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Hydraulic Laboratory Technical Memorandum, PAP-1201

Sonar Inspection Report for Coalinga Canal Panel Buckling

Central Valley Project – Westlands Water District

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

September 2021

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Central Valley Project – Westlands Water District

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U.S. Department of the Interior
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Acronyms

ft	feet
cfs	cubic feet per second
degree	°
KML	Kongsberg Mesotech LTD
GPS	global positioning system
OM&R	operation, maintenance, and replacement
Reclamation	Bureau of Reclamation
TSC	Technical Service Center

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Purpose

This sonar inspection was conducted as part of the concrete liner repair effort on the Coalinga Canal, specifically to determine the extent and severity of several cracking and buckling locations that had been previously identified by Westlands Water District.

Introduction

This memorandum contains observations regarding the canal lining with buckled panels at specific buckling sites identified by field inspectors. The Technical Service Center's (TSC) Hydraulic Investigations and Laboratory Services Group was requested to use a scanning sonar system to image the canal lining because the canal could not be dewatered for inspection. The scanning sonar system is capable of detecting broken, cracked, or offsets in concrete lining over a variety of scanning ranges and image resolutions in clear or turbid water.

Background

Reclamation has constructed more than 8,000 miles of canals, many of which are facing aging infrastructure issues. The age of these canals varies from relatively recent construction to over 100 years old. Approximately 90 percent of Reclamation's canals have been transferred to entities that now have operation, maintenance, and replacement (OM&R) responsibility. Canals are typically single-purpose irrigation facilities; therefore, the responsibility for the OM&R and related costs of such canal systems lies with the operating entity.

Methods and Materials

Scanning Sonar

A Kongsberg Mesotech MS1000 scanning sonar system (Figure 1) was used for imaging the canal linings in the selected reaches. The MS1000 system, with a high-resolution geared fan/cone sonar

head, was used to collect an accurate two-dimensional representation of underwater structural features. This sonar has a range of 1.5 to 330 feet (ft) with a resolution of about 0.06 ft. A detailed specification sheet for the sonar system is included as appendix 1. The scanning sonar was used using a fan-shaped acoustic beam, which has a 30-degree (°) wide beam angle. This 30° beam angle causes a blind spot directly below the sonar system called a nadir. This can be seen in all the sonar images that were taken for this report.

Figure 1, Photograph of the KML MS1000 scanning sonar system. (courtesy of KML)

Sonar Images

For this project, the sonar was deployed on a wheeled cart with the sonar oriented perpendicular to the canal liner upstream or downstream of the damaged section. Typically, the sonar cart was lowered 1-5 ft into the canal and held stationary. A series of sonar images were collected at various scanning ranges from each fixed location. The sonar cart was then moved to a new location and a new set of sonar images were collected to capture the other side of the buckled location. Sonar images were primarily of the canal side slope lining and a portion of the canal invert. The sonar images are plan views of the canal side slope. The images of the canal bottom are an oblique view, which makes interpretation more qualitative.

An acoustic shadow is defined as the area through which sound waves fail to propagate due to some obstruction or disruption. In the sonar images these are shown by the darker regions. Conversely, areas with a strong acoustic return produce a brighter orange/yellow color. The use of acoustic shadows allows for sonar images to be interpreted at a deeper level than just analyzing the strength of the return. For sonar images presented in this report, the primary acoustic shadows will be caused by buckles, the offsets and cracks associated with them, and the vegetation growing in the canal. Vegetation can be identified by the object moving between sonar scans indicating that it is moving in the flow. A structural feature will not move between sonar scans and can be identified as part of the canal liner.

Canal Positioning

A global positioning system (GPS) system built into the iPad Pro was used to provide geographic coordinates for each inspection location. This data was stored in the inspection notes with an accuracy of ±10 ft. Mile markers were also measured using a tape or surveyor's wheel from the nearest known mile marker location.

Coalinga Canal

The Coalinga Canal, constructed from 1968 to 1973, carries water south from the San Luis Canal (California Aqueduct) through the Pleasant Valley Pumping Plant to the city of Coalinga. The canal is 12 miles long and is located 106 miles south-west from Fresno, California. The canal capacity is 1,100 cfs. Conditions at the site during the inspection were as follow: air temperature between 85-95 degrees and water temperature of 72 degrees.

Location

Six different locations were inspected within the first reach of the canal after the Pleasant Valley pumping plant. These locations are summarized below in Table 1.

Table 1. - Coalinga Canal Inspection Sites. Mile posts were set from the Westland Water District.

