plan views and sections to develop appropriate quantities required to construct zoned earthfill dams, which were not included in the conceptual-level cost estimate.
2. **REVISE THE CONCEPTUAL LEVEL COST ESTIMATE** -
    a. Update the cost estimate using revised quantities developed in step 1.
    b. Revise unit and lump sum prices based on recent bid tabulations for projects similar in size and scope.
    c. Add reasonable expected costs for dam and reservoir seepage control. These costs are expected to be significant.

d. Develop an updated project cost and determine if the project remains financially feasible. If the project remains feasible, proceed to recommendation number 3.

3. **DOCUMENT PROJECT WATER AVAILABILITY AND NET YIELD** - Determining the timing and quantity of flow available for the project provides the necessary foundation to justify the project. The projected net annual yield is necessary to identify a reasonable cost-benefit ratio for evaluating project financial feasibility. The PER should be updated to include the following:

   a. Present data and analysis used to estimate the average annual quantity of Gila River flow that can be diverted. Based on historical flow and diversion records, estimate the projected flow amounts and timing of when the project would be in priority to divert based on project diversion limitations and river flow constraints.

   b. An average net yield for the project should be developed taking into account system losses to include evaporation, seepage, and transit. Once the net yield is identified, a revised cost-benefit ratio should be computed.

   c. Based on past and projected future hydrologic cycles for the Gila River Basin, identify if project viability remains valid during times of extended drought. The quantity of water available to the project during the higher than average precipitation cycles should be estimated and compared to the timing of the expected project deliveries to estimate if excess water stored during wetter hydrologic cycles will be available during drought cycles when considering project system losses.

4. **GILA RIVER SEDIMENT CONTROL** - Develop strategies and address sediment control for the diverted Gila River water in addition to the surface runoff flowing into the storage reservoirs.

5. **PERFORM ADDITIONAL LIMITED SCOPE GEOTECHNICAL INVESTIGATIONS** - Perform additional geotechnical investigations at the recommended Alternate 2B storage reservoir sites limited in scope but sufficient to identify the following:

   a. Subsurface soil profile and material properties of the reservoir basins, proposed dam footprints, and abutment soils to determine their suitability for constructing a zoned earthfill dam. Identifying soil permeabilities' suitability for core material and filter material would be the primary focus.

   b. The depth to bedrock and bedrock properties along the dam footprints.

   c. Identify and quantify additional, and preferably close, borrow sources of suitable dam core material, slope protection material, and general embankment material.

   d. Subsurface soil profile and material properties at the recommended Category 2 Diversion location. Identifying the soil permeability, gradations, plasticity index, and depth to bedrock if shallow, would be the primary focus.

   e. Update the information developed in Task 1 or in the PER, as appropriate, based on this site-specific data.

RJH/jmm