

# RECLAMATION

*Managing Water in the West*

Technical Review Report

## 2018 Work Scope for Appendix No. 6 Findings of the Technical Review Team



U.S. Department of the Interior  
Bureau of Reclamation  
Technical Service Center  
Denver, Colorado

November 2018

## **Mission Statements**

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

**Technical Review Report**

# **2018 Work Scope for Appendix No. 6 Findings of the Technical Review Team**

*Prepared by:*

**Bureau of Reclamation Technical Review Team  
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*for:*

**Water Resources Agency  
Ministry of Economic Affairs, Taiwan**

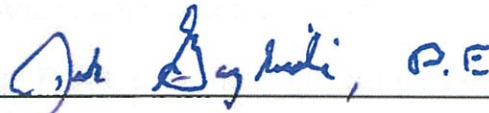


**U.S. Department of the Interior  
Bureau of Reclamation  
Technical Service Center  
Denver, Colorado**


**November 2018**

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2018 Final Report Under Appendix No. 6

A technical review of specific issues related to Naio-Zuei-Tan Artificial Dam, Sun Moon Lake, Hushan Reservoir, Renyitan Spillway, Nan-Hua Submerged Weir, Tseng-wen-Nan-Hua Interconnecting Pipeline, JhongJhung Artificial Dam, as well as a 1-day training course focused on Dam Safety and Instrumentation and Monitoring was performed by the undersigned members of the Bureau of Reclamation Technical Review Team through Appendix 6 cooperation and at the request of the Water Resources Agency, Ministry of Economic Affairs in Taiwan. Our findings and conclusions are outlined in the report following.

 P.E. 11/7/2018

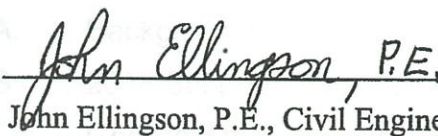
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### C. General Observations, Comments and Issues

The 2018 work scope included a site visit by the Team for a follow-up briefing regarding progress that WRA has made on the 2016 recommendations. The following points are highlighted from these discussions:

- During the discussion, it was mentioned that the groundwater was up to 2 meters below the chute and the stilling basin floor.
- Water that previously was eroding the foundation materials below the spillway chute now can more easily enter the free draining materials under the floor slabs and behind the chute walls with the repairs. These seepage flows can then enter the drain pipes either under the floor slabs, or within the backfill materials behind the chute walls.
- In addition, the briefing revealed that WRA was considering replacement of the existing spillway due to their concerns that the existing repairs were not sufficient.

### D. Summary Recommendations

Based on the Team's review of the available information as well as the comments and observations cited above and on the team's current understanding of the Renyitan Spillway repairs and progress made in addressing the 2016 comments, the Team offers the following additional recommendations:

- It is Reclamation's opinion that the spillway does not need additional repairs at this time.
- Periodic use of ground penetrating radar could provide an early warning that foundation materials are being eroded
- Monitoring of the three Parshall flumes downstream of the stilling basin could provide an early warning that foundation materials are being eroded.
- Monitoring of the chute walls for settlement and deflection could provide an early warning that foundation materials are being eroded.
- A potential failure mode (PFM) analysis using qualitative estimates could be used to develop a more robust, or better understanding of this PFM. Doing so would provide more sound guidance regarding whether additional measures (including replacing the spillway) should be taken to reduce risk for dam failure.
- Remove all trees planted on the right side of the spillway stilling basin to allow for better observation, and to prevent clogging of the drain pipes.

Results from ground penetrating radar, monitoring of Parshall flumes, and chute and floor slab surveys could reasonably provide enough advanced warning of

potential problems, so that they could be addressed in a timely manner through construction repairs.

## VII. Issues Related to Feasibility of Submerged Weir at Nan-Hua Reservoir

### A. Background

Nanhua Dam and Reservoir are located near Tainan in WRA's Southern Region. Similar to Tsengwen Dam, the Nanhua Reservoir has extreme sedimentation challenges. Specifically, Nanhua Reservoir has experienced a significant loss of storage as a result of sediment deposition in the reservoir resulting in a 39-percent decrease in the design storage volume. Similar to Tsengwen, a new sediment sluicing tunnel was constructed in 2017. Design features included an intake structure followed by a 52-meter-long intake tunnel, a gate chamber with vertical access shaft, a 1,290-meter-long sediment sluicing tunnel, an outlet structure, and an access tunnel. The plan configuration of the project is shown in figure 16.

