Improving Sediment Management at the Isleta Diversion Dam

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Abstract

The Isleta Diversion Dam (IDD) is located on the Rio Grande within the Pueblo of Isleta (POI) approximately 15 miles south of Albuquerque, NM. Since the 1930s when the IDD began delivering water to irrigators on both sides of the river through the Middle Rio Grande Valley, excessive sedimentation around the IDD and in the associated irrigation infrastructure has been problematic and costly to manage. The sedimentation also threatens the cultural and traditional needs of the POI. Impacts of excessive sedimentation include reduced canal capacities that impair reliable irrigation deliveries, disruptions to irrigation deliveries because of sedimentation sluicing operations, and decades of accumulation of unsightly dredged-sediment spoil on POI lands. Following an October 2016 settlement between the POI, the U.S. government (represented by the U.S. Bureau of Reclamation (Reclamation), the Middle Rio Grande Conservancy District (MRGCD), and the Bureau of Indian Affairs, the Technical Team (TT) was established, in part, to address these sedimentation issues.

The IDD TT considered multiple approaches to improving sedimentation management around the IDD. Reclamation, MRGCD, and the POI's technical consultant Tetra Tech agreed on hydrographic data collection and several different analyses to develop a cost effective, multi-pronged solution to reduce sedimentation and better manage impacts. During the above average 2019 spring runoff Tetra Tech completed three rounds of measurements of sediment transport and discharge. Tetra Tech carried out a modified Einstein procedure on an extensive gage record in Albuquerque and routed total bed material loads downstream using a one-dimensional mobile-bed model to inform sediment delivery to the IDD. A mobile-bed physical model that included portions of the IDD and eastern canal headworks was designed and operated in the Hydraulics Laboratory at Reclamation's Technical Service Center (TSC). The upper portion of the main east side canal was modified to increase sediment storage capacity, reduce sediment diversions into lateral canals, and allow for more efficient removal of diverted sediment.

The collaborative approach taken by the TT resulted in a multi-pronged solution that is expected to exceed expectations for both reducing impacts of sedimentation and the expected cost to construct and operate the structural modifications to the IDD. This paper and the associated oral presentation summarize several analyses performed since 2017; selected references provide more-thorough information.

Introduction

The IDD, located on the POI (Figure 1), was built in the 1930s and is operated by the MRGCD to supply irrigation deliveries; in the 1950s Reclamation rehabilitated the structure. Over decades of irrigation deliveries, the IDD has also diverted large amounts of sediment from the Rio Grande. The resulting sedimentation in the irrigation canals, particularly near the dam on the east side of the river, has caused temporary disruptions of irrigation water on some canals and necessitated extensive dredging and disposal of dredge spoils. In October 2016, the POI, Reclamation, and the MRGCD signed the “Agreement of compromise and settlement regarding the Isleta Diversion Dam”. These parties agreed, in part, to reduce sediment management issues near the IDD to the greatest extent possible. In addition, because of the current Biological Opinion (USFWS 2016), fish passage at the IDD is required in both the upstream and downstream directions for the endangered Rio Grande Silvery Minnow. TT members GeoSystems Analysis and Tetra Tech developed a comprehensive Bosque and Riverine Restoration plan to help the POI improve habitat in the river and riparian corridor. While fish passage and restoration were important facets of the project, this paper focuses on the sediment management issues.

The preliminary engineering and analysis phase of the project, which has included regular consultation amongst the TT, has been completed (Tetra Tech 2019a, 2022). This phase included a fluvial geomorphic assessment, estimation of the sediment supply to the IDD, field data collection, mobile-bed physical modeling, and development of alternatives. These analyses focused primarily on the delivery of sediment to the IDD and the canal headworks. Because some sediment will still be diverted into canal headworks, the MRGCD has also constructed improvements to the east side canals near the IDD to allow for sediment to be removed more efficiently with fewer disruptions of irrigation deliveries.

In October 2016 as part of the settlement, the POI, Reclamation, MRGCD, and BIA agreed to establish the TT to help resolve technical issues, including canal sedimentation, and continue working together during implementation of solutions. Subsequently, Tetra Tech and GeoSystemsAnalysis were added to the TT to support the POI. The TT has met on a twice-monthly basis, allowing for collaboration and sharing of resources and maintaining a desirable schedule. On a quarterly basis, TT representatives formally report to their managers in a principals’ team meeting to ensure efforts are focused, within the authority of each entity, and funds are being effectively stewarded. The collaboration helped bring about solutions that exceeded initial expectations of how much the sedimentation issue could be mitigated and the cost for mitigating. Work to improve sediment management would not have been as successful if it were not for the collaboration of the TT.

Fluvial Geomorphology Analysis

The fluvial geomorphology analysis included a literature review, analysis of repeat longitudinal and cross section survey data, and a morphometric parameter analysis using aerial photography. The geomorphology of the reach of the Rio Grande between Cochiti Dam (approximately 60 river miles upstream of IDD) and Elephant Butte Reservoir (approximately 120 river miles downstream of IDD) has been evaluated by several people (e.g., Lagasse, 1980; Graf, 1994; Scurlock, 1998; Mussetter Engineering, Inc. [MEI], 2002; MEI, 2005; Makar, 2010; and Baird, 2012). Thus, the literature review and other analyses summarized herein is focused on the details most relevant to the IDD sediment management.