Location	Mile Post	Latitude	Longitude	Bank
1	3.43	N 36.28719°	W 120.25976°	Right
2	3.70	N 36.28398°	W 120.25797°	Right
3	4.27	N 36.27646°	W 120.25542°	Left
4	3.72	N 36.28363°	W 120.25757°	Left
5	3.72	N 36.28363°	W 120.25757°	Left
6	3.43	N 36.28814°	W 120.25954°	Left

Results

Sonar inspections were conducted on September 8th, 2021. Three different buckling locations were identified by Westlands Water District and inspected by TSC personnel. The three locations were broken up into six inspection sites with each buckle having at least one broken panel on each bank. The right bank was surveyed first in the downstream direction then, the left bank was surveyed in the upstream direction. The locations of each of the buckles can be seen below in the satellite image, Figure 2. All the acoustic images presented were collected with a 45-ft acoustic range for consistency. However, all sonar record collected were reviewed in the analysis.

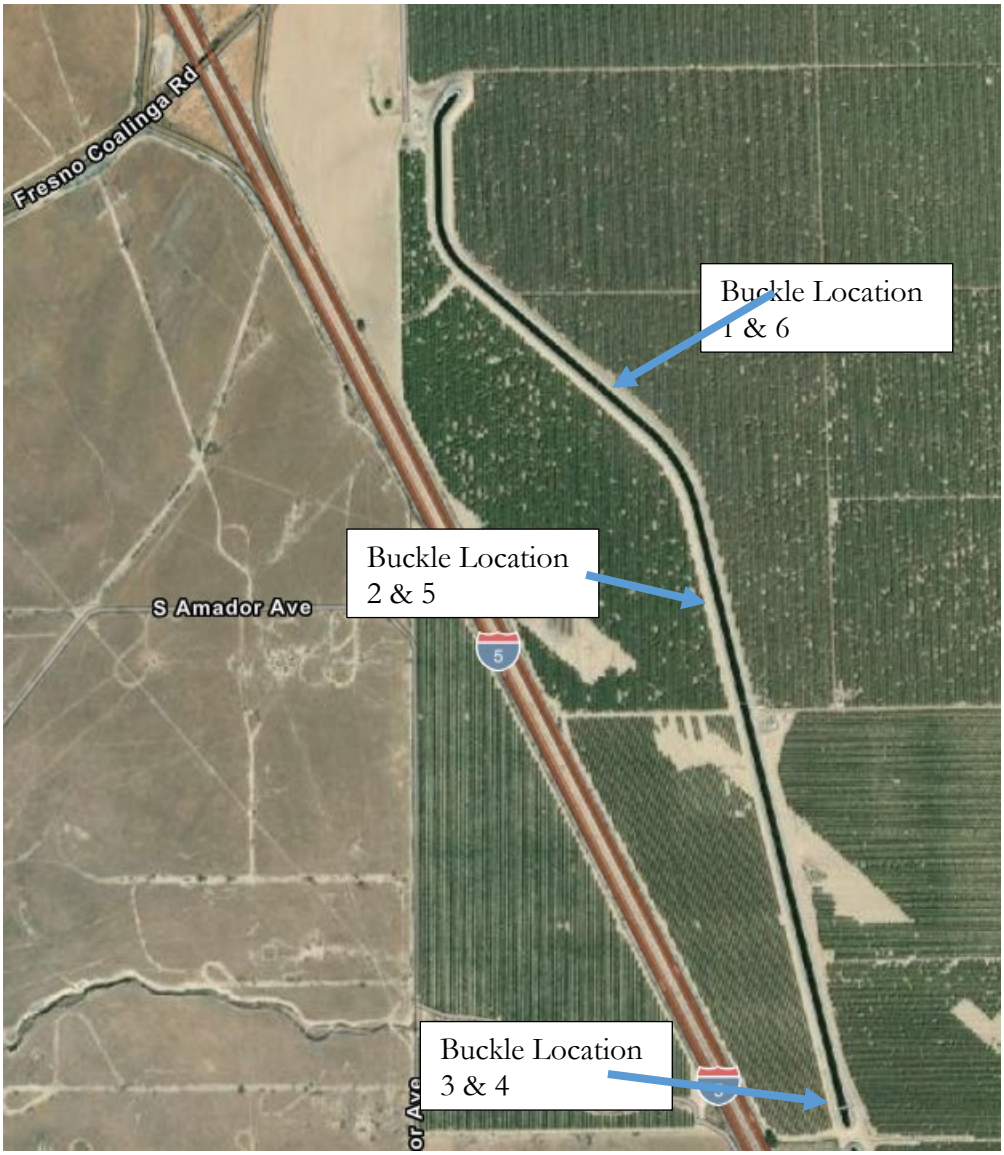

Figure 2. An aerial photo of the Coalinga Canal sonar inspection locations. This image comes courtesy of Reclamation's BOR GIS program.