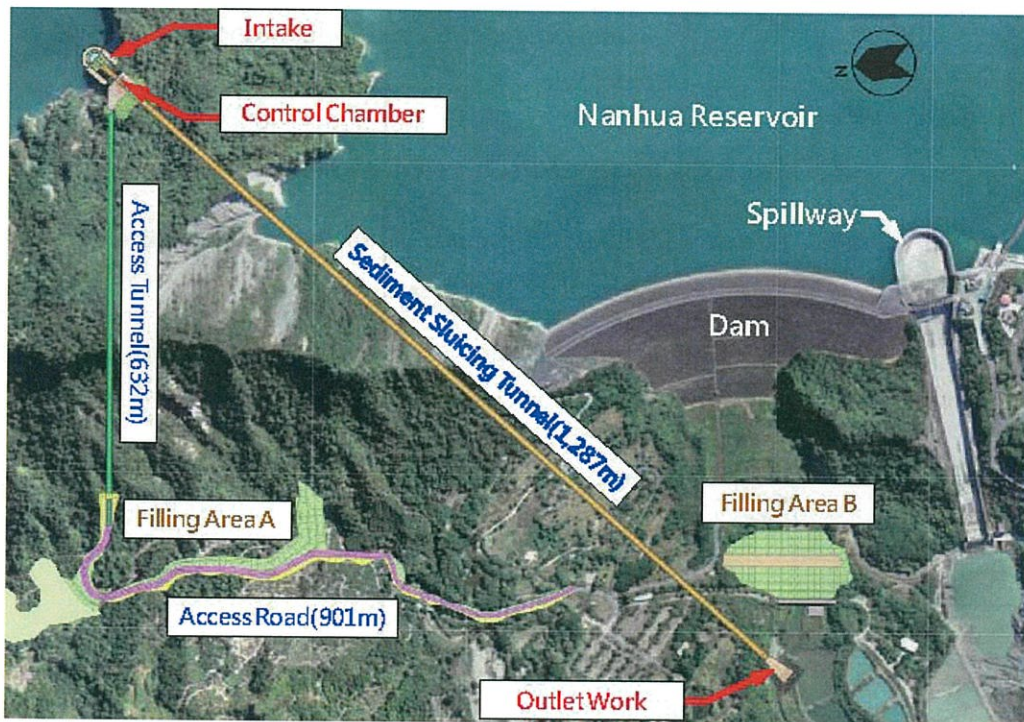


Figure 16. Satellite image plan view of the sediment sluicing tunnel at Nanhua Reservoir

To supplement the sediment reducing efforts at Nanhua, a submerged weir structure has been proposed and a feasibility level design has been completed as shown in plan view on Figure 17 and in cross section in Figure 18.

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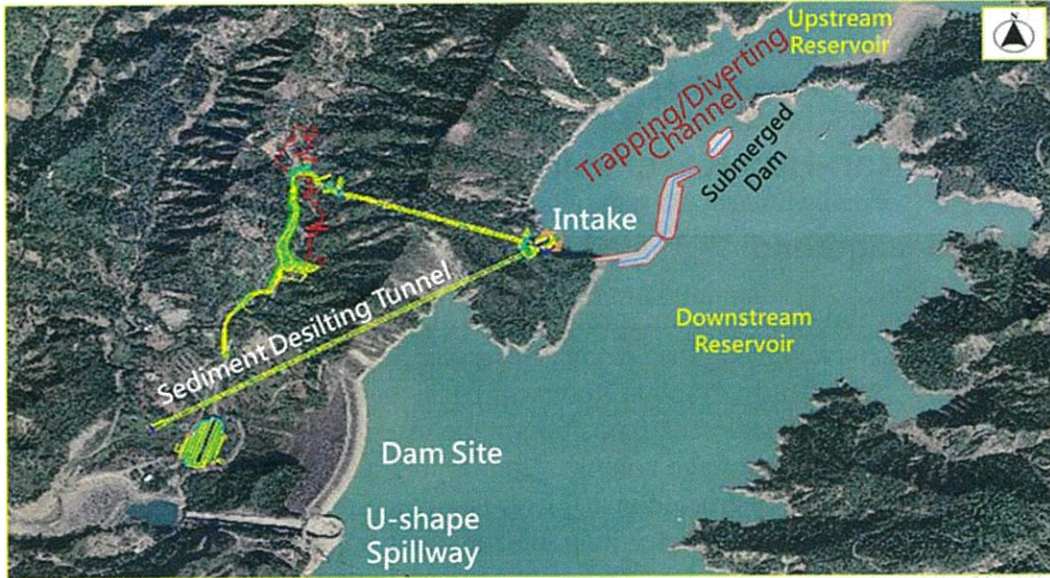


