APPENDIX E

Engineering Appendix

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APPENDIX E-1

ENGINEERING APPENDIX

ENGINEERING DESIGN

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I. Engineering Scope

Various engineering services were provided in support of the feasibility study for the Resacas at Brownsville, Texas Ecosystem Restoration project. Those services were generally geared toward evaluating hydraulic models produced as part of a previous study, evaluating previously collected survey data, assessing the existing conditions of the resaca systems and calculating estimated construction quantities and costs associated with implementation of the various restoration measures under consideration. Feasibility level designs were also conducted for providing a method of controlling the water surface elevations in resaca segments where a vegetation restoration measure was being considered and for supplying water to hydraulically disconnected resaca segments included in the study.

II. Existing Data Sources

Every effort was made to obtain and use the most recent existing survey data and hydraulic models for the study area. The large footprint of the study area would have made gathering all new survey information extremely costly and time consuming. Therefore, survey information from various sources was utilized to establish the existing conditions for the study. A brief description of each source is described in the paragraphs below.

A. Field Survey

Limited survey data of various resaca segments was obtained in 2003 and 2004 by the Brownsville Public Utilities Board (BPUB) to determine available water depths and thickness of sedimentation throughout their resaca system. The surveys consisted of taking various measurements, but the primary data used in this study were cross sections taken across selected resaca segments. The cross sections included survey points located of the top of sediment, top of clay layer beneath the sediment and water surface elevation at the cross section location. While the age of the survey data was of some concern, it was decided that it was suitable for use in the feasibility study. An entry was made in the risk register to account for any variation that may have occurred over time at the locations of the surveyed cross sections.

B. LiDAR Survey

For areas where no ground based survey data was available, LiDAR survey data was used. The LiDAR data consisted of a single band, 10 meter resolution survey of Cameron, Willacy, and Kenedy Counties published by the NOAA Coastal Services Center and the US Geological Survey in 2012. The portion of the data in Cameron

County, in which this study is situated, was said to have originated from LiDAR data sets collected for the Texas Water Development Board (TWDB) in 2005 and 2006.

C. HEC-RAS Model

The BPUB provided HEC-RAS (Hydrologic Engineering Center's River Analysis System) models of Town Resaca, Resaca de la Guerra and Resaca del Rancho Viejo for use in this feasibility study. The models were originally developed by Ambiotec Group in cooperation with Rice University in 2003/2004 and later updated in 2011 to add Resaca del Rancho Viejo. The models were produced as part of a March 2006 Flood Protection Plan developed for the City of Brownsville and the Texas Water Development Board. Additional information on the HEC-RAS model is provided in the Hydrology and Hydraulics Appendix E-4.

III. Field Investigation

During a site visit July 25-29, 2016, BPUB personnel led a tour of the resaca systems and explained how they were connected and operated both for irrigation water supply during dry periods and for drainage during rainfall events. Measurements were taken of hydraulic structures, ecosystem surveys of potential restoration sites were conducted, to assess the possibility of linking multiple resaca segments into continuous corridors.

During the field investigation some resaca culverts were found to be different sizes than those coded in the HEC-RAS model. The culverts observed in the field were larger diameter pipes than those in the model. The discrepancy was discussed and it was decided to continue using the HEC-RAS model for the following reasons:

1. It was not anticipated that the larger culvert sizes would have an impact on any of the restoration measures being considered. This is because the resacas would be in a low flow condition for the vast majority of the proposed project life. Any high water events caused by storms would be of a short enough duration and include low enough velocities that restoration measures would not be negatively impacted.
2. A detailed model of the irrigation water delivery system would be required in order to establish water surface elevations during various operational conditions and to design a method of fluctuating those water surface elevations to mimic historical seasonal variations. Developing such a detailed model is beyond the scope of this General Investigation. An entry has been made into the risk register to account for risks associated with making feasibility level decisions without having a detailed model. Development of the detailed model will be performed during PED activities.

IV. Construction Quantity Estimation

A. Earthwork Quantities

Once the PDT had identified the initial array of restoration areas and associated measures, earthwork quantities were estimated using the surveyed cross sections, where available. The surveyed cross sections were plotted using MicroStation and InRoads CAD software packages. The bank sculpting and dredging measures were superimposed onto the plotted cross sections and associated cross sectional areas of dredge and fill were measured. These cross sectional areas were multiplied by the length of the proposed measure to estimate the total volume of earthwork associated with each measure for that area. A typical cross section showing the dredging and bank sculpting measures is presented in Figure E-1-1. Additional cross sections used in calculating earthwork quantities are shown in Figure E-1-2 through Figure E-1-9.

For areas where dredging or bank sculpting was proposed but no surveyed cross sections were available, average values from similar resaca segments were used. Dredge volumes were approximated by multiplying the area to be dredged by the depth of dredging required. Where dry resaca segments were to be excavated and provided with a source of water, the earthwork volumes were approximated in the same manner as for dredge volumes and water supply components were designed using available survey and LiDAR data. A summary of calculated quantities is provided in Table E-1-1. The Natural Resources Appendix A describes the restoration measures. Ecosystem restoration, design and real estate drawings of the resaca measures are located at the end of the main report.

