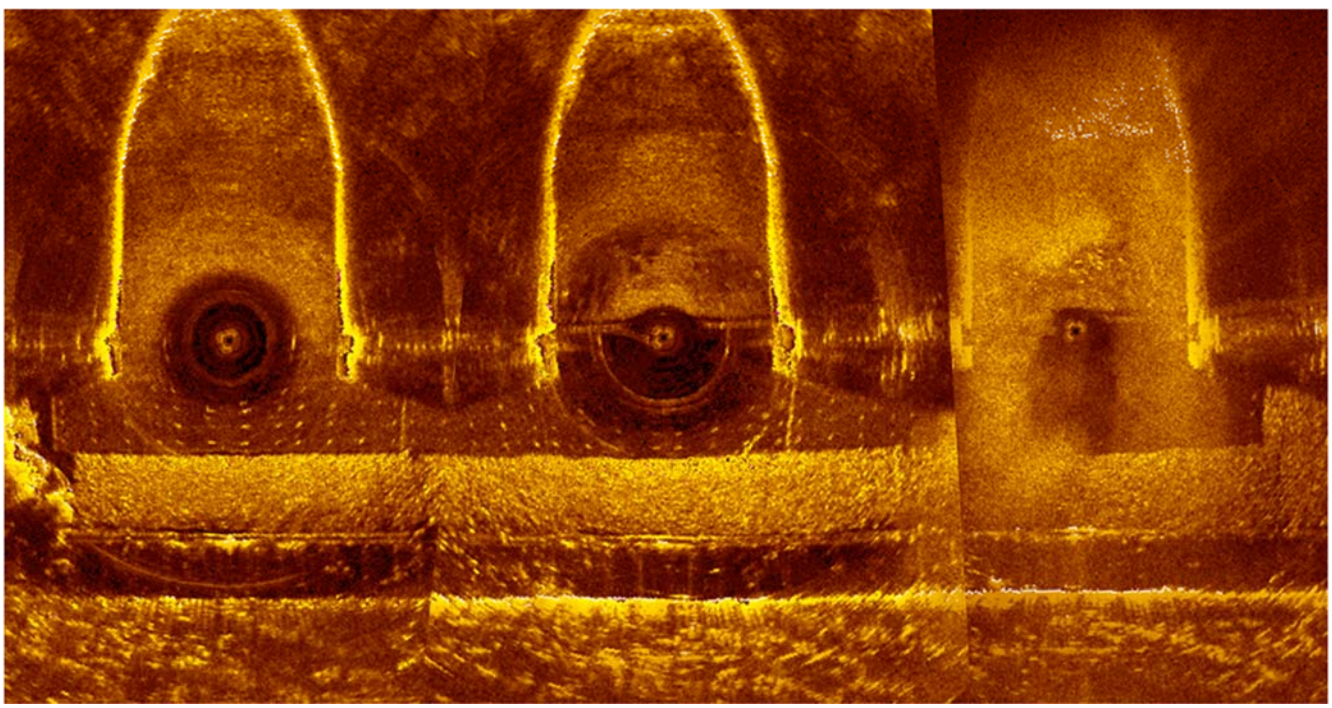
RECLAMATION
Managing Water in the West

Hydraulic Laboratory Technical Memorandum PAP-1145

Buffalo Bill Power Plant Tailrace Barrier Fence

As-Built Sonar Inspection

Pick-Sloan Missouri Basin Program



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

November 2016

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Introduction

The Technical Service Center's (TSC) Hydraulic Investigations and Laboratory Services Group (86-68460) was requested to perform an as-built sonar imaging inspection of repairs made to the Buffalo Bill Power Plant tailrace. The purpose of this sonar inspection was to document the as-built configuration of tailrace repairs which included: concrete abrasion repairs, the installation of stainless steel panels and a barrier fence. Furthermore, an existing tailrace protection dike was rebuilt.

Background

Buffalo Bill Power Plant is located on the right (south) bank of the Shoshone River approximately 5 miles west of Cody, Wyoming. The plant has three Francis turbine units which went on-line in 1992 and have a combined rating of 1.8 MW. Water for power generation is supplied from Buffalo Bill Dam, approximately 1 mile upstream from the plant.

The Shoshone Power Plant is located at the base of Buffalo Bill Dam and discharges into the Shoshone River. Its primary purpose is to maintain a minimum instream flow upstream from the Buffalo Bill Power Plant. The river outlet works at Buffalo Bill Dam is used during periods of high river flows to maintain reservoir levels. The outlet works have a capacity of 3,800 ft^3/sec.

The draft tubes are oriented to discharge northward, perpendicular to the river channel. The downstream exit of each draft tube has bulkhead slots and an embedded stainless steel bulkhead seat across the invert at elevation 5044.0 ft. There is also an upper bulkhead seat at El. 5048.5 ft. The units are bulk headed and dewatered on a regular schedule to perform power plant maintenance.