Buckling Location 1 – Mile Post 3.43 Right Bank

Four sonar scans were taken on the upstream and downstream side of the buckle location. The panels were measured to be 3 inches thick with the buckle protruding 13 inches above the canal embankment grade. As seen in Figure 3. A photo taken of Buckle 1 from the right bank at mile post 3.43. The buckle occurred on the construction joint between the two panels.the buckle was in the construction joint between two panels and does not extend laterally beyond the two affected panels.

Figure 3. A photo taken of Buckle 1 from the right bank at mile post 3.43. The buckle occurred on the construction joint between the two panels. Flow is from left to right.

Figure 4 contains the upstream (left) and downstream (right) sonar records from Buckle 1 at mile post 3.43. Both acoustic records show the extent of the buckle as defined by the acoustic shadow caused by the displaced liner. Based on the dark region behind the buckled liner it appears that the buckle does not extend along the canal invert. A large 5 to 6 ft long object can be seen on the top edge of the buckle indicated by linear feature that generated a strong acoustic return. The rest of the concrete was relatively smooth upstream and downstream from the buckle location.

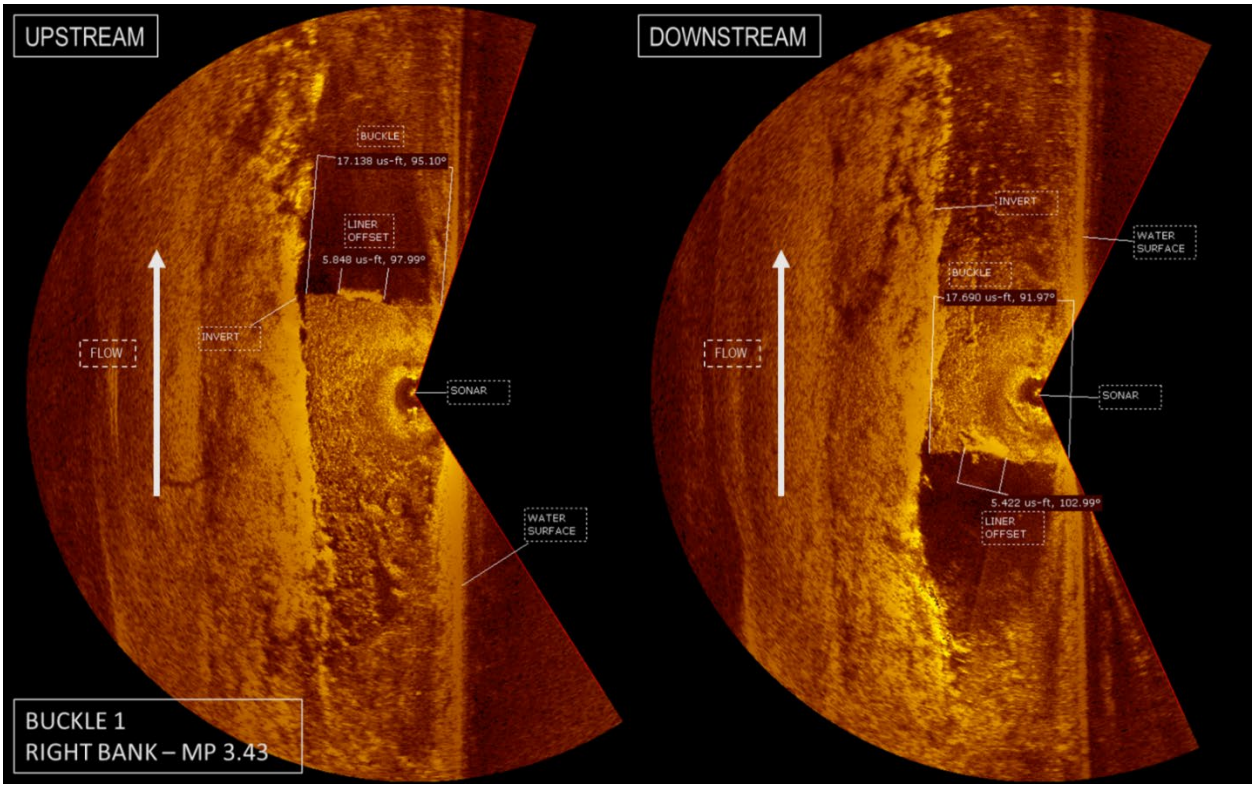

Figure 4. The upstream (left) and downstream (right) sonar records from Buckle 1 at mile post 3.43. The image resolution was set to high, and the acoustic range was 45-ft and the sector angle was 230°. Flow is from bottom to top. The sonar is in the center of the scan area, the invert is defined by a strong return across the length of the sonar image toward the middle of the canal and the water surface is similarly defined on the embankment side.