Figure 17. – Proposed location of submerged weir and desilting tunnel at Nanhua Reservoir.

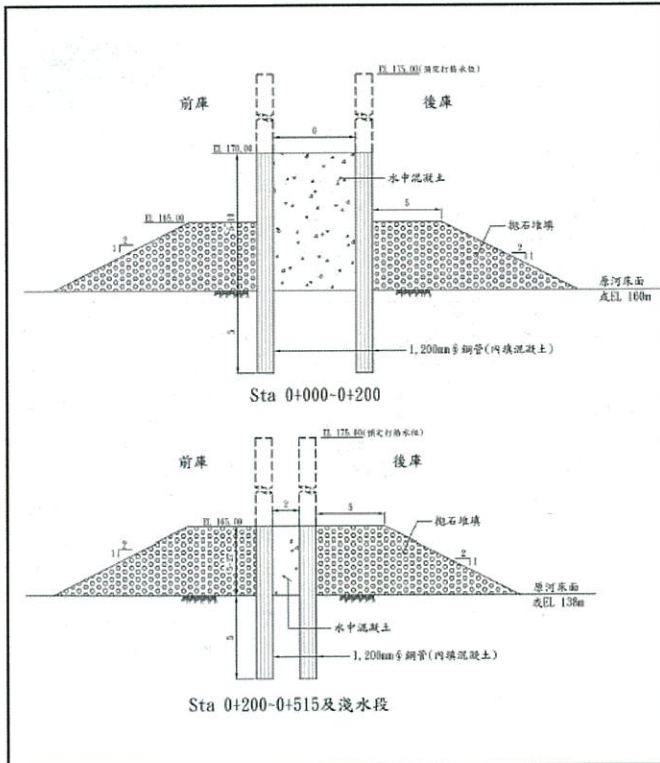


Figure 18. – Section of proposed submerged weir at Nanhua Reservoir

## **B. 2018 Scope Focus**

This 2018 work scope included a visit by Team A to the Nanhua Reservoir and Tsengwen Reservoir. Team A was first tasked with evaluating a planned submerged weir to be constructed at Nanhua Reservoir to capture sediment upstream of the dam's appurtenant features as a supplemental feature to the existing sediment sluicing tunnel. The sediment would then be flushed or removed during times of low reservoir levels.

Specific items of concern regarding the construction of the submerged weir include:

- The stability of the right bank of the reservoir rim adjacent to the intake of the sediment sluicing tunnel based on known geologic faults in this area.
- Consolidation of the sediment during normal operations could increase the density making it more resistant to being sluiced and result in significant uncertainty as to the effectiveness of the sluicing operations.
- Scour within the sluicing tunnel is a concern that is being evaluated
- Erosion potential of the submerged weir
- Sediment removal operations for the submerged weir

## **C. General Observations, Comments and Issues**

The site visit and briefing to Reclamation resulted in the following key items for discussion:

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Photo 5. - Adverse Geology Related to Portal for Sluicing Tunnel

- The proposed submerged weir and sluicing tunnel portal are located at the toe of a bedrock dip slope that has unfavorable bedding orientations and historic landslides. See Photos 5 and 6. The long-term stability of this slope as it affects the project is a concern. Monitoring has indicated horizontal movement of the bedrock of approximately 0.5 cm per year.



Photo 6. - Portal to Sluicing Tunnel

- Concern that coarser material (sand, gravel, cobbles, and boulders (up to 1 meter diameter)) will damage the concrete lining of the tunnel as velocities approach 30 m/sec.
- In the event the sluicing tunnel is overwhelmed during torrential rain, there is concern that high-velocity flows could erode the submerged dam. However, the concrete core (2 meters thick) would likely remain intact.

