AYRES
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March 5, 2024

Mark Ritterbush
Water Services Manager
City of Grand Junction

Re: Juniata Reservoir – Alternatives Review for Repair Options

Dear Mr. Ritterbush:

This letter builds upon a letter from Ayres dated October 27, 2023, which discussed an underwater investigation of leakage at the Juniata low level intake wye and included computations showing that the existing intake has insufficiently sized air vents. The assumption of that letter was that the existing air intake pipes had corroded and were allowing reservoir water to enter the low level outlet.

To confirm that the air vents were indeed the problem, Potable Divers visited the dam in November to confirm dimensions of the intake plus plug the air vents so that a camera could see inside the intake's wye better. The plan was to use a camera inside the wye to find the leak and confirm pipe condition. The test was successful in plugging the air intake lines, and an innovative use of a blind flange with camera port and air vent did allow the low level outlet to be partially dewatered and televised in the first eight feet of pipe. Unfortunately, divers learned that the air vents were not the only problem. A leak on the left wye was discovered in the camera footage, and the leak appears to be more than just a pin hole in size. The City then reclosed the low level pipe's downstream valve and requested a meeting with the State Engineers Office (SEO).

On December 8, 2023, Ayres participated in a conference call with the City and SEO. Participants included Randi Kim (randik@gjcity.org), Mark Ritterbush (markri@gjcity.org), Slade Connell (sladec@gjcity.org), Jason Ward (Jason.Ward@state.co.us), Jackie Blumberg (jackie.blumberg@state.co.us), and Pete Haug (HaugP@AyresAssociates.com). During the call, Ayres noted several concerns about the low level intake.

- First, the intake was constructed in 1978 and is 46 years old. The low level pipe consists of multiple diameter and material changes. The low level pipe prior to 1978 was 24-inch diameter corrugated metal pipe that was spray lined with an inch of cement mortar on the inside (22-inch inside diameter). During the 1978 embankment raise, the mortar lined pipe was extended upstream and downstream with 24-inch inside diameter reinforced concrete pipe. However, only eight years after intake construction, the low level outlet pipe was reduced from 24-inch inside diameter concrete pipe to 14.7-inch inside diameter structural rated (SDR 11, 200 psi or so) polyethylene pipe. The polyethylene pipe did not go through the 24-inch wye at the upstream end of the pipe nor did it go through the 24-inch valve (constructed later) at the downstream end of the pipe. In other words, the current pipe system goes from two 12-inch steel pipes to a 12+12=24 inch steel wye to a 24-inch reinforced concrete pipe that has a 14.7-inch plastic pipe inside it to a 24-inch reinforced concrete pipe with a 24-inch valve to an 18-inch or so plastic pipe that extends through the downstream outlet headwall. In short, the low level pipe system likely has a good strength in the polyethylene lined sections, but the transition areas (pipe diameter changes, pipe material changes) are likely the weakest points in the pipe system.

  The SEO expressed a concern that if the current leak on the wye is repaired, they still want the entire pipe televised to look for other locations that need repair.

- Second, Ayres noted that the low level and mid level outlet can draw down the reservoir five feet in six days per the C-661B drawings, and this drawdown rate is not as fast as the state standard (five feet in five days). Ayres asked the City if this system was robust enough to handle the City's expected future growth and resiliency needs.