Observation of Concern

The buckling at this location seemed to be a constant 13-inch rift along the panel joint from the edge of the panel down to the invert with a piece of the liner on the peak of the buckle. Based on the sonar images, the buckling does not appear to extend into the canal invert.

Buckling Location 2 – Mile Post 3.70 Right Bank

Five sonar scans were taken on the upstream and downstream side of the buckle location. The buckle was protruding 10 inches above the canal embankment. As seen in Figure 5, the buckle location above the water surface was near the middle of the panel.

Figure 5. A photo of Buckle 2 taken from the right bank of the canal at mile post 3.70. The buckle occurred near the middle of the panel and jogged to the downstream side just below the water surface. Flow is from left to right in this photo.

Figure 6 contains the upstream (left) and downstream (right) sonar records from Buckle 2 at mile post 3.70. Both acoustic records show the buckle was non-linear (L-shaped) from what was seen above the water surface in Figure 5. In the upstream image, there appears to be two buckles that caused significant shadows behind them. The total horizontal extent of the upstream buckle was measured to be 13-14 ft. The individual buckles being about 7-ft and about 11-ft-long, respectively. In the downstream image, the two upstream buckles were in shadow and were not visible.

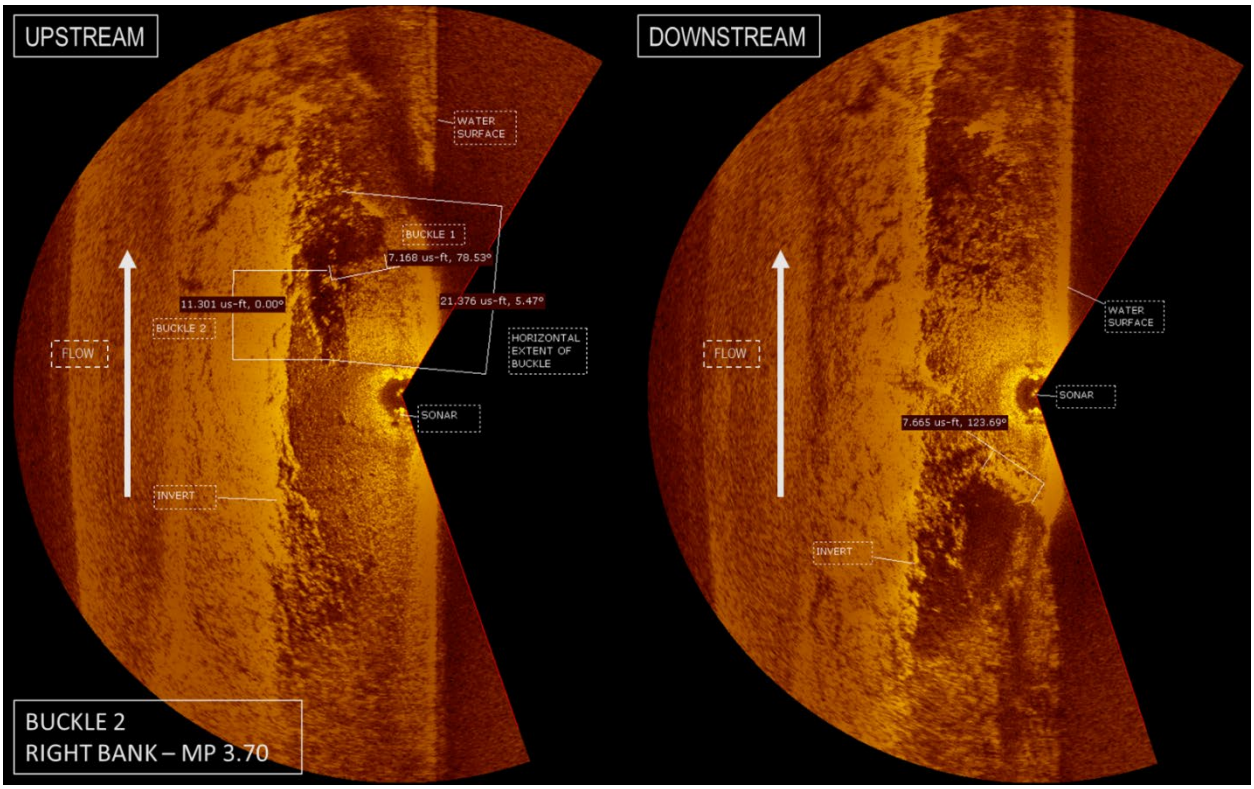

Figure 6. The upstream (left) and downstream (right) sonar returns from Buckle 2 at mile post 3.70.