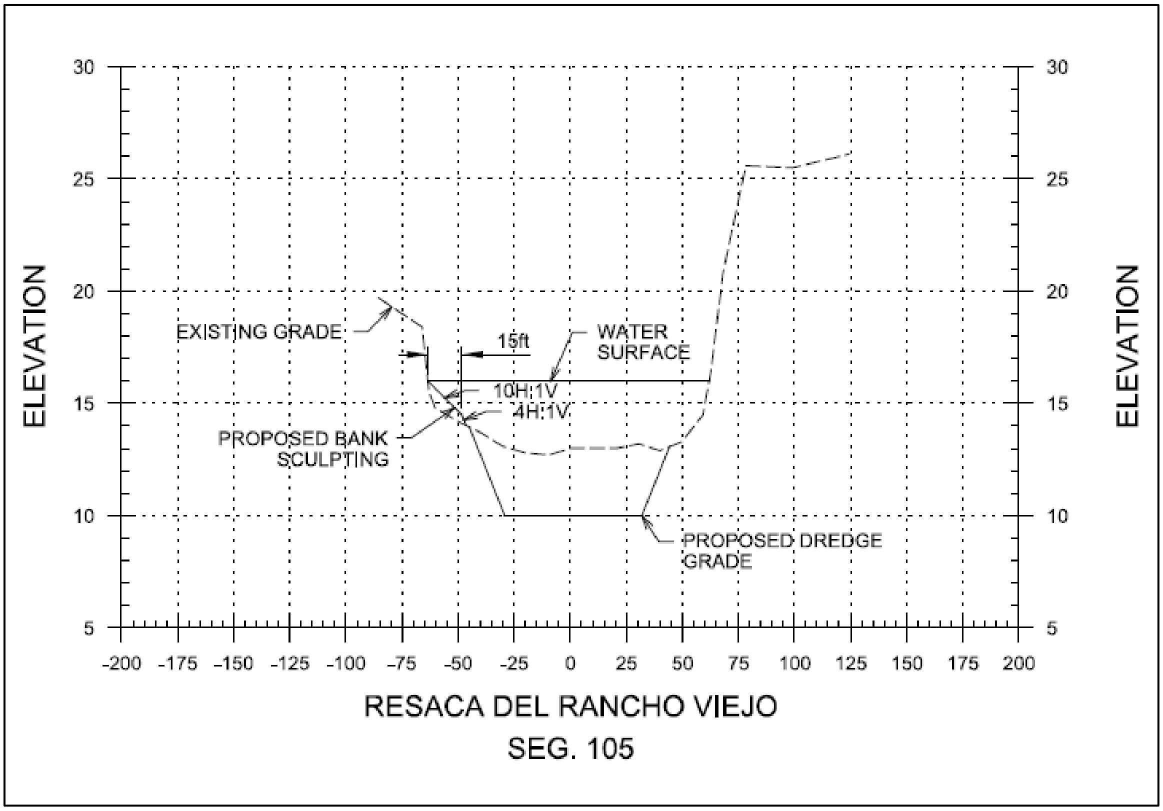

Figure E-1-1: Typical section with dredging and bank sculpting

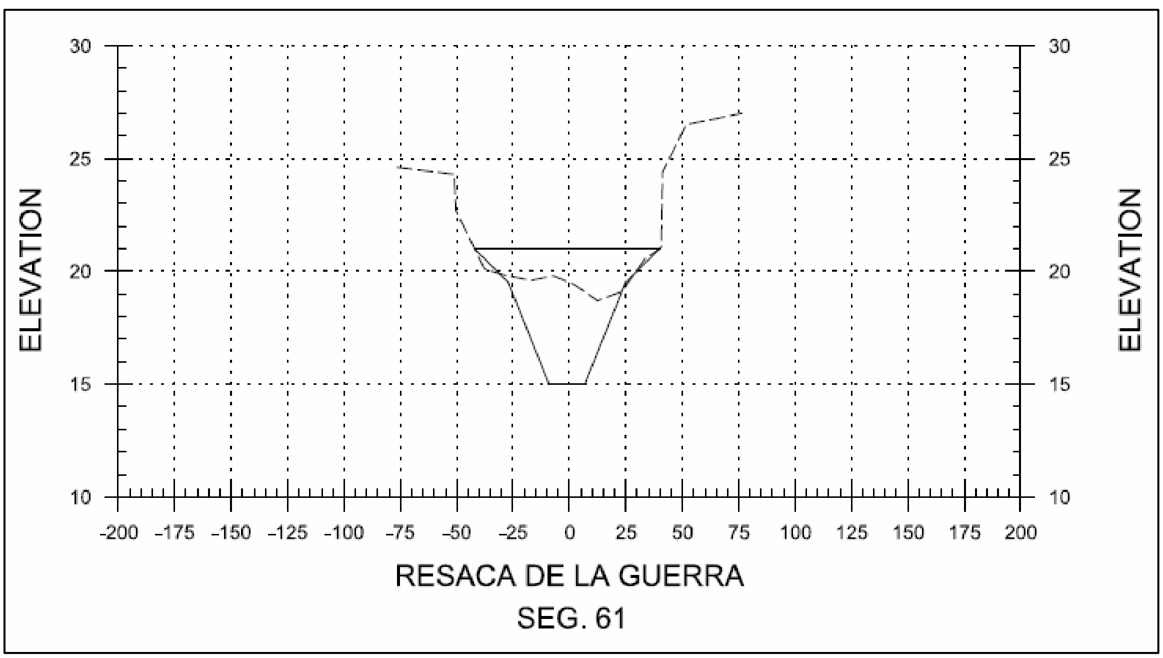

Figure E-1-2: Surveyed cross section of Segment 61

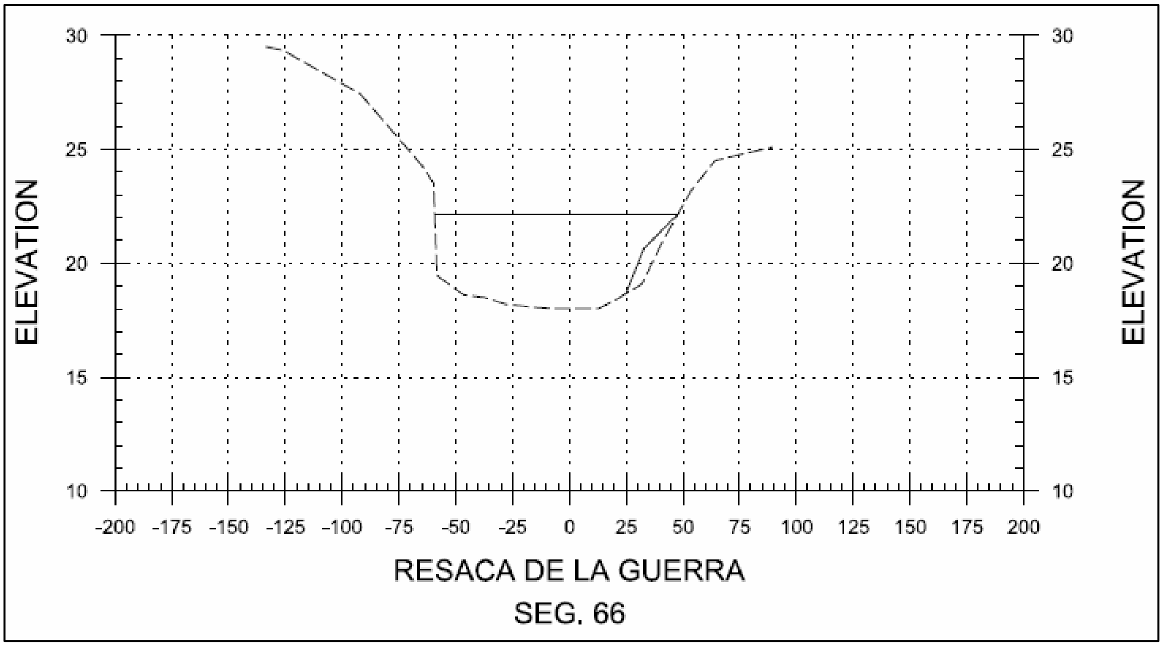

Figure E-1-3: Surveyed cross section of Segment 66

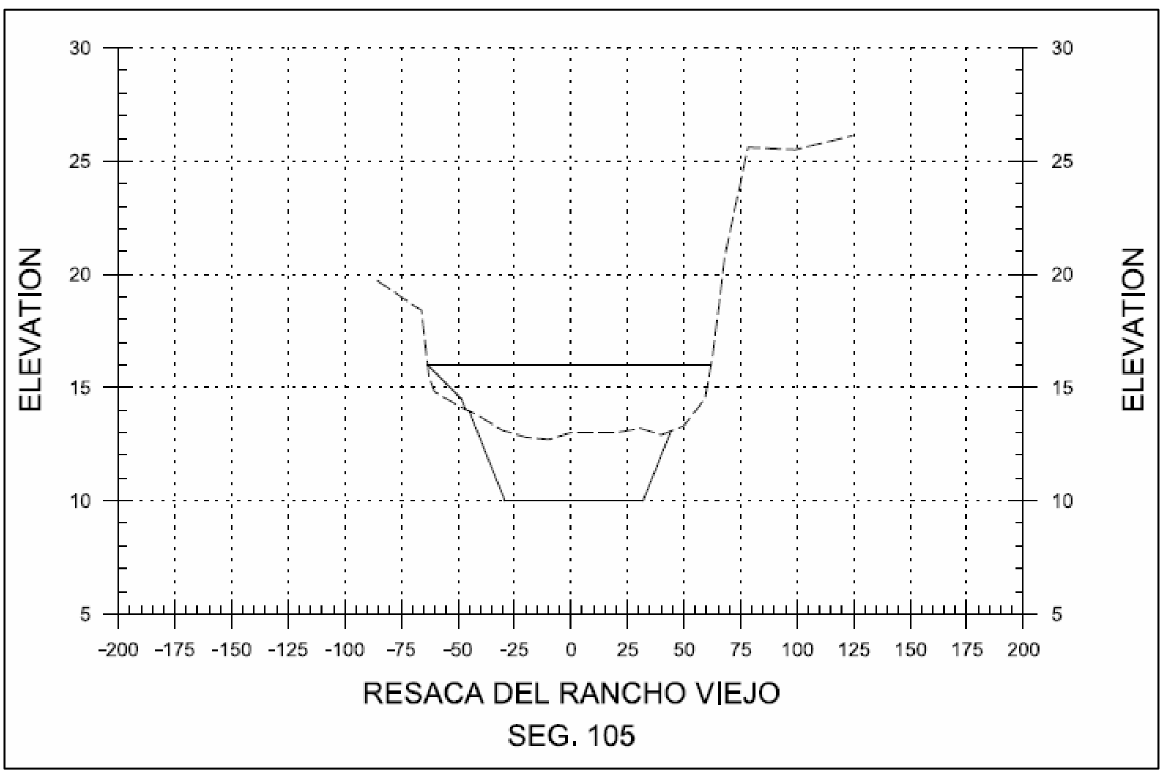

Figure E-1-4: Surveyed cross section of Segment 105

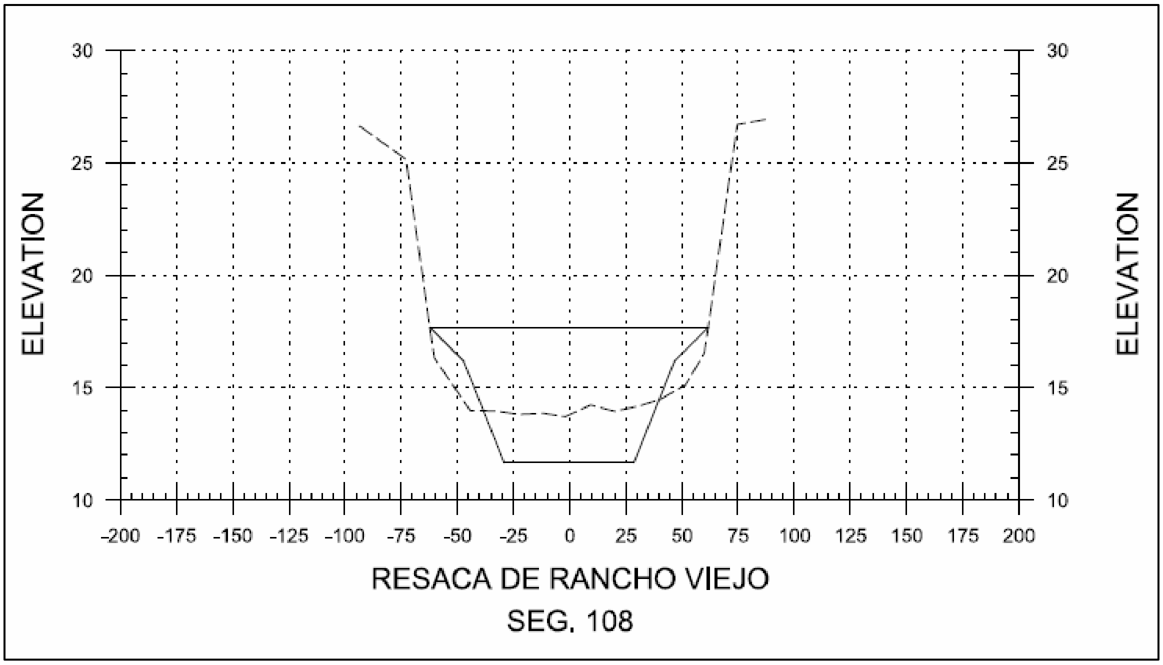

Figure E-1-5: Surveyed cross section of Segment 108

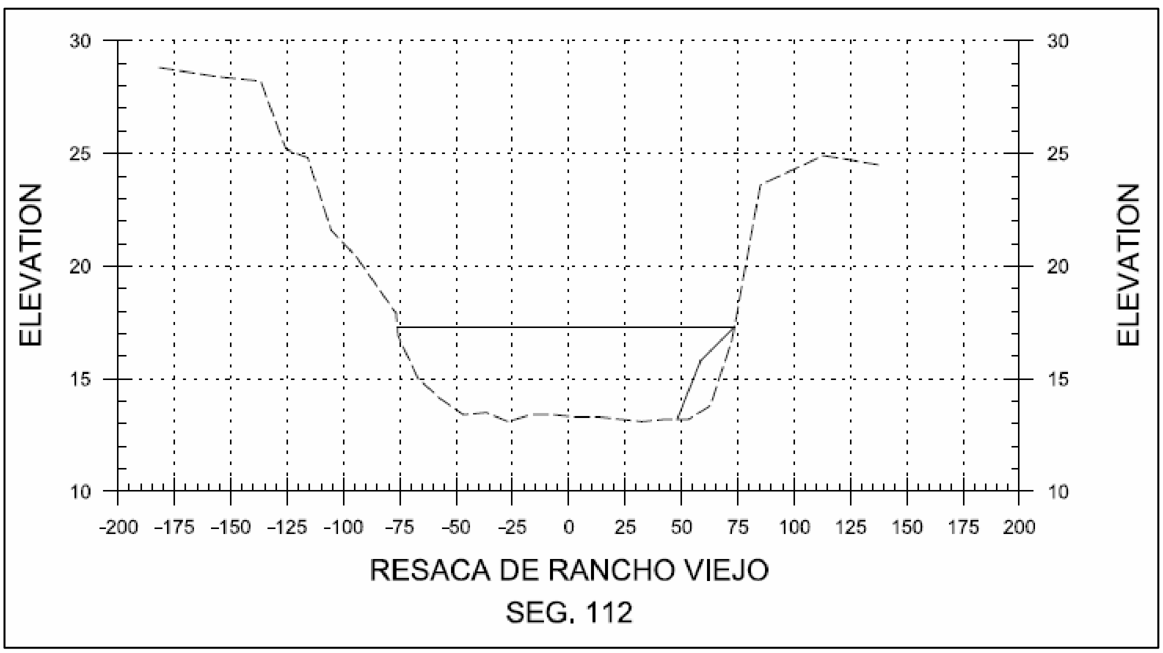

Figure E-1-6: Surveyed cross section of Segment 112

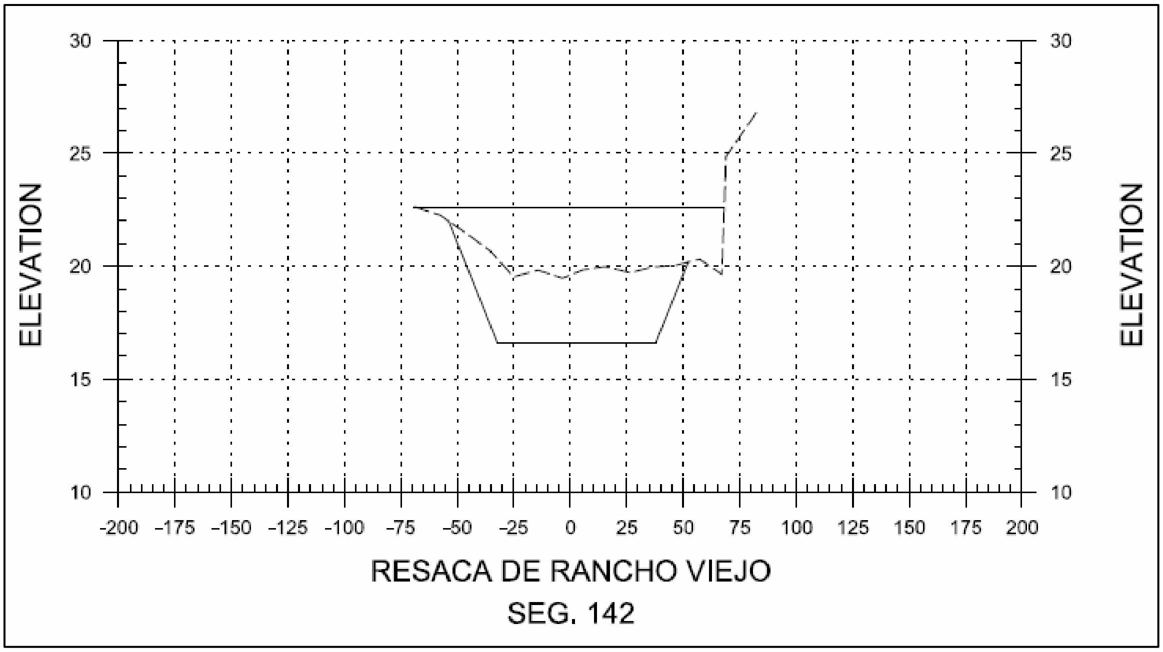

Figure E-1-7: Surveyed cross section of Segment 142

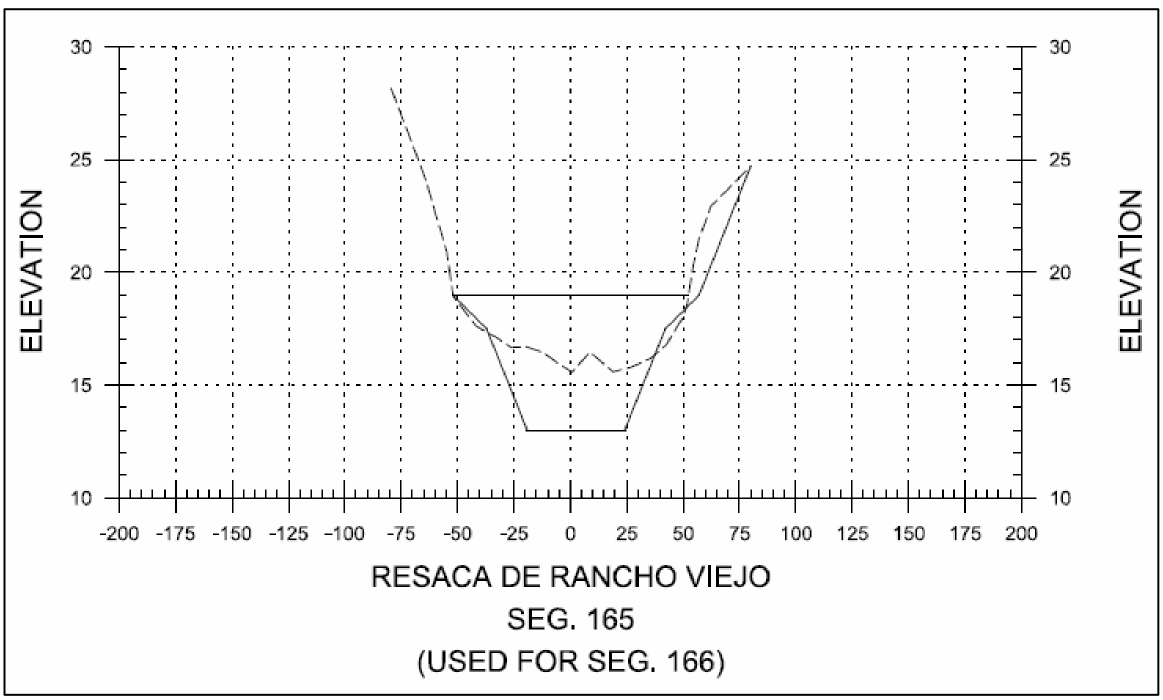

Figure E-1-8: Surveyed cross section of Segment 165

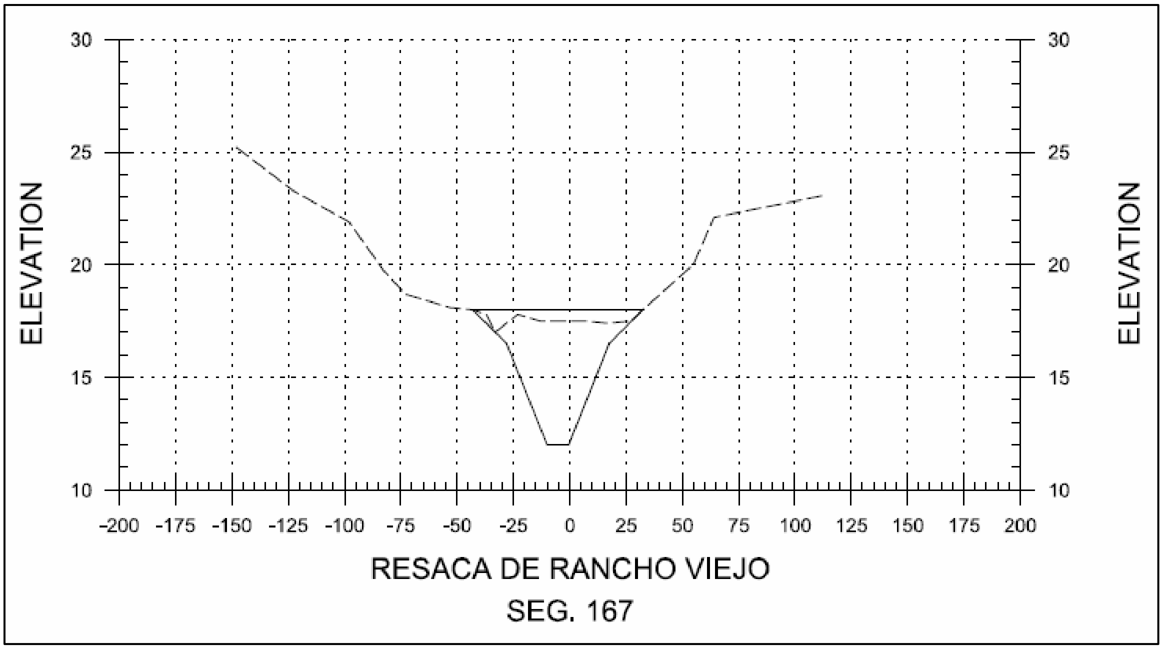

Figure E-1-9: Surveyed cross section of Segment 167

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Table E-1-1: Quantity Calculations for All Restoration Alternatives

Resaca Segment	Resaca System	Connection Required	Excavate			Dredge			Bank Grade			Riparian Grass/Forbe	Riparian Woody Veg.	Emergent Aquatic Veg.	Invasive Species Control
		Material/Equipment	Area	Depth	Volume	Area	Depth	Volume	Length	Fill/LF	Volume	Area	Area	Area	Area
			(ft^2)	(ft)	(yd^3)	(ft^2)	(ft)	(yd^3)	(ft)	(ft^2/LF)	(yd^3)	(ac)	(ac)	(ac)	(ac)
3	Town					30,121	3	3,347							
4	Town					79,814	3	8,868							
5	Town					139,781	3	15,531	735	30	817	2.07	2.07	0.25	2.07
6/7	Town					668,619	3	74,291	3,771	24	3,352	7.37	7.37	1.30	7.37
8	Town					132,066	5	24,457							
10	Town					220,020	4	32,596	2,268	55	4,620	1.64	1.64	0.42	1.64
13	Town					233,877	4	34,648	1,260	22	1,027	2.64	2.64	0.43	2.64
17/18/19	Town					1,102,145	5	204,101	18,208	10	6,744	21.39	21.39	6.27	64.82
39	Town					15,588	3	1,732	635	22	517	0.51	0.51	0.31	0.51
40	de la Guerra								3,545	22	2,889	28.34	28.34	1.22	31.49
41	de la Guerra								2,575	22	2,098	20.35	20.35	0.89	20.35
42	de la Guerra								4,950	22	4,033	47.75	47.75	1.70	53.05
43	de la Guerra											30.59	30.59		33.99
44 East	de la Guerra								1,420	22	1,157	7.53	7.53	0.49	7.53
44 West	de la Guerra								1,280	22	1,043	11.08	11.08	0.44	11.08
45	de la Guerra								525	22	428	4.87	4.87	0.18	4.87
46	de la Guerra								2,525	22	2,057	2.05	2.05	0.87	4.09
53	de la Guerra					70,769	3	7,863							
54	de la Guerra					374,988	3	41,665							
59	de la Guerra								1,710	22	1,393	2.03	2.03	0.59	3.03
60	de la Guerra					78,686	5	14,571							
61	de la Guerra					981,628	2	72,713	768	5	142	1.65	1.65	0.26	3.30
62	de la Guerra					77,441	5	14,341	658	14	341	0.61	0.61	0.23	1.21
66	de la Guerra					286,169	2	21,198	1,600	14	830	6.63	6.63	0.55	13.25
67 East	de la Guerra								1,015	22	827	5.83	5.83	0.35	6.48
67 Central	de la Guerra								1,015	22	827	3.11	3.11	0.35	3.46
67 West	de la Guerra								1,870	22	1,524	7.43	7.43	0.64	8.26
71 East	de la Guerra								669	22	545	3.29	3.29	0.23	3.65
71 West	de la Guerra								320	22	261	3.40	3.40	0.11	3.78
72	de la Guerra								2,336	22	1,903	7.16	7.16	0.80	7.96
74	de la Guerra					216,996	3	24,111							
75	de la Guerra					431,283	3	47,920	5,540	22	4,514	0.96	0.96	1.91	1.07
76	de la Guerra								620	22	505	0.65	0.65	0.21	0.65
78	de la Guerra								4,376	22	3,566	2.60	2.60	1.51	2.60

Resaca Segment	Resaca System	Connection Required	Excavate			Dredge			Bank Grade			Riparian Grass/Forbe	Riparian Woody Veg.	Emergent Aquatic Veg.	Invasive Species Control
		Material/Equipment	Area	Depth	Volume	Area	Depth	Volume	Length	Fill/LF	Volume	Area	Area	Area	Area
			(ft^2)	(ft)	(yd^3)	(ft^2)	(ft)	(yd^3)	(ft)	(ft^2/LF)	(yd^3)	(ac)	(ac)	(ac)	(ac)
79	de la Guerra								1,860	22	1,516	2.75	2.75	0.64	2.75
81	de la Guerra								1,166	22	950	4.02	4.02	0.40	4.02
82	de la Guerra					259,151	4	38,393	2,644	22	2,154	14.57	14.57	0.91	14.57
83	de la Guerra					549,508	4	81,409							
84	de la Guerra					338,179	4	50,101	3,191	22	2,600	9.41	9.41	1.10	9.41
93	de la Guerra	1500 LF 12" PVC w/ 1 HP Pump	190,058	6	42,235				5,148	0	0	1.08	1.08	1.77	4.36
94	de la Guerra	80 LF 24" RCP w/ Overflow Box & HW	208,578	6	46,351				3,750	0	0	1.19	1.19	1.29	4.79
95	de la Guerra	120 LF 18" PVC w/ Gate Valve	909,158	6	202,035				9,670	0	0	18.78	18.78	3.33	20.87
96	de la Guerra								1,345	22	1,096	12.43	12.43	0.46	12.43
161	de la Guerra	130 LF 18" PVC w/ Gate Valve	1,273,136	3	141,460				14,815	0	0	18.83	18.83	5.10	18.83
98	del Rancho Viejo								4,887	22	3,982	16.13	16.13	1.68	17.92
99	del Rancho Viejo								3,118	22	2,541	8.15	8.15	1.07	9.06
100 North	del Rancho Viejo								1,475	22	1,202	5.63	5.63	0.51	6.26
100 South	del Rancho Viejo								455	22	371	1.69	1.69	0.16	1.88
101	del Rancho Viejo								6,762	22	5,510	45.31	45.31	2.33	45.31
104	del Rancho Viejo								4,727	22	3,852	18.64	18.64	1.63	18.64
105	del Rancho Viejo					553,399	4	81,985	6,409	10	2,374	29.04	29.04	2.21	29.04
108	del Rancho Viejo					94,192	3	10,466	2,053	26	1,977	2.91	2.91	0.71	2.91
109	del Rancho Viejo					305,559	3	33,951	3,171	22	2,584	9.08	9.08	1.09	9.08
110	del Rancho Viejo								2,345	22	1,911	7.60	7.60	0.81	10.13
111	del Rancho Viejo					504,508	3	56,056	2,201	22	1,793	1.33	1.33	0.76	1.33
112 South	del Rancho Viejo								1,210	37	1,658	7.49	7.49	0.42	8.32
112 North	del Rancho Viejo								1,255	37	1,720	6.12	6.12	0.43	6.80
116/117	del Rancho Viejo	600 LF 18" PVC w/ Gate Valve				593,740	3	65,971	6,070	22	4,946	9.76	9.76	2.09	14.58
142	del Rancho Viejo					910,196	4	134,844	5,047	22	4,112	6.61	6.61	1.74	9.86
149	del Rancho Viejo					79,300	4	11,748	3,229	22	2,631	5.17	5.17	1.11	6.89
150	del Rancho Viejo					108,287	5	20,053							
151	del Rancho Viejo					106,462	5	19,715							
165	del Rancho Viejo	600 LF 18" RCP w/ Gate Valve & HW	186,657	3	20,740				3,855	0	0	4.65	4.65	1.33	5.17
166	del Rancho Viejo	300 LF 18" RCP w/ Gate Valve & HW	185,444	3	20,605				5,071	0	0	6.44	6.44	1.75	7.15
167/148	del Rancho Viejo					826,230	4	122,404	17,321	0	0	50.94	50.94	5.96	56.60
1000	del Rancho Viejo								10,137	22	8,260	12.05	12.05	3.49	48.21
1001	del Rancho Viejo								4,790	22	3,903	15.61	15.61	1.65	15.61
				Totals:	**473,425**			**1,371,050**			**99,438**	**559.28**	**559.28**	**65.30**	**663.16**

B. Water Level Control Quantities

Water levels in the existing resacas were already being maintained by the local sponsor through the use of overflow boxes, gated culverts, and weirs to maintain minimum pool levels in resaca segments. Some of the existing weir structures included slots for the installation of flash boards, which would allow the upstream pool levels to be adjusted by adding or removing boards. In locations with gated culverts, the pool levels were maintained by opening or closing the gates as needed. Some gates were equipped with Supervisory Control And Data Acquisition (SCADA) systems that would automatically adjust the gate based on pool levels. Other structures, such as fixed weirs and overflow boxes, did not allow for any manipulation of the upstream water surface elevations.

Changes to the existing system would be required to provide for adequate water level control to support the ecosystem restoration effort. Specifically, pool levels where vegetative measures were proposed would need to be lowered during certain periods of the year to simulate natural conditions. The existing control structures were evaluated to determine their ability to lower normal pool levels. Modifications were proposed for those structures which would not allow for this control and which included vegetative restoration measures within their upstream pool limits. Table E-1- 2 is a summary of the proposed control structure modifications and additions.

Water control structures are shows on the 12 figures at the end of Appendix E. Each figure includes a symbol indicating the locations and type of control structure, and the resaca segments that would benefit. The table shows the figure page number.

Table E-1- 2: Water Control Structure Modifications

System	Segment	Benefit Segments	Structure Name	Proposed Modifications	Figure Sheet Number
de la Guerra	41	40, 41	Outlet to North Main Drain	Add adjustable weir to existing overflow box	Sheet 1
de la Guerra	42	42, 43, 44, 45, 46	Outlet to North Main Drain	Add adjustable weir to existing overflow box	Sheet 2
de la Guerra	94	94	New Southmost Rd. Weir	Install sheet pile wall with adjustable weir	Sheet 3
de la Guerra	93	94	Fonsi Dr. Overflow Rd.	Add adjustable weir to existing overflow box	Sheet 3
de la Guerra	59	59, 54, 53	Hackberry Weir	Demo existing weir, install sheet pile wall with adjustable weir	Sheet 4
de la Guerra	95	95	(New Connection)	120 LF 18” PVC w/ Gate Valve	Sheet 5
de la Guerra	161	161	(New Connection)	130 LF 18” PVC w/ Gate Valve	Sheet 5
del Rancho Viejo	99	99, 98	Drainage District #1 Ditch	Add adjustable weir to existing overflow box	Sheet 6
del Rancho Viejo	100	100, 101, 1001, 1000, 104	Heron Cv. Gate Valve/Overflow Structure	Add SCADA control to existing gate valve or replace gate valve with adjustable weir	Sheet 7
del Rancho Viejo	105	105	Cameron Park Berm “Sandbag” Weir	Demo existing weir, install sheet pile wall with adjustable weir	Sheet 8
del Rancho Viejo	109	109, 110, 111, 112, 167	Sleepy Hollow Overflow Box	Add adjustable weir to existing overflow box	Sheet 9
del Rancho Viejo	116	116, 117	(New Connection)	600 LF 18” PVC w/ Gate Valve	Sheet 12
del Rancho Viejo	142	142, 149, 150, 151	Lakeway Overflow Box	Add adjustable weir to existing overflow box	Sheet 11
del Rancho Viejo	166	166	(New Connection)	300 LF 18” RCP w/ Gate Valve and HW	Sheet 10

Two versions of a U.S. Bureau of Reclamation (USBR) adjustable weir were selected for use where modifications to existing structures were required. The first, USBR 103-D-1239, is a 2 or 3 foot wide weir that can be raised or lowered 14 or 16 inches, respectively and is bolted to an existing concrete structure. The 3 foot wide version of this weir was proposed for installation on existing overflow box structures. The second weir version, USBR 103-D-1242, is a 3 foot wide movable weir that can be raised up to 18.5 inches and is self-contained with its own frame assembly. This weir was proposed for use where the existing structures would have to be removed and replaced with new sheet pile weirs. A drawing of each weir configuration is provided in Figure and Figure E-1-11.

The amount of adjustability of the proposed weirs was confirmed to be sufficient to mimic the desired seasonal variations in water levels. 14 to 18.5 inches of adjustment would be capable of drawing the water down enough to expose the 15-foot shelf planted with aquatic emergent vegetation as desired. Furthermore, since the adjustable weirs will be designed such that the weir crest will be no higher than the existing control structure invert, the addition of these control structures will not induce flooding or otherwise reduce the capability of the resaca system to convey high flows. They will only be able to lower the upstream water surface elevations.

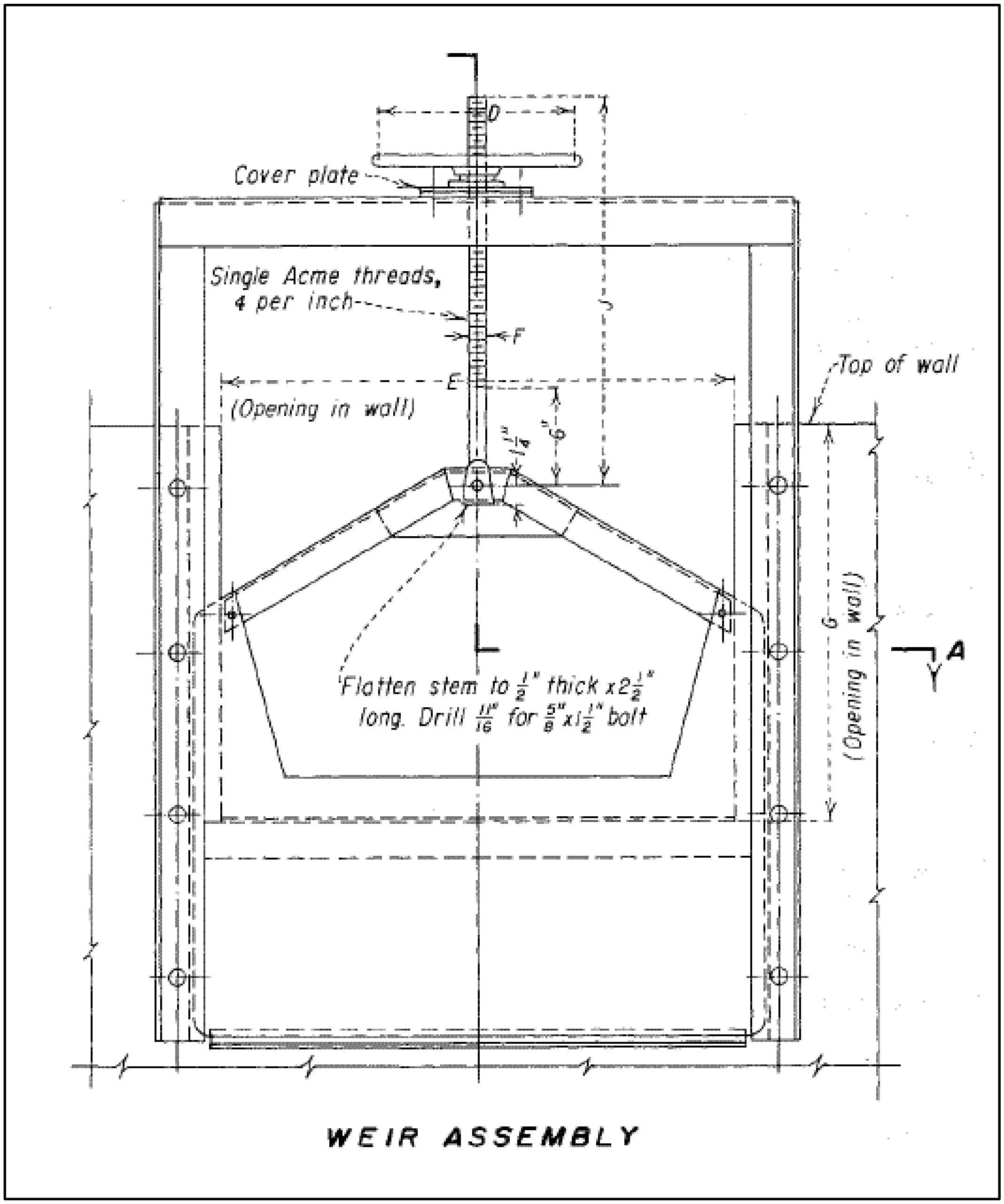


Figure E1-10 : U.S.Bureau of Reclamation Adjustable Weir, 103-D-1239

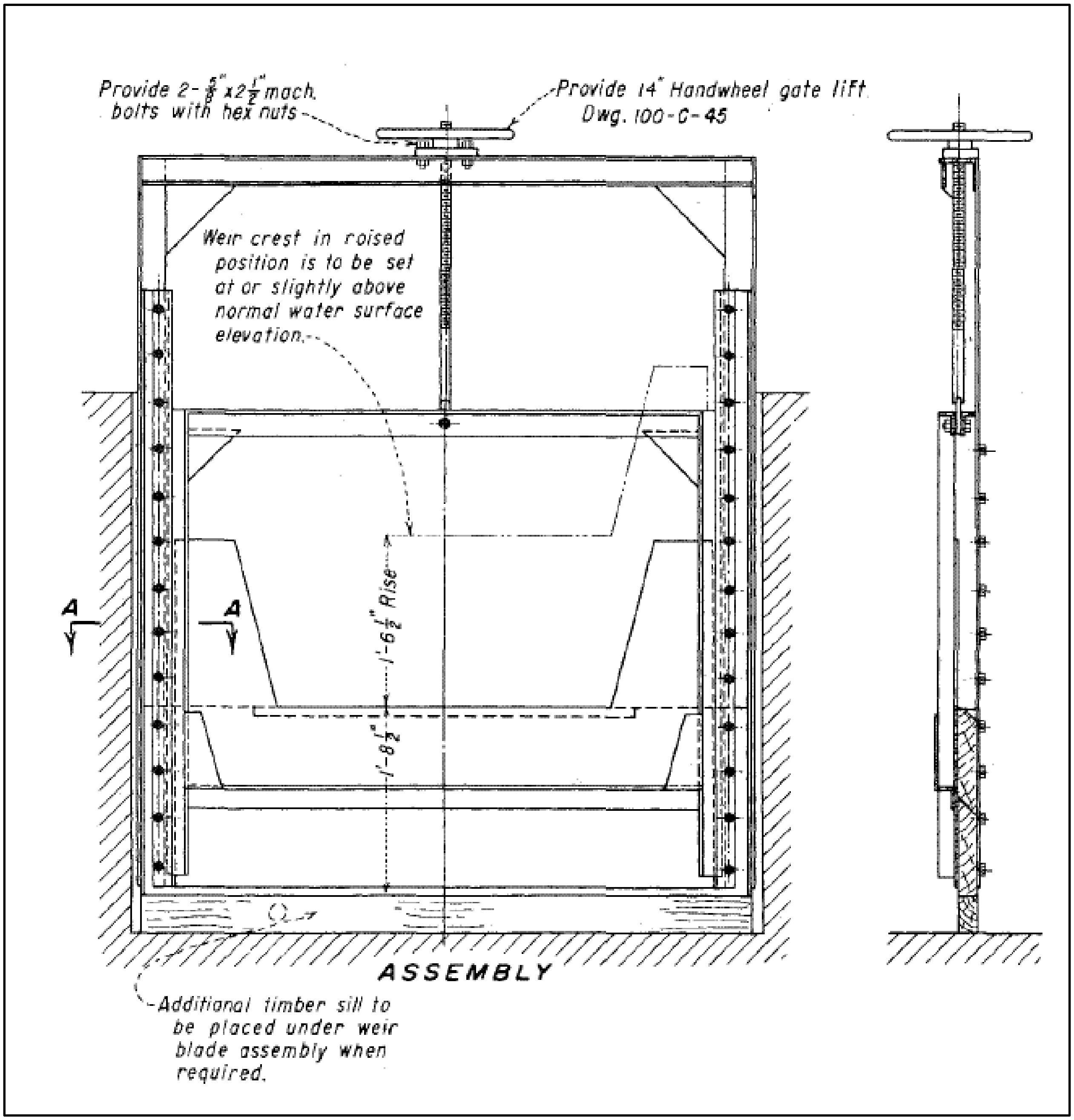


Figure E-1-11: U.S. Bureau of Reclamation Movable Weir, 103-D-1242

C. Disconnected Resaca Segments

Some of the resaca segments included in the study were no longer hydraulically connected to either resaca system, resulting in them remaining dry for most of the year. To utilize those disconnected resacas in the project, provisions were made to supply them with water through artificial means. Maps depicting these artificial connections are provided in the Water Control Structure Map section. The connections are also shown in the Design Drawings provided in the Drawings section of the main report.