Previous Inspections

A dive inspection in January 2011 documented damage to the draft tube and tailrace concrete. Figure 1 is a drawing which documents the damage discovered by the divers. In August 2011, an initial scanning sonar survey produced images of damage in the tailrace/draft tube area to document the extent of the concrete damage[1]. In April 2013, a follow-up scanning sonar survey was performed to

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[1] Scanning Sonar Survey Report-Buffalo Bill Power Plant Tailrace, Hydraulic Laboratory Technical Memorandum, PAP-1043, November 2011.

collect three-dimensional (3D) point cloud data to support the design and construction of tailrace repairs and rock exclusion measures.[2]

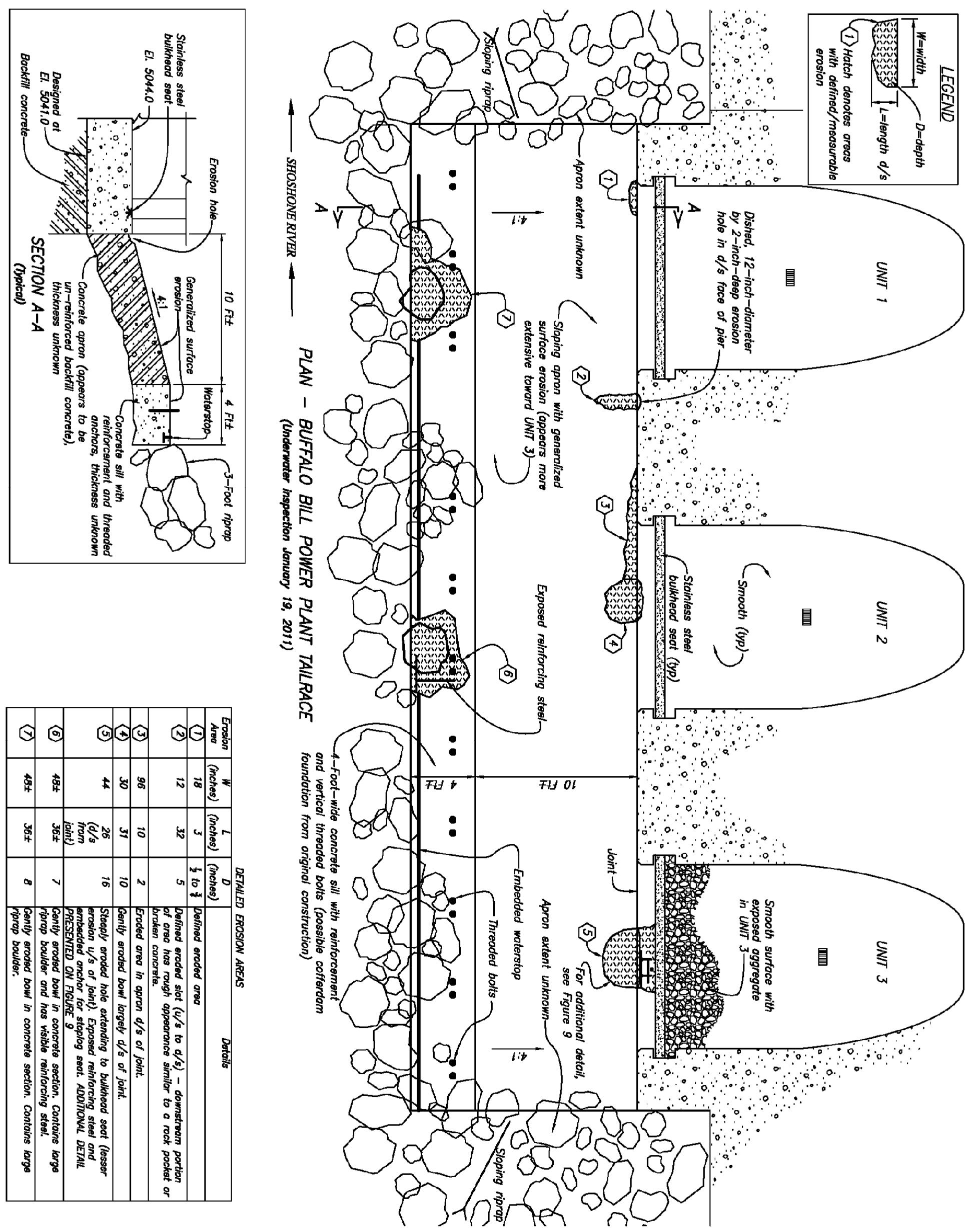

Figure 1. Drawing of tailrace and draft tube damage observed by Reclamation divers during their January 2011 underwater inspection.

[2] Sonar Point Cloud Survey - Buffalo Bill Power Plant Tailrace, Hydraulic Laboratory Technical Memorandum, PAP-1078, September 2013.

The Buffalo Bill Power Plant tailrace repair project was completed in March 2015. The contractor worked with the project staff to perform repairs on the tailrace apron which involved the installation of stainless steel plates to prevent future concrete erosion damage. The design called for installing anchored stainless steel plating and barrier fence sections along the length of the tailrace apron. The tailrace repair project also called for adding riprap to an existing tailrace protection dike located immediately upstream from the power plant. Boulders weighing up to two tons were used to reinforce the dike (see figure 2). As-built sonar images were collected on October 20, 2015.

Figure 2. Photograph of tailrace protection dike repairs in 2015.

Project Operations

During sonar imaging, the Buffalo Bill Power Plant (BBPP) was taken offline and the jet flow gate and Shoshone Power Plant were releasing about 270 ft^3/sec to the Shoshone River upstream from BBPP. The river water surface elevation was computed to be at El. 5058.9 ft based on a distance of 23.0 ft measured from the power plant deck (El. 5081.9 ft). According to power plant personnel there was a butterfly valve discharging into the Unit 3 tailrace along with some wicket gate leakage. Once sonar imaging was completed the BBPP was brought back online.