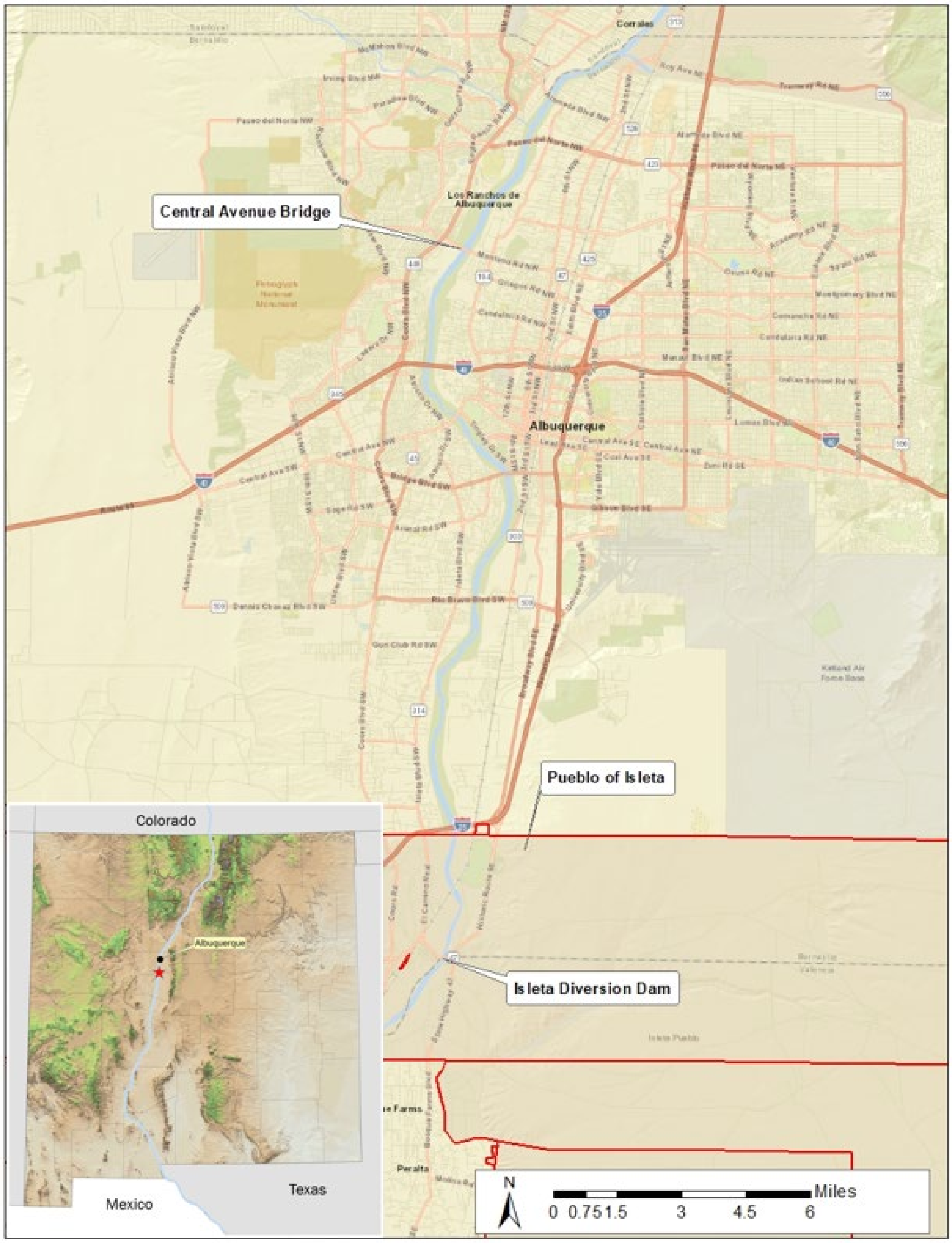

Figure 1. Project vicinity

In the 1930s when the IDD was constructed, large scale channelization and construction of major dams had not yet occurred. Following major flooding in 1942 and 1943, the U.S. Congress passed the Flood Control Act of 1948, which authorized the development of the Rio Grande Comprehensive Plan. By 1956, implementation of the plan commenced. By 1962, more than 100,000 jetty jacks had been constructed to channelize the river (Lagasse, 1980). By 1973 the construction of both Cochiti and Jemez Canyon Dams was complete. Both dams are located upstream of the IDD and were operated to trap sediment and reduce flooding. The combined interactions of these various projects induced geomorphic responses that included (1) reduced sediment loads and coarsening of the bed material; (2) reduced channel widths; and (3) channel incision that, in combination with limited flood flows, led to hydraulic disconnection of the floodplain. While the Rio Grande through the POI narrowed substantially, the presence and operation of the IDD, maintained a wider channel at the dam (Figure 1). Between 1962 and 1992, Reclamation used dredging to prevent the establishment of perennial vegetation on islands and bars (MEI, 2002). Some of the narrowing that occurred after 1992 is attributed to the termination of this dredging program.