In most cases, the disconnected resacas in question were situated such that they could be serviced through a gated culvert pipe flowing by gravity from either another resaca segment or from an irrigation canal. In one location, resaca segment 93, a pumped pipeline would be required to convey flow from the nearest resaca system. Pipe and pump sizing for each artificial connection were estimated based on similar configurations already being used by BPUB for other resaca segments. Detailed design for each connection would be developed during PED.

V. Water Control Structure Maps

The following pages present the Water Control Structure Maps

PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE
PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 41

RESACAS AT BROWNSVILLE, TEXAS ECOSYSTEM RESTORATION AND FEASIBILITY STUDY

0 550 1,100 Feet

N W E S

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 1 of 12

US Army Corps of Engineers®
Memphis District

PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE
PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 42

RESACAS AT BROWNSVILLE, TEXAS
ECOSYSTEM RESTORATION AND
FEASIBILITY STUDY

0 850 1,700 Feet

N W E S

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 2 of 12

US Army Corps of Engineers® Memphis District

PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE

PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 93 & 94

RESACAS AT BROWNSVILLE, TEXAS
ECOSYSTEM RESTORATION AND
FEASIBILITY STUDY

0 405 810
Feet

N W E S

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 3 of 12

US Army Corps of Engineers®
Memphis District

PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE

PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 59

RESACAS AT BROWNSVILLE, TEXAS ECOSYSTEM RESTORATION AND FEASIBILITY STUDY

0 550 1,100 Feet

N S W E

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 4 of 12

US Army Corps of Engineers®
Memphis District

PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE
PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 95 & 161
RESACAS AT BROWNSVILLE, TEXAS
ECOSYSTEM RESTORATION AND
FEASIBILITY STUDY

0 500 1,000 Feet

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 5 of 12

US Army Corps
of Engineers®
Memphis District

PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE

PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 99

RESACAS AT BROWNSVILLE, TEXAS ECOSYSTEM RESTORATION AND FEASIBILITY STUDY

0 700 1,400 Feet

N W E S

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 6 of 12

US Army Corps of Engineers®
Memphis District

PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE

PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 100

RESACAS AT BROWNSVILLE, TEXAS
ECOSYSTEM RESTORATION AND
FEASIBILITY STUDY

0 1,250 2,500 Feet

N E S W

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 7 of 12

US Army Corps of Engineers®
Memphis District

PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE

PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 105

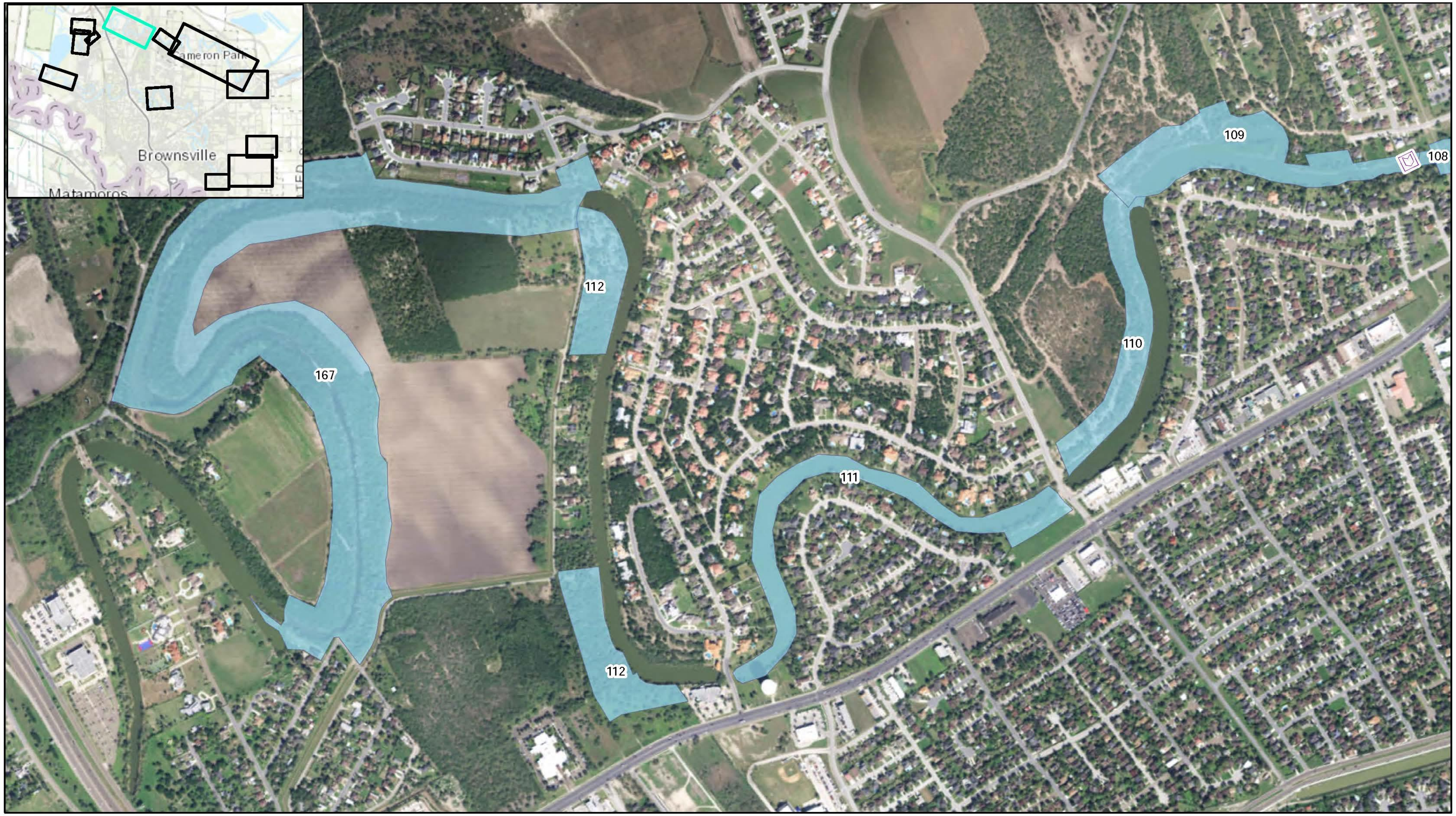
RESACAS AT BROWNSVILLE, TEXAS ECOSYSTEM RESTORATION AND FEASIBILITY STUDY

0 362.5 725 Feet

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 8 of 12

US Army Corps of Engineers® Memphis District



PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE
PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 109

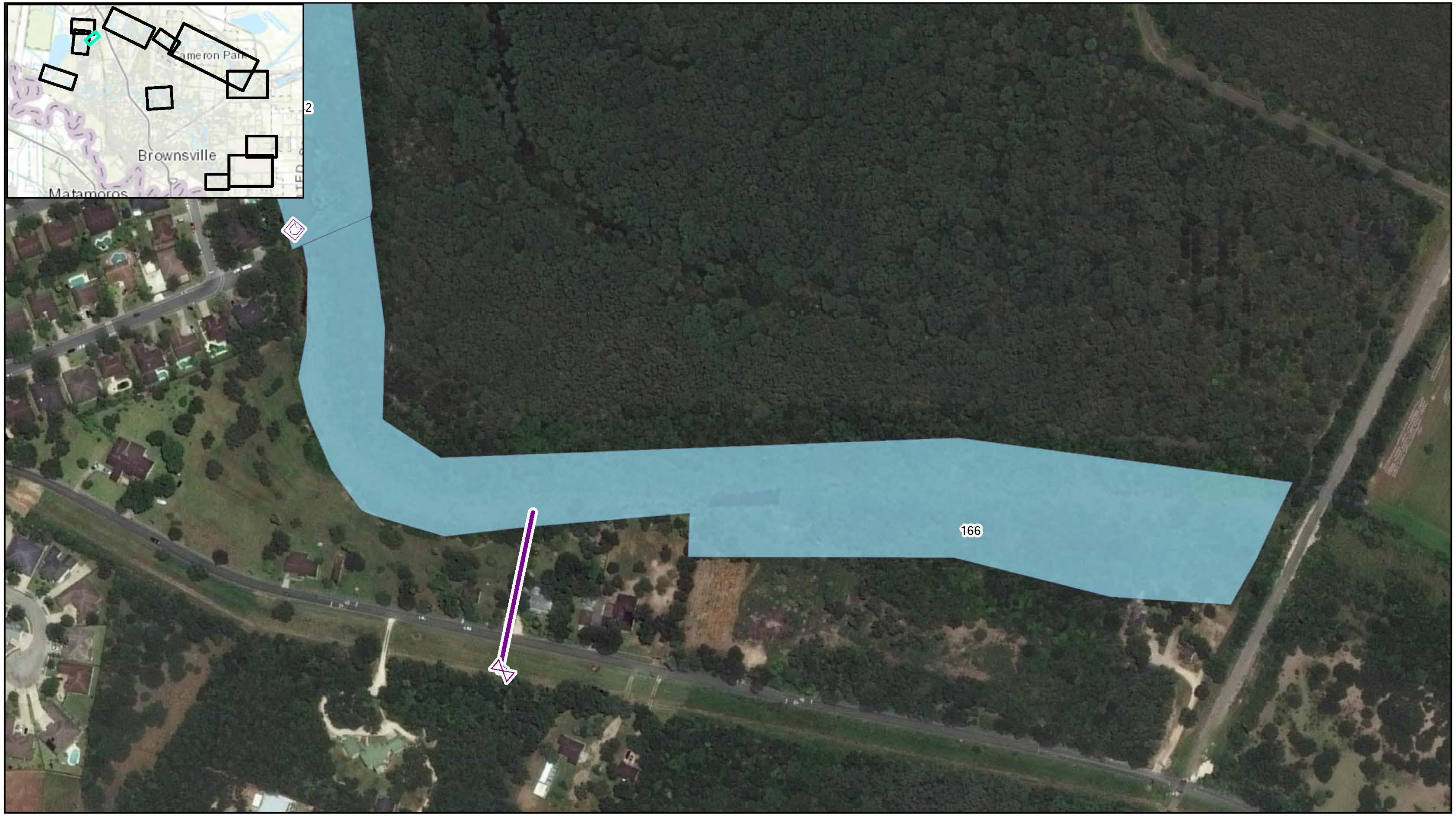
RESACAS AT BROWNSVILLE, TEXAS
ECOSYSTEM RESTORATION AND
FEASIBILITY STUDY

0 700 1,400 Feet

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 9 of 12

US Army Corps of Engineers®
Memphis District



PUMP

SLUICE GATE

WEIR

WEIR IN EXISTING STRUCTURE

PIPE

ALT. 5 MEASURES

99 SEGMENT NO.

WATER CONTROL SEGMENT 166

RESACAS AT BROWNSVILLE, TEXAS ECOSYSTEM RESTORATION AND FEASIBILITY STUDY

0 205 410 Feet

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 10 of 12

US Army Corps of Engineers®
Memphis District

PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE
PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 142

RESACAS AT BROWNSVILLE, TEXAS ECOSYSTEM RESTORATION AND FEASIBILITY STUDY

0 425 850 Feet

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 11 of 12

US Army Corps of Engineers®
Memphis District

PUMP
SLUICE GATE
WEIR
WEIR IN EXISTING STRUCTURE
PIPE
ALT. 5 MEASURES
99 SEGMENT NO.

WATER CONTROL SEGMENT 116

RESACAS AT BROWNSVILLE, TEXAS
ECOSYSTEM RESTORATION AND
FEASIBILITY STUDY

0 395 790 Feet

DATUM: NORTH AMERICAN 1983
PROJECTION: STATE PLANE
ZONE: 4205 TEXAS SOUTH

Sheet 12 of 12

US Army Corps of Engineers® Memphis District

VI. Project Implementation

A. Pre-Construction Engineering and Design (PED)

Prior to initiating pre-construction engineering and design phase, the design team must develop a Project Management Plan (PMP) defining the PED scope, work breakdown structure, schedule, and budget. Additional items in the PMP are related to value management and engineering, quality control, communication, change management, and acquisition strategy. The team must develop, negotiate, and agree upon the draft PMP prior to initiation of the PED phase. The team also has to prepare a Design Documentation Report (DDR), plans and specifications (P&S), execute a Project Partnership Agreement (PPA), and complete contract awards.

The DDR would include the final design of project features. The team would complete needed ground surveys, utility surveys, and drilling and testing for subsurface (geotechnical) conditions as necessary to complete the final design. The PED would define the resaca dredging, water control structures, and erosion protection locations based on surveys, hydraulic analysis, and testing. Design parameters for all project features would be defined for development of the plans and specifications. The project archeologist would continue their coordination with the State Historic Preservation Office to ensure archeological resource investigations and mitigation requirements continue to be met with a qualified archeologist on site during construction for monitoring, identification, and proper documentation/preservation of any cultural resources that might be uncovered during construction.

The P&S would include the development of project construction drawings and specifications, estimation of final quantities, and completion of the government cost estimate. The PED team would make available the drawings and specifications to contractors interested in bidding on the construction of the proposed project. The PED would develop as many as 4 sets of P&S for the dredging, aquatic features, bank slope, and riparian vegetation. Arrangements for onsite archeological monitoring during construction should be finalized prior to the conclusion of P&S so they may be documented in the PPA.

A PMP for the construction phase must be developed, negotiated, and agreed upon by all parties of the construction phase prior to initiation of the construction phase. The PPA is a binding agreement between the Federal government and the non-Federal sponsor which must be approved and executed prior to the start of construction. The PPA sets forth the obligations of each party. The non-Federal sponsor must agree to meet the requirements for non-Federal responsibilities which will be identified in future legal documents.

Post-Implementation OMRR&R Management Plan

An operations management plan would be developed during PED.

1. Real Estate Acquisition

The non-Federal sponsor is responsible for the lands, easements, rights-of-way, relocations, and disposal areas required for project construction, operation, and maintenance of Brownsville resaca ecosystem restoration project. Following the Execution of the PPA, a right of way map would be provided to the non-Federal sponsor. The maps would delineate the real estate necessary for construction, operation, and maintenance of the proposed project. The Galveston District's real estate office would coordinate all real estate activities with the Brownsville Public Utilities Board Real Estate Office. The District Chief of Real Estate is required to certify in writing that sufficient real property interest is available to support construction of the contract prior to any solicitation of construction contracts for Brownsville resaca project.

2. Contract Advertisement and Award

A construction contract would be solicited and advertised once the PPA is executed, the plans and specifications are completed, and the rights of entry are provided to SWG. The non-Federal sponsor must provide any applicable cash contribution prior to awarding the contract. The contract would be awarded to the lowest responsive bidder and notice to proceed can be expected within 30-45 days from bid opening.

3. Project Construction

After award of the construction contract, the Government would manage project construction. About 15 contracts may be awarded. Inherent with contracts would be a warranty period specified for actual construction items and plantings. Construction of the dredging, water control structures, and bank sculpting is estimated to take 6 to 12 months to complete for each restoration area. Planting of riparian habitats would begin in areas where the bank slope work is complete. Planting would occur over at least two seasons within the same restoration area. There would be a 2 year contract period beyond each specific planting period to ensure the aquatic and riparian vegetation is alive and thriving. This activity includes removing any non-native or invasive species, watering (if needed), and replacement vegetation to ensure a minimum survival rate. Performance standards for the establishment of vegetation and control of non-native and invasive species would be refined during PED. During construction, an archeologist will monitor excavation. Should any significant cultural resources be identified, mitigation procedures would take place prior to further excavation. Total implementation time is expected to be 9 to 12 months per restoration area.

System	Segment	Benefit Segments	Structure Name	Proposed Modification
de la Guerra	41	40, 41	Outlet to North Main Drain	Add adjustable weir to existing overflow box
de la Guerra	42	42, 43, 44, 45, 46	Outlet to North Main Drain	Add adjustable weir to existing overflow box
de la Guerra	94	94	New Southmost Rd. Weir	Install sheet pile wall with adjustable weir
de la Guerra	93	93	Fonsi Dr. Overflow Box	Add adjustable weir to existing overflow box
de la Guerra	59	59, 54, 53	Hackberry Weir	Demo existing weir, install sheet pile wall with adjustable weir
de la Guerra	95	95	(New Connection)	120 LF 18" PVC w/ Gate Valve
de la Guerra	161	161	(New Connection)	130 LF 18" PVC w/ Gate Valve
del Rancho Viejo	99	99, 98	Drainage District #1 Ditch	Add adjustable weir to existing overflow box
del Rancho Viejo	100	100, 101, 1001, 1000, 104	Heron Cv. Gate Valve / Overflow Structure	Add SCADA control to existing gate valve or replace gate valve with adjustable weir
del Rancho Viejo	105	105	Cameron Park Berm "Sandbag" Weir	Demo existing weir, install sheet pile wall with adjustable weir
del Rancho Viejo	109	109, 110, 111, 112, 167	Sleepy Hollow Overflow Box	Add adjustable weir to existing overflow box
del Rancho Viejo	116	116, 117	(New Connection)	600 LF 18" PVC w/ Gate Valve
del Rancho Viejo	142	142, 149, 150, 151	Lakeway Overflow Box	Add adjustable weir to existing overflow box
del Rancho Viejo	166	166	(New Connection)	300 LF 18" RCP w/ Gate Valve & HW

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APPENDIX E-2

ENGINEERING APPENDIX

COST ENGINEERING

Introduction

This project consists of environmental restoration along former water courses (resaca) of the Rio Grande in Brownsville, Texas located in Cameron County. There are three resacas in Brownsville; two would be included in this project. They are Resaca De La Guerra and Resaca Del Rancho Viejo. The resaca excluded from this project is the Town Resaca. The project would consist of eight environmental restoration measures including:

- Dredging
- Riparian Soil Supplementation with Dredged Material
- Planting Riparian Species
- Bank Slope Restoration
- Bank Stabilization
- Plant Aquatic and Emergent Vegetation
- Water Control Structure/Flow Management
- Invasive Plant Species Management

The goal is to provide connectivity between the resaca meanders for wildlife habitat.

Design Information

To restore habitat for the measures would be implemented in varying degrees at each resaca area to provide connectivity and restore the damaged and destroyed habitat. The quantities for the restoration measures are shown below in Table E-2-1.

Acquisition Assumptions

The estimator assumed that the project would be constructed over a 16-year period with about $15-16 million to be awarded each year. The primary type of contract would be a competitive bid process.

Cost Analysis

Alternatives were evaluated using cost effectiveness and increment cost analysis. The estimated project costs associated with each plan reflect the cost side of the benefit cost ratio. Preliminary costs were developed for formulation screening. More detailed costs were developed for the recommended plan.

Alternatives were identified for evaluation. A preliminary design for each was prepared, and design quantities were estimated. A construction cost was then estimated based on the quantities.

The quantities for the recommended plan, Alternative 5, are shown in Table E-2-1. Material quantities were provided by the U.S. Army Corps of Engineers (USACE) Memphis District Design Branch.

The only deviation from these quantities was associated with the various plant habitat on the project. The design engineer provided plant quantities in acres. The Galveston District biologist provided additional application rates for the various plant species as follows:

- Riparian Planting – 300 plants per acre
- Emergent Habitat Planting – 40 feet c-c spacing
- Emergent Habitat Planting (Herbaceous) – 3 feet center-to-center spacing

Using the plant space calculator available at http://wwwusers.math.umn.edu/~white004/personal/plantcalc.html, the cost estimator populated plant quantities for the three species as shown in Table E-2-1.

Restoration areas were identified at 64 locations across Resaca de La Guerra, Resaca Del Rancho Viejo, and Town Resaca. Because there was an opportunity to compose alternatives from any combination of the 64 locations, costs were estimated for each. Costs were formulated for each restoration measure and element of work. The different elements of work are shown in Table E-2-1. Costs were prepared using a detailed cost estimate format, including the use of USACE MII software.

Within the software a bid schedule of quantities was constructed based upon design and used as a basis to formulate costs. There are four subgroups to the direct cost formulation for each bid item. They include labor, equipment, materials, and subcontracting. The software breaks down the costs into these subgroups and distributes indirect overheads and profit to the various cost elements.

Restoration plans within each resaca were initially screened through several iterations using the Cost Effective/Incremental Cost Analysis (CE/ICA) in the USACE Institute of Water Resources (IWR) Planning Suite 2.0.6.1. The Planning Suite is a USACE certified model used to assist in the identification of a cost effective recommended plan that can be incrementally justified both economically and ecologically.

The CE/ICA analysis uses annualized implementation costs. The annualized costs for the formulation level analysis for each restoration area is shown in Table E-2-2.

Labor

Labor rates were reviewed from Davis Bacon wage rates provided at http://www.wdol.gov/dba.aspx. The labor rates in these estimates were provided in the MII 2015 cost book consistent with the USACE Galveston District standard operating practice.

Equipment

Equipment was selected based on historic experience, preference, and crew makeup. Within the MII software there is an RSMeans Database from which equipment can be selected. Every few years these databases for labor and equipment are re-evaluated and indexed to the current year. The equipment manual is divided based on region with Brownsville, located in Region VI. The software fuel prices were adjusted to local costs using the AAA fuel gage report website (http://gasprices.aaa.com). Because Brownsville is not found in the database, the fuel prices for the next closest city in proximity (Corpus Christi, Texas) were used. Because fuel prices have remained stable for the last five years, current rates were presumed to be adequate as escalation would be captured in future re-pricing of the estimate. Standard practice at the Memphis District has been to deduct 0.40 cents per gallon from on road fuel to arrive at a close cost for off-road fuel based upon market research.