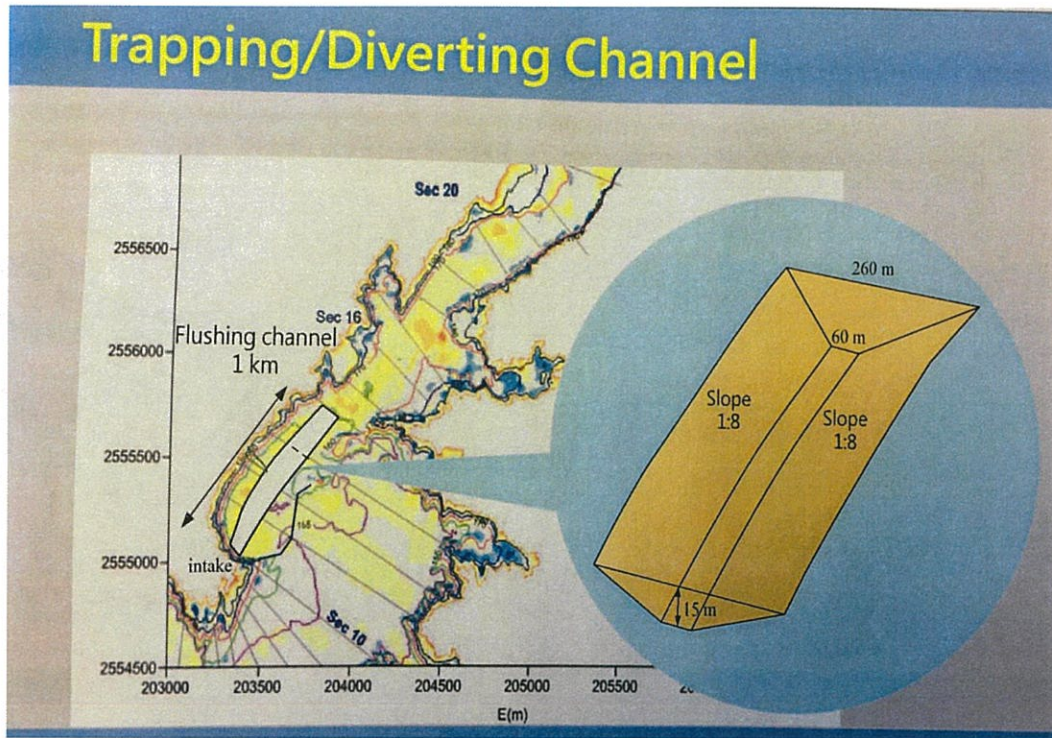


Figure 19. - Proposed Design for Trapping/Diverting Channel

- Figure 19 shows a design for a trapezoidal channel excavated into the upper reservoir basin as an alternative to the submerged weir to divert sediment into the desilting tunnel. There is concern about the effectiveness of this solution.

#### D. Summary Recommendations

Based on the Team's review of the available information as well as the comments and observations cited above and on the team's current understanding of the project, the Team offers the following recommendations:

- Submerged Weir and Portal –
  - Continue monitoring of survey points on the dip slope above the portal. Also consider use of newer technologies such as terrestrial lidar, radar, INSAR, photogrammetry to obtain baseline topographic survey so that detailed measurements of displacement can be monitored for comparison with future surveys.

- Perform a detailed slope stability analysis using all available data and the existing slope geometry, then perform a sensitivity analysis to assess the potential effects of erosion at the base of the slope.
- Concrete lining damage - If not already considered, the compressive strength of the concrete lining could be further increased by adding silica fume to the mix design. Initiating and maintaining periodic inspections will be important. If damage does occur to the concrete lining, then concrete repairs can be made in a timely manner.
- Concrete lining damage - With time, it may be found that it is more economical to install a steel liner than to continue to make reoccurring costly concrete repairs. Dam safety and/or life loss do not appear to be a concern. This is because damage to the lining will be found and repaired in a timely manner, due to periodic inspections.
- Consider constructing a physical model to assess how the submerged weir will perform during such a flood event
- Regarding how to improve the likelihood that the rock-fill materials associated with the submerged weir will stay in place, the following could be considered.
  - Flatter slopes
  - Use of larger sized riprap
  - Grouted riprap
  - Other armoring for the riprap, such as a reinforced concrete overlay.
- Consider use of a physical model and/or consultation with sedimentation experts (Appendix 8) regarding an alternative to the submerged weir or trapping/diversion channel.