Equipment

Scanning Sonar

A Kongsberg Mesotech MS1000 scanning sonar system was used for the imaging and profile data collection at the power plant draft tube and tailrace structure. The MS1000 system with a 675 kHz scanning sonar was used to collect an accurate two dimensional representation of underwater structural features and detailed bathymetric data. This sonar has a range of 1.5 to 330 ft with a resolution of about 0.06 ft. A detailed specification sheet for the sonar system is included as an appendix to this report.

The scanning sonar was used in two modes for this project:

1) Sonar imaging was performed using the fan beam transducer which has a 30° wide beam angle. The sonar was deployed in a vertical orientation to collect images of the tailrace repairs.

2) Acoustic profiling was performed using the cone beam transducer which has a 1.7 ° beam angle. The sonar was deployed in a horizontal orientation to collect cross sectional profiles of the tailrace repairs.

Motion Reference Unit

A Think Sensor Research motion reference unit (TSR-100 MRU) was integrated into the MS1000 data acquisition system to allow monitoring of sonar's orientation (pitch, roll, and heading). The MRU has a digital compass, pressure and water temperature sensors.

Data Collection

The sonar imaging and cross section profiling were performed on October 20, 2015 with the assistance of Rick Topham and Jack Buffkin. The river water temperature during sonar measurements was consistent at 55.6 °F and the water was turbid from river outlet works releases which contained suspended sediment.

For acoustic imaging and profiling data collection the scanning sonar equipment was deployed through the bulkhead gate openings. For acoustic imaging the sonar was deployed vertically (figure 3). For acoustic profiling the sonar was oriented horizontally.

For both orientations, the sonar was clamped to the bulkhead and lowered into position by the gantry crane. Acoustic images were also collected by lowering the sonar over the power plant wall, but these images were distorted because the sonar was unstable because it was hanging in the water and was exposed to the river current. As a result, these images are not included in this report.

Figure 3. Photograph of scanning sonar and MRU (white cylinder).

Results

Sonar Images

Sonar images presented below were collected from the centerline of each unit and at the upstream corner of the power plant. In general, plan view images were collected with 12 and 15 ft acoustic ranges. These ranges were sufficient to image the tailrace floor, bulkhead seat, the stainless steel plates, the 4H:1V sloping concrete apron, and the 4-ft-wide concrete sill that contains the newly installed barrier fence.

Unit 1 Plan View Images

Figure 4 is a plan view acoustic image of Unit 1 tailrace collected using a 12 ft acoustic range. Various pertinent repair components in the image are annotated. This image shows the joints (2) of the plate type 2 near the edges of the annotation box and the fastener layout. There are two other plate type 2 joints in front of Unit 1, but their orientation with respect to the sonar beam (with a shallow beam incident angle) prevented the joints from showing up clearly in the image. A careful review of the sonar records did not indicate any rocks had passed through the barrier fence. The Unit 1 tailrace and concrete apron appears to be clear of large rocks and debris. Note: Components of the barrier fence were not imaged clearly from this sonar position. To obtain detailed sonar images of the barrier fence a tripod-mounted sonar would have to be deployed closer to the fence using a boat or boom truck. These images would provide some indication if rocks were accumulating against the fence. If over time rocks build up against the fence and form a rock ramp, this could allow river rocks to pass over the fence and accumulate in the tailrace.

Figure 5 is a plan view acoustic image of Unit 1 tailrace collected using a 15 ft acoustic range with as-built dimensions on the various components. This image was rotated 90 degrees to facilitate dimensioning.

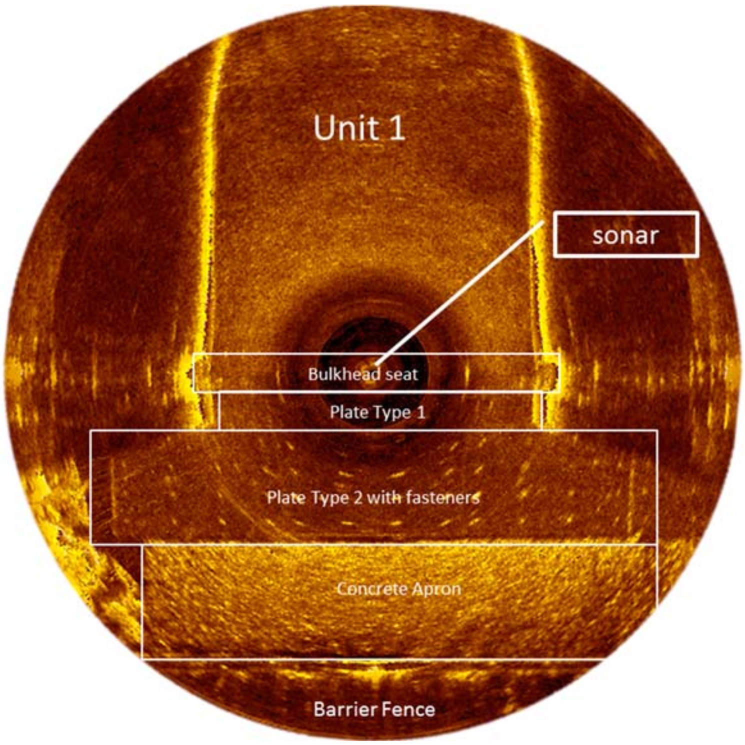

Figure 4. Plan view image of Unit 1 tailrace collected with a 12 ft acoustic range. Various pertinent features in the images are annotated. Note: Components of the barrier fence were not clearly imaged from this sonar position.