Material

Material prices were obtained from local suppliers within the Brownsville area. Quotes were obtained for pervious backfill and topsoil including delivery. Riparian shrubs, riparian turfing, emergent habitat planting, emergent habitat planting (herbaceous), and general turfing quotes were provided by The Nature Conservancy in Brownsville.

Subcontracting

To populate direct costs within the project, labor and equipment were combined into crews. Production rates were applied to the crews based on the knowledge and experience of the estimator. Once the materials and crews are tied to the quantities and production rates, they produce the direct costs for that item of work. The estimator assumed the landscaping and environmental controls portion of the work would be subcontracted. The prime contractor was assumed to construct the remaining items including the dredging work.

Table E-2-1: Alternative 5 - Scheduled Quantity Values

Segment	Silt Fence	A.	B.	C.	D.	*E.*	F.	G.	H.	I.	J.	K.	L.	M.
No.	LF	EA	EA	EA	Acres	CY	EA	Acres	EA	Acres	EA	CY	EA	CY
40	3,545	2		1	31.49	*2889*	9441	31.47	38	31.49	6,818			944
41	2,575	2		1	15.80	*2098*	6105	20.35	27	20.35	4,973		1	861
42	4,950	1		1	35.18	*4033*	15913	53.04	53	53.05	9,500		1	1,319
43	4,800	3		1	33.99		10194	33.98		33.99				
44	2,700	2		1	5.55	*2200*	5583	18.61	29	18.61	5,197			718
45	525	1		1	4.87	*428*	1461	4.87	5	4.87	1,005			139
46	2,525	2		1	4.09	*2057*	1224	4.08	27	4.09	4,862			667
53		1	1	1								7,863		
54		1	1	1								41,665		
59	1,710	1		1	1.68	*1,393*	909	3.03	18	3.03	3,297		1	472
60		1	1	1								14,571		
61	768	1	1	1	3.81	*142*	999	3.33	8	3.3	1,453	72,713		236
62	658	1	1	1	1.38	*341*	357	1.19	7	1.21	1,285	14,341		194
66	1,600	1	1	1	14.02	*830*	3990	13.30	17	13.25	3,073	21,198		1,111
67	3,900	3		1	10.46	*3,178*	5460	18.20	42	18.2	7,488			1,051
71	989	2		1	5.45	*806*	2226	7.42	10	7.43	1,900			278
72	2,336	1		1	4.37	*1,903*	1548	5.16	25	7.96	4,471			694
75	5,540	1	1	1	0.25	*4,514*	513	1.71	60	1.07	10,674	47,920		764
84	3,191	2	1	1	5.58	*2,600*	2814	9.38	34	9.41	6,147	50,101		833
93	5,148	2		1	13.25		1296	4.32	55	4.36	9,892	*42,235	1	958
94	3,750	2		1	9.67		1431	4.77	40	4.79	7,209	*46,351	1	694
95	9,670	2		1	20.87		6246	20.82	104	20.87	18,610	*202,035	1	2,778
96	1,345	2		1	12.43	*1,096*	3729	12.43	14	12.43	2,570			431
161	14,815	2		1	18.83		5700	19.00	160	18.83	28,502	*141,460	1	4,444
98	4,887	1		1	7.88	*3,982*	5376	17.92	52	17.92	9,389			1,417
99	3,118	1		1	5.95	*2,541*	2718	9.06	33	9.06	5,979		1	861
100	1,930	2		1	7.72	*1,573*	2442	8.14	21	8.14	3,744		1	500
101	6,762	1		1	21	*5,510*	13053	43.51	73	45.31	13,021			1,833
104	4,727	1		1	5.71	*3,852*	5589	18.63	51	18.64	9,109			1,278
105	6,409	1	1	1	11.72	*2,374*	8067	28.89	69	29.04	12,351	81,985	1	1,750
108	2,053	1	1	1	1.91	*1,977*	789	2.63	22	2.91	3,968	10,466		236
109	3,171	1	1	1	8.17	*2,584*	2421	8.07	34	9.08	6,091	33,951	1	1,333

Segment	Silt Fence	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.
No.	**LF**	**EA.**	**EA.**	**EA.**	**Acres**	**CY**	**EA**	**Acres**	**EA**	**Acres**	**EA**	**CY**	**EA**	**CY**
110	2,345	1		1	8.68	*1,911*	2940	9.80	25	10.13	4,526			639
111	2,201	1	1	1	0.38	*1,793*	477	1.59	23	1.33	4,247	56,056		139
112	2,465	2		1	15.47	*3,378*	4536	15.12	26	15.12	4,750			667
117	6,070	3	1	1	15.17	*4,946*	4383	14.61	65	14.58	11,680	65,971	1	944
142	5,047	1	1	1	8.79	*4,112*	7059	23.53	54	9.86	9,724	134,844	1	1,333
149	3,229	3	1	1	8.73	*2,631*	2073	6.91	34	6.89	6,203	11,748		556
150		1	1	1								20,053		
151		1	1	1								19,715		
166	5,071	1		1	11.29		2109	7.03	55	7.15	9,780	*20,605	1	1,306
167	17,321	1	1	1	60.62		16440	54.80	187	56.60	33,308	122,404		4,028
201	10,137	1		1	29.47	*8,260*	14448	48.16	109	48.21	19,504			2,736
202	4,790	3		1	9.71	*3,903*	4683	15.61	51	15.61	9,221			1,361
Total	**168,773.00**	**67**	**18**	**44**	**491.39**	***85,835***	**186,742**	**624.47**	**1,757**	**618.17**	**315,521**	**1,280,251**	**14**	**41,867**
**** Items with this denotation indicate the Resaca is dry therefore land based equipment was used in lieu of dredging equipment.***														

- A. – Construction Entrance and Exit (ea)
- B. – Turbidity Curtain (ea)
- C. – Environmental Protection (ea)
- D. – Clearing and Grubbing (acres)
- E. – Pervious Backfill (cy)
- F. – Riparian Planting (Shrubs) (ea)
- G. – Riparian Turfing (acres)
- H. – Emergent Habitat Planting (ea)
- I. – Removal of Invasive Species (acres)
- J. - Emergent Habitat Planting (Herbaceous) (ea)
- K. – Dredging (cy)
- L. – Control Structure Modifications (ea)
- M. – Top Soil (cy)

Table E-2-2: Restoration Area Project First Costs, IDC and Annual Cost (Oct. 2015 Prices, 3.125 percent Discount Rate, 75 Year Period of Analysis, 6 Month Construction Period

Restoration Area	Project First Cost	Interest During Construction	Investment Cost	Annualized Investment Cost	Annualized OMRRR	Annual Cost
R3-4-5	$3,200,000	$25,000	$3,225,000	$112,000	$2,000	$114,000
R6-7	9,346,000	72,000	9,419,000	327,000	8,000	335,000
R8	2,456,000	19,000	2,475,000	86,000	0	86,000
R10-13	7,267,000	56,000	7,323,000	254,000	5,000	259,000
R17-18--39	29,954,000	232,000	30,186,000	1,047,000	66,000	1,113,000
R40	5,372,000	42,000	5,413,000	188,000	29,000	217,000
R41	5,604,000	43,000	5,647,000	196,000	19,000	215,000
R42	3,295,000	25,000	3,320,000	115,000	49,000	164,000
R43	1,969,000	15,000	1,984,000	69,000	30,000	99,000
R44	2,834,000	22,000	2,856,000	99,000	17,000	116,000
R45E	597,000	5,000	601,000	21,000	4,000	25,000
R45-46	1,200,000	9,000	1,209,000	42,000	4,000	46,000
R53	1,342,000	10,000	1,352,000	47,000	0	47,000
R54	3,835,000	30,000	3,864,000	134,000	0	134,000
R59	1,381,000	11,000	1,391,000	48,000	3,000	51,000
R60	1,669,000	13,000	1,682,000	58,000	0	58,000
R61	9,765,000	76,000	9,841,000	342,000	3,000	345,000
R62	1,972,000	15,000	1,987,000	69,000	1,000	70,000
R66	3,878,000	30,000	3,908,000	136,000	12,000	148,000
R67	3,017,000	23,000	3,040,000	105,000	17,000	123,000
R71	1,702,000	13,000	1,715,000	60,000	7,000	66,000
R72	917,000	7,000	924,000	32,000	8,000	40,000
R74	2,552,000	20,000	2,571,000	89,000	0	89,000
R75	5,700,000	44,000	5,744,000	199,000	3,000	202,000
R76	466,000	4,000	469,000	16,000	1,000	17,000
R77-78	1,234,000	10,000	1,243,000	43,000	4,000	47,000
R79	940,000	7,000	947,000	33,000	3,000	36,000
R81	1,096,000	8,000	1,105,000	38,000	4,000	42,000
R82	6,367,000	49,000	6,416,000	223,000	14,000	236,000
R83	8,404,000	65,000	8,469,000	294,000	0	294,000
R84	7,131,000	55,000	7,187,000	249,000	9,000	259,000
R93	3,155,000	24,000	3,179,000	110,000	5,000	116,000
R94	3,041,000	24,000	3,064,000	106,000	5,000	112,000
R95	9,889,000	76,000	9,966,000	346,000	21,000	367,000
R96	2,350,000	18,000	2,368,000	82,000	11,000	94,000
R161	8,240,000	64,000	8,304,000	288,000	21,000	309,000
R98	3,838,000	30,000	3,868,000	134,000	17,000	152,000
R99	2,384,000	18,000	2,402,000	83,000	9,000	92,000
R100	2,121,000	16,000	2,137,000	74,000	8,000	82,000

Restoration Area	Project First Cost	Interest During Construction	Investment Cost	Annualized Investment Cost	Annualized OMRRR	Annual Cost
R101	7,737,000	60,000	7,797,000	271,000	42,000	313,000
R104	3,218,000	25,000	3,243,000	113,000	18,000	131,000
R105	14,295,000	111,000	14,405,000	500,000	18,000	518,000
R108	2,270,000	18,000	2,287,000	79,000	3,000	83,000
R109	5,803,000	45,000	5,848,000	203,000	9,000	212,000
R110	2,020,000	16,000	2,035,000	71,000	10,000	80,000
R111	880,000	7,000	887,000	31,000	2,000	32,000
R112	2,998,000	23,000	3,021,000	105,000	14,000	119,000
R116-117	9,225,000	71,000	9,296,000	323,000	15,000	337,000
R142	14,626,000	113,000	14,739,000	511,000	10,000	522,000
R149	3,001,000	23,000	3,024,000	105,000	7,000	112,000
R150	2,245,000	17,000	2,262,000	78,000	0	78,000
R151	2,298,000	18,000	2,316,000	80,000	0	80,000
R165	3,069,000	24,000	3,092,000	107,000	6,000	113,000
R166	1,908,000	15,000	1,923,000	67,000	55,000	122,000
R167-148	19,543,000	151,000	19,694,000	683,000	46,000	729,000
R1000	7,866,000	61,000	7,927,000	275,000	46,000	321,000
R1001	3,271,000	25,000	3,296,000	114,000	15,000	130,000

Indirect Costs

All direct costs had indirect costs applied. Indirect costs are the costs that are not specifically associated with any one item of work but with multiple items of work. Indirect costs applied include job office overhead, home office overhead, profit, and bond. These items are distributed as a percentage over the construction items. Job office overhead is generally found to range between 5-10 percent in the U.S. but it can be more based on the project itself. Home office generally ranges between 7-15 percent but can also be more based upon government allowed expenses and accounting practices. Profit generally ranges from 3-12 percent based upon competition and type of work. Bond generally ranges from 1-2 percent and is based on the contractors past history of performance.

Segment Evaluation – Indirect Costs

When estimating costs for each segment of work, a project schedule was forecast for that segment and the corresponding days were used to calculate the job office overhead costs. The Home office percentage used was 8 percent and profit percentage used was 10 percent. This was based upon historical rates seen for similar projects of this type. Bond rates were determined based on the Class B surety rates within the MII software. The abbreviated risk analysis was used to calculate risks for each item of work and then applied to each segment accordingly. A copy of the risk analysis used in the segment evaluation is shown in the cost appendix. (See Engineering Appendix E, Cost and Schedule Risk Assessment E-3.) The rates above were used for the prime contractor. For the subcontractor's costs, the estimator used the following rates:

- subJOOH – 5 percent
- subHOOH – 5 percent
- Profit – 10 percent
- Bond – Bond Table calculated using Class B.

The Recommended Plan Evaluation – Indirect Costs

The recommended plan was Alternative 5. The subcontractor rates for Alternative 5 were not adjusted. The following rates were used for the prime contractor:

- JOOH – 10 (%)
- HOOH – 10 (%)
- Profit - 10 (%)
- Bond – Bond Table calculated using Class B.

The alternatives were composed of the (64) restoration areas among the three resacas.

Table E-2-3: Final Array Costs

Alternative Composition					
1	**2**	**4**	**5**	**6**	**7**
40, 41, 42, 43, 44, 45E, 45, 46, 53, 54, 59, 60, 61, 62, 66, 67, 71, 72, 75, 84, 93, 94, 95, 96, 161	Alternative 1	Alternative 1	Alternative 1	Alternative 1	Alternative 1
	98, 99, 100, 101, 104, 105, 108, 109, 110, 111, 112, 167, 148, 1000, 1001	Alternative 2	Alternative 2	Alternative 2	Alternative 2
		142, 149, 150, 151, 166	Alternative 4	Alternative 4	Alternative 4
			116, 117	Alternative 5	Alternative 5
				77, 78, 79, 81, 82, 83	Alternative 6
					165

See Table E-2-4 for the cost evaluation of the six alternatives.

*(*Dollars in* Table E-2-4 *are based October 2015 prices and a federal discount rate of 3.125 percent. Final costs of Alternatives reflect minor adjustments made in response to Risk Analysis and agency technical review evaluations. Final values for Alternative 5 are shown in the Certified Cost Estimate,* Exhibit E-2-1).

Table E-2-4: Derivation of Annual Costs for the Recommended Plan
($1,000, October 2017 Prices, 2.75 Percent Discount Rate)

Cost and Benefit Category	Alternative					
	1	2	4	5	6	7
First Cost ($1,000)	90,318	172,198	196,277	205,501	223,542	226,611
AAC ($1,000)	3,273	6,232	7,108	7,428	8,050	8,157
IDC	652	1,258	1,444	1,515	1,654	1,678
OMRR&R	248	506	578	593	618	624
Project Acres	448.7	826.2	884.2	914.5	963.0	968.6
FWP AAHU	393	762	815	846	883	888
FWOP AAHU	153	329	346	362	376	378
Net Benefit	240	433	470	483	507	510
Benefit/Acre	0.53	0.92	0.92	0.93	0.92	0.92
Incremental Benefit	240	193	37	13	23	3
AAC/AAHU ($1,000)	13.6	14.4	15.1	15.4	15.9	16.0
Incremental AAC	13.6	6.8	1.9	0.7	1.2	0.2
Incremental AAC/AAHU ($1,000)	13.6	15.4	23.5	23.7	26.7	37.5
Total Cost./Acre ($1,000)	201.28	208.42	221.98	224.71	232.13	233.96
AAC/Acre ($1,000)	7.29	7.54	8.04	8.12	8.34	8.42

Table E-2-5 shows the annualized costs, for the recommended project, Alternative 5, at October 2017 prices, 2.75 percent interest for a 75 year period of analysis.

Table E-2-5: Projected Project Contract Award Schedule for the Brownsville CityWide Project

Investment		
	Estimated First Cost	$202,492
	Annual Interest Rate	2.750%
	Period of Analysis (years)	75
	Construction Period (months)	12
	Compound Interest Factor	12.15
	Capital Recovery Factor	0.0316356
	Interest During Construction	$2,772
	Investment Costs	$205,264
Annual Charges		
	Interest	$5,645
	Amortization	$849
	OMRRR ($/yr)	$624
	Total Annual Charges	$7,118

Total Project Cost Summary (TPCS)

The total project cost summary (TPCS) includes all the costs that would be incurred for implementation of the project. It is important to note that the study costs are not included in the Planning account of the TPCS. The Lands and Damages estimate was provided by the Galveston District Real Estate Division, Mr. David Mairs, Realty Specialist. The percentages for E&D and S&A were provided by the Galveston District Project Management Team.

The chart of accounts is as follows:

- 01 – Lands and Damages
- 02 - Relocations
- 06 – Fish and Wildlife Facilities (construction costs for ecosystem restoration)
- 30 – Planning, E&D
- 31 – Supervision and Administration

Schedule

During the course of the study, an overall project award schedule was prepared with the help of the PDT and is as shown in Table E-2-6. The PDT felt the recommended plan would be executed in one contract per year with a duration spanning several years. Once this was known, it made it easier for the estimator to develop costs for mobilization and demobilization for the overall project.

Table E-2-6: Projected Project Contract Award Schedule

Construction Year Start	Resaca Areas
2021	149, 150, 151
2022	116, 117, 142
2023	166
2024	148, 167
2025	108, 109, 110, 111, 112
2026	104, 105
2027	98, 99, 100, 101, 1000, 1001
2028	161
2029	84
2030	75, 95
2031	53, 54, 59, 60
2032	61
2033	62, 66, 67, 71, 72, 96
2034	93, 94
2035	45, 46
2036	40, 41, 42, 43, 44

WALLA WALLA COST ENGINEERING
MANDATORY CENTER OF EXPERTISE

COST AGENCY TECHNICAL REVIEW

CERTIFICATION STATEMENT

SWG - PN 444605 Resacas at Brownsville Ecosystem Restoration Study

The Resacas at Brownsville Ecosystem Restoration Study cost, as presented by the Galveston District, has undergone a successful Cost Agency Technical Review (Cost ATR) performed by the Walla Walla District Cost Engineering Mandatory Center of Expertise (Cost MCX) team. The Cost ATR included study of the project scope, report, cost estimates, schedules, escalation, and risk-based contingencies. This certification signifies the cost products meet the quality standards as prescribed in ER 1110-2-1150 Engineering and Design for Civil Works Projects and ER 1110-2-1302 Civil Works Cost Engineering.

Certification Date: 12 February 2018

FY18 Project First Cost:	$202,492,000
Fully Funded Costs:	$255,597,000

Note: It remains the responsibility of the District to correctly reflect these cost values and to implement effective project management controls and implementation procedures including risk management through the period of Federal participation.

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Date: 2018.02.12 06:55:39 -08'00'

FOR: Michael P. Jacobs, PE, CCE
Chief, Cost Engineering MCX
Walla Walla District

Exhibit E-2-1: Certified Cost Estimate

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: Brownsville Resacas Feasibility Eco Restoration ALT 5
PROJECT N P2# 444605
LOCATION: Brownsville, TX

DISTRICT: Galveston District **PREPARED: 12/13/2017**
POC: Welch, Jerry, Chief Cost Engineering, Memphis District

This Estimate reflects the scope and schedule in report; Feasibility Study - Recommended Plan

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
						Program Year (Budget EC): 2018; Effective Price Level Date: 1 OCT 17									
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	**TOTAL ($K)**	Spent Thru: **1-Oct-16** ($K)	**TOTAL FIRST COST** ($K)	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*		*K*	*L*	*M*	*N*	*O*
02	RELOCATIONS (USACE)	$4,131	$826	20%	$4,957	0.0%	$4,131	$826	$4,957	$0	$4,957	22.0%	$5,038	$1,008	$6,045
02	RELOCATIONS (USFWS)	$546	$109	20%	$656	0.0%	$546	$109	$656	$0	$656	22.0%	$666	$133	$800
06	FISH & WILDLIFE FACILITIES - USACE	$82,614	$16,523	20%	$99,137	0.0%	$82,614	$16,523	$99,137	$0	$99,137	22.0%	$100,758	$20,152	$120,909
06	FISH & WILDLIFE FACILITIES - USFWS	$10,928	$2,186	20%	$13,114	0.0%	$10,928	$2,186	$13,114	$0	$13,114	22.0%	$13,328	$2,666	$15,994
	CONSTRUCTION ESTIMATE TOTALS (USACE):	$86,745	$17,349		$104,093	0.0%	$86,745	$17,349	$104,093	$0	$104,093	22.0%	$105,796	$21,159	**$126,955**
	CONSTRUCTION ESTIMATE TOTALS (USFWS):	$11,475	$2,295		$13,770	0.0%	$11,475	$2,295	$13,770	$0	$13,770	22.0%	$13,995	$2,799	**$16,794**
01	LANDS AND DAMAGES (USACE)	$37,995	$7,599	20%	$45,595	0.0%	$37,995	$7,599	$45,595	$0	$45,595	19.6%	$45,431	$9,086	$54,517
01	LANDS AND DAMAGES (USFWS)	$434	$87	20%	$521	0.0%	$434	$87	$521		$521	19.6%	$519	$104	$623
30	PLANNING, E & D (USACE)	$15,237	$3,047	20%	$18,284	0.0%	$15,237	$3,047	$18,284	$0	$18,284	45.5%	$22,175	$4,435	$26,610
30	PLANNING, E & D (USFWS)	$1,981	$396	20%	$2,377	0.0%	$2,058	$412	$2,470	$0	$2,470	45.5%	$2,860	$572	$3,432
31	CONSTR. MANAGEMENT (USACE)	$13,012	$2,602	20%	$15,614	0.0%	$13,012	$2,602	$15,614	$0	$15,614	50.8%	$19,626	$3,925	$23,551
31	CONSTR MANAGEMENT (USFWS)	$1,721	$344	20%	$2,065	0.0%	$1,788	$358	$2,146		$2,146	50.8%	$2,596	$519	$3,115
	PROJECT COST TOTALS:	$168,599	$33,720	20%	$202,319		$168,743	$33,749	**$202,492**	$0	**$202,492**	26.2%	$212,997	$42,599	$255,597

ESTIMATED TOTAL PROJECT COST: $255,597
ESTIMATED TOTAL USACE PROJECT COST: **$231,634**
ESTIMATED TOTAL USFWS PROJECT COST: **$23,963**

____________________ **Welch, Jerry, Chief Cost Engineering, Memphis District**

____________________ **Shakhar, Misir, Project Management Galveston District**

____________________ **Nelson, Timothy J., Chief Real Estate, G**

____________________ **Harper, Brian K., Chief Planning, Regional Planning Env. Center**

____________________ **Callahan, Shane, Chief Design Branch, Memphis District**

____________________ **Hrametz, Josheph, Chief Operations, Galveston District**

____________________ **Carelock, Don, Chief Construction, Galveston District**

____________________ **Williams, Byron D., Chief PM-PB, Galveston District**

____________________ **Miller, Valerie, Chief DPM, Galveston District**

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TPCS

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Brownsville Resacas Feasibility Eco Restoration ALT 5
LOCATION: Brownsville, TX
This Estimate reflects the scope and schedule in report; Feasibility Study - Recommended Plan

DISTRICT: Galveston District PREPARED: 12/13/2017
POC: Welch, Jerry, Chief Cost Engineering, Memphis District