## **VIII. Issues Related to Proposed Interconnecting Pipeline Between Tsengwen and Nan-Hua Reservoirs**

### **A. Background**

Tsengwen Dam and Reservoir are located near Tainan, in WRA's Southern Region. Tsengwen Dam is a 133-meter-high zoned earthfill and rock embankment with a total volume of over 9 million m<sup>3</sup>. The dam has a crest length of 440 meters and the dam impounds a reservoir volume of 708 million m<sup>3</sup>. The



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Tsengwen Reservoir provides a water supply for public and industrial use. This project was originally designed to maximize regional water supplies.

Appurtenant features at Tsengwen Dam include a gated spillway structure with three multilevel bays and chute sections. The maximum spillway discharge is 9,470 cubic meters per second. The dam also includes an underground powerplant that is delivered water via a multilevel power sloped intake structure located at the left abutment of the dam. The sloped intake structure also includes a river outlet conduit.

Similar to other reservoirs in Taiwan, the Tsengwen Reservoir faces extreme sedimentation challenges which led to construction of a new sediment sluicing tunnel that was completed in 2016. The sluicing tunnel project features included an intake or “elephant trunk” pipe, a gate chamber with vertical access shaft, a tunnel, a bifurcated plunge pool type energy dissipation structure, a construction access adit, and a public road access detour tunnel. The sediment sluicing tunnel is aligned through the left reservoir bank.

To enhance water resources management and to provide regional potable-water backup during drought, a pipeline is currently being designed to link Tsengwen Reservoir with the Nanhua Purification Plant and the Nanhua/Kaoping pipeline. The total length of the new pipeline is about 23km and the designed delivery capacity is 800,000m<sup>3</sup>/day. The overall layout of the interconnecting pipeline is shown in figure 20.