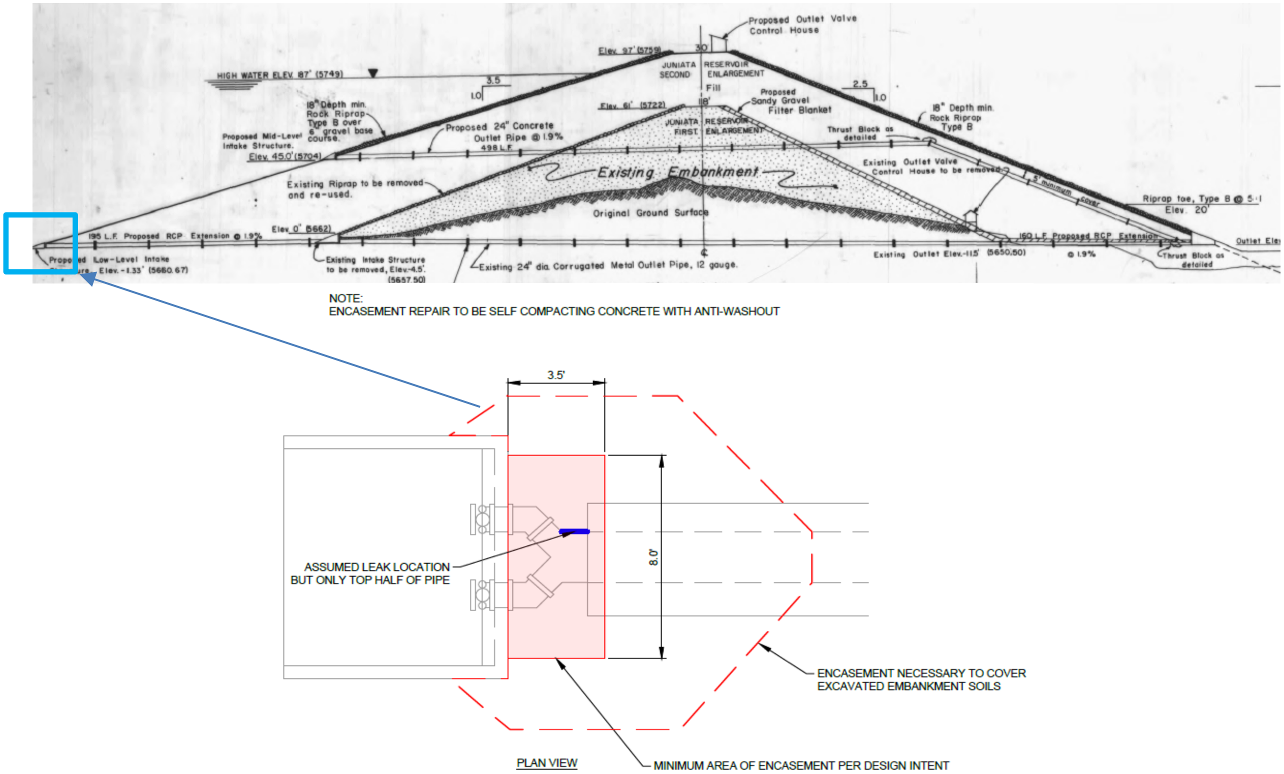
The SEO noted that if the low level pipe is not repaired, there is a risk that the situation could get worse and then the SEO would have to order lake level restrictions. The SEO agreed with Ayres that there is no immediate threat to dam safety as long as the downstream valve remains closed.

The SEO asked if the City had considered drawing down the reservoir and doing a robust repair "in the dry" such that whatever the dam needed to make it fully repaired could be done well and the full system would be able to be thoroughly inspected. This led to some discussion about what else on the dam might need repairs at the same time. The City and Ayres had discussed minor leakage along the downstream toe, pondered if a larger outlet pipe would improve future water delivery options, etc. The City's key concern was that Juniata's 7000 acre feet of water is the largest water supply for Grand Junction, and in a drought it might take several years to refill the reservoir.

The December meeting concluded with the SEO asking the City to consider if underwater repairs were the right option. While tactfully stated, the key SEO concern was that underwater repairs would not be as robust as repairs done "in the dry" and the SEO wanted the City to make a strong case for why the state should accept an underwater repair instead of a full drawdown. Ayres noted that there are several large national diving firms that Ayres could contact for advice, and then Ayres could also develop a drawdown repair option that the City could couple with the value of water lost to drawdown and risk of slow refill. The SEO asked that once Ayres and the City had looked into these options, the SEO be re-consulted to discuss a final plan forward.

In closing, the SEO stated that the overarching position of the state was that the repair project should do no harm to the existing structure, and harms could include creating slope instability or new seepage paths. The SEO suggested that perhaps better repairs could be done "in the dry" (full reservoir drawdown) and ultimately if the state suspected a dam safety concern then the SEO would order a pool restriction or drawdown. The City requested time from the state to evaluate options for underwater repairs as well as "in the dry" repairs.

With this direction and following the December 8 call, Ayres developed a concept sketch of an underwater repair option that involved encasing the leaking section of pipe in concrete. In summary, this conceptual design would involve removal of existing soil around the existing intake and placement of concrete in the red shaded area shown on the next page.



Using the above repair concept, Ayres reached out to J. F. Brennan Marine (Brennan) and met with four of their senior staff to discuss prices and construction challenges. Brennan said they could certainly do the work as conceptually drawn, and that they were confident that placing concrete around the pipe could be done in a manner that would not impact dam safety. When pressed on costs, Brennan had some discussion amongst their team and stated the costs would be $500,000 to $1,000,000 with a higher probability that costs would tend toward the upper end of that range. The key cost would be limited diver work time in this depth of water. Brennan did say that by lowering the reservoir significantly, some savings in diver down time could be realized. They also stated that they had hypobaric chambers and options to help run a continuous crew of divers, but the large team required to do this work would be much of the speculated construction costs.