As a result of the width and backwater effects, the unit discharge and bed material transport capacity are lower in the few thousand feet upstream and downstream of the dam relative to the rest of the Rio Grande through the POI, causing river deposition proximal to the dam. Baird (2012) estimated that this depositional reach extends 1.5 to 2 river miles upstream of the IDD. Before the Rio Grande through the POI narrowed, the IDD site was located in a constriction, indicating that there was higher sediment transport capacity and the channel near the IDD site was not historically depositional. This indicates that the IDD width and location made more sense in the 1930s; however, because of flood regulation and channel evolution, the dam design now creates or exacerbates sedimentation issues.

Near the IDD in recent decades, the longitudinal thalweg elevations profile and bed material gradations show minor fluctuations but there is not a progressive shift in either parameter. Average bed elevations have increased slightly in recent decades. The bed of the river is predominately sand with limited fine gravel.

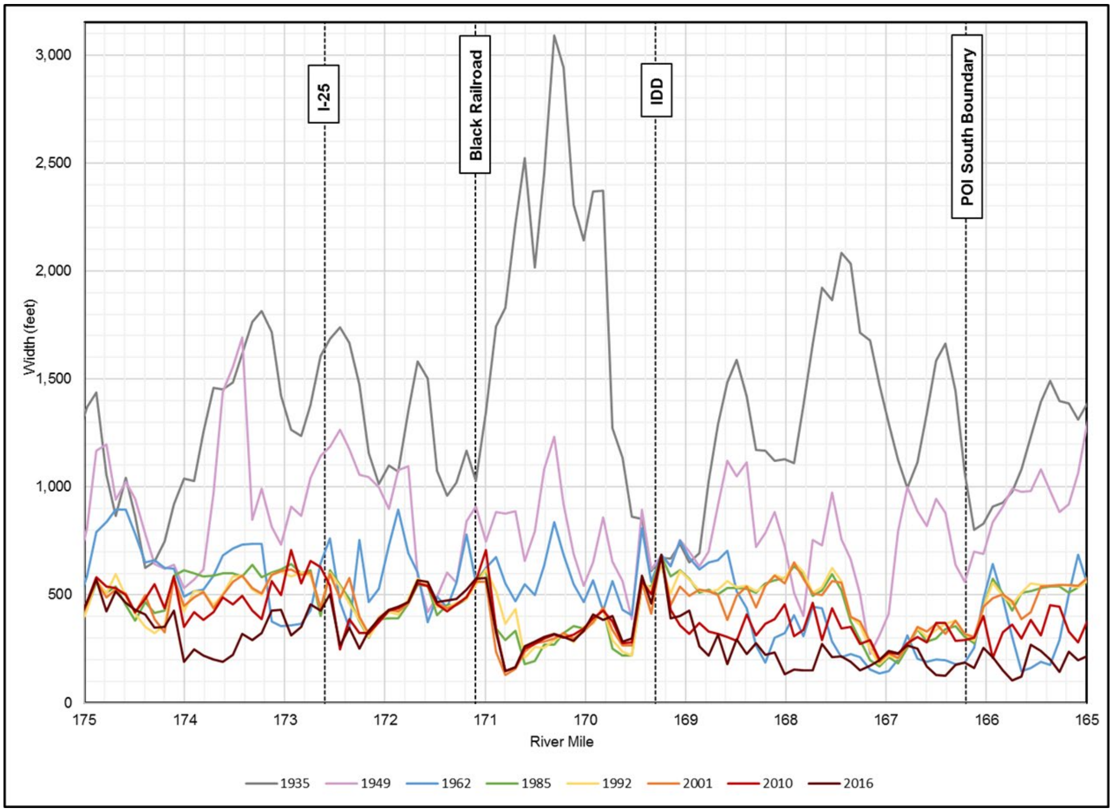

Figure 2. Channel width through time near the IDD based on historical aerial photography

Sediment Supply Analysis

A key consideration in how to address the sedimentation issues at the IDD was the variability in the magnitude, timing, and gradation of the sediment loads the Rio Grande delivers to the IDD. On behalf of the TT Tetra Tech applied two numerical modeling tools to simulate this sediment delivery: (1) a Bureau of Reclamation Automated Modified Einstein Procedure (BORAMEP) analysis of the total sediment load passing a USGS gaging station on the Rio Grande in Albuquerque, and (2) a one-dimensional, mobile-bed HEC-RAS model of the transport and deposition of the total bed material loads passing the USGS gaging station over approximately 14 river miles to the IDD.

Total Sediment Supply Passing Central Avenue

Hydraulic engineers typically use measurements of sediment transport as the observed reference for evaluating the performance of sediment transport simulations. However, such measurements are time consuming and expensive to collect and analyze, limiting their availability. Further, the measurement methods have limitations that can confound accurate interpretations of transported loads and gradations. Fortunately, since May 1969 the USGS has measured hydraulic conditions and associated sediment transport rates at the stream gaging station on the Rio Grande at Albuquerque (USGS No. 08330000, located on the Central Avenue Bridge). These measurements provide the longest consistent record of sediment transport near the IDD.