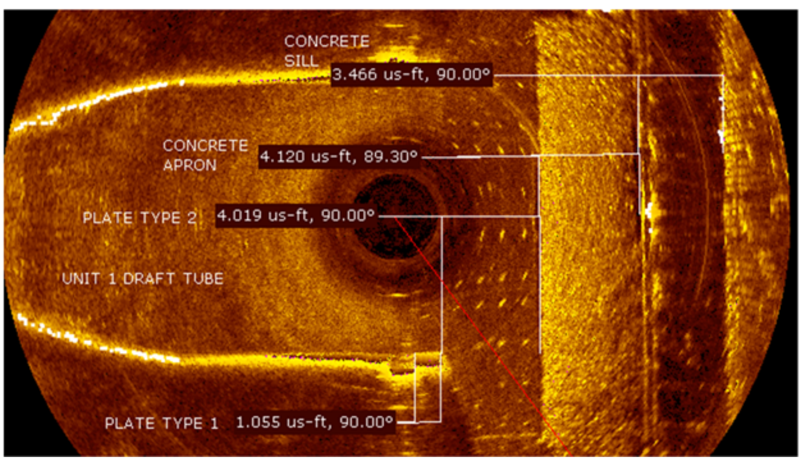

Figure 5. Rotated plan view image of Unit 1 tailrace collected with a 15 ft acoustic range. Various pertinent features in the images are annotated with dimensions in an as-built condition.

Unit 2 Plan View Images

Figure 6 is a plan view acoustic image of Unit 2 tailrace collected using a 12 ft acoustic range. Pertinent features in the image are annotated. This image shows a single joint of the plate type 2, near the right side of Unit 2. The joint is slanted 9 degrees with respect to the bulkhead seat. The other joint is partially visible near the left side of Unit 2, and it appears to be slanted. The slanted joints could be a distortion in the acoustic image because the rows of fasteners are also slanted at a similar angle. There is a plate type 2 joint on the centerline of Unit 2, but its orientation with respect to the sonar (at a very shallow beam incident angle) prevented this joint from showing up in the image.