Ayres asked for alternative suggestions from Brennan.

- They mentioned that they could also drive sheetpile around the structure and fully dewater it in a deep caisson. They showed Ayres photos of a $50 million project that used this kind of caisson, but they also stated that the caisson alone might be more costly than Ayres' proposed repair.
- Ayres asked about construction options that could cost less than $1 million. Brennan asked if we had looked into Cured In Place Pipe (CIPP) liners and mentioned that they thought a custom liner shape could be fabricated and installed for $150,000 to $250,000 – if Ayres could find a manufacturer who could provide the liner.

After thanking Brennan for their insights, Ayres then reached out to seven CIPP manufacturers to look for a liner that both could be rated to 80 feet of head (what we believe would be the design condition at full pool) and sewn to match the variable diameter of the existing wye. Only one manufacturer had a liner that was rated for 80 feet of head and the manufacturer was not confident that the liner could mold well to the 12-inch to 24-inch to 14.7-inch to 24-inch to 12-inch diameter changes.

After not finding a construction option that was significantly less than $1M, Ayres then looked at repair options for a full drawdown (“in the dry”). The value of water in the reservoir was not computed, but 7000 acre feet of drawn down water volume plus the risk of slow refill during a drought was deemed something that the City should develop a value. For “in the dry” repairs, Ayres developed the following construction sequence:

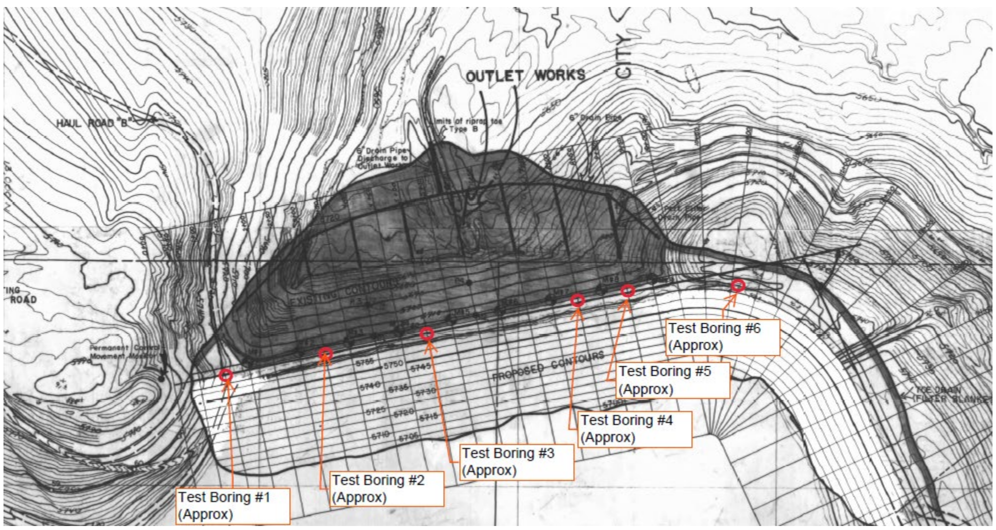
1. Draw the reservoir down through the mid level outlet at a reasonable rate.
2. Draw the reservoir down through the low level outlet at a reasonable rate. Based on rates established elsewhere for earthen embankments, this drawdown might take from spring through June.
3. Then additional time (month or so) would be required to allow the lakebed to dry enough for contractor access. Concurrently, the low level and mid level outlet pipes would be televised from the downstream end of the pipe.
4. The contractor would then remove the soils around the low level inlet and encase the wye (similar to the figure on previous page) with concrete.
5. A pair of new air lines from the low level outlet would be trenched into the riprap and encased in concrete all the way up to the maximum reservoir pool. Existing hydraulic lines would also be encased in that concrete. If the City desired to save money, the hydraulic and air lines could be just excavated into the embankment and covered with soil and then riprap (perhaps saving $100,000 to $150,000 in price).