The USGS's sediment transport measurements at the Central Avenue gage primarily include suspended sediment concentrations, suspended sediment gradations, and bed sediment gradations. The suspended sediment measurements represent only the measured portion of the total sediment load. Colby and Hembree developed the Modified Einstein Procedure (MEP) in 1955 by modifying Einstein's (1950) pioneering sediment transport relationship to estimate the total sediment load by size fraction using measured hydraulics, bed material gradations, and suspended sediment loads and gradations, Then the unmeasured load is the difference between the total load from MEP and the suspended load. Reclamation developed the BORAMEP software to calculate total load using MEP (Holmquist-Johnson et al. 2009). Based on BORAMEP results, the unmeasured load is composed mostly of sand and coarser sediment. At the IDD the unmeasured load was expected to be impactful on the excessive sedimentation, so the TT recognized the value in estimating the unmeasured load passing the Central Avenue Gage. Given the scatter in rating curves of sediment transport as a function of discharge, increasing the size of the sample of measurements contributed to the reliability of the rating curves.

To establish the period of analysis Tetra Tech reviewed: (1) a double mass curve of cumulative suspended sediment load as a function of cumulative runoff volume, (2) cumulative 10-year-long total runoff and suspended sediment load passing the Central Ave. Gage, (3) specific gage analysis, and (4) bed material gradations. The period of interest was set to the 26 years from water year (WY) 1992 through 2017, inclusive. Over the past few decades Reclamation has contracted with the USGS to collect about 12 measurements per year of needed hydraulic and sediment transport inputs for MEP analyses at the Central Avenue gage. The USGS catalogs the measured inputs by date in the National Water Information System (NWIS). The NWIS web portal shows not all inputs needed for the BORAMEP calculations are recorded for each measurement. For this reason, the available records were manually screened to identify missing information and evaluate opportunities to estimate the missing information. For example, at-a-station hydraulic geometry relationships (Leopold and Maddock 1953) were developed and applied to estimate missing measurements of velocity, hydraulic depth, and top width. Similarly, missing water temperatures were estimated using records at a USGS gaging station about 9 miles upriver. The result was 254 candidate measurements for the BORAMEP analyses.

Of the 254 candidate measurements, BORAMEP accepted 206. Most of the rejected measurements had insufficient overlap between the gradations of the transported suspended sediment load and the bed material, which was unsurprising because the Rio Grande transports substantial sand in suspension and wash load. Using the convenient simplification of Einstein (1950), citing Einstein et al. (1940), the limiting grain size for wash load was set to be the diameter for which 10 percent of the bed material gradation is finer (D_{10}). The USGS measurements indicate a D_{10} of about 0.25 mm; however, the conventional break between sand and silt of 0.0625 mm was used as the threshold between wash load and bed material load because very fine sand and fine sand, while potentially wash load in the Rio Grande, can become bed material load in the irrigation canals. Thus, the BORAMEP analyses produced 8 sediment rating curves for very fine sand through medium gravel (0.0625 mm to 16 mm). The MEP can produce extremely low rates of gravel transport, confounding development of rating curves for gravel transport. An incipient motion analysis was used to remove points with extremely low gravel transport so these points would not exert undue influence on the gravel transport rating curves. The rating curves still showed transport rates by size fraction varying by up to two orders of magnitude for a given discharge. Seasonal effects and other temporal drivers were considered as possible explanations for the scatter, but no basis was identified to partition the points. Thus, all points for each size fraction were considered as a single dataset for developing each of the 8 rating curves. The minimum variance unbiased estimator (MVUE) described by Cohn et al. (1989) was used to correct for negative retransformation bias that occurs when fitting linear trendlines to log-transformed data using least-squares regression (Thomas 1985; Ferguson 1986; Kock and Smillie 1986). The MVUE uniquely adjusts each point along the rating curve, which makes the points non-linear in log space. As a result, log-log interpolation between adjacent, corrected points on the rating curves was used to integrate the relationships overflow hydrographs.

Daily sediment transport by size fraction using the average daily discharge recorded at the Central Avenue gage was calculated using log-log interpolation of the bias corrected rating curves. The WY totals were then used to calculate average gradations for each WY. Over the 26 years in the period of interest, on average about 84 percent of the total bed material load passing the Central Avenue gage is between 0.125 mm and 1 mm (fine sane to coarse sand), so it was not surprising that the sedimentation in the canals heading at the IDD was primarily composed of sand.

Simulation of Total Delivery to the IDD

A limitation in the calculated sediment loads and gradations passing the Central Avenue gage is that this location is about 14 river miles from the IDD. Previous geomorphic analyses and available reports indicated that a portion of the sediment transported past the Central Avenue gage is stored along the 14 river miles to reduce the delivery to the IDD. In early 2019 Tetra Tech completed development, testing, calibration, validation, and application of mobile-bed, sediment transport modeling of the Rio Grande between Cochiti Dam and the headwaters of Elephant Butte Reservoir. Tetra Tech recently completed this work under contract to the USACE

Albuquerque District, with funding from the Middle Rio Grande Endangered Species Program. The USACE Albuquerque District supported application of this HEC-RAS model to this project. Between the Central Avenue bridge and the IDD the model geometry was based on 2012 surveys of the channel and floodplain, with surveyed section spacing of about 50 feet. Bed material gradations were based on samples Tetra Tech collected in 2013 for the USACE Albuquerque District.

Applying the bias corrected sediment rating curves at the upstream boundary (Central Avenue) and simulating 37 years of daily average flows indicated that about 35 percent of the bed material load passing the Central Avenue gage is deposited in the channel and overbanks, thereby reducing delivery to the IDD. Annual bed material delivery to the IDD averaged about 620,000 tons, ranging from a low of about 50,000 tons during the drought conditions of 2003 to a high of about 2.1 million tons during the wet conditions of 1995. About 90 percent of this delivery is fine sand to coarse sand (0.125 mm to 1 mm), with about 50 percent of the total delivery being medium sand (0.25 to 0.5 mm).