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			13-Dec-17	Program Year (Budget EC):			2018	FULLY FUNDED PROJECT ESTIMATE				
		Effective Price Level:			1-Oct-17	Effective Price Level Date:			1 OCT 17					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 10 or CONTRACT 10													
02	RELOCATOINS (USACE)	$4,131	$826	20.0%	$4,957	0.0%	$4,131	$826	$4,957	2028Q1	22.0%	$5,038	$1,008	$6,045
02	RELOCATIONS (USFWS)	$546	$109	20.0%	$656	0.0%	$546	$109	$656	2028Q1	22.0%	$666	$133	$800
06	FISH & WILDLIFE FACILITIES - USACE	$82,614	$16,523	20.0%	$99,137	0.0%	$82,614	$16,523	$99,137	2028Q1	22.0%	$100,758	$20,152	$120,909
06	FISH & WILDLIFE FACILITIES - USFWS	$10,928	$2,186	20.0%	$13,114	0.0%	$10,928	$2,186	$13,114	2028Q1	22.0%	$13,328	$2,666	$15,994
	CONSTRUCTION ESTIMATE TOTALS (USACE):	$86,745	$17,349	20.0%	$104,093		$86,745	$17,349	$104,093			$105,796	$21,159	$126,955
	CONSTRUCTION ESTIMATE TOTALS (USFWS):	$11,475	$2,295	20.0%	$13,770		$11,475	$2,295	$13,770			$13,995	$2,799	$16,794
01	LANDS AND DAMAGES (USACE)	$37,995	$7,599	20.0%	$45,595	0.0%	$37,995	$7,599	$45,595	2027Q1	19.6%	$45,431	$9,086	$54,517
01	LANDS AND DAMAGES (USFWS)	$434	$87	20.0%	$521	0.0%	$434	$87	$521	2027Q1	19.6%	$519	$104	$623
30	PLANNING, ENGINEERING & DESIGN													
2.2%	Project Management	$1,908	$382	20.0%	$2,290	0.0%	$1,908	$382	$2,290	2027Q1	44.4%	$2,755	$551	$3,306
2.0%	Planning & Environmental Compliance	$1,735	$347	20.0%	$2,082	0.0%	$1,735	$347	$2,082	2027Q1	44.4%	$2,505	$501	$3,006
3.6%	Engineering & Design	$3,149	$630	20.0%	$3,779	0.0%	$3,149	$630	$3,779	2027Q1	44.4%	$4,546	$909	$5,455
1.0%	Reviews, ATRs, IEPRs, VE	$867	$173	20.0%	$1,041	0.0%	$867	$173	$1,041	2027Q1	44.4%	$1,252	$250	$1,503
1.0%	Life Cycle Updates (cost, schedule, risks)	$935	$187	20.0%	$1,122	0.0%	$935	$187	$1,122	2027Q1	44.4%	$1,350	$270	$1,620
1.0%	Contracting & Reprographics	$867	$173	20.0%	$1,041	0.0%	$867	$173	$1,041	2027Q1	44.4%	$1,252	$250	$1,503
1.5%	Engineering During Construction	$1,301	$260	20.0%	$1,561	0.0%	$1,301	$260	$1,561	2028Q1	50.8%	$1,963	$393	$2,355
1.7%	Planning During Construction	$1,449	$290	20.0%	$1,738	0.0%	$1,449	$290	$1,738	2028Q1	50.8%	$2,185	$437	$2,622
1.3%	Adaptive Management & Monitoring	$1,290	$258	20.0%	$1,548	0.0%	$1,290	$258	$1,548	2027Q1	44.4%	$1,862	$372	$2,235
2.0%	Project Operations	$1,735	$347	20.0%	$2,082	0.0%	$1,735	$347	$2,082	2027Q1	44.4%	$2,505	$501	$3,006
30	PLANNING, ENGINEERING & DESIGN	$1,981	$396	20.0%	$2,377	3.9%	$2,058	$412	$2,470	2027Q1	39.0%	$2,860	$572	$3,432
31	CONSTRUCTION MANAGEMENT (USACE)													
10.5%	Construction Management	$9,108	$1,822	20.0%	$10,930	0.0%	$9,108	$1,822	$10,930	2028Q1	50.8%	$13,738	$2,748	$16,486
2.0%	Project Operation:	$1,735	$347	20.0%	$2,082	0.0%	$1,735	$347	$2,082	2028Q1	50.8%	$2,617	$523	$3,140
2.5%	Project Management	$2,169	$434	20.0%	$2,602	0.0%	$2,169	$434	$2,602	2028Q1	50.8%	$3,271	$654	$3,925
31	CONSTRUCTION MANAGEMENT (USFWS)	$1,721	$344	20.0%	$2,065	3.9%	$1,788	$358	$2,146	2028Q1	45.2%	$2,596	$519	$3,115
	CONTRACT COST TOTALS:	$168,599	$33,720		**$202,319**		$168,743	$33,749	**$202,492**			$212,997	$42,599	**$255,597**

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TPCS

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APPENDIX E-3

Engineering Appendix

Contents:

Cost Engineering
Cost Schedule Risk Analysis (CSRA

US Army Corps
of Engineers®

City of Brownsville (Resacas), Texas

Project Cost and Schedule Risk Analysis Report

Prepared for:

U.S. Army Corps of Engineers,

Sacramento District

Prepared by:

U.S. Army Corps of Engineers

Cost Engineering Technical Center of Expertise, Walla Walla, WA

June 13, 2017

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EXECUTIVE SUMMARY

The US Army Corps of Engineers (USACE), Galveston District, presents this cost and schedule risk analysis (CSRA) report regarding the risk findings and recommended contingencies for the City of Brownsville (Resacas), Texas. In compliance with Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008, a *Monte-Carlo* based risk analysis was conducted by the Project Development Team (PDT) on remaining costs. The purpose of this risk analysis study is to present the cost and schedule risks considered, those determined and respective project contingencies at a recommended 80% confidence level of successful execution to project completion.

The Study, evaluating the need for ecosystem restoration of the resacas in the city of Brownsville, is the first of its type for the region. Resacas (oxbow lakes) are former channels of the Rio Grande River that have been cut off from the river, having no inlet or outlet. Before land development and water control, floodwaters from the Rio Grande drained into resacas from the surrounding terrain. During the past decades, siltation and development have reduced the capacity of the resacas, and the city would like to investigate economical ways of preserving and restoring the resacas to a natural state. It is estimated that 99% of the riparian habitat along the U.S. side of the Rio Grande River has been cleared (USFWS 1997). The lower Rio Grande Valley is one of the most biologically diverse ecological regions in North America and a critical migratory stopover for birds moving between the Americas. Yet more than 75% of the region's wildlife habitat has been replaced by human development and agriculture. The resacas become more valuable as time passes given the unpredictable nature of the contamination in the Rio Grande and continuing drought conditions. The Feasibility Cost Sharing Agreement was signed on 17 April 2002. The study has not been in the President' Budget since FY08. Since then, the project has been minimally funded in appropriations. Therefore the completion of the study is to be determined. The study effort will evaluate the environmental restoration of the resacas, improved flood protection, enhanced water storage, and ecosystem restoration.

The current project base cost for the City of Brownsville Resacas estimate is approximately $126.1M excluding Lands and Damages and contingency and expressed in FY 2017 dollars. This CSRA study included all estimated construction costs, Planning, Engineering, Design and Construction Management costs. Based on the results of the analysis, the Cost Engineering Mandatory Center of Expertise for Civil

Works (MCX located in Walla Walla District) recommends a contingency value of $25.2M or approximately 20% of base project cost at an 80% confidence level of successful execution.

Cost estimates fluctuate over time. During this period of study, minor cost fluctuations can and have occurred. For this reason, contingency reporting is based in cost and per cent values. Should cost vary to a slight degree with similar scope and risks, contingency percent values will be reported, cost values rounded.

Table ES-1. Construction Contingency Results

Base Case Construction Cost Estimate	$126,066,000		
Confidence Level	**Construction Value ($$) w/ Contingencies**	**Contingency (%)**	**Contingency ($)**
50%	$146,236,560	16%	$20,170,560
80%	**$151,279,200**	**20%**	**$25,213,200**
90%	$153,800,520	22%	$27,734,520

KEY FINDINGS/OBSERVATIONS/ASSUMPTIONS & RECOMMENDATIONS

The PDT worked through the risk register in April and May 2017. The key risk drivers identified through sensitivity analysis suggest a cost contingency of $20.6M and schedule risks adding a potential 49 months; all at an 80% confidence level.

Cost Risks: From the CSRA, the key or greater Cost Risk items of include:

- <u>CA1 – Acquisition Strategy</u> – Cost estimate is based on full and open large business contractor markups. Given relatively simple construction requirements and small dollar values (some $5M each or less) it is very likely large portions of this work could be awarded to Small Disadvantaged Business.

- ET1 – Variations in Quantities – Survey data for dredging was lacking. Limited survey information was available for estimating dredge quantities was. Limited survey data was extrapolated to those areas that had no data.
- ET2 – Level of Estimate – Estimate is a feasibility level estimate based on with estimated crews, production rates and material quotes. Level of Estimate varies between a Class 4 and Class 3 with associated Risk Levels.

Moderate risks, when combined, can also become a cost impact.

- CO4 – Market Conditions & Bidding Climate – Bidding climate could lead to higher awarded construction costs. Mechanical Marine Dredging is highly specialized work with few available contractors in the area.
- ET3 – Fuel Variations – Fuel cost has varied significantly recently and will most likely continue to fluctuate for the life of this project. Estimate is based on current AAA fuel rates.

Schedule Risks: From the CSRA, the key or greater Schedule Risk items include:

- PR1 – Federal Funding – Schedule is entirely funding dependent. Baseline schedule requires some $10M to $15M per year for total project. Federal share would be some $10M / year. There is currently funding uncertainty for Environmental Restoration projects.
- PM4 – Native Plantings – Native Plantings will need to be coordinated with nurseries to insure plants are available. The Nature Conservancy and Commercial Supply all appear to have limited additional supply capacity. Their ability to provide plants for quantities required is uncertain. Schedule risk exists early on as supply growers are developed. Worst case the first construction season could be missed as suppliers are developed.

Recommendations: The CSRA study serves as a “road map” towards project improvements and reduced risks over time. The PDT must include the recommended cost and schedule contingencies and incorporate risk monitoring and mitigation on those identified risks. Further iterative study and update of the risk analysis throughout the project life-cycle is important in support of remaining within an approved budget and appropriation.

MAIN REPORT

1.0 PURPOSE

Within the authority of the US Army Corps of Engineers (USACE), Galveston District, this report presents the efforts and results of the cost and schedule risk analysis for City of Brownsville (Resacas), Texas. The report includes risk methodology, discussions, findings and recommendations regarding the identified risks and the necessary contingencies to confidently administer the project, presenting a cost and schedule contingency value with an 80% confidence level of successful execution.

2.0 BACKGROUND

The Study, evaluating the need for ecosystem restoration of the resacas in the city of Brownsville, is the first of its type for the region. Resacas (oxbow lakes) are former channels of the Rio Grande River that have been cut off from the river, having no inlet or outlet. Before land development and water control, floodwaters from the Rio Grande drained into resacas from the surrounding terrain. During the past decades, siltation and development have reduced the capacity of the resacas, and the city would like to investigate economical ways of preserving and restoring the resacas to a natural state. It is estimated that 99% of the riparian habitat along the U.S. side of the Rio Grande River has been cleared (USFWS 1997). The lower Rio Grande Valley is one of the most biologically diverse ecological regions in North America and a critical migratory stopover for birds moving between the Americas. Yet more than 75% of the region's wildlife habitat has been replaced by human development and agriculture. The resacas become more valuable as time passes given the unpredictable nature of the contamination in the Rio Grande and continuing drought conditions. The Feasibility Cost Sharing Agreement was signed on 17 April 2002. The study has not been in the President' Budget since FY08. Since then, the project has been minimally funded in appropriations. Therefore the completion of the study is to be determined. The study effort will evaluate the environmental restoration of the resacas, improved flood protection, enhanced water storage, and ecosystem restoration.

3.0 REPORT SCOPE

The scope of the risk analysis report is to identify cost and schedule risks with a resulting recommendation for contingencies at the 80 percent confidence level using the risk analysis processes, as mandated by U.S. Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The report presents the contingency results for cost risks for construction features. The CSRA does not include consideration for life cycle costs.

3.1 Project Scope

The formal process included extensive involvement of the PDT for risk identification and the development of the risk register. The analysis process evaluated the Micro Computer Aided Cost Estimating System (MCACES) cost estimate, project schedule, and funding profiles using Crystal Ball software to conduct a *Monte Carlo* simulation and statistical sensitivity analysis, per the guidance in Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

The project technical scope, estimates and schedules were developed and presented by the District. Consequently, these documents serve as the basis for the risk analysis.

The scope of this study addresses the identification of concerns, needs, opportunities and potential solutions that are viable from an economic, environmental, and engineering viewpoint.

3.2 USACE Risk Analysis Process

The risk analysis process for this study follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering MCX. The risk analysis process reflected within this report uses probabilistic cost and schedule risk analysis methods within the framework of the Crystal Ball software. Furthermore, the scope of the report includes the identification and communication of important steps, logic, key assumptions, limitations, and decisions to help ensure that risk analysis results can be appropriately interpreted.

Risk analysis results are also intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule risk analysis should be considered as an ongoing process conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting and scheduling.

In addition to broadly defined risk analysis standards and recommended practices, this risk analysis was performed to meet the requirements and recommendations of the following documents and sources:

- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Engineering MCX.
- Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008.
- Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

4.0 METHODOLOGY / PROCESS

The Cost Engineering MCX performed the Cost and Schedule Risk Analysis, relying on local District staff to provide expertise and information gathering. The District PDT conducted initial risk identification via meetings with the Walla Walla Cost Engineering MCX facilitator in May 2016. The initial risk identification meeting also included qualitative analysis to produce a risk register that served as the draft framework for the risk analysis.

Participants in the risk identification meeting on April 24, 2017 included:

Name	Office	Representing
Jeromy Carpenter	MVM	Cost Engineer
Josh Giannini	MVM	Civil Engineer
David Mairs	SWG	Real Estate
William Bolte	NWW	Risk Facilitator

Follow up discussions were held on May 8, 2017 included:

Name	Office	Representing
Jeromy Carpenter	MVM	Cost Engineer
Daniel Allen	SWF	Environmental Planner
Shakhar Misir	SWG	Project Manager
William Bolte	NWW	Risk Facilitator

The risk analysis process for this study is intended to determine the probability of various cost outcomes and quantify the required contingency needed in the cost estimate to achieve the desired level of cost confidence. Per regulation and guidance, the P80 confidence level (80% confidence level) is the normal and accepted cost confidence level. District Management has the prerogative to select different confidence levels, pending approval from Headquarters, USACE.

In simple terms, contingency is an amount added to an estimate to allow for items, conditions or events for which the occurrence or impact is uncertain and that experience suggests will likely result in additional costs being incurred or additional time being required. The amount of contingency included in project control plans depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans. The risk of overrun is expressed, in a probabilistic context, using confidence levels.

The Cost MCX guidance for cost and schedule risk analysis generally focuses on the 80-percent level of confidence (P80) for cost contingency calculation. It should be noted that use of P80 as a decision criteria is a risk averse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level. The selection of contingency at a particular confidence level is ultimately the decision and responsibility of the project's District and/or Division management.

The risk analysis process uses *Monte Carlo* techniques to determine probabilities and contingency. The *Monte Carlo* techniques are facilitated computationally by a commercially available risk analysis software package (Crystal Ball) that is an add-in to Microsoft Excel. Cost estimates are packaged into an Excel format and used directly for cost risk analysis purposes. The level of detail recreated in the Excel-format schedule is sufficient for risk analysis purposes that reflect the established risk register, but generally less than that of the native format.

The primary steps, in functional terms, of the risk analysis process are described in the following subsections. Risk analysis results are provided in Section 6.

4.1 Identify and Assess Risk Factors

Identifying the risk factors via the PDT is considered a qualitative process that results in establishing a risk register that serves as the document for the quantitative study using the Crystal Ball risk software. Risk factors are events and conditions that may influence or drive uncertainty in project performance. They may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risk factors may have either favorable or unfavorable impacts on project cost and schedule.

A formal PDT meeting was held with the District office and project owners for the purposes of identifying and assessing risk factors. The meeting included capable and qualified representatives from multiple project team disciplines and functions, including project management, cost engineering, design, environmental compliance, real estate, construction, contracting and representatives of the sponsoring agencies.

The initial formal meetings focused primarily on risk factor identification using brainstorming techniques, but also included some facilitated discussions based on risk factors common to projects of similar scope and geographic location. Additionally, numerous conference calls and informal meetings were conducted throughout the risk analysis process on an as-needed basis to further facilitate risk factor identification, market analysis, and risk assessment.

4.2 Quantify Risk Factor Impacts

The quantitative impacts (putting it to numbers of cost and time) of risk factors on project plans were analyzed using a combination of professional judgment, empirical data and analytical techniques. Risk factor impacts were quantified using probability distributions (density functions) because risk factors are entered into the Crystal Ball software in the form of probability density functions.

Similar to the identification and assessment process, risk factor quantification involved multiple project team disciplines and functions. However, the quantification process relied more extensively on collaboration between cost engineering and risk analysis team members with lesser inputs from other functions and disciplines. This process used an iterative approach to estimate the following elements of each risk factor:

- Maximum possible value for the risk factor
- Minimum possible value for the risk factor
- Most likely value (the statistical mode), if applicable
- Nature of the probability density function used to approximate risk factor uncertainty

- Mathematical correlations between risk factors
- Affected cost estimate and schedule elements

The resulting product from the PDT discussions is captured within a risk register as presented in section 6 for both cost and schedule risk concerns. Note that the risk register records the PDT's risk concerns, discussions related to those concerns, and potential impacts to the current cost and schedule estimates. The concerns and discussions support the team's decisions related to event likelihood, impact, and the resulting risk levels for each risk event.

4.3 Analyze Cost Estimate and Schedule Contingency

Contingency is analyzed using the Crystal Ball software, an add-in to the Microsoft Excel format of the cost estimate and schedule. *Monte Carlo* simulations are performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified by the PDT. Contingencies are calculated by applying only the moderate and high level risks identified for each option (i.e., low-level risks are typically not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies as the project and risks evolve).

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the baseline cost estimate. Each option-specific contingency is then allocated on a civil works feature level based on the dollar-weighted relative risk of each feature as quantified by *Monte Carlo* simulation. Standard deviation is used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of all the project feature cost contingency being allocated to features with relatively higher estimated cost uncertainty.

5.0 PROJECT ASSUMPTIONS

The following data sources and assumptions were used in quantifying the costs associated with the project.

a. The District provided estimate files electronically. The files transmitted and resulting independent review, served as the basis for the final cost and schedule risk analyses.

b. The cost comparisons and risk analyses performed and reflected within this report are based on design scope and estimates that are at the feasibility level of design.

c. Schedules are analyzed for impact to the project cost in terms of delayed funding, uncaptured escalation (variance from OMB factors and the local market) and unavoidable fixed contract costs and/or languishing federal administration costs incurred throughout delay.

d. The Cost Engineering MCX guidance generally focuses on the eighty-percent level of confidence (P80) for cost contingency calculation. For this risk analysis, the eighty-percent level of confidence (P80) was used. It should be noted that the use of P80 as a decision criteria is a moderately risk averse approach, generally resulting in higher cost contingencies. However, the P80 level of confidence also assumes a small degree of risk that the recommended contingencies may be inadequate to capture actual project costs.

e. Only high and moderate risk level impacts, as identified in the risk register, were considered for the purposes of calculating cost contingency. Low level risk impacts should be maintained in project management documentation, and reviewed at each project milestone to determine if they should be placed on the risk “watch list”.

6.0 RESULTS

The cost and schedule risk analysis results are provided in the following sections. In addition to contingency calculation results, sensitivity analyses are presented to provide decision makers with an understanding of variability and the key contributors to the cause of this variability.

6.1 Risk Register

A risk register is a tool commonly used in project planning and risk analysis. The actual risk register is provided in Appendix A. The complete risk register includes low level risks, as well as additional information regarding the nature and impacts of each risk.

It is important to note that a risk register can be an effective tool for managing identified risks throughout the project life cycle. As such, it is generally recommended that risk registers be updated as the designs, cost estimates, and schedule are further refined, especially on large projects with extended schedules. Recommended uses of the risk register going forward include:

- Documenting risk mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.
- Providing project sponsors, stakeholders, and leadership/management with a documented framework from which risk status can be reported in the context of project controls.
- Communicating risk management issues.
- Providing a mechanism for eliciting feedback and project control input.
- Identifying risk transfer, elimination, or mitigation actions required for implementation of risk management plans.

6.2 Cost Contingency and Sensitivity Analysis

The result of risk or uncertainty analysis is quantification of the cumulative impact of all analyzed risks or uncertainties as compared to probability of occurrence. These results, as applied to the analysis herein, depict the overall project cost at intervals of confidence (probability).

Table 1 provides the construction cost contingencies calculated for the P80 confidence level and rounded to the nearest thousand. The construction cost contingencies for the P5, P50 and P90 confidence levels are also provided for illustrative purposes only.

Table 1. Construction Cost Contingency Summary

Base Case Construction Cost Estimate	$126,066,000		
Confidence Level	**Construction Value ($$) w/ Contingencies**	**Contingency (%)**	**Contingency ($)**
50%	$146,236,560	16%	$20,170,560
80%	**$151,279,200**	**20%**	**$25,213,200**
90%	$153,800,520	22%	$27,734,520

6.2.1 Sensitivity Analysis

Sensitivity analysis generally ranks the relative impact of each risk/opportunity as a percentage of total cost uncertainty. The Crystal Ball software uses a statistical measure (contribution to variance) that approximates the impact of each risk/opportunity contributing to variability of cost outcomes during *Monte Carlo* simulation.

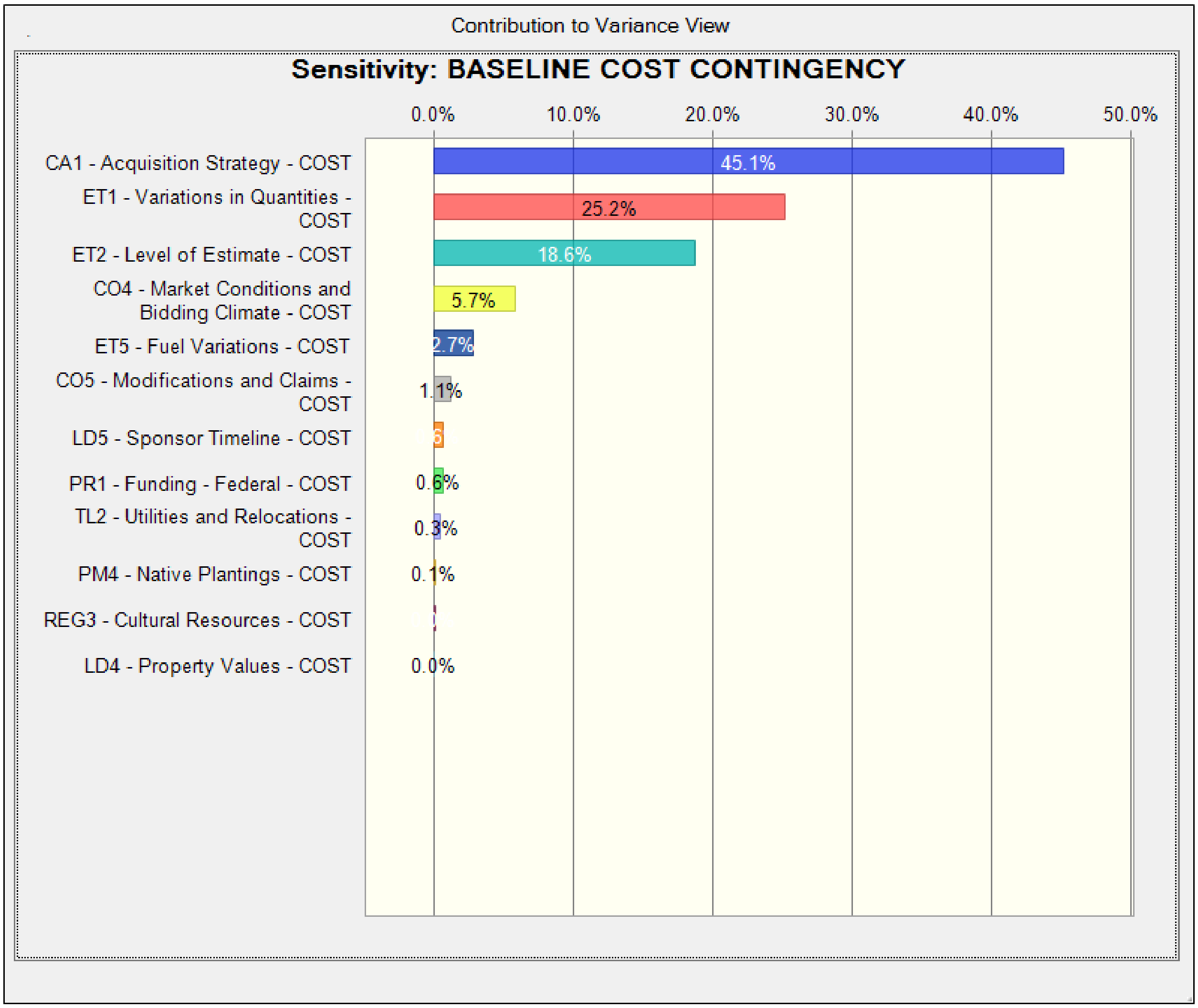
Key cost drivers identified in the sensitivity analysis can be used to support development of a risk management plan that will facilitate control of risk factors and their potential impacts throughout the project lifecycle. Together with the risk register, sensitivity analysis results can also be used to support development of strategies to eliminate, mitigate, accept or transfer key risks.