Observation of Concern

The buckling at this location consisted of a measured 10-inch rift along the panel mid-section from the edge of the panel down to the water surface level and two to three separate buckles below the water surface. The 21-ft horizontal extent of the buckling appears to span two panels. Based on the sonar images the buckling does not appear to extend into the canal invert.

Buckling Location 3 – Mile Post 4.27 Right Bank

Five sonar scans were taken at the midpoint and downstream side of the buckle location. There was a small offset above the canal liner visible above the water surface, Figure 7.

Figure 7. A photo of Buckle 3 as seen from the right bank at mile post 4.27. The buckle was just upstream of a control structure. Flow is from left to right.

As seen in Figure 8, the buckle was diagonal and was more significant than the offset above the water surface. Dense vegetation on the buckle edge makes the exact dimensions of the buckle uncertain but it was estimated to be 13-15 ft in length. The buckle shadow indicates that it did not extend to the canal invert canal. The bridge piers and weir wall of the control structure downstream of the buckle are visible in the downstream sonar scan, the lines that come off the piers were likely acoustic reflections caused by the rounded edge of the pier. The area behind the piers is not visible because of its acoustic shadow. Dense vegetation was typical in this area of the canal. Flow is from bottom to top.

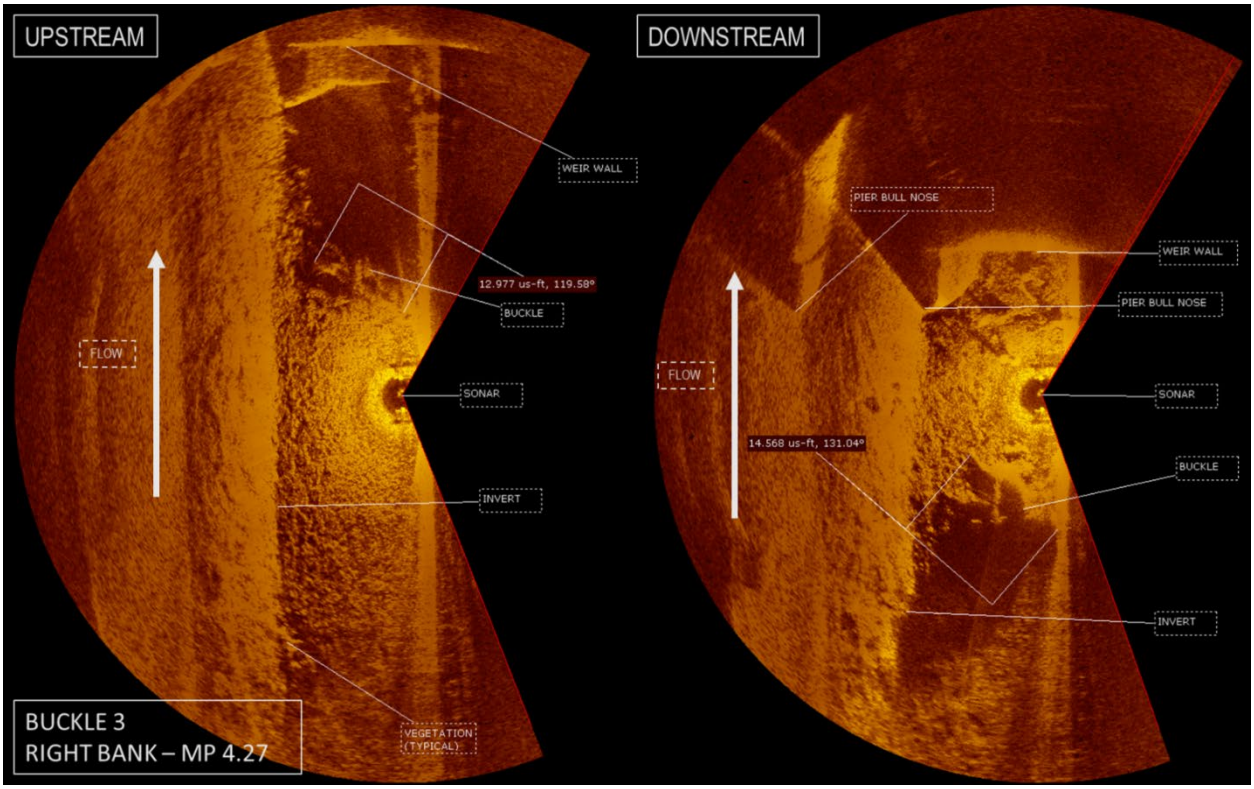

Figure 8. The upstream (left) and downstream (right) sonar returns from Buckle 3 at mile post 4.27. Flow is from bottom to top.

Observation of Concern

The buckling at this location appears to be a 13 to 15 ft long diagonal crack below the water surface. Based on the sonar images seen above, the buckling does not extend to the canal invert.