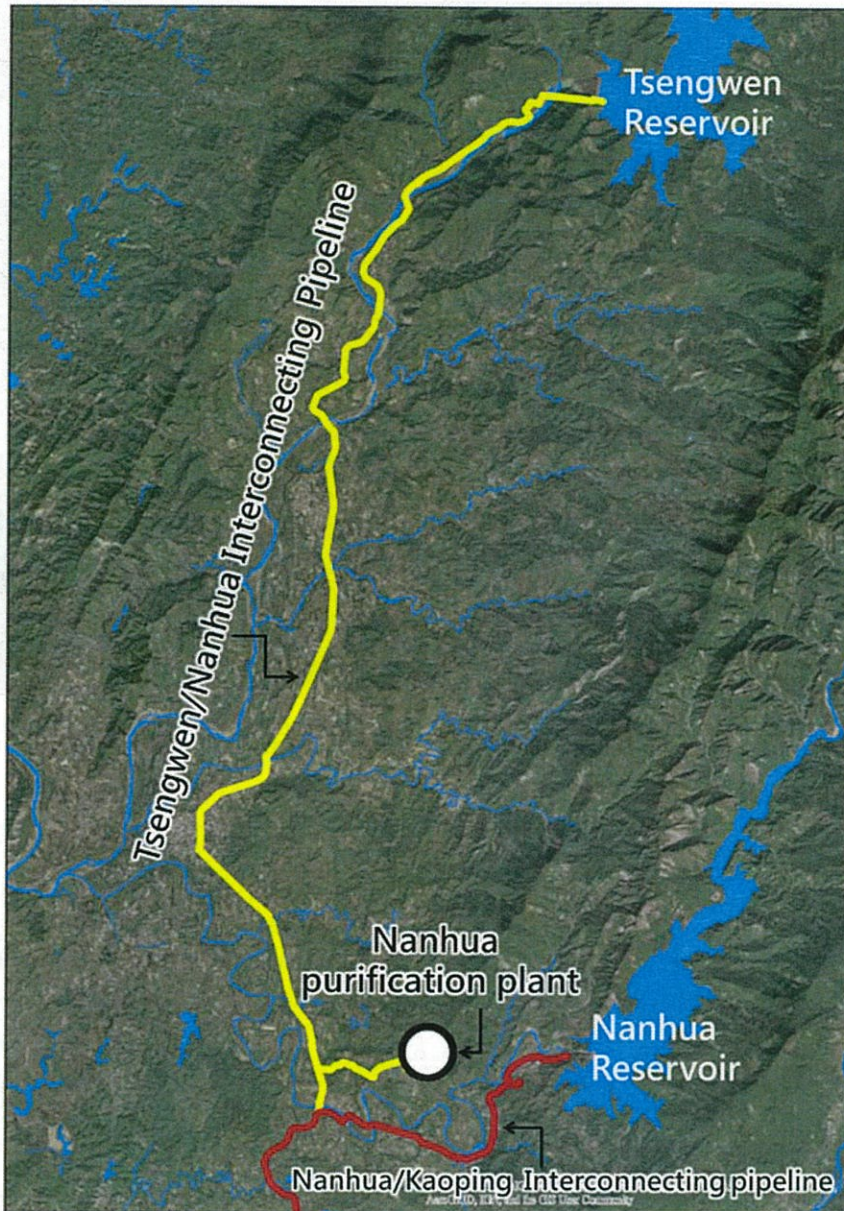


Figure 20. Plan Layout of Tsengwen/Nanhua Interconnecting Pipeline

The pipeline will connect to the power penstock of the Tsengwen powerplant via a new 4.5m diameter tunnel bored from the existing 12m diameter Diversion Tunnel No. 2. The pipeline will then be installed along the diversion tunnel and cross beneath Tsengwen River bed and convey flows downstream to the Nanhua Purification Plant or to the basin downstream of Nanhua Reservoir. Flow rate of this pipeline will be regulated by a fixed cone valve. The layout of the new intake tunnel is shown below in Figures 21 and 22.

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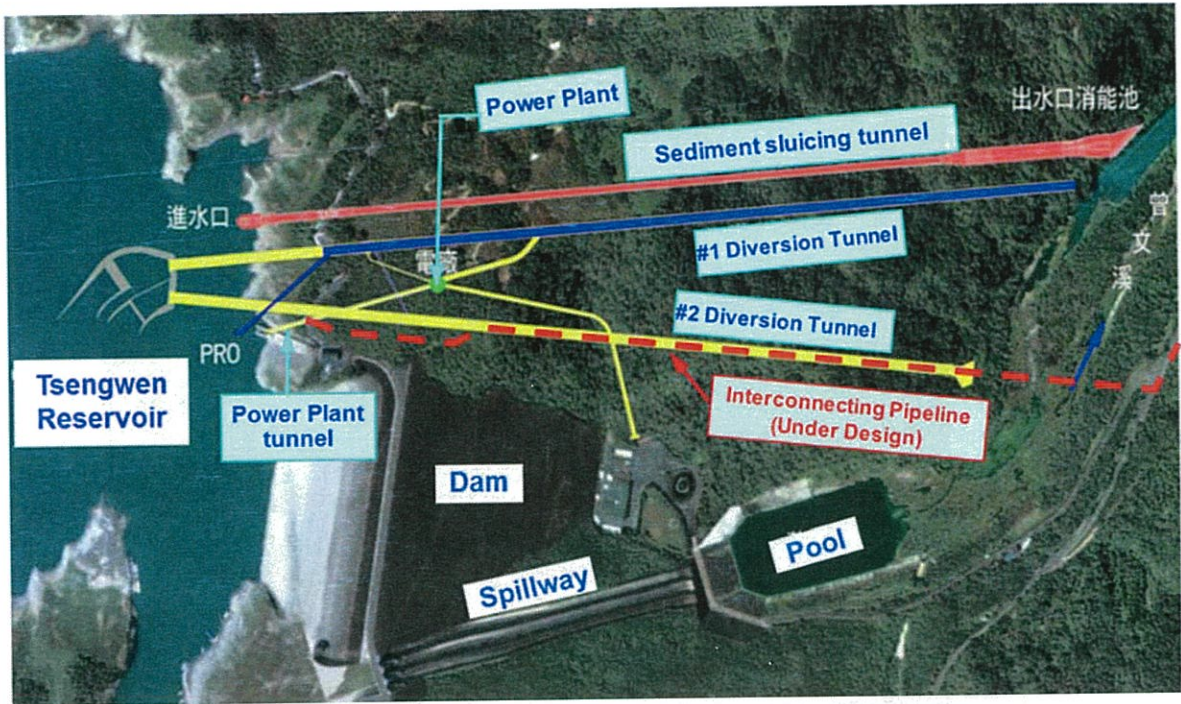