6.2.2 Sensitivity Analysis Results

The risks/opportunities considered as key or primary cost drivers and the respective value variance are ranked in order of importance in contribution to variance bar charts. Opportunities that have a potential to reduce project cost and are shown with a negative sign; risks are shown with a positive sign to reflect the potential to increase project cost. A longer bar in the sensitivity analysis chart represents a greater potential impact to project cost.

Figure 1 presents a sensitivity analysis for cost growth risk from the high level cost risks identified in the risk register. Likewise, Figure 2 presents a sensitivity analysis for schedule growth risk from the high level schedule risks identified in the risk register.

Figure 1. Cost Sensitivity Analysis



6.3 Schedule and Contingency Risk Analysis

The result of risk or uncertainty analysis is quantification of the cumulative impact of all analyzed risks or uncertainties as compared to probability of occurrence. These results, as applied to the analysis herein, depict the overall project duration at intervals of confidence (probability).

Table 2 provides the schedule duration contingencies calculated for the P80 confidence level. The schedule duration contingencies for the P50 and P90 confidence levels are also provided for illustrative purposes.

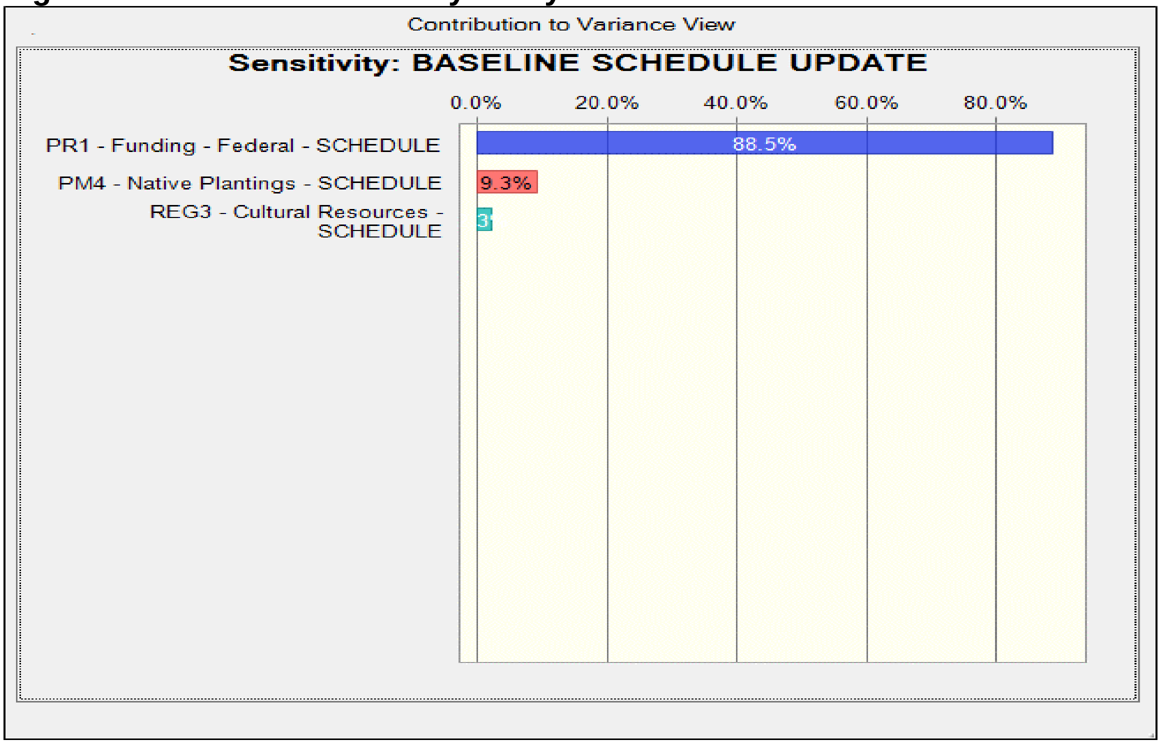
Schedule duration including contingency was quantified as 49 months based on the P80 level of confidence. These contingencies were used to calculate the projected residual fixed cost impact of project delays that are included in the Table 1 presentation of total cost contingency. The schedule contingencies were calculated by applying the high level schedule risks identified in the risk register for each option to the durations of critical path and near critical path tasks.

The schedule was not resource loaded and contained open-ended tasks and non-zero lags (gaps in the logic between tasks) that limit the overall utility of the schedule risk analysis. These issues should be considered as limitations in the utility of the schedule contingency data presented. Schedule contingency impacts presented in this analysis are based solely on projected residual fixed costs.

Table 2. Schedule Duration Contingency Summary

Risk Analysis Forecast **(base schedule of 195 months)**	**Duration w/ Contingencies** **(months)**	**Contingency** **(months)**
50% Confidence	226	31
80% Confidence	244	49
90% Confidence	252	57

Figure 2. Schedule Sensitivity Analysis



7.0 MAJOR FINDINGS/OBSERVATIONS/RECOMMENDATIONS

This section provides a summary of significant risk analysis results that are identified in the preceding sections of the report. Risk analysis results are intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as projects progress through planning and implementation. Because of the potential for use of risk analysis results for such diverse purposes, this section also reiterates and highlights important steps, logic, key assumptions, limitations, and decisions to help ensure that the risk analysis results are appropriately interpreted.

7.1 Major Findings/Observations

Project cost and schedule comparison summaries are provided in Table 3 and Table 4 respectively. Additional major findings and observations of the risk analysis are listed below.

The PDT worked through the risk register in April and May 2017. The key risk drivers identified through sensitivity analysis suggest a cost contingency of $25.2M and schedule risks adding a potential 49 months; all at an 80% confidence level.

Cost Risks: From the CSRA, the key or greater Cost Risk items of include:

- CA1 – Acquisition Strategy – Cost estimate is based on full and open large business contractor markups. Given relatively simple construction requirements and small dollar values (some $5M each or less) it is very likely large portions of this work could be awarded to Small Disadvantaged Business.
- ET1 – Variations in Quantities – Survey data for dredging was lacking. Limited survey information was available for estimating dredge quantities was. Limited survey data was extrapolated to those areas that had no data.
- ET2 – Level of Estimate – Estimate is a feasibility level estimate based on with estimated crews, production rates and material quotes. Level of Estimate varies between a Class 4 and Class 3 with associated Risk Levels.

Moderate risks, when combined, can also become a cost impact.

- CO4 – Market Conditions & Bidding Climate – Bidding climate could lead to higher awarded construction costs. Mechanical Marine Dredging is highly specialized work with few available contractors in the area.
- ET3 – Fuel Variations – Fuel cost has varied significantly recently and will most likely continue to fluctuate for the life of this project. Estimate is based on current AAA fuel rates.

Schedule Risks: From the CSRA, the key or greater Schedule Risk items include:

- PR1 – Federal Funding – Schedule is entirely funding dependent. Baseline schedule requires some $10M to $15M per year for total project. Federal share would be some $10M / year. There is currently funding uncertainty for Environmental Restoration projects.
- PM4 – Native Plantings – Native Plantings will need to be coordinated with nurseries to insure plants are available. The Nature Conservancy and Commercial Supply all appear to have limited additional supply capacity. Their ability to provide plants for quantities required is uncertain. Schedule risk exists early on as supply growers are developed. Worst case the first construction season could be missed as suppliers are developed.

Table 3. Construction Cost Comparison Summary (Uncertainty Analysis)

PROJECT FIRST COST BASE ESTIMATE	**$126,066,000**		
Confidence Level	**Project First Cost**	**Contingency**	**Contingency %**
0%	$127,326,660	$1,260,660	1%
5%	$136,151,280	$10,085,280	8%
10%	$138,672,600	$12,606,600	10%

15%	$139,933,260	$13,867,260	11%
20%	$141,193,920	$15,127,920	12%
25%	$141,193,920	$15,127,920	12%
30%	$142,454,580	$16,388,580	13%
35%	$143,715,240	$17,649,240	14%
40%	$143,715,240	$17,649,240	14%
45%	$144,975,900	$18,909,900	15%
50%	$146,236,560	$20,170,560	16%
55%	$146,236,560	$20,170,560	16%
60%	$147,497,220	$21,431,220	17%
65%	$148,757,880	$22,691,880	18%
70%	$148,757,880	$22,691,880	18%
75%	$150,018,540	$23,952,540	19%
80%	**$151,279,200**	**$25,213,200**	**20%**
85%	$152,539,860	$26,473,860	21%
90%	$153,800,520	$27,734,520	22%
95%	$156,321,840	$30,255,840	24%
100%	$173,971,080	$47,905,080	38%

Table 4. Construction Schedule Comparison Summary (Uncertainty Analysis)

Base Schedule Duration	195.0 Months		
Confidence Level	**Duration**	**Contingency**	**Contingency %**
0%	197.0 Months	1.9 Months	1%
5%	204.8 Months	9.8 Months	5%
10%	208.7 Months	13.7 Months	7%
15%	210.6 Months	15.6 Months	8%
20%	214.5 Months	19.5 Months	10%
25%	216.5 Months	21.5 Months	11%
30%	218.4 Months	23.4 Months	12%
35%	220.4 Months	25.4 Months	13%
40%	222.3 Months	27.3 Months	14%
45%	224.3 Months	29.3 Months	15%
50%	226.2 Months	31.2 Months	16%
55%	228.2 Months	33.2 Months	17%
60%	232.1 Months	37.1 Months	19%

65%	234.0 Months	39.0 Months	20%
70%	236.0 Months	41.0 Months	21%
75%	239.9 Months	44.9 Months	23%
80%	**243.8 Months**	**48.8 Months**	**25%**
85%	247.7 Months	52.7 Months	27%
90%	251.6 Months	56.6 Months	29%
95%	259.4 Months	64.4 Months	33%
100%	280.8 Months	85.8 Months	44%

7.2 Recommendations

Risk Management is an all-encompassing, iterative, and life-cycle process of project management. The Project Management Institute's (PMI) *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, *4th edition*, states that "project risk management includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project." Risk identification and analysis are processes within the knowledge area of risk management. Its outputs pertinent to this effort include the risk register, risk quantification (risk analysis model), contingency report, and the sensitivity analysis.

The intended use of these outputs is implementation by the project leadership with respect to risk responses (such as mitigation) and risk monitoring and control. In short, the effectiveness of the project risk management effort requires that the proactive management of risks not conclude with the study completed in this report.

The Cost and Schedule Risk Analysis (CSRA) produced by the PDT identifies issues that require the development of subsequent risk response and mitigation plans. This section provides a list of recommendations for continued management of the risks identified and analyzed in this study. Note that this list is not all inclusive and should not substitute a formal risk management and response plan.

The CSRA study serves as a "road map" towards project improvements and reduced risks over time. The PDT must include the recommended cost and schedule contingencies and incorporate risk monitoring and mitigation on those identified risks. Further iterative study and update of the risk analysis throughout the project life-cycle is important in support of remaining within an approved budget and appropriation.

Risk Management: Project leadership should use of the outputs created during the risk analysis effort as tools in future risk management processes. The risk register should be updated at each major project milestone. The results of the sensitivity analysis may also be used for response planning strategy and development. These tools should be used in conjunction with regular risk review meetings.

Risk Analysis Updates: Project leadership should review risk items identified in the original risk register and add others, as required, throughout the project life-cycle. Risks should be reviewed for status and reevaluation (using qualitative measure, at a minimum) and placed on risk management watch lists if any risk's likelihood or impact significantly increases. Project leadership should also be mindful of the potential for secondary (new risks created specifically by the response to an original risk) and residual risks (risks that remain and have unintended impact following response).

Brownsville, Texas Resaca City Wide Feasibility Study

Risk Matrix

Likelihood of Occurrence	Impact or Consequence of Occurrence: Negligible	Marginal	Significant	Critical	Crisis
Certain	Moderate	Moderate	High	High	High
Very Likely	Low	Moderate	High	High	High
Likely	Low	Moderate	High	High	High
Unlikely	Low	Low	Moderate	Moderate	High
Very Unlikely	Low	Low	Low	Low	Moderate

Overall Project Scope

Resacas (oxbow lakes) are former channels of the Rio Grande River that have been cut off from the river, having no inlet or outlet. The study effort will evaluate the environmental restoration of the resacas, improved flood protection, enhanced water storage, and ecosystem restoration.

SEE ASSUMPTIONS TAB FOR COST VALUE RANGES DEVELOPMNENT

Negligible--- *Less than*			**$630,330**		**6 Months**
Marginal ---*between*	**$630,331**	**and**	**$2,521,320**	**6 Months**	**and 10 Months**
Significant ---*between*	**$2,521,321**	**and**	**$3,781,980**	**10 Months**	**and 20 Months**
Critical--- *between*	**$3,781,981**	**and**	**$6,303,300**	**20 Months**	**and 39 Months**
Crisis ---*Over*	**$6,303,301**			**39 Months**	

Risk No.	Risk/Opportunity Event	Concerns	PDT Discussions	Project Cost: Likelihood*	Impact*	Risk Level*	Rough Order Impact ($)	Project Schedule: Likelihood*	Impact*	Risk Level*	Rough Order Impact (mo)	Variance Distribution
Contract Risks (Internal Risk Items are those that are generated, caused, or controlled within the PDT's sphere of influence.)												
	PROJECT & PROGRAM MGMT											
PM1	Environmental Restoration Project	Environmental Restoration Project intended to restoring native habitat to the Resacas (oxbow lakes) improving aqua habitat.	Overall fairly simple construction with overall minimal design and construction.	Very Unlikely	Marginal	LOW		Unlikely	Negligible	LOW		
PM2	Mechanical Dredging - Marine	9"-10" Mechanical Dredging (cutter suction head with pipelin pumping) some three to five feet of some 45 Resacas segments (64 segments were in the feasibility study).	Scope of work is well defined and unlikely to change. Some 800,000CY will be in-water marine dredging. Sponsor has self performed dredging work in the past and owns there own mechanical cutter suction dredge. Availability of other additional contractors may be limited. See Bidder Competition Risk mentioned below for risk modelin Dredge material is dewatered and disposed of offsite with multiple handlings (costs included in estimate). Dredge material may be suitable planting shelfs but suitability will need to be confirmed and cost savings evaluated (potential opportunity) . Resacas will also be used as raw water storage.	Likely	Significant	HIGH		Unlikely	Negligible	LOW		
PM3	Mechanical Dredging - Land Based	Some 400,000CY of Resacas dredging can be performed from shore with conventional excavation equipment.	Scope of work is well defined and unlikely to change. Dredge material is dewatered and disposed of offsite with multiple handlings (costs included in estimate). Dredge material may be suitable planting shelfs but suitability will need to be confirmed and cost savings evaluated (potential opportunity) . Relatively low risk feature of work with multiple contractors available to perform.	Unlikely	Marginal	LOW		Unlikely	Negligible	LOW		
PM4	Native Plantings	Invasive and Non-Native species will be removed from about 1,000 acres or more and replanted in either native plantings or turfing.	Mitigation requirements are not driving planting areas. Brownsville Pub Utility Board (BPUB) Sponsor is very supportive of the project and will attempt to restore as much area as justifiable. Native Plantings will need to be coordinated with nurseries to insure plants are available. The Nature Conservancy and Commercial Supply appear to limited additional supply capacity. Their ability to provide plan for quantities required is uncertain. Schedule Risk if sufficient supply is not available. Lousville Aqutic Ecosystem Research Facility (a department of ERDC) has also been contacted about supplying plants. As project continues to develop PDT must coordinate with suppliers to insure adequate capacity. Commercial growers may need to be actively contacted in order to develop the capacity to supply the project. Schedule risk exists early on as supply growers are developed. Worst case the first construction season could be missed as suppliers are developed. PDT costs could also be impacted due to delay.	Unlikely	Marginal	LOW		Unlikely	Significant	MODERATE		

PM5	Control Structure Modifications	Control Structures are intended to mimic seasonal water levels for aquatic species establishment.	Most work involves adding adjustable weirs to existing structures to control water levels. HECRAS model has been established water flows During dry periods HECRAS model is not as accurate. During PED water flow models will need additional refinement but weir structure configurations and requirements are not likely to change.	Unlikely	Marginal	LOW		Unlikely	Marginal	LOW		
PM6	Planting Shelf	Planting shelf at water edge consisting of offsite material with topsoil overcoat will be required for planting establishments	Scope is well defined and unlikely to change. Estimate assumptions (offsite material) is likely conservative.	Unlikely	Marginal	LOW		Unlikely	Negligible	LOW		
PM7	Turfing	Native grass turfing will be planted in an effort to control non-native species intrusion.	Turfing costs are well established and scope risk is negligible.	Very Unlikely	Negligible	LOW		Very Unlikely	Negligible	LOW		
PM8	Staffing - Design	A regional design staff has been used in the Feasibility study development.	Project is scheduled for some 16years or more. Yearly staffing requirements are not that extensive and districts are likely to be able to staff with existing personnel as project funds become available. Design Staffing risk is minimal.	Very Unlikely	Negligible	LOW		Very Unlikely	Negligible	LOW		
PM9	Staffing - Construction	Brownsville TX is located on the far southern border. Local staff availability for Construction Management will need to be coordinated.	USACE Corps Field Office is located in Brownsville. Sufficient CM staff should available to oversee project. Cost and Schedule Risk is low.	Very Unlikely	Negligible	LOW		Very Unlikely	Negligible	LOW		
PM10						0				0		
	CONTRACT ACQUISITION RISKS											
CA1	Acquisition Strategy	Cost estimate is based on full and open large business contractor markups. Given relatively simple construction requirements and small dollar values (some $5M each or less) it is very likely large portions of this work could be awarded to Small Disadvantaged Business.	Districts have SDB goals. It is likely this project could be used to supplement districts overall SDB contracting goals.	Likely	Critical	HIGH		Likely	Marginal	MODERATE		
CA2	Multiple Contracts	Schedule assumes 1 construction contract per year (some 1 contracts total).	Funding limitations could lead to schedule delays with multiple additional contracts required. Funding risk is discussed and modeled below.	Very Unlikely	Negligible	LOW		Very Unlikely	Negligible	LOW		
CA3						0				0		
CA4						0				0		
	TECHNICAL RISKS											
TL1	Survey Data	Survey data for dredging was lacking.	Limited survey information was available for estimating dredge quantities was. Limited survey data was extrapolated to those areas that had no data. Quantities varied from 3' to 5' of excavation. Environmental intent is 5' deep Resacas. BPUB spot checked various locations to confirm assumptions. See quantity variations modeled below.	Likely	Marginal	MODERATE		Very Unlikely	Negligible	LOW		
TL2	Utilities and Relocations	Estimate assumes some 5% of construction costs for roads, bridges and utilities.	Placeholder costs. Utilities may be impacted for site access, construction clearance or excavation/construction. Some sites do have known and probably unknown existing utilities but it is currently not studied what relocations would be required. Cost uncertainty is moderate and could vary +/-10% from estimated.	Likely	Marginal	MODERATE		Very Unlikely	Negligible	LOW		
TL3	Material Disposal	Scope assumes offsite disposal.	Estimate includes disposal costs and dump fee ($5/CY) for some 1.2M CY. If material could be reused disposal costs could decrease. If assumed landfill is unable to accommodate all material additional landfill site may be required. Overall cost and technical risk is neutral.	Unlikely	Marginal	LOW		Very Unlikely	Negligible	LOW		
TL4	HTRW	No HTRW has been experienced in any pervious work performed by the local sponsor.	Resacas are currently used for raw water storage. HTRW risks are unlikely.	Unlikely	Marginal	LOW		Very Unlikely	Negligible	LOW		

TL5						0				0		
	LANDS AND DAMAGES RISKS											
LD1	Real Estate Footprint	Real Estate footprint has been evaluated by parcels in an attempt to minimize the number of impacted parcels.	Real Estate has included a rough approximation for renting staging areas across the various site locations. Real Estate is fairly well defined and not likely to change. Additional Real Estate requirements are unlikely beyond what is assumed in the baseline model.	Unlikely	Negligible	LOW		Unlikely	Negligible	LOW		
LD2	Real Estate Acquisition	Some 75% of the property is residential (personal) and 25% city owned. Some 663 parcels in all are impacted.	Some 60% to 70% of property acquistions will be purchase of the submerged water areas and would not affect the owners effective property usage. Dry land property acquisitions will focus on agricultural properties that would not impact private residences. There are a few agricultural areas owned adjacent to residences that ma require condementation actions (say some 10 at most). The project schedule is flexibile and would allow difficult properties to be worked around until made available. BPUB will need to condemn properties on behalf of the City of Brownsville. Brownsville is aware and have granted that authority. Schedules could be delayed if the condemnation process is required. Public hearings are scheduled in the coming months and a better understanding of the public concerns will be available.	Unlikely	Negligible	LOW		Unlikely	Marginal	LOW		
LD3	Subdivision CCR and HOA Rights	Local subdivision CCRs allow the local owners the rights to clear brush and maintain yards. Environmental restoration work would involve the establishment of native plants that should not be cut and cleared.	CCR/HOA rights of the subdivisions will need to be condemned for area within the property footprints. Public hearings and court negotiations will need to be conducted to determine the value of the CCR and negotiate settlements. Dollar impacts are likely marginal but schedule could be delayed significantly Similar to Risk LD2, project schedule is flexible and will be able to work around areas until issues are resolved. Schedule impacts are unlikely	Unlikely	Negligible	LOW		Unlikely	Marginal	LOW		
LD4	Property Values	Real Estate estimate includes real property costs but does not include loss of aesthetic value.	Homes on Resacas will loose waterfront access due to native plantings. A comparison will need to be performed evaluating the difference in property values between those homes on Resacas versus comparable homes not on Resacas. Those costs are not included in the current baseline Real Estate estimate. Areas are primarilay agricultural tracts without houses. Assumes some half of the 10 residential parcels will have impacted views/property values at an impact of some $25K each. A mass appraisal is schedule for June 2017 and a better understanding of those potential cost impacts should be available then.	Likely	Marginal	MODERATE		Unlikely	Negligible	LOW		
LD5	Sponsor Timeline	Some 40-50 private property parcel acquisitions will be required per year. In addition some will need to be condemnations.	BPUB has a limited staff available but has planned to augment with contracting support. Initial real estate acquisitions may impact first contract awards but as project progresses sponsor should be staffed an in a battle rhythm to meet out year timelines. Initial schedule risks are discused in Risk LD2. BPUB administrative costs of approximately $2000/parcel may be understated. For Ecosystem Restoration Projects, sponsor credit costs can not excee 35% of the project costs. 01 and 02 account costs already exceed 35% of the total project cost. Additional contract	Likely	Marginal	MODERATE		Unlikely	Negligible	LOW		
LD6				Unlikely	Negligible	LOW		Unlikely	Negligible	LOW		