Field Data Collection

Despite the application of the two numerical modeling tools to simulate sediment delivery to the IDD, the processes that linked operation of the IDD to sedimentation in the canals were understood only on an anecdotal basis. The TT decided to measure hydraulics and sediment transport near the IDD (including in irrigation canals heading at the IDD) during floods would inform the sediment transport dynamics within the IDD, thus informing the TT on how best to alter operations or make structural modifications to reduce sedimentation and associated impacts on reliable irrigation deliveries. As the Pueblo's technical consultant and on behalf of the TT Tetra Tech completed three one-week-long rounds of hydraulic and sediment transport measurements during the spring 2019 runoff in the Rio Grande (Tetra Tech 2019b).

Measurements included hydraulics (velocities, discharge, water-surface profiles) and sediment transport (depth-integrated and point suspended sediment concentrations, bedload transport, bed material gradations) at 14 locations around the IDD (Figure 3). Velocity and discharge were measured using either a RiverRay™ ADCP or a Marsh-McBirney Flo-Mate 2000. Bedload transport was measured using either a handheld Helley-Smith sampler or a cable-deployed Helley-Smith sampler following the single equal-width increment (SEWI) method (Edwards and Glysson 1999). Depth-integrated suspended sediment concentration measurements were collected using a handheld DH-48 sampler or a cable-deployed D-74 sampler following the SEWI method used for the bedload transport measurements. Suspended sediment point concentrations were measured using a P-72 sampler following protocols in Edwards and Glysson (1999). Volumetric bed material samples were collected following minimum sample mass requirements in ASTM D6913-04. The USGS New Mexico Water Science Center in Albuquerque completed laboratory analyses of sediment masses, concentrations, and gradations applying standard USGS protocols.

The hydraulic and sediment transport measurements greatly improved the understanding of the sediment transport dynamics around the IDD and in the irrigation infrastructure heading at the IDD. Conceptually the measurements informed a framework for evaluating sedimentation impacts around the IDD. This framework, envisioned in the downstream direction, included (1) reducing the inflow of sediment to the sluiceways, (2) reducing sediment diverted into the canal headings, (3) better managing sedimentation in the sluiceways, and (4) better managing sedimentation in the canals. This four-component framework helped clarify why the west sluiceway and the Belen Highline Canal experience less-impactful sedimentation than the east sluiceway and the various canals heading at this sluiceway. As visually observed during the 2019 spring runoff the primary difference was turbulence of flow approaching the sluiceways and turbulence in the sluiceways. This finding guided consideration of structural modifications proposed to the east sluiceway. For example, the depth-integrated suspended sediment transport measurements show that about 90 percent of the total bed material load entering the sluiceway was transported in suspension, so decreasing turbulence was key to reducing energy available to maintain this sediment in suspension. Further, structural modifications that could eliminate all bedload would only induce about a 10-percent reduction on sediment delivery into the sluiceway. Additionally, the influence of turbulence was a key factor in the TT considering whether to evaluate structural modification options using numerical modeling tools versus a scaled physical model. The state of the science concerning sediment transport algorithms in 3D numerical modeling software raised concern about sufficient accuracy, so the TT elected to use a scaled physical model. The field data collection was key for developing and testing the physical model.

Figure 3. Location of hydraulic and sediment transport measurements.

Development of Options

A total of 35 sediment management options were developed as candidate solutions to reduce sedimentation around the IDD and in canals heading at the dam. Twenty-nine of these options were developed during a preliminary phase, and six options were developed later, concurrent with the physical modeling. Development of an option included conceptual level cost estimates and design drawings (plans, profiles, and/or typical details). Tetra Tech prepared many of the design drawings; Reclamation's TSC prepared the balance. Tetra Tech proposed, and the TT accepted, evaluating each option using 10 sediment management goals and 20 evaluation criteria. Goals were scored as either meeting the goal (i.e., 1) or not meeting the goal (i.e., 0). Options that did not meet all the goals were either removed from further consideration or combined with other options. Scoring for each evaluation criteria ranged from zero to three with agreed upon standards to make scoring of options consistent and reduce subjectivity.

Physical Modeling

Reclamation's Hydraulics Laboratory in Denver, CO constructed a 1:8 scale physical model of a section of the eastern side of the Rio Grande including a portion of IDD and the Peralta Main Canal headworks for evaluation of options to improve the sediment separation between the sluiceway and the headworks. The 1:8 scale mobile-bed physical model represented 10 east side river gates (IDD Gates 21-30) and the east side diversion including the sluiceway, Peralta Main Canal headworks, and appurtenances (Figure 4). The 1:8, Froude scaling was selected to have 10 east side gates fit within the available floor space in the Hydraulics Laboratory. Sediment was scaled using fall velocity to enable sediment to be transported both in the bed and in suspension in the physical mode.