Buckling Location 4 – Mile Post 4.27 Left Bank

Five sonar scans were taken on the upstream and downstream side of the buckle location. The buckle protruded 20.5 inches above the canal embankment in the section visible above the water surface. Figure 9 shows the buckle in the middle of the panel with the control structure in the background.

Figure 9. A photo of Buckle 4 as seen from the left bank at mile post 4.27. The buckle is just upstream of a control structure. A large clump of vegetation can be seen stuck on the escape ladder just upstream of the buckle. The sonar cart can be seen to the left of the buckle. Flow is from right to left.

As seen below in Figure 10, the buckle was at a slight diagonal and is continuous with what was seen above the water line in Figure 9. The buckle was measured to be 18-19 ft long and does not appear to extend into the invert of the canal. This buckle location was near a control structure with the weir wall visible in both images and the bridge piers visible in the downstream image. The area behind the piers is not visible because of the acoustic shadow. Dense vegetation was typical in this area of the canal with a particularly large clump that caused a strong acoustic return on upstream image. There also appears to be some debris that deposited on the liner downstream from the buckle.

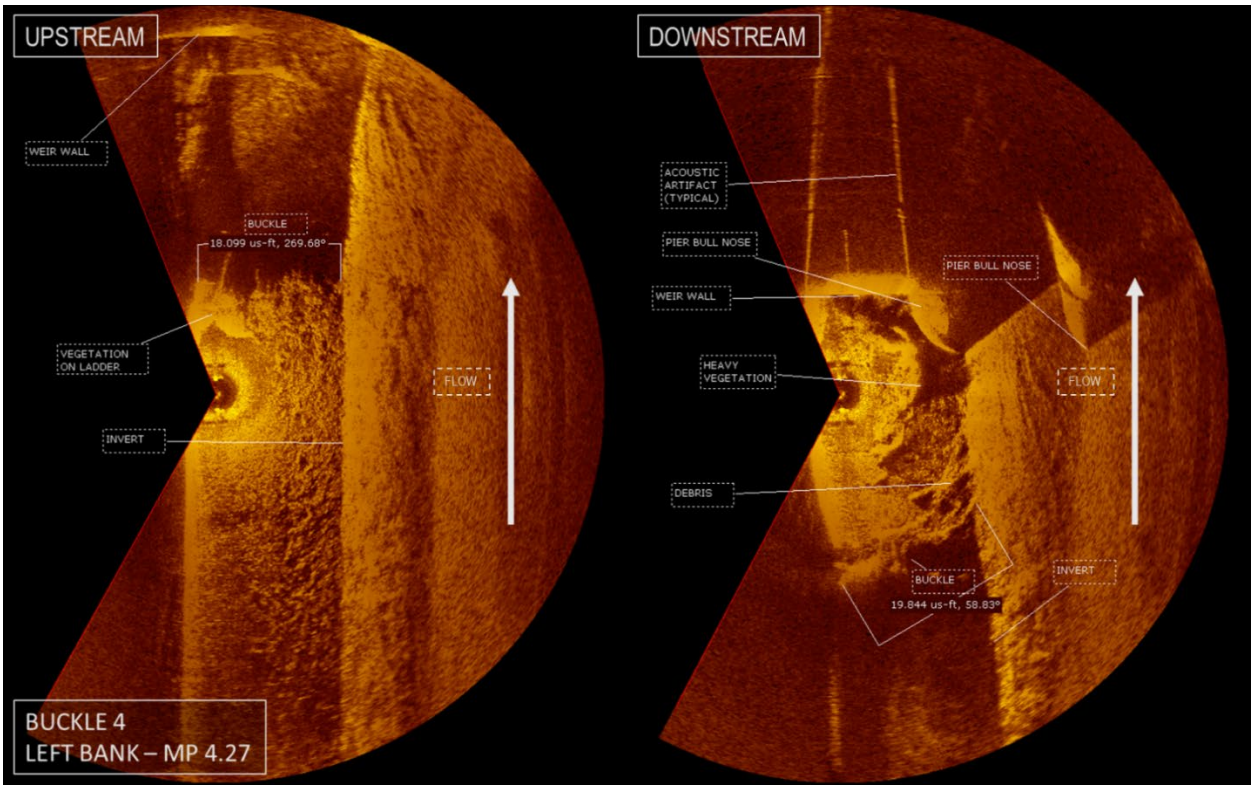

Figure 10. The upstream (left) and downstream (right) sonar returns from Buckle 4 at mile post 4.27. Flow is from bottom to top.

Observation of Concern

The buckling at this location seems to a be a constant 20.5-inch rift along the panel mid-section from the edge of the panel extending 18 to 19 ft down to the canal invert. Based on the sonar images the buckling did not appear to extend across the invert of the canal.