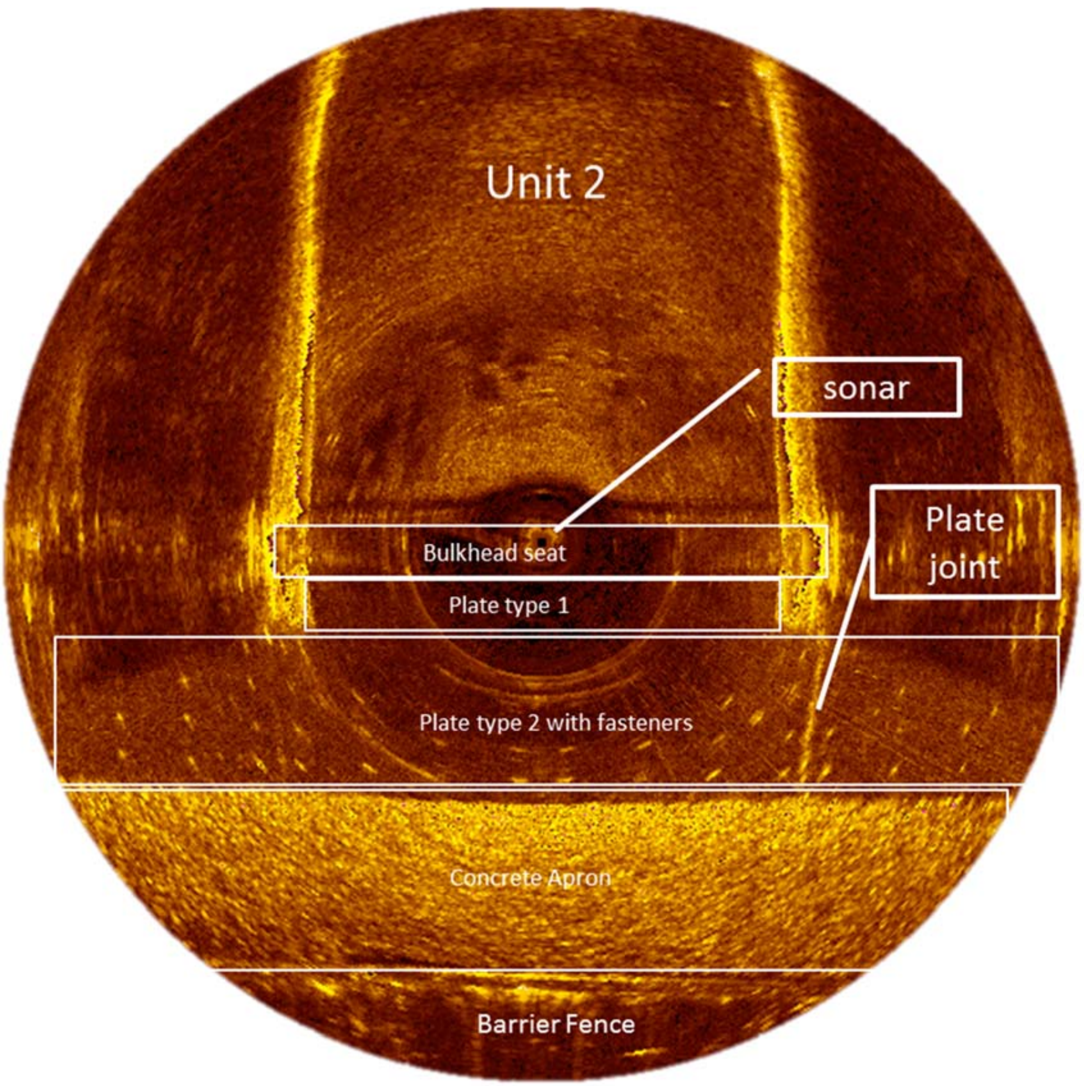

Figure 6. Plan view image of Unit 2 tailrace collected with a 12 ft acoustic range. Various pertinent features in the images are annotated. Note: Structural components of the barrier fence were not clearly imaged from this sonar position.

Figure 7 is a plan view acoustic image of Unit 2 tailrace collected using a 15 ft acoustic range with as-built dimensions on the various components of the repair. This image was rotated 90 degrees to facilitate dimensioning.

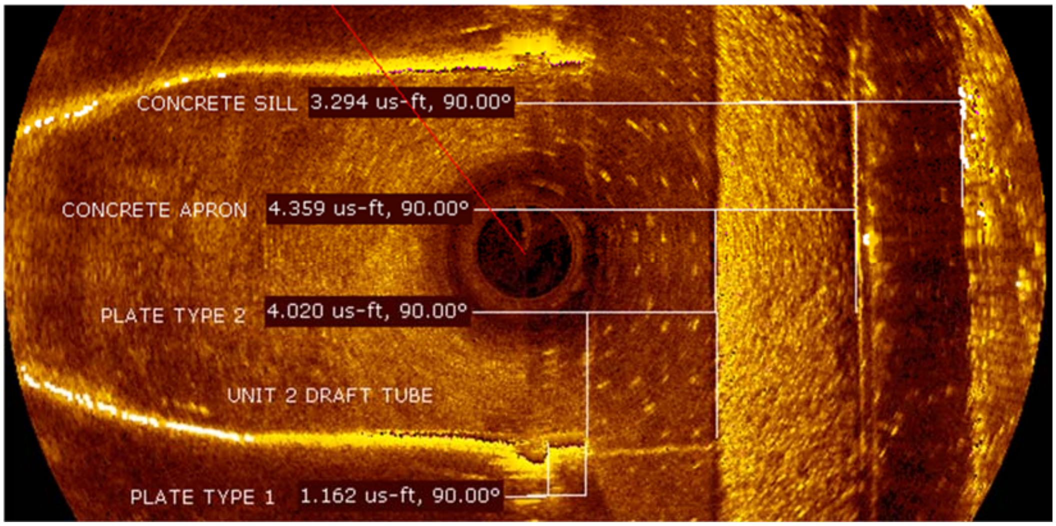

Figure 7. Rotated plan view image of Unit 2 tailrace collected with a 15 ft acoustic range. Various pertinent features in the images are dimensioned in an as-built condition.

Unit 3 Plan View Image

Figure 8 is a plan view acoustic image of Unit 3 tailrace collected with a 12 ft acoustic range. Pertinent features in the image are annotated. This image does not contain the level of detail of the Unit 1 and 2 images because of aeration caused by flow released from a butterfly valve and wicket gate leakage. This flow also created an eddy that holds debris or fish in the Unit 3 draft tube. The concrete apron and tailrace plates appear to be clear of rocks and debris.

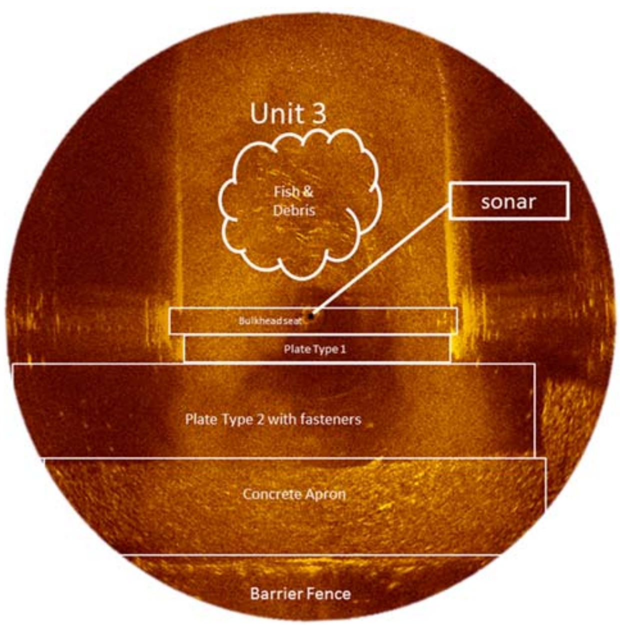

Figure 8. Plan view acoustic image of Unit 3 tailrace collected with a 12 ft acoustic range. Pertinent features in the images are annotated. Note: aeration from releases from a butterfly valve prevented detailed imaging from this sonar position.