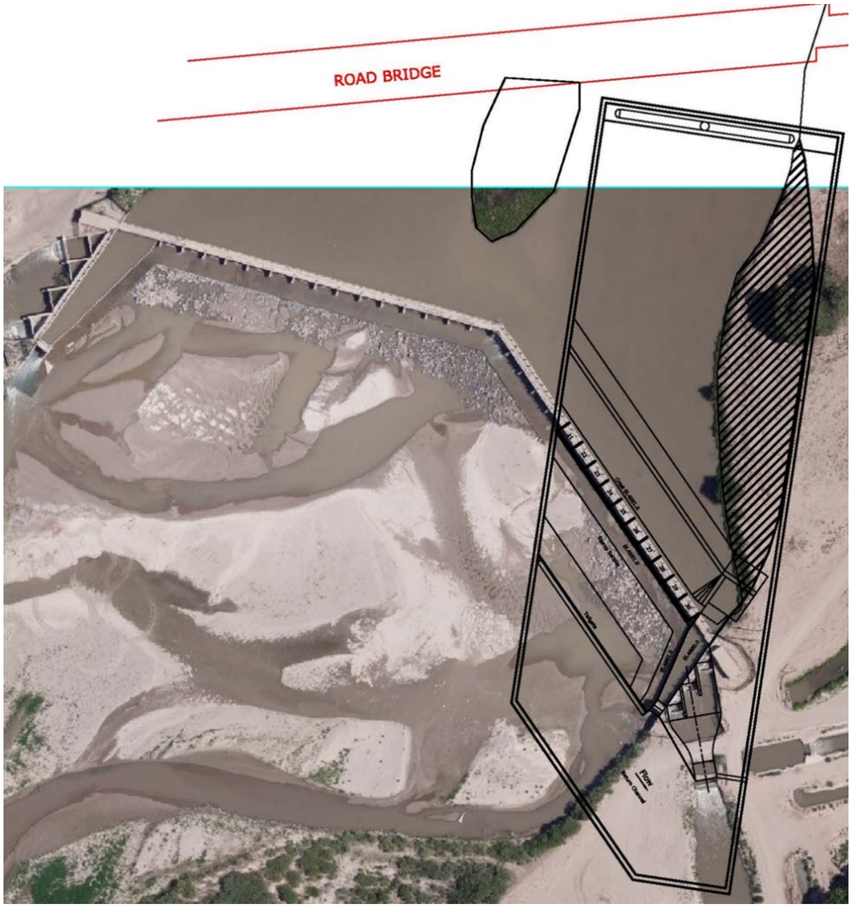

Figure 4. Aerial overlay showing extents of the 1:8 scale physical model covering a portion of the Rio Grande, IDD and Peralta headworks. The hatched area shows the east bank removal for realignment as part of the Options that were physically modeled.