Buckling Location 5 – Mile Post 3.72 Left Bank

Five sonar scans were taken on the upstream and downstream side of the buckle location. The buckle in this location traversed several panels longitudinally just below the water surface. Figure 11 shows the buckle and vegetation as seen from the left bank.

Figure 11. A photo taken of Buckle 5 from the left bank at mile post 3.72. The buckle did not extend above the water surface. The flow in this photo is from right to left.

As seen below in Figure 12, the buckle was estimated to be 17 to19 ft long starting just below the water surface and did not extend across the invert of the canal. There appears to be a significant amount of vegetation attached to the peak of the buckle that can be seen in Figure 11 and Figure 12.

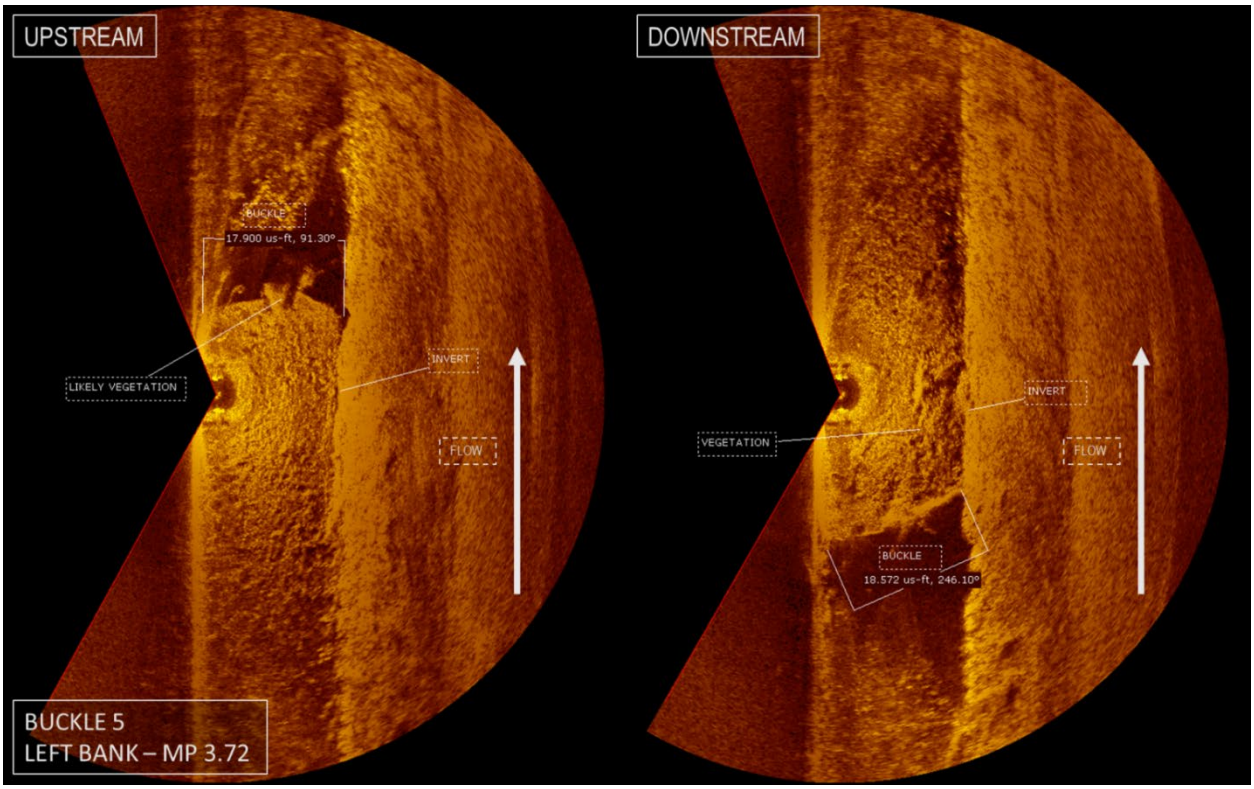

Figure 12. The upstream (left) and downstream (right) sonar images from Buckle 5 at mile post 3.72. Flow is from bottom to top.

Observation of Concern

The buckling at this location started just below the water and continued diagonally about 18 ft down to the canal invert. Based on the sonar images the buckling did not extend into the invert of the canal.

Buckling Location 6 – Mile Post 3.43 Left Bank

Five sonar scans were taken on the upstream side and 7 were taken on the downstream side of the buckle location. The buckle protruded 12 inches above the canal embankment. This can be seen in Figure 13 below.

Figure 13. A photo of Buckle 6 taken from the left bank at mile post 3.43. The buckle was in the joint between two panels and extended 6-8 inches above the canal embankment. Flow is from right to left.