	REGULATORY AND ENVIRONMENTAL RISKS											
REG1	Planting Establishments	Replantings may be required to establish sufficient stands of native species.	Estimate includes 25% replanting and assumed sufficient.	Unlikely	Marginal	LOW		Unlikely	Marginal	LOW		
REG2	Endangered Species	A consultation has been completed with Fish and Wildlife and NGOs. This project will supply endangered habitat. No endangered species are present.	The likelihood of impacts from encountering endangered species is minimal.	Unlikely	Marginal	LOW		Unlikely	Marginal	LOW		
REG3	Cultural Resources	Cultural surveys will be competed during PED. Programatic agreement has been reached with SHPO.	Excavations are not very deep. It's likely palo-lithic artificats may be located but baseline estimate includes costs to cover documentation surveys, onsite archelogist during excavations and collection of artifacts necessary. Risk exists additional cultural resources could be discovered but cost ar schedule impacts are likely marginal.	Likely	Marginal	MODERATE		Likely	Marginal	MODERATE		
REG4	Mitigation Requirements	Project is an environmental restoration project.	Mitigation ratios are not required. Changes in mitigation required are n likely.	Unlikely	Negligible	LOW		Unlikely	Negligible	LOW		
REG5				Unlikely	Negligible	LOW		Unlikely	Negligible	LOW		
	CONSTRUCTION RISKS											
CO1	Residential Construction	Much of the work is residential Brownsville areas. Construction could have impacts on surrounding residence traffic.	Cost estimate includes turbidity curtains, silt fence, traffic controls and flagging, construction site access points, street sweeping etc.	Unlikely	Marginal	LOW		Unlikely	Marginal	LOW		
CO2	Street Repairs	Heavy truck haul traffic through residential areas will be required for some 400,000cy of excavated material.	Baseline Estimate includes residential street resurfacing. Low cost risk	Unlikely	Marginal	LOW		Unlikely	Marginal	LOW		
CO3	Temporary Construction Easements and Lay Down Areas	Real Estate estimate includes costs for temporary staging areas.	Exact locations have not been located but representative costs have be included.	Unlikely	Marginal	LOW		Unlikely	Marginal	LOW		
CO4	Market Conditions and Bidding Climate	Bidding climate could lead to higher awarded construction costs. Mechanical Marine Dredging is highly specialized work with few available contractors in the area.	Landscape and Environmental Restoration is fairly simple work with ma available contractors. As economy continues to improve, contractor competition for Federal Projects is no longer as advantageous for dredging work. Most other work is fairly simple with multiple contracts capable of performing the work. Mechanical Marine Dredging could experience limited bidder competition. Limited marine dredging competition could lead to 10% higher marine dredging costs.	Likely	Marginal	MODERATE		Unlikely	Marginal	LOW		
CO5	Modifications and Claims	Possibility of Mods and Claims impacting construction costs	Relatively simple projects with minimal technical requirements should minimize the extent of potential construction modifications. Worst case cost growth for restoration would be 4% cost growth. Closure structure work could experience worst case 10% cost growth.	Likely	Marginal	MODERATE		Unlikely	Marginal	LOW		
CO6	Government Furnished Material	Native plantings are likely to be separately procured from nurseys and provided as GFM to planting contractors.	Early coordination with nursery will be required to insure GFM plantings are available in a timely manner.	Unlikely	Marginal	LOW		Unlikely	Marginal	LOW		

CO7				Unlikely	Negligible	LOW		Unlikely	Negligible	LOW		
	ESTIMATE AND SCHEDULE RISKS											
ET1	Variations in Quantities	Survey data for dredging was lacking.	Limited survey information was available for estimating dredge quantities was. Limited survey data was extrapolated to those areas that had no data. Quantities varied from 3' to 5' of excavation. Environmental intent is 5' deep Resacas. BPUB spot checked various locations to confirm assumptions. Overall quantities are likely fairly accurate.	Likely	Marginal	MODERATE		Unlikely	Negligible	LOW		
ET2	Level of Estimate	Level of Estimate varies between a Class 4 and Class 3 with associated Risk Levels	Estimate is a feasibility level estimate based on with estimated crews, production rates and material quotes. Cost estimate fluctuation is likely neutral.	Likely	Marginal	MODERATE		Unlikely	Negligible	LOW		
ET3	Inflation Greater than National Average	If local inflation should be greater than CWCCIS national average the buying power of the project could be impacted	Brownsville has experienced fairly standard cost growth. Inflation greater than CWCCIS is not likely.	Unlikely	Marginal	LOW		Unlikely	Negligible	LOW		
ET4	Labor Rates	Galveston District standard estimating practice is to use default Cost Book Seattle labor rates for budgetary estimate	Seattle Labor rates likely overstate local rates (potential cost opportunity). Risk Model does not attempt to quantify savings.	Unlikely	Marginal	LOW		Unlikely	Negligible	LOW		
ET5	Fuel Variations	Fuel cost has varied significantly recently and will most likely continue to fluctuate for the life of this project. Estimate is based on current AAA fuel rates.	Fuel fluctuation for large earth moving projects is always a concern and captured here.	Likely	Marginal	MODERATE		Unlikely	Negligible	LOW		
ET6				Unlikely	Negligible	LOW		Unlikely	Negligible	LOW		
	Programmatic Risks	(External Risk Items are those that are generated, caused, or controlled exclusively outside the PDT's sphere of influence.)										
PR1	Funding - Federal	Schedule is entirely funding dependent.	Baseline schedule requires some $10M to $15M per year for total project Federal share would be some $10M / year. There is currently funding uncertainty for Environmental Restoration projects. Its likely project could experience critical schedule delays (2yrs to 3yrs) which would also impact PDT costs.	Unlikely	Marginal	LOW		Likely	Critical	HIGH		
PR2	Funding - Sponsor	Sponsor is currently self performing areas of work and is likely to meet there funding commitments.	Sponsor funding risk is minimal.	Unlikely	Marginal	LOW		Unlikely	Marginal	LOW		
PR3	Community Support	Community has yet to become fully engaged with the project.	While community is supportive of environmental restoration, specific restoration impacts and the publics acceptance have yet to be fully vetted. Public meeting is scheduled for 31May. For now, risk is considered neutral.	Unlikely	Marginal	LOW		Unlikely	Marginal	LOW		
PR4	Political Support	Political Climate will affect available funding.	Sponsor is activiely engaged with congressional and ASA USACE HQ to bring visability to project.	Unlikely	Marginal	LOW		Unlikely	Marginal	LOW		

*Likelihood, Impact, and Risk Level to be verified through market research and analysis (conducted by cost engineer).

1. Risk/Opportunity identified with reference to the Risk Identification Checklist and through deliberation and study of the PDT.
2. Discussions and Concerns elaborates on Risk/Opportunity Events and includes any assumptions or findings (should contain information pertinent to eventual study and analysis of event's impact to project).
3. Likelihood is a measure of the probability of the event occurring -- **Very Unlikely**, **Unlikely**, **Moderately Likely**, **Likely**, **Very Likely.** The likelihood of the event will be the same for both Cost and Schedule, regardless of impact.
4. Impact is a measure of the event's effect on project objectives with relation to scope, cost, and/or schedule -- **Negligible**, **Marginal**, **Significant**, **Critical**, or **Crisis.** Impacts on Project Cost may vary in severity from impacts on Project Schedule.
5. Risk Level is the resultant of Likelihood and Impact **Low**, **Moderate**, or **High**. Refer to the matrix located at top of page.
6. Variance Distribution refers to the behavior of the individual risk item with respect to its potential effects on Project Cost and Schedule. For example, an item with clearly defined parameters and a solid most likely scenario would probably follow a triangular or normal distribution. A risk item fo respect to effects on cost or schedule (i.e. "anyone's guess") would probably follow a uniform or discrete uniform distribution.
7. The responsibility or POC is the entity responsible as the Subject Matter Expert (SME) for action, monitoring, or information on the PDT for the identified risk or opportunity.
8. Correlation recognizes those risk events that may be related to one another. Care should be given to ensure the risks are handled correctly without a "double counting."
9. Affected Project Component identifies the specific item of the project to which the risk directly or strongly correlates.
10. Project Implications identifies whether or not the risk item affects project cost, project schedule, or both. The PDT is responsible for conducting studies for both Project Cost and for Project Schedule.
11. Results of the risk identification process are studied and further developed by the Cost Engineer, then analyzed through the Monte Carlo Analysis Method for Cost (Contingency) and Schedule (Escalation) Growth.

APPENDIX E-4

HYDROLOGY AND HYDRAULICS

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HYDROLOGY AND HYDRAULICS

Introduction

This appendix discusses the interim hydrologic and hydraulic (H&H) data gathering efforts and engineering analyses for the Resacas Ecosystem Restoration Study in Brownsville, Texas. The H&H analysis was used to select the recommended plan, the National Ecosystem Restoration (NER) plan.

The study area focused on the Resaca De La Guerra, Resaca Del Rancho Viejo, a Town Resaca. These water systems are used for multiple purposes which include recreation, irrigation, and flood control. Figure E-4- 1 shows the location of the project area. These water systems are regulated by the Brownsville Public Utility Board (BPUB).

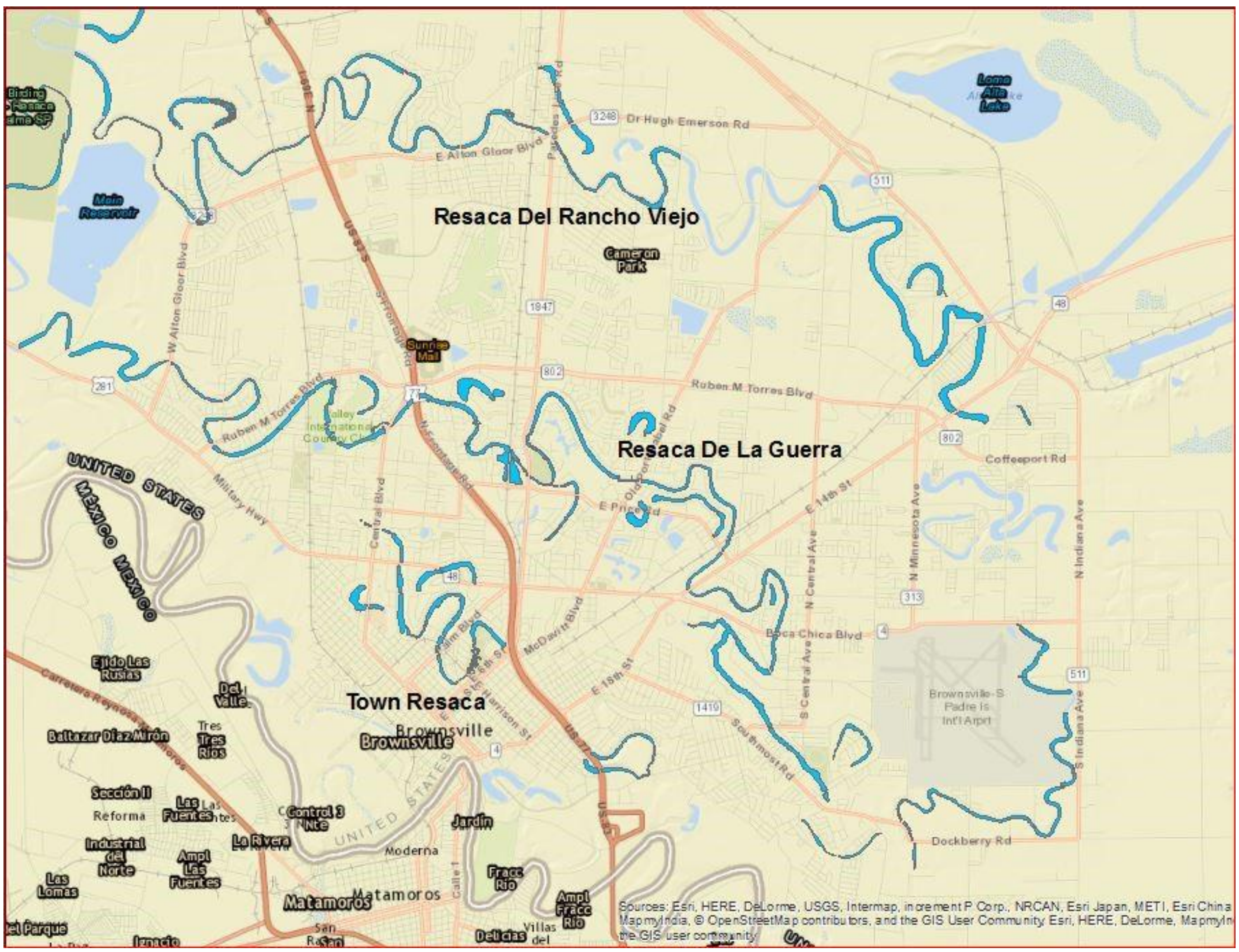

Figure E-4- 1: Location of Resacas in Project Area

The analyses were conducted to assess if restoration alternatives were sustainable, resilient, and to assess potential negative environmental impacts. The sections below will discuss the analyses and include recommendations for the next phase of investigation – preconstruction engineering and design.

Regional Data

Units and Coordinate System

All units are in US Customary Units (US), unless stated otherwise. Vertical and elevation data are in feet, referenced to NAVD 88 datum, unless noted otherwise. Horizontal coordinates shown are in Texas State Plane Zone 5426, FIPS 4205 TX-South. The project horizontal datum is NAD 83.

Climate

The project area is located in Brownsville where the climate is subtropical and subhumid, with hot summers and mild winters. Temperatures range from an average low of 50 degrees F to 69 degrees F in January and from an average high of 75 degrees F to 94 degrees F in July. Rainfall averages 27 inches per year. Snowfall is exceedingly rare. Figure E-4-2 below shows the average monthly rainfall and temperature for Brownsville.

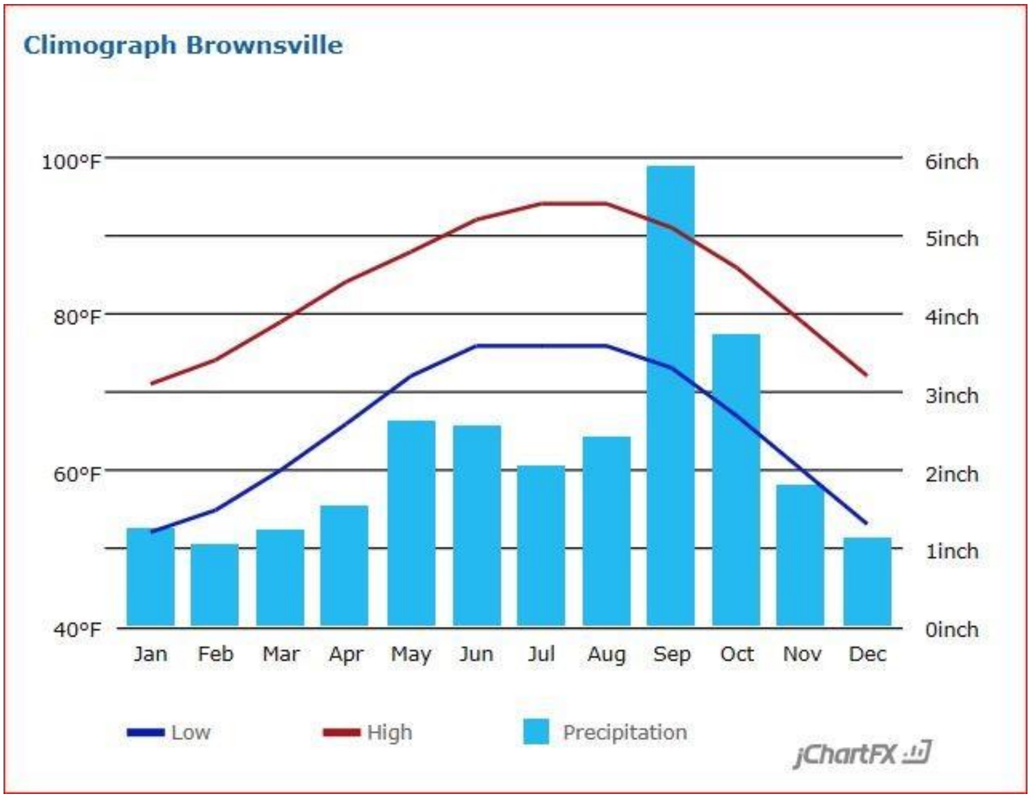

Figure E-4-2: Climograph for Crownsville, Texas

Data Collection

Previous Studies

The most recent H&H study conducted in the project area was the "Flood Protection Plan – Phase II" in August 2011 by Ambiotec Civil Engineering Group, Inc. This study was an extension of the "Flood Protection Plan" study conducted in March 2006 by Ambiotec Civil Engineering Group, Inc., Texas Water Development Board, and Rice University. The hydrologic and hydraulic models provided by these previous studies served as the base models for this study.

The purpose for both of these studies was to evaluate potential flood risk within the City of Brownsville. The studies considered impacts from future development, coastal storm surge, and implementation of proposed structural and non-structural flood risk management measures. These studies noted they were intended for planning purposes only and were not be used for engineering design.

The H&H analyses also considered the “Master Drainage Plan – Volumes I & II” completed in July 1987 by Hogan and Rasor, Inc for the City of Brownsville. Volume II provided the most pertinent data, which include existing normal water surface elevations for each segment of the resacas, and historic flood index elevations.

The “2015 Water and Wastewater Master Plan and System Models” by AECOM in April 2016 and the “Water Conservation and Drought Contingency Plan” by Brownsville Public Utility Board in May 2014 was also considered.

Hydraulic Structure Inventory

To understand the water management process of the resacas system, two field reconnaissance trips were conducted in July 2016 and in December 2016. Data collected included photos and measurements of each hydraulic structure in the base hydraulic models, comparison of observed structures versus structures in the hydraulic models, and a brief explanation of the type and purposes of structures. This data was input into ArcGIS Online. A view of the hydraulic structure inventory for Town Resaca and Resaca del la Guerra can be seen in Figure E-4-3 and in Figure E-4-4 for Resaca Rancho Viejo. Notes collected about each hydraulic structure for the three resacas systems can be seen in Table E-4-1, Table E-4-2, and Table E-4-3.

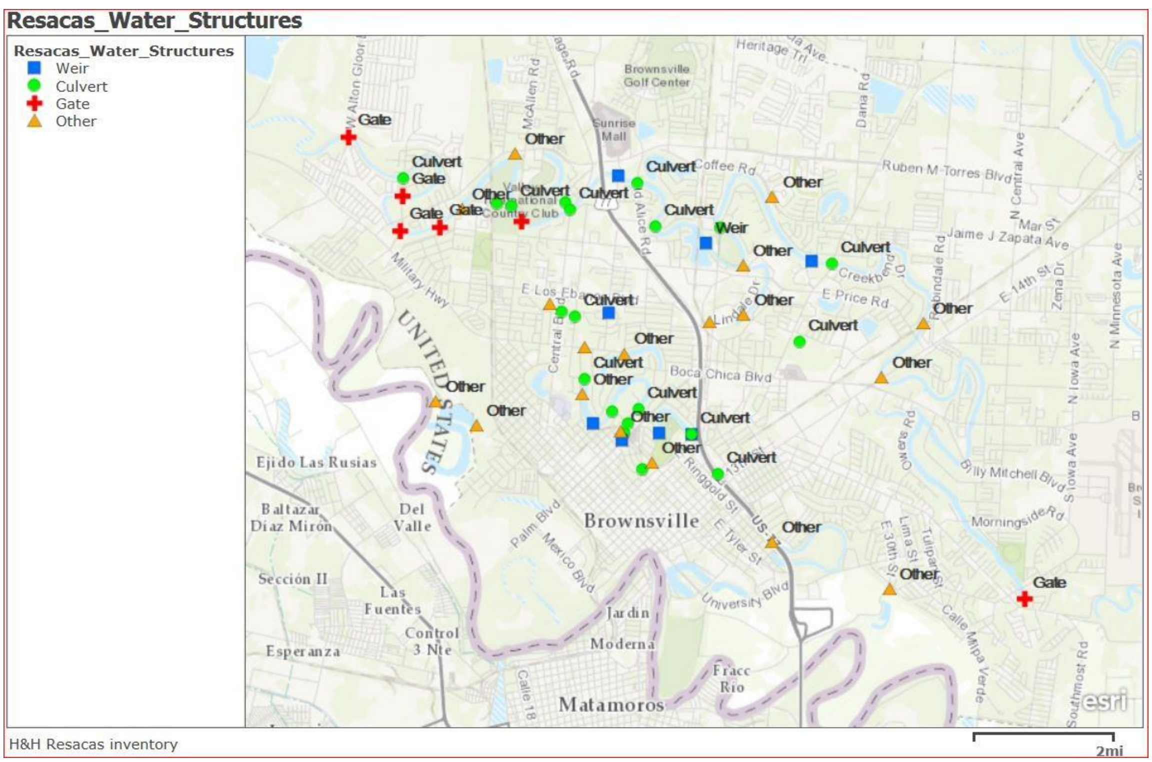

Figure E-4-3: Hydraulic Structure Inventory on ArcGIS Online for Resaca de la Guerra and Town Resaca