Unit 3 Profile View Image

The sonar was removed and reinstalled in a horizontal orientation to collect a sectional profile of Unit 3. The sonar was lowered to El. 5049.88 ft. which is near the upper bulkhead seal plate. Figure 9 is a profile view image along the Unit 3 centerline collected with a 15 ft acoustic range. As-built dimensions measured on the profile image indicate the 4:1 concrete apron is about 4.4 ft long and the concrete sill is approximately 2.8 ft wide. Likewise, the width of type 1 and type 2 plates were measured to be about 1.2 and 4.07 ft wide, respectively. It is important to note, that the dimensioning accuracy of acoustic images is dependent on the image resolution (i.e. acoustic range) and the interpretation of the analyst. As a result, dimensions on images with similar features may not agree perfectly.

The Unit 3 centerline profile image shows the relatively smooth steel and concrete surfaces that are free of any significant debris. It is interesting that many of the structural supports of the barrier fence are not visible in the acoustic image.

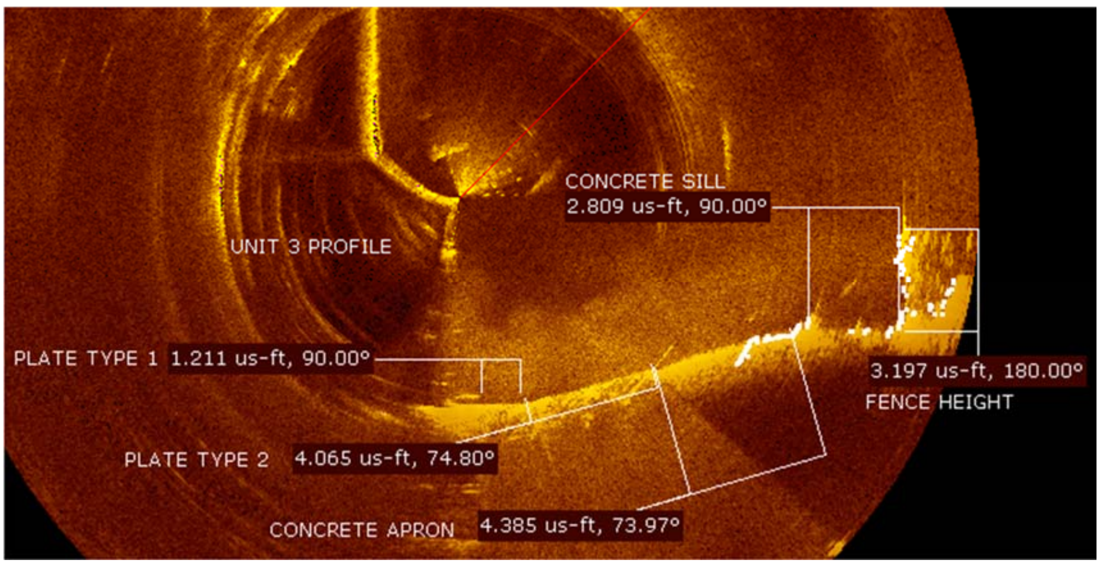

Figure 9. Profile view image of Unit 3 centerline collected with a 15 ft acoustic range. Various pertinent features in the image are annotated and dimensioned in an as-built condition.

Composite Plan View Image

Figure 10 is a composite plan view image of the three tailrace images (22.5 ft acoustic range) draped over a drawing of the Buffalo Bill Power Plant tailrace. The composite image shows slight discrepancies between the plan views of design drawing and the acoustic images. Specifically, the concrete apron and sill widths are not the size indicated on the drawing. In the composite image the effects of Unit 3 aeration on image quality is readily apparent.

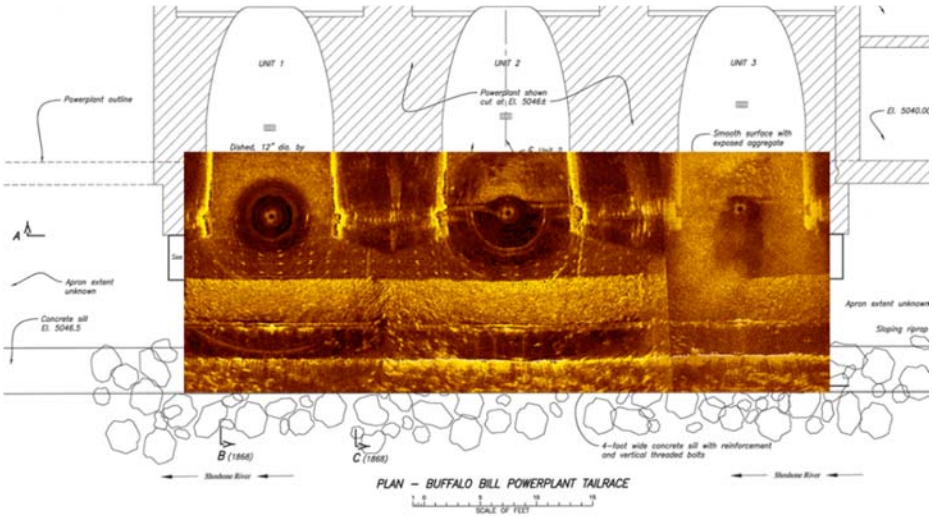

Figure 10. Composite of three plan view acoustic images of the Buffalo Bill Power Plant tailrace draped over a plan view drawing of the tailrace.