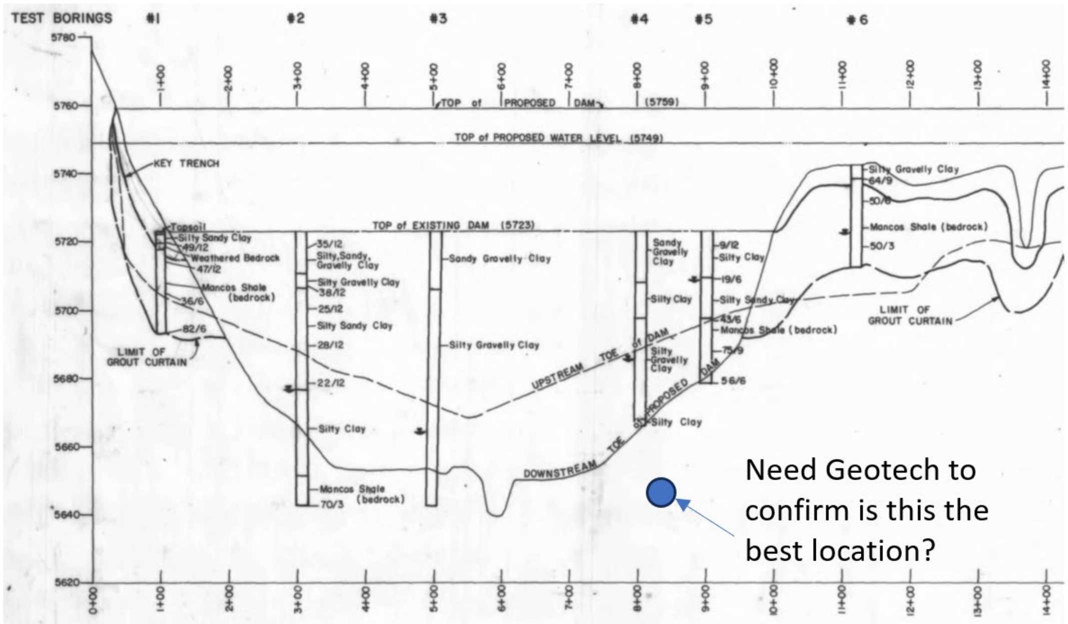
The cost to do the above repairs plus encase the air and hydraulic lines in concrete was approximated in the $300,000 to $500,000 range. One big risk of doing this type of repair is that the full drawdown of the City’s key reservoir might lead to several years of diminished water supply, especially during a drought year. A downside of doing this repair is that the repair left the City with essentially the same reservoir discharge capacity that existed prior to the current leakage problems – and Ayres was not sure if the City had plans to upsize the reservoir for future resiliency or capacity improvement projects. Here are some options for additional improvement that Ayres believes the City should consider doing if the reservoir is drawn down:

- First, the existing low level outlet’s 24-inch valve (located in the downstream embankment) is manually operated within a vault inside the embankment and requires considerable effort to open and close. If the reservoir is drawn down, reworking the valve seals or improving the valve operability may be possible.
- Second, wet spots on the toe could be mitigated with an engineered filter blanket.
- Third, to reduce the risk of future internal erosion along the existing low level and mid level outlets, a downstream collar of engineered filter sand could be added around the two outlet pipes. Given that the polyethylene pipe is probably a robust design within the embankment, Ayres suggests that the engineered filter collar would be most beneficial from the valve vault and downstream.
- Fourth, the entire low level intake would be removed and replaced by a new structure that contained only a single 18-inch valve.
- Fifth, any repairs done to the low level system should be also checked to see if they should be done for the mid level system.

All of the alternatives above were not evaluated for costs. However, Ayres then considered what other options might be prudent to consider given the above concerns coupled with the existing system not meeting the state’s minimum drawdown requirement (five feet in five days) and with unknown future water needs. In short, if the existing system is found to be insufficient, does it make sense to replace some or all of the outlet works entirely? An open cut through a 99- to 111-foot tall embankment would be a costly project, likely greater than $10 million. Ayres has a good relationship with a tunneling firm in Colorado and setup a call to discuss options with their tunneling expert. The call between Ayres and Lithos (now part of GEI) resulted in the following opinions.