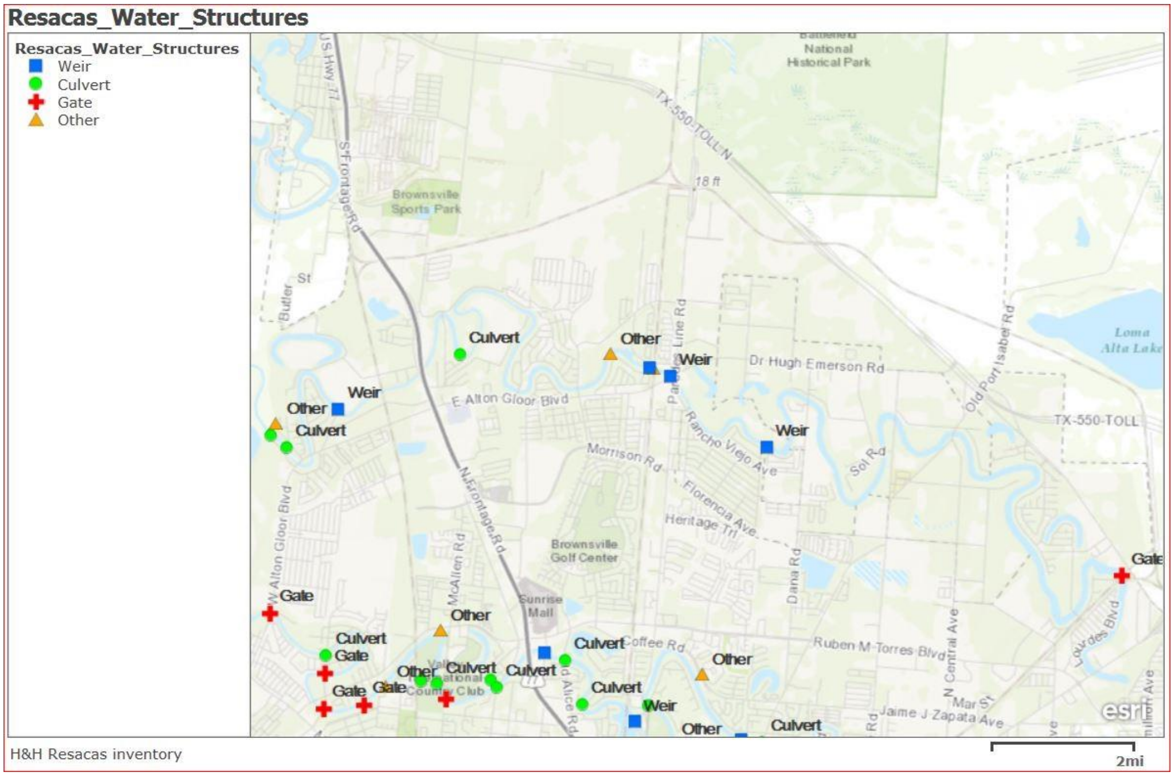

Figure E-4-4: Hydraulic Structure Inventory on ArcGIS Online for Resaca del Rancho Viejo

Table E-4-1: Town Resaca Field Reconnaissance Notes

Resaca	Station	Location	Structure Type	Number of Barrels	Size (ft.) (Dia. or W	Length (ft.)	Upstream Invert Ele	Downstream Invert Ele	Slope (%)	Notes
Town Resaca	394+50	Los Ebanos Blvd.	Circular Culvert	1	1.5	94	24.53	24.44	0.10	
Town Resaca	390+00	Weir at 8" Valve	Weir	1	67	10	29.90	29.90	0.00	
Town Resaca	376+00	Central Blvd.	Circular Culvert	1	1.5	126	22.00	27.20	-4.13	
Town Resaca	370+00	Coria Blvd.	Circular Culvert	1	1.25	70	22.00	21.50	0.71	Culvert measured 42" Dia. during 7/27/2016 site visit.
Town Resaca	351+50	Boca Chica Blvd.	Circular Culvert	1	2	130	25.20	23.00	1.69	Culvert measured 48" Dia. during 7/27/2016 site visit.
Town Resaca	337+00	Belthair St.	Circular Culvert	1	1.5	71	22.50	22.50	0.00	Culvert measured 36" Dia. during 7/27/2016 site visit.
Town Resaca	316+00	Putegnat Weirs (Resaca Blvd.)	Weir	1	98	10	26.50	26.50	0.00	Weir length & crest width not modeled correctly. Should be modeled as 2 weirs, combined length 14.875' L x 2" W.
Town Resaca	303+00	Calle Retama (west crossing)	Box Culvert	1	10 x 8	71	21.00	22.85	-2.61	
Town Resaca	281+00	Pedestrian Bridge	Box Culvert	1	12 x 6.5	40	20.60	19.00	4.00	
Town Resaca	264+00	Ringold	Box Culvert	1	10 x 10	70	17.63	19.73	-3.00	
Town Resaca	255+00	Calle Retama (east crossing)	Box Culvert	1	10 x 8	86	19.30	20.00	-0.81	
Town Resaca	251+00	Railroad	Box Culvert	1	9 x 4	55	22.00	19.80	4.00	
Town Resaca	247+00	Palm Blvd.	Box Culvert	1	10 x 6	148	19.74	18.86	0.59	
Town Resaca	244+50	Rotary Park Weir (Palm Blvd.)	Weir	1	261	10	25.64	25.64	0.00	Weir length & crest width not modeled correctly. Should be 5' L x 2" W.
Town Resaca	226+00	Old Alice Rd.	Box Culvert	2	9 x 4	65	19.50	19.50	0.00	
Town Resaca	221+00	Railroad	Box Culvert	3	8 x 10	68	21.87	21.34	0.78	
Town Resaca	203+00	Zoo Dam/Weir	Weir	1	69	10	22.53	22.53	0.00	Weir length & crest width not modeled correctly. Should be 45' L x 1' W.
Town Resaca	172+00	Interstate Culvert	Box Culvert	2	9 x 9	1395	19.74	19.30	0.03	Appears to be upstream culvert under Interstate. Should be extended to 12th St.
Town Resaca	158+00	Railroad	Box Culvert	2	10 x 8	67	19.30	19.70	-0.60	Unclear what this culvert is supposed to be. Remnant of model from before Interstate?
Town Resaca	154+00	12th St.	Box Culvert	2	10 x 9	90	19.63	19.85	-0.24	Should be incorporated into upstream culvert under Interstate.
Town Resaca	140+00	13th St.	Box Culvert	2	10 x 9	1910	19.30	19.30	0.00	
Town Resaca	110+00	24th St. Bridge	Bridge	1	Cross Section	52	N/A	N/A	N/A	
Town Resaca	107+75	Weir near 24th St.	Weir	1	200	20	19.95	19.95	0.00	
Town Resaca at "Duck Head"	104+00	Highway 77 Bridge (north crossing)	Bridge	1	Cross Section	73	N/A	N/A	N/A	
Town Resaca at "Duck Head"	047+00	E. Ringgold St. (at "Duck Head")	Circular Culvert	1	3.33	58	17.27	17.26	0.02	
Town Resaca at "Duck Head"	047+00	E. Ringgold St. (at "Duck Head")	Circular Culvert	2	1.5	58	18.20	18.10	0.17	
Town Resaca at "Duck Head"	038+00	Highway 77 Bridge (south crossing)	Bridge	1	Cross Section	75	N/A	N/A	N/A	Twin 36" RCP culvert near sta. 15+25 missing from model.
Town Resaca Ditch	045+00	East Ave. Bridge	Bridge	1	Cross Section	40	N/A	N/A	N/A	
Town Resaca Ditch	026+00	Impala Dr. Bridge	Bridge	1	Cross Section	50	N/A	N/A	N/A	Pump station not modeled.
Town Resaca Ditch	017+00	Calle Milpa Verde Bridge	Bridge	1	Cross Section	55	N/A	N/A	N/A	
Town Resaca Ditch	004+00	Tulipan St. Bridge	Bridge	1	Cross Section	50	N/A	N/A	N/A	

Table E-4-2: Resaca de la Guerra Field Reconnaissance Notes

Resaca	Statio	Location	Structure Type	Number of Barrels	Size (ft.) (Dia. or W	Length (ft.)	Upstream Invert Ele	Downstream Invert Ele	Slope (%)	Notes
Resaca de la Guerra	843+00	W. Alton Gloor Blvd.	Circular Culvert	1	3	90	28.70	28.50	0.22	
Resaca de la Guerra	809+00	Laredo Rd. (north crossing)	Box Culvert	1	8 x 4	49	27.25	26.98	0.56	
Resaca de la Guerra	761+60	Laredo Rd. Overflow (mid. crossing)	Box Culvert	1	39.6 x 1	10	31.49	28.87	26.20	Overflow structure modeled as box culvert. Why not model as weir? Structure not found during 7/27/2016 site visit.
Resaca de la Guerra	760+00	Laredo Rd. (mid. crossing)	Box Culvert	2	6 x 2	60	28.87	28.60	0.45	Upstream (east) side: south box sandbagged, north box has 24" dia. gate valve (SCADA
Resaca de la Guerra	740+00	W. Ruben M. Torres Sr. Blvd.	Circular Culvert	2	4	120	28.10	28.05	0.04	
Resaca de la Guerra	736+00	Laredo Rd. Overflow (south crossing)	Box Culvert	1	27 x 1	10	30.30	30.30	0.00	Overflow structure modeled as box culvert. Why not model as weir? Structure not found during 7/27/2016 site visit.
Resaca de la Guerra	734+00	Laredo Rd. (south crossing)	Circular Culvert	2	4	75	25.00	24.95	0.07	Box with 42" dia. gate valve (SCADA controlled) restricting flow on upstream end of culvert.
Resaca de la Guerra	702+00	Weir near Siene River Dr.	Weir	1	10	35	27.80	27.80	0.00	Earthen berm across resaca. 42' cut through weir appears between 1/2009 and 1/2011.
Resaca de la Guerra	680+00	Railroad Bridge	Bridge	1	Cross Section	35	N/A	N/A	N/A	
Resaca de la Guerra	666+00	VICC Northwest Access Rd.	Circular Culvert	2	1.5	40	28.00	27.50	1.25	
Resaca de la Guerra	656+00	VICC Cart Path Bridge	Bridge	1	Cross Section	6	N/A	N/A	N/A	
Resaca de la Guerra	640+00	Fairway Dr./Los Ebanes Ln.	Circular Culvert	1	2	115	27.70	27.60	0.09	
Resaca de la Guerra	633+00	VICC Cart Path/Las Palmas Ln.	Circular Culvert	1	1.5	240	27.50	27.10	0.17	Culvert modeled through area where pond & gate valve control structure observed on
Resaca de la Guerra	612+00	VICC Pedestrian Bridge	Bridge	1	Cross Section	6	N/A	N/A	N/A	Bridge was demolished sometime between 10/2008 and 1/2009.
Resaca de la Guerra	605+00	Old Highway 77 Bridge	Bridge	1	Cross Section	25	N/A	N/A	N/A	
Resaca de la Guerra	600+00	Central Blvd.	Circular Culvert	1	4	120	27.50	27.40	0.08	
Resaca de la Guerra	586+00	Highway 77	Box Culvert	1	5 x 5	350	25.00	24.00	0.29	
Resaca de la Guerra	575+00	Stationary Laredo Bank Weir	Weir	1	5	1	26.00	26.00	0.00	
Resaca de la Guerra	565+00	Old Alice Rd.	Circular Culvert	2	4.33	75	24.00	23.90	0.13	
Resaca de la Guerra	535+00	Hidden Valley Dr.	Circular Culvert	2	2	65	24.00	23.90	0.15	Google Earth aerial imagery indicats 3 culvert pipes at this location.
Resaca de la Guerra	504+00	Shorelake Dam/Weir (Lakeshore Dr.)	Weir	1	190	1	27.36	27.36	0.00	Weir not modeled correctly. Should reflect a rectangular channel approx. 15' wide & ?' deep.
Resaca de la Guerra	498+00	Paredes Line Rd.	Circular Culvert	1	4.33	80	22.60	22.50	0.13	Pedestrian bridge upstream not modeled.
Resaca de la Guerra	460+00	Palo Verde Dr.	Circular Culvert	1	3.5	70	23.00	22.50	0.71	
Resaca de la Guerra	370+00	Hackberry Weir (645 Hackberry Ln.)	Weir	1	150	2	26.00	26.00	0.00	Weir not modeled correctly. Should reflect a rectangular channel approx. 10' wide & ?' deep.
Resaca de la Guerra	364+00	Old Port Isabel Rd.	Box Culvert	2	8 x 8	60	20.00	19.30	1.17	
Resaca de la Guerra	285+00	Railroad Bridge	Bridge	1	Cross Section	60	N/A	N/A	N/A	
Resaca de la Guerra	275+00	E. Price Rd.	Box Culvert	1	10 x 8	63	18.40	18.30	0.16	
Resaca de la Guerra	250+00	BPUB Resaca Pump #4 Weir (Hwy 48)	Weir	1	25	75	23.16	23.16	0.00	
Resaca de la Guerra	156+00	Boca Chica Blvd.	Box Culvert	2	10 x 8	100	17.70	17.70	0.00	Skipped Highway 48 upstream.
Resaca de la Guerra	155+00	Weir near Boca Chica Blvd.	Weir	1	300	10	22.48	22.48	0.00	Unclear what is being modeled with this structure. No evidence of weir on aerial imagery.
Resaca de la Guerra	136+00	Billy Mitchell Blvd.	Circular Culvert	3	3.5	90	17.00	17.00	0.00	
Resaca de la Guerra	111+00	Acacia Lake Dr. Bridge	Bridge	1	Cross Section	30	N/A	N/A	N/A	
Resaca de la Guerra	047+00	Morningside Rd. (west crossing)	Circular Culvert	2	2.5	65	16.50	15.40	1.69	
Resaca de la Guerra	047+00	Morningside Rd. (west crossing)	Circular Culvert	1	1.25	65	16.50	15.40	1.69	
Resaca de la Guerra	005+00	Morningside Rd. (east crossing)	Circular Culvert	3	2.5	100	14.50	14.00	0.50	
Resaca de la Guerra	000+60	Outlet to North Main Drain	Box Culvert	1	30 x 1	6	19.03	15.20	63.83	Overflow structure modeled as box culvert. Why not model as weir?

Table E-4-3: Resaca del Rancho Viejo Field Reconnaissance Notes

Resaca	Statio	Location	Structure Type	Number of Barrels	Size (ft.) (Dia. or W	Length (ft.)	Upstream Invert Ele	Downstream Invert Ele	Slope (%)	Notes
Resaca del Rancho Viejo	906+00	Northeast corner of reservoir	Circular Culvert	1	2	33	24.40	24.13	0.82	
Resaca del Rancho Viejo	889+00	Near aqueduct east of reservoir	Circular Culvert	1	4	150	24.25	22.40	1.23	
Resaca del Rancho Viejo	868+50	W. Alton Gloor Blvd. (west crossing)	Circular Culvert	1	5	103	21.16	20.78	0.37	Dawn Dr. Culvert upstream missing from model. Constructed between 11/2006 & 10/2008.
Resaca del Rancho Viejo	858+00	W. Alton Gloor Blvd. (east crossing)	Circular Culvert	1	5	113	20.04	19.99	0.04	
Resaca del Rancho Viejo	795+00	Sandy Hill Dr. Overflow	Box Culvert	1	24 x 1	8	23.87	17.98	73.63	Overflow structure modeled as box culvert. Why not model as weir with culvert downstream?
Resaca del Rancho Viejo	794+00	Sandy Hill Dr. Overflow (outlet pipe)	Circular Culvert	1	1.5	60	17.98	17.99	-0.02	
Resaca del Rancho Viejo	769+00	Old Railroad (west of Highway 77)	Circular Culvert	1	8.5	100	19.71	19.63	0.08	
Resaca del Rancho Viejo	769+00	Old Railroad (west of Highway 77)	Circular Culvert	1	8.5	100	20.23	19.36	0.87	
Resaca del Rancho Viejo	748+00	Highway 77	Circular Culvert	2	6	440	16.37	16.36	0.00	
Resaca del Rancho Viejo	720+00	Resaca Point Rd.	Box Culvert	1	4 x 4	60	13.64	13.35	0.48	Earthen berm downstream (Professional Estates Subdivision) near Klegerg Ave. & Robert Ln. missing from model.
Resaca del Rancho Viejo	619+00	Duncan Rd.	Circular Culvert	1	3	25	16.05	16.05	0.00	Road crossing removed between 1/2009 & 5/2010.
Resaca del Rancho Viejo	575+00	Rustic Manor Dr.	Box Culvert	2	8 x 6	80	11.36	11.36	0.00	
Resaca del Rancho Viejo	536+00	Stagecoach Trail	Box Culvert	1	8 x 6	81	12.08	12.09	-0.01	
Resaca del Rancho Viejo	512+00	Weir near north part of Ridgeline Dr.	Weir	1	20	81	17.00	17.00	0.00	
Resaca del Rancho Viejo	490+00	Hike & Bike Trail Overflow	Box Culvert	3	5 x 2	65	17.50	14.05	5.31	Overflow structure modeled as box culvert. Why not model as weir with culvert
Resaca del Rancho Viejo	480+00	E. Alton Gloor Blvd. & Paredes Line Rd.	Box Culvert	1	14 x 1	460	17.92	13.72	0.91	Overflow structure modeled as box culvert. Why not model as weir with culvert
Resaca del Rancho Viejo	413+00	Weir near Katarina Ave.	Weir	1	5	40	16.00	16.00	0.00	
Resaca del Rancho Viejo	362+00	Dana Ave.	Circular Culvert	1	5	86	12.31	11.83	0.56	
Resaca del Rancho Viejo	276+50	Sol Rd.	Circular Culvert	1	5	33	11.73	11.62	0.33	
Resaca del Rancho Viejo	254+00	Robindale Rd.	Circular Culvert	1	5	42	10.36	10.19	0.40	
Resaca del Rancho Viejo	215+00	Old Port Isabel Rd. Bridge	Bridge	1	Cross Section	30	N/A	N/A	N/A	"check top elevation" noted in model.
Resaca del Rancho Viejo	071+00	Charmaine Ln.	Circular Culvert	1	4	32	11.18	9.99	3.72	
Resaca del Rancho Viejo	029+00	Heron Cove Ln. Overflow	Box Culvert	1	12.6 x 1	89	17.44	8.11	10.48	Overflow structure modeled as box culvert. Why not model as weir with culvert
Resaca del Rancho Viejo	023+50	FM 511 Bridge	Bridge	1	Cross Section	75	N/A	N/A	N/A	
Resaca del Rancho Viejo	012+00	Railroad (east of FM 511)	Circular Culvert	1	6.7	110	3.86	3.26	0.55	
Resaca del Rancho Viejo	012+00	Railroad (east of FM 511)	Circular Culvert	1	5	110	10.18	10.41	-0.21	
Resaca del Rancho Viejo	012+00	Railroad (east of FM 511)	Circular Culvert	1	5	110	10.69	10.52	0.15	

Topographic, Bathymetric, and Survey Data

Detailed terrain data was obtained in the form of LiDAR data from Cameron County, Texas. The LiDAR data was collected with 1-meter resolution. Bathymetry data for this study comes from the base hydraulic models. The original coordinate system was converted to Texas State Plane Zone 5426, FIPS 4205 TX-South. That was accomplished using the script shown in Table E-4-3.

Table E-4-4: Python Script to Post-process LIDAR Data to Import to HEC-RAS-MAPPER

```
# -*- coding: utf-8 -*-
#Author: Mohamamd "Shahidul" Islam, PH.D., P.E.
# Civil (Hydraulic) Engineer
# H&H Branch
#H&H Branch Chief: Coraggio Maglio, P.E.
# USACE at Galveston District, Galveston,TX
# Description: This script will read the raw Lidar dataset (which is readable format only),
#define co-ordinate system and merge the raw dataset for their use in HEC-RAS model
# ---------------------------------------------------------------------------
# Import arcpy module
import arcpy
import glob
lidar_dir= r'E:\lidar_raw_data' # FOlder contains raw Lidar DATA
raster_folder=r'E:\processed_raster' # Folder to contain mosaic raster data
mosaic_filename="test_mosaic.tif" # Mosaic raster data set name
listing = glob.glob(lidar_dir+'\*.dem')
for filename in listing:

# Process: DEM to Raster
    arcpy.DEMToRaster_conversion(filename, filename[:-4]+'_r', "FLOAT", "1")

# Process: Define Projection
    arcpy.DefineProjection_management(filename[:-4]+'_r',
"PROJCS['NAD_1983_StatePlane_Texas_South_FIPS_4205_Feet',GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Lambert_Conformal_Conic'],PARAMETER['False_Easting',984250.0],PARAMETER['False_Northing',16404166.66666666],PARAMETER['Central_Meridian',-98.5],PARAMETER['Standard_Parallel_1',26.16666666666667],PARAMETER['Standard_Parallel_2',27.83333333333333],PARAMETER['Latitude_Of_Origin',25.66666666666667],UNIT['Foot_US',0.3048006096012192]],VERTCS['NAVD_1988_Foot_US',VDATUM['North_American_Vertical_Datum_1988'],PARAMETER['Vertical_Shift',0.0],PARAMETER['Direction',1.0],UNIT['Foot_US',0.3048006096012192]]")
listing_raster=glob.glob(lidar_dir+'\*_r')
arcpy.MosaicToNewRaster_management(listing_raster, raster_folder, mosaic_filename,
"PROJCS['NAD_1983_StatePlane_Texas_South_FIPS_4205_Feet',GEOGCS['GCS_North_American_1983',DATUM['D_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222101]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Lambert_Conformal_Conic'],PARAMETER['False_Easting',984250.0],PARAMETER['False_Northing',16404166.66666666],PARAMETER['Central_Meridian',-98.5],PARAMETER['Standard_Parallel_1',26.16666666666667],PARAMETER['Standard_Parallel_2',27.83333333333333],PARAMETER['Latitude_Of_Origin',25.66666666666667],UNIT['Foot_US',0.3048006096012192]],VERTCS['NAVD_1988_Foot_US',VDATUM['North_American_Vertical_Datum_1988'],PARAMETER['Vertical_Shift',0.0],PARAMETER['Direction',1.0],UNIT['Foot_US',0.3048006096012192]]", "32_BIT_FLOAT", "",
"1", "BLEND", "FIRST")
```

H&H Analysis

Without Project Hydraulic Modeling

The hydraulic models are based on the referenced hydraulic studies. The previous study developed hydraulic models for the Lower Resaca del Rancho Viejo (LRRV) and for the watershed regions of Resaca de la Guerra (RDLG), North Main Drain (NMD), and Town Resaca (TR) (RDLG, NMD, TR) that share hydraulic connections. The models were developed using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS). These models had several limitations including model domain with several hydraulically incorrect intersecting cross-sections (see green line in Figure E-4-5), and outdated topographic and land use data. These models were updated with the latest topographic datas and modified cross-sections.

The latest topographic datasets were post-processed for their conversion into RAS-Mapper. These topographic datasets were then used in HEC-RAS 5.0.3 to update station–elevation data along the overbank regions of all cross-sections. Elevation data within the channel of the cross-sections were kept the same as of the previous model. Figure E-4-6 shows an example of the topographic update in the current model versus the previous model for XS 33252.91of the LRRV model.

During review of the base models it was discovered that many cross-sections had to be modified because of intersecting cross-sections. During this modification, original model cross-section stationing was kept the same. The green color in Figure E-4-7 denotes the location of the original LRRV model cross-sections whereas the red-color denotes the updated LRRV model cross-section locations. Table E-4-5 lists the cross-section changes that are made for the LRRV model and Table E-4-6 lists the cross-section changes made to the merged HEC-RAS model (i.e., linked RDLG, NMD, TR models). Figure E-4-7 and Figure E-4-8 display the cross-sections of the LRRV and merged model, respectively. Both models also incorporate updated culvert data from the reconnaissance trips. Land use in the region has changed since the previous analysis in 2011, so changes were made to roughness coefficients to reflect the land use changes. These changes were based on the Google Earth satellite imagery, roughness coefficients were changed if Manning's n values of observed land use were significantly different from the previous model.

Both updated LRRV and merged (RDLG,NMD,TR) HEC-RAS models were simulated for steady flow conditions. Figure E-4-9,Figure E-4-10, and Figure E-4-11 display water surface elevation profiles along the reaches of LRRV, RDLG, and TR, respectively. The computed water surface elevations (WSEs) for both models did not significantly deviate from previous studies.