Sonar Images of Tailrace Protection Dike

The tailrace protection dike is meant to prevent mobilized river bed material from entering the tailrace area. The original dike had eroded over the years and was no longer functioning as designed. As a result, the dike was reconstructed to be stable during flood releases and to prevent rocks from entering the tailrace. Figure 11 is a plan view of the power plant and the tailrace protection dike. Figure 12 shows a section view of the original and re-designed tailrace protection dike.

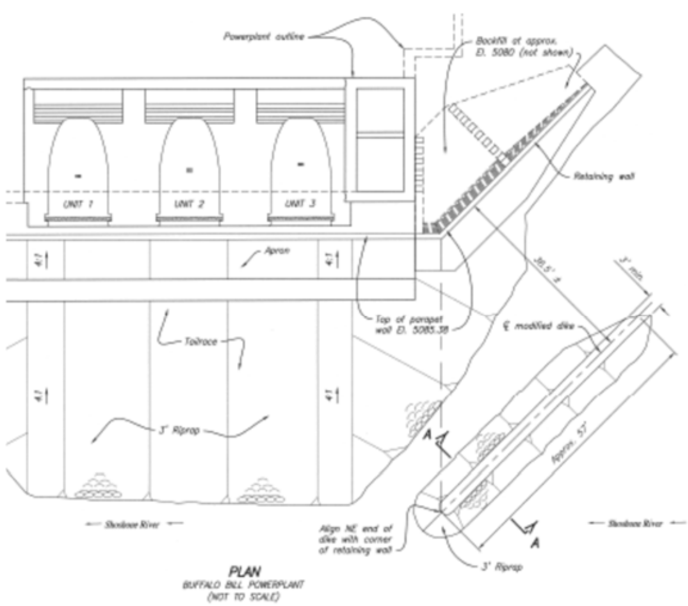

Figure 11. Plan view drawing of the Buffalo Bill Power Plant and tailrace protection dike.

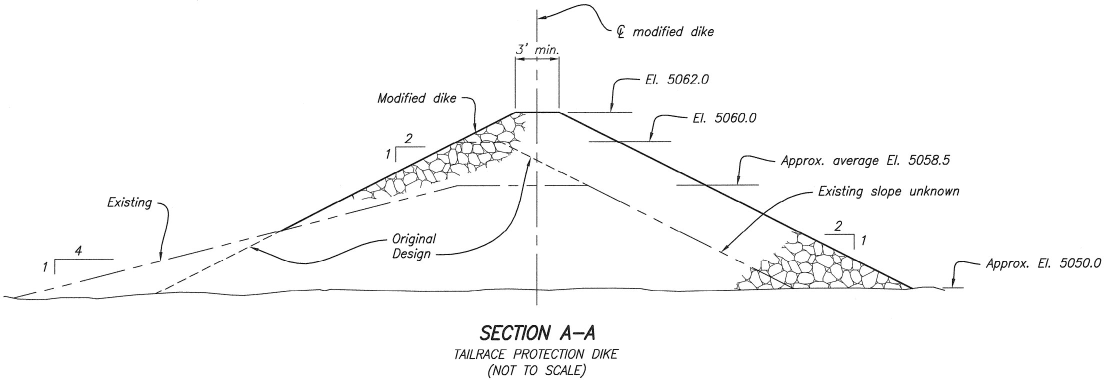

Figure 12. Section view of the original and re-designed tailrace protection dike.

An acoustic image was collected at the corner of the parapet wall and retaining wall to document the as-built condition of the tailrace protection dike. The sonar was lowered 24 ft below the power plant deck (to El. 5057.88 ft) which was one foot below the water surface. Figure 13 is an acoustic image collected with a 15 ft range draped over an aerial photograph of the power plant. This image shows the as-built condition of the downstream face of the dike and the presence of an angular piece of debris (about 4.5 ft long) adjacent to the retaining wall. Note: for this sonar location the image of the dike extends from the water surface to about El. 5056 ft.