Figure 21. - Plan View of Intake Segment of the Tsengwen/Nanhua Interconnecting Pipeline

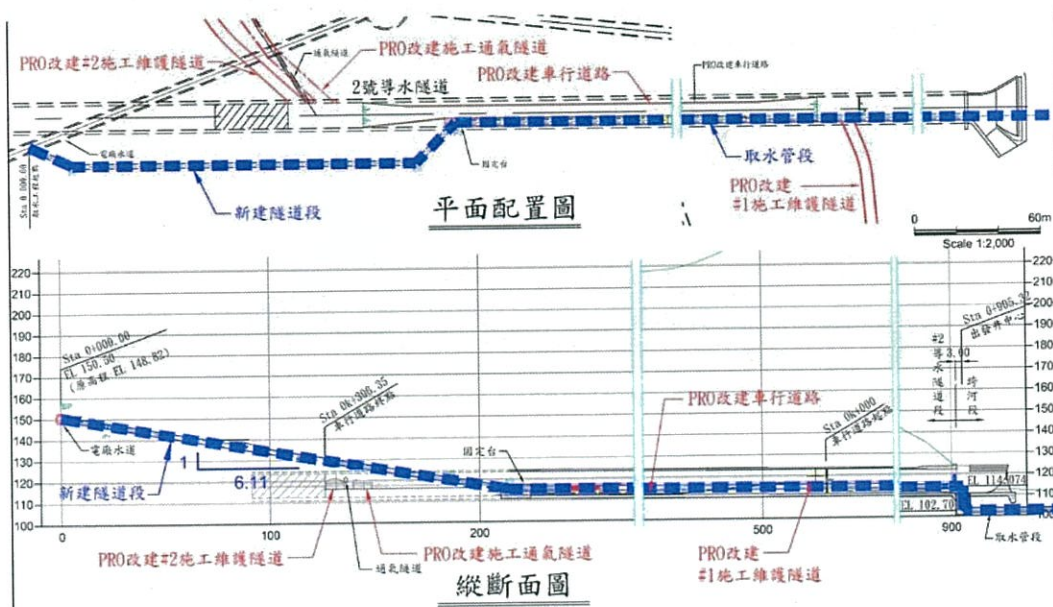


Figure 22. - Layout of the New Intake Tunnel of the Tsengwen/Nanhua Pipeline

### B. 2018 Scope Focus

Team A was tasked with evaluating the potential impacts of the new pipeline on existing the existing facilities at Tsengwen Dam. The WRA requested Reclamation consultation regarding the impact of the new tunnel excavation on the safety of the existing tunnels. For an initial evaluation, the WRA used a simplified calculation from Hoek and Brown.

In addition, the WRA has asked Reclamation to review potential water hammer effects on the powerplant system due to closure of intake pipe. The pipeline is to be connected to the penstock. With a closure of its flow control valve, water hammer will affect flow rate and discharge through the turbine/generator unit. WRA requested that Reclamation assess the transient analyses that was performed to better understand the effects of the water hammer pressure on the existing power system.

A portion of the pipeline will be installed in existing Tsengwen Diversion Tunnel No. 2 and will occupy part of the cross-sectional area of the tunnel as shown in Figure 23. WRA is interested in Reclamation's opinion regarding whether the ventilation required for Permanent River Outlet (PRO) will be affected.