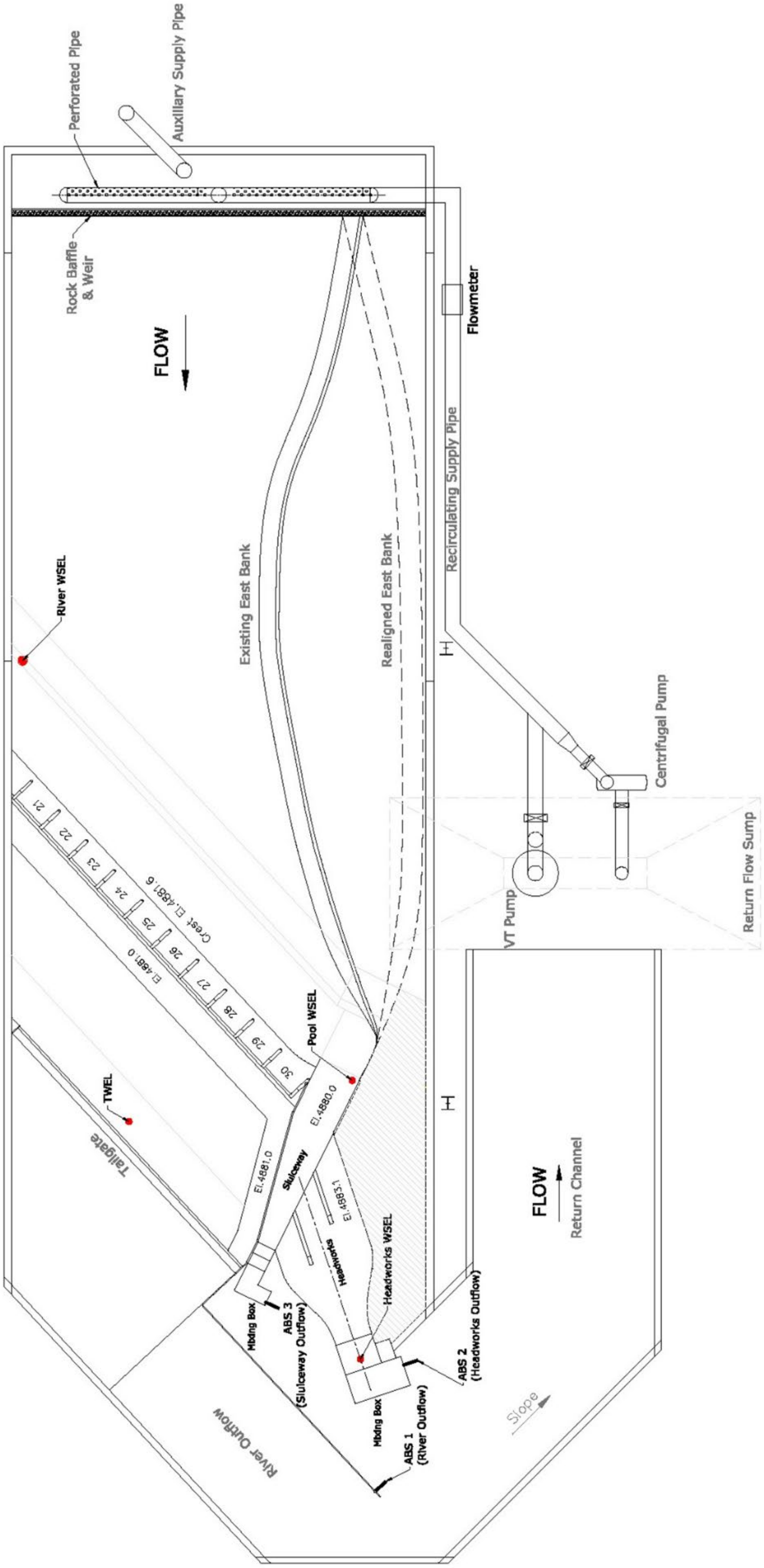

Figure 5. Schematic layout of 1:8 scale physical model (elevations are shown at prototype scale) (Kubitschek, 2022)

Figure 6. Graded bed of scaled sand prior to the start of a mobile bed test

The physical model was tested and calibrated using measurements collected during the 2019 spring runoff. The model used acoustic backscatter sensors to continuously measure sediment concentrations in the river, exiting the sluiceway, and entering the east side canals. These measurements allow for comparing the ratios of sediment concentration entering the canals (C_H) to the concentration in the river (C_R), which eliminated the need to match concentrations between simulations. The modular construction of the model facilitated changing configurations of the east sluiceway to measure changes in the sedimentation management around the IDD. Diversion of sediment increases as the discharge exiting the sluiceway increases (Figure 7), therefore multiple sluiceway gate openings were tested.

Multiple options were tested in the physical model. Three options tested (Figure 7) resulted in the greatest reduction in sediment diversion: (A) modify the east bank alignment upstream of the east sluiceway, (B) modify the east sluiceway to have a 3.5% floor slope, and (C) widen the east sluiceway with a 4% floor slope. Testing indicated that combining east bank re-alignment with either sluiceway modification option yielded the best results for decreasing the quantity of diverted sediment. Widening the sluiceway resulted in the greatest reduction in sediment diversion.