In Figure 14 below, the buckle can be seen extending down to the canal invert but not across it. The buckle was measured to be 17-18 ft long below the water surface. A large amount vegetation can be seen casting an acoustic shadow in the downstream image in close proximity to the sonar head. Additional vegetation can be seen on the peak of the buckle in both images.

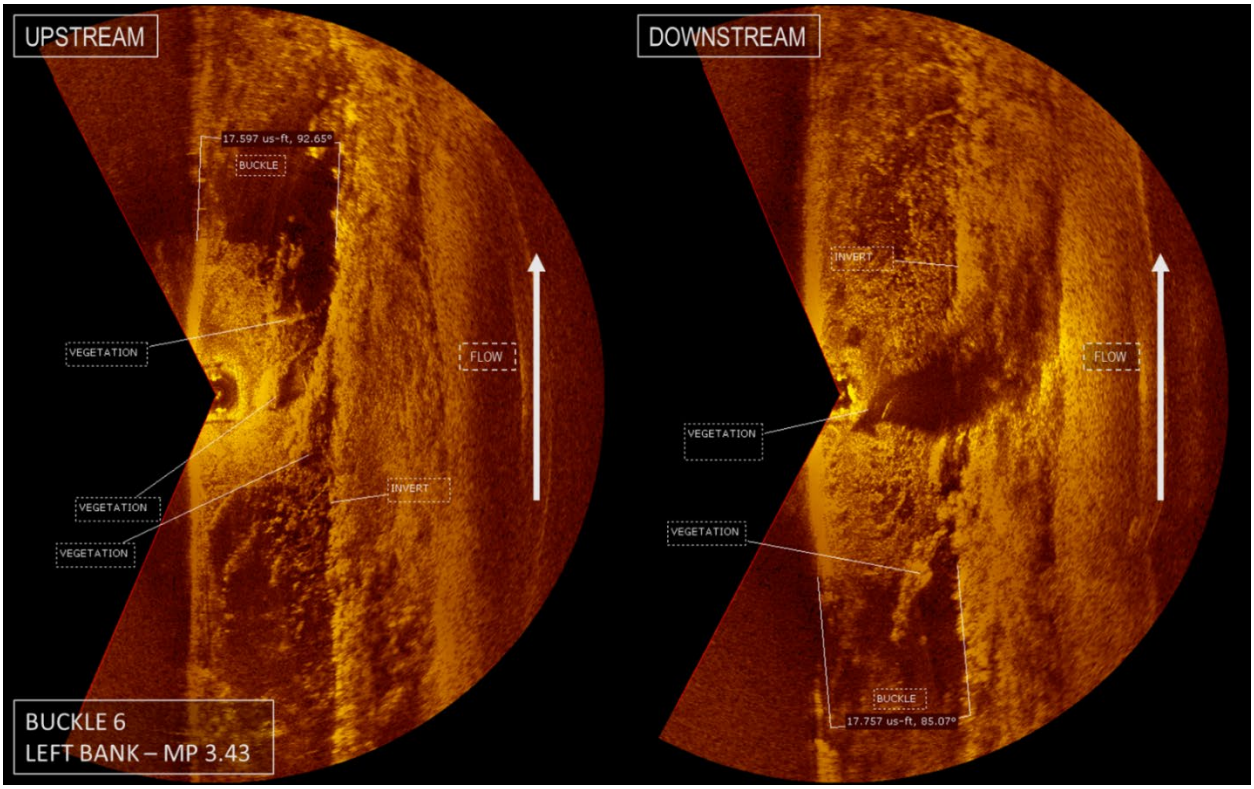

Figure 14. The upstream (left) and downstream (right) sonar returns from Buckle 6 at mile post 3.43. The resolution was set to high, and the range was set to 45-ft. Vegetation can be seen on the two panels that are affected by the buckle. Flow is from bottom to top.

Observation of Concern

The buckling at this location seemed to be a constant 6-8 inch rift along the panel joint from the edge of the panel down to the invert. Based on the sonar images seen above, the buckling does not extend into the canal invert.

Conclusions and Recommendations

All six inspection sites were successfully imaged with scanning sonar. Of the six sites inspected on the Coalinga Canal, sonar images detected signs of significant liner damage at all sites with Buckle 2 showing the most extensive damage with two or three buckles below the water surface impacting two panels along a 21-ft extent. All sites inspected with the scanning sonar indicated buckles that extend down to the invert but do not indicate buckling of the canal invert. At some locations, dense vegetation obscured portions of the buckled panels from the sonar images. If future sonar investigations are warranted, it is recommended that they be done immediately after the canal is treated to remove aquatic vegetation.

Appendix – I Specification Sheet for Kongsberg 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