- There seem to be no options for drilling through the existing embankment or using pipe-bursting techniques to replace the low level outlet works with a larger pipe. Embankments are sensitive to low stress zones that can be created during boring or disturbances, especially when grouting or compacted backfill is not possible. These low stress zones create pathways for soil migration, leading to internal erosion (piping). In both Ayres' and Lithos' opinions, no practicable options exist for replacing the low level outlet in-situ, and abandonment of this outlet (if chosen as the final option) would be best done by grouting the pipe to permanently block it from flow passage.
- Ayres asked about options to go through the bedrock formation that was left and right and under the embankment. Noting the curvature of the outlet stream, Ayres pondered if a new bedrock tunnel from reservoir to downstream stream could be done between Test Borings #4 and #6 as shown in the below image. Lithos suggested that the Mancos Shale formation can be tunneled through, either with directional boring or tunnel boring machine, but in either case more geotechnical exploration would be needed to confirm the local site conditions were acceptable and to also figure out if secondary grouting would be necessary. Lithos noted that test boring data does not currently go much deeper than the top of foundation bedrock, and new borings would be needed wherever the new outlet was planned.





Borings from 1978 Plans

- Lithos suggested that if the City was interested in exploring a new low level outlet pipe through the bedrock, a feasibility study should be conducted. There are generally two options for tunneling – a tunnel boring machine and directional boring. Both have pros and cons, as listed below.
  - Tunnel boring machine requires a minimum diameter of about 48-inch pipe, but it can drill, line, and possibly even grout the bedrock sidewalls all in one pass. Boring machines do not like sharp curves, so the tunnel alignment should be as straight as possible. Given the costs to mobilize a machine and complete a new outlet pipe (new intake, new outlet, grout the old low level pipe, restore site conditions, etc.) the cost would likely be in the $10 million range.
  - Directional boring is faster and can handle curves in the pipe alignment, but directional boring is not able to do grouting at the same time as the boring and pipe sleeve are installed. Lithos expected that based on their past history with Mancos Shale, a program of secondary grouting would be needed, but without seeing more geotechnical data from the site they did not know the extent of such grouting. Ayres asked about what the maximum pipe size was possible with today's directional boring machines, and Lithos suggested that 18-inch was possible but newer technology might even allow a 24-inch pipe (this might be the outer diameter, need to check with boring companies). With a budget for secondary grouting included plus abandonment of the existing low level system, a directionally bored outlet pipe would probably cost in the $3 million to $5 million range.
  - Lithos pointed out that more feasibility study would be needed to vet the above options, including a review of geotechnical conditions, possible vibration concerns, etc.

Ayres summarized the above alternatives into a PowerPoint presentation and the City arranged for a call with the SEO. During the February 14, 2024, call with the SEO, Ayres presented these options in brief and asked for SEO feedback. The SEO stated that embankment drilling and drilling under the embankment was prohibited by state rules, and Ayres responded that this rule appears to not apply to drilling through the bedrock near the abutments. The City expressed apprehension at draining the reservoir unless the construction repairs were going to make this the only drawdown in the next couple decades. In other words, whatever was needed for this dam should all be completed during the drawdown so that a future drawdown could be avoided for several decades.

To allow for broader SEO participation, a second call with the SEO on February 22, 2024, continued the conversation. The SEO said they did not want the decision for final repairs to solely rest on the current dam's shortfall in meeting the five feet in five day drawdown requirement. The SEO also said the state did not see significant risk with the polyethylene lined portion of the existing outlets. From the state's perspective, the full drawdown and repair of the existing intake (or perhaps repair of both low and mid level intakes) would be the better plan forward as long as the City did not need additional water release capacity in the future. The City did some rough approximation of future water needs and thought that their water supply consultant (Black and Veatch) should be able to determine future water needs. The call concluded with the following action plan:

1. Ayres would document the project call history and concept level review findings in a letter (this document).
2. The City would reach out to their water supply consultant to check on Juniata flow capacity needs.
3. The City would develop a plan to meet water supply needs even if a drought prolonged the refill of Juniata during dry years.
4. The City would decide if they wanted to proceed with final design of a repair "in the dry" or if additional feasibility studies were needed. They would keep the SEO informed of their plan.

Ayres notes that the review, findings, and communication described above are highly dependent on best available information, and we recognize how updates in new findings and information may impact the above conclusions. As always, should information in this report be found to need correction or updating, Ayres appreciates the opportunity to revise this report.

In closing, Ayres is grateful for the opportunity to explore the complex decision options for Juniata Reservoir. As the project has progressed, new information has quite often changed the course of decision, and Ayres appreciated the City's willingness to dialogue with the SEO and preserve dam safety as the priority while seeking a good solution to balance all the other project concerns. As the City's terminal reservoir and largest reservoir, Juniata is a critical resource and whatever solution is selected in the end should endeavor to restore Juniata such that it does not need a drawdown in the next couple decades. Thank you for the opportunity to complete this feasibility / concept-level review and look forward to the opportunity to participate in next steps.

Sincerely,

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