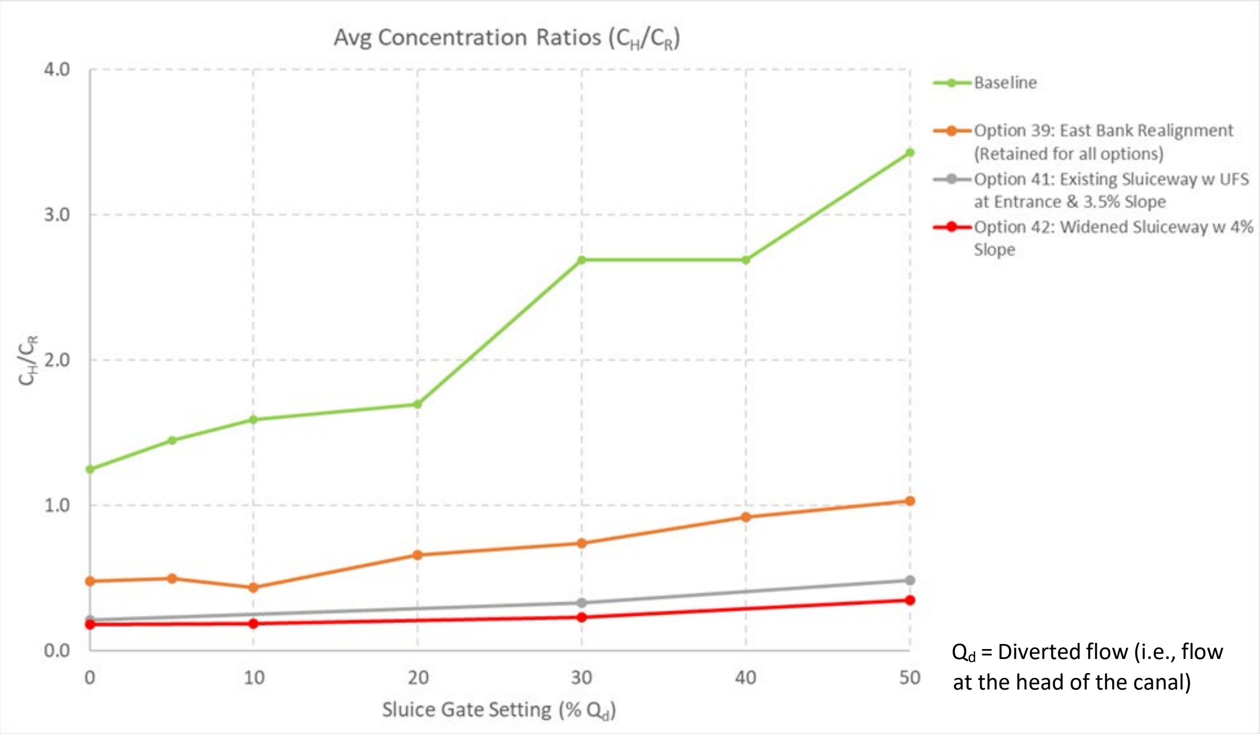

Figure 7. Graded bed of scaled sand prior to the start of a mobile bed test

Evaluation of Options

Tetra Tech assigned conceptual level cost estimates based on: quantities estimated from the conceptual level design drawings, standard percentages of construction costs for mobilization/demobilization (7-15%), staging and site preparation (2.5-5%), permitting and environmental support (1.5%), planning and design (10%), and construction supervision and administration (7.5%). A 45% contingency was assigned to all cost estimates because of the conceptual nature of the options, the importance of maintaining irrigation diversions throughout construction, and the complexities of modifying aging infrastructure. Annual operations and maintenance (O&M) costs were assigned as a percentage of each line item of the cost estimate that would require operation or maintenance. The average-annual cost of sediment removal for the initial 29 options was estimated in categories based on anecdotes of the average number of days dredging activities would be required, the size of crews removing sediment, and the expected dredging equipment. For the six options developed concurrently with the physical model, sediment removal costs were estimated using estimates of average annual sediment supply based on the 1D mobile bed modeling analysis and C_H/C_R ratios measured during physical modeling. Total project O&M costs were estimated assuming a 50-year design life. Details for this process as well as itemized costs estimates for several options are presented in Tetra Tech (2019a, 2022).

Ultimately, three options met all the goals and scored highest after considering all evaluation criteria: (A) modify the east bank alignment upstream of the east sluiceway, (B) modify the east sluiceway to have a 3.5% floor slope, and (C) widen the east sluiceway with a 4% floor slope.

Physical model testing indicated that combining the east bank re-alignment with either sluiceway modification option yielded the best results for decreasing the quantity of diverted sediment. Widening the sluiceway resulted in the greatest reduction in sediment diversion. However, this option came with higher uncertainty in construction efforts and associated fees because the sluiceway foundation could require modification and, possibly, repair to accommodate the widening and new wall. To better quantify this impact, multiple cost estimates were developed (Table 1). The total life cycle costs for the widened sluiceway (Option C) and sloping the floor of the existing sluiceway (Option B) were approximately equal. The TT identified the risk that irrigation diversions were more likely to be disrupted by the construction of the widened sluiceway (Option C). This risk was not acceptable to the MRGCD or POI. Thus, the TT recommended that design of the re-aligned east bank and modification of the east sluiceway to include a sloped floor (i.e., no widening) move forward. While the various modeling exercises were valuable, the final recommendation also came down to the TT's comfort with risks and collaboration with engineers experienced with the construction of modifications to aging infrastructure. The extensive modeling provided the needed confidence in decisions based on performance quantified with the C_H/C_R.

Table 1. Summary of conceptual costs for select options

ID	Option	Total Construction Cost	Total Annual O&M	Project Life O&M	Total Life Cycle Cost
A	Modify east bank alignment upstream of east sluiceway	\$330,000	\$187,000	\$9,350,000	\$9,680,000
B	Existing East Sluiceway Modified to have a 3.5-percent Floor Slope	\$520,000 - \$1,130,000	\$112,000	\$5,600,000	\$6,120,000 - \$6,730,000
C	Widened East Sluiceway with a 4-percent Floor Slope	\$1,670,000 - \$2,680,000	\$89,400	\$4,470,000	\$6,140,000 - \$7,150,000
A&B	See above	\$850,000 - \$1,460,000	\$113,000[1]	\$5,650,000	\$6,500,000 - \$7,110,000
A&C	See above	\$2,000,000 - \$3,010,000	\$91,000[1]	\$4,550,000	\$6,550,000 - \$7,560,000

Key Outcomes

The most important outcome of the TT's collaborative approach to evaluating sedimentation management issues at the IDD is the identification of a proposed option to structurally modify the IDD that appears likely to produce high-value improvement in sedimentation management. This outcome was achieved because of the completion of the various analyses described herein. For example, the analyses of the fluvial geomorphology of the Rio Grande near the IDD established the basis for the TT to identify candidate options to improve sedimentation management. The sediment supply analyses informed the magnitudes and gradations of sediment the Rio Grande delivers to the IDD, which helped evaluate long-term performance of the candidate options under a wide range of hydrologic conditions. The hydraulic and sediment transport measurements greatly improved the TT's understanding of the sediment transport dynamics around the IDD and in the irrigation infrastructure heading at the IDD. The TT identified many options to modify the structure of the IDD and operations, and the greater understanding of the sedimentation issues provided a means for screening the options for further analysis. Further analyses included physical modeling, conceptual designs and cost estimates, and numerical modeling. The physical modeling provided a quantifiable means for comparing the performance of structural modifications. The conceptual designs and cost estimates were key for the TT to evaluate whether incremental differences in performance were justified by additional construction and O&M costs.

Ultimately the TT selected the structural modification that provided the second-best performance in terms of reducing sedimentation around the east sluiceway because the highest performing option provided only incremental increase in performance for about the same cost over the 50-year design life. Thus, the value of the TT's preferred option was identified only through the extensive analyses that led to a solution none of the stakeholders had considered at the outset of the Project. Equally as valuable is the confidence the TT has in recommending the preferred option because of the understanding of the hydraulic processes and sediment transport dynamics that have been driving sedimentation management challenges around the IDD for almost a century.

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