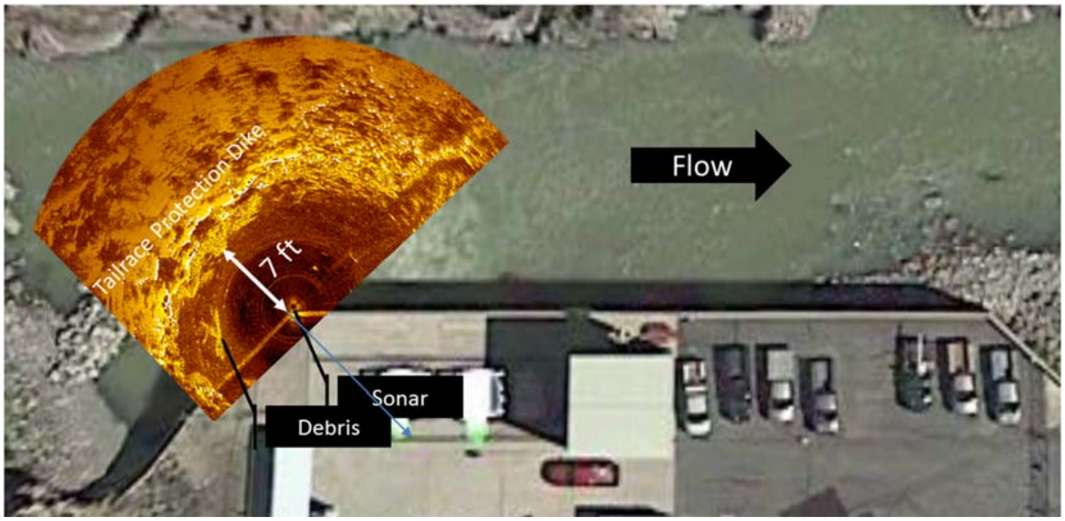

Figure 13. Plan view acoustic image draped over an aerial photograph of the Buffalo Bill Power Plant. This acoustic image shows the downstream face of the dike, a piece of unknown debris, and a 7 ft clear distance from the power plant to the face of the dike.

Conclusions

It is important to note that sonar images of the draft tube and tailrace repair features are not photographs and are open to interpretation. However, careful review of the sonar images and design drawings provided a high level of detail of the as-built conditions.

Flow conditions in the Shoshone River after the tailrace repairs reached a peak flow of 6,400 CFS on June 12, 2015. Sonar plan view images collected four months later (on Oct 20, 2015) did not reveal any rocks or sediment deposits in the newly repaired tailrace.

Sonar images were analyzed to determine as-built dimensions of the repair plates and the barrier fence. The only significant difference was the measured length of the concrete apron (about 4.4 ft) was shorter than the repair drawings indicated (about 6 ft).

Plan view images collected from the bulkhead gate deployments did not capture the structural elements of the barrier fence. If these features are of particular interest, images should be collected from a tripod positioned closer to the barrier fence.

An acoustic profile image collected along the Unit 3 centerline did not show any offsets or debris on the repaired tailrace apron. The acoustic profile did create a good image of the vertical face of the barrier fence.

A plan view acoustic image of the tailrace protection dike was collected to document the as-built condition. This image can be used to compare with future images to evaluate if the dike has changed shape or lost rocks over time.

Appendix 1

Specification Sheet

1071-Series Sonar – Geared Fan/Cone Sonar Head

3000 m "High Resolution" Geared Fan/Cone Sonar Head Digital Telemetry

KONGSBERG

P/N 974-23050000

This version of the 1071-Series Sonar has been specifically designed to produce the highest resolution scanning sonar images possible with 675 kHz. Its design is targeted at bottom clearance, body recovery, underwater construction, pipeline inspection, cable route survey, bridge/pier inspection and applications where data clarity supercedes any other requirement.

This sonar head should also be considered in conditions where the in-water temperatures are lower than 4° C, or higher than 20° C. Domed, oil-filled heads may acoustically defocus beyond these temperature ranges. This sonar head incorporates the electronic advantages of increased sampling rates, wider receiver bandwidth, increased power output, and a very narrow horizontal beam pattern with the fan transducer. The telemetry is RS 485 and RS 232 compatible, and is automatically sensed and configured. The transducer is of a bare-shaft design, but the motor-end is oil compensated to prevent water ingress into the main electronic stack via the transducer shaft.

The sonar head is compatible with the MS1000 and MS900D Surface Processors. To take full advantage of the advanced features and high resolution this head has to be operated with the MS1000 processor.

Operating Frequency	675 kHz
Beam Width	0.9° X 30° Fan/1.7 X 1.7° Cone (nominal)
Range	0.5 - 100 Metres typical; 150 Metres obtainable
Range Resolution	≥ 19 mm (@ 1500m/sec speed of sound, 25 µs transmit pulse)
Sampling Resolution	≥ 2.5 mm
Scan Angle	360° continuous
Mechanical Step Size	≥ 0.225°
Scan Speed	nom 11 sec/360° @ 10 m and 1.8° step size (@ 230 kbits/sec.) nom 36 sec/360° @ 100m and 1.8° step size (@ 230 kbits/sec.)
Transmit Pulse Lengths	25 - 2500 µs
Transmit Power	OFF, 50 W nom, 500 W nom
Receiver Bandwidth	12/100 kHz
TVG Control	-20 to +100 dB
Telemetry	RS 485/RS 232 auto switching asynchronous serial data
Telemetry Rates	Downlink: 9600 Baud Uplink selectable: 230K, 115K, 57K, 38K, 19K, 9600 bits/sec automatic (to suit cable telemetry)
Power Requirements	33W, 22 - 60VDC
Temperature Ranges	-10 to +40° C operating -30 to +40° storage
Operating Depth	3000 meters
Connector	Seacon RMG-4-BCL (optional connectors; inquire to factory)
Materials	Aluminum 6061-T6, 300-Series SS
Dimensions	Diameter 3.5"/89 mm Length 22.4"/569 mm Transducer width 5.5"/140 mm
Weight	In air 13.5 lbs/6.1 kg, In water 6.5 lbs/2.9 kg
Options:	-7801 Built-in Security Key

Specifications subject to change without notice
P/N 974-23057901 Iss 1.5

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