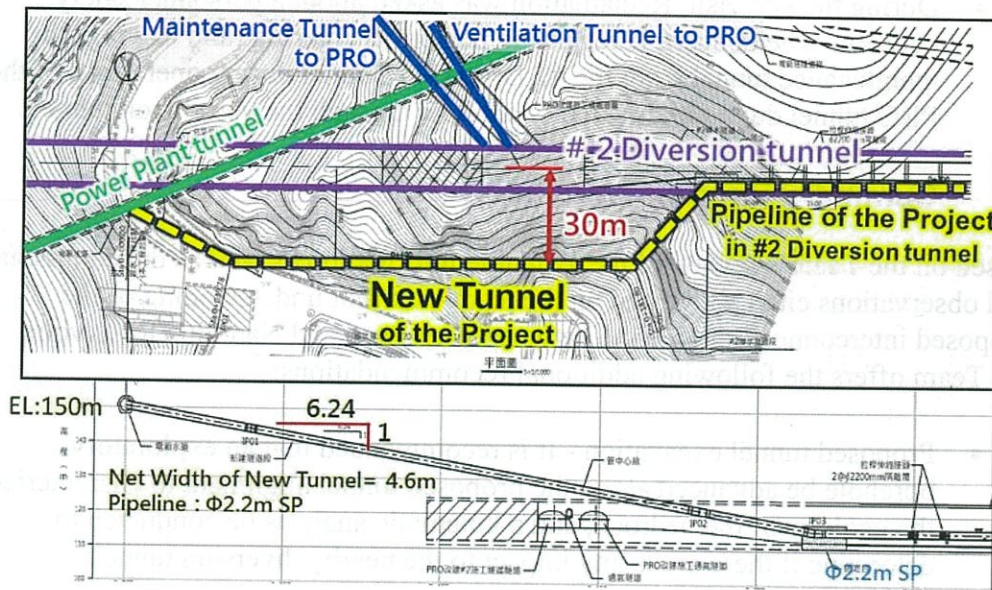


Figure 23. Tunnel Alignment and Profile

### C. General Observations, Comments and Issues

The site visit and briefing to Reclamation resulted in the following key items for discussion:

- There is concern that proposed new tunnel excavation (shown in yellow will impact the integrity of the existing diversion tunnels. Analysis has been conducted using the simplified strength model of Hoek and Brown. This analysis does not address the site specific sandstone and shale foundation materials or associated discontinuities (joint sets, shear zones, faults etc.).
- A potential concern for water hammer was addressed by WRA due to the relatively slow closure rate of the gate (e.g., about 5 minutes); calculations have already shown that transient pressures due to water hammer will not be a problem for the power plant system.
- Regarding ventilation requirements for the PRO, the decrease in cross-sectional area in the #2 Diversion Tunnel (due to construction of the pipeline and its support) is about 19 percent. There is concern that a reduced cross sectional area could have adverse effect on ventilation requirements for the PRO.
- During the site visit, Reclamation was asked about a personnel safety concern. The concern is regarding personnel entering (and leaving) the maintenance tunnel from the #2 Diversion Tunnel during operations of the PRO tunnel due to high velocity air flow through the ventilation tunnel.

### D. Summary Recommendations

Based on the Team's review of the available information as well as the comments and observations cited above and on the team's current understanding of the proposed interconnecting pipeline between Tsengwen and Nan-Hua Reservoirs the Team offers the following additional recommendations:

- Proposed tunnel excavation - It is recommended that an exploratory borehole be advanced along the proposed tunnel alignment to characterize the geology of the bedrock, and a kinematic analysis be conducted to determine if there are is any impact to the nearby diversion tunnels (removable blocks, etc.)
- Water Hammer - The gate can always be closed at an even slower rate to further reduce concerns.

- Ventilation - If not done already, air-demand calculations can be completed to determine if the PRO can operate as designed, and if air velocities will be excessive in the system.
- Personnel Safety - A concrete wall could be constructed within the #2 Diversion Tunnel to separate the high velocity air flow from personnel entering (or leaving) the maintenance tunnel. The wall would be constructed parallel to air / personnel traffic, be approximately be approximately 3 meters in height, 0.3 meters thick, and an appropriate length. Personnel could then safely, and comfortably, access the maintenance tunnel during operation of the PRO tunnel.

## **IX. Technical Training – “Dam Safety Focused Instrumentation and Monitoring Programs”**

### **A. Training Objectives**

The 2018 work scope included a full day training course conducted by Team B regarding Reclamation's approach for developing instrumentation and monitoring plans specifically focused on potential failure modes associated with their embankment and concrete dams. See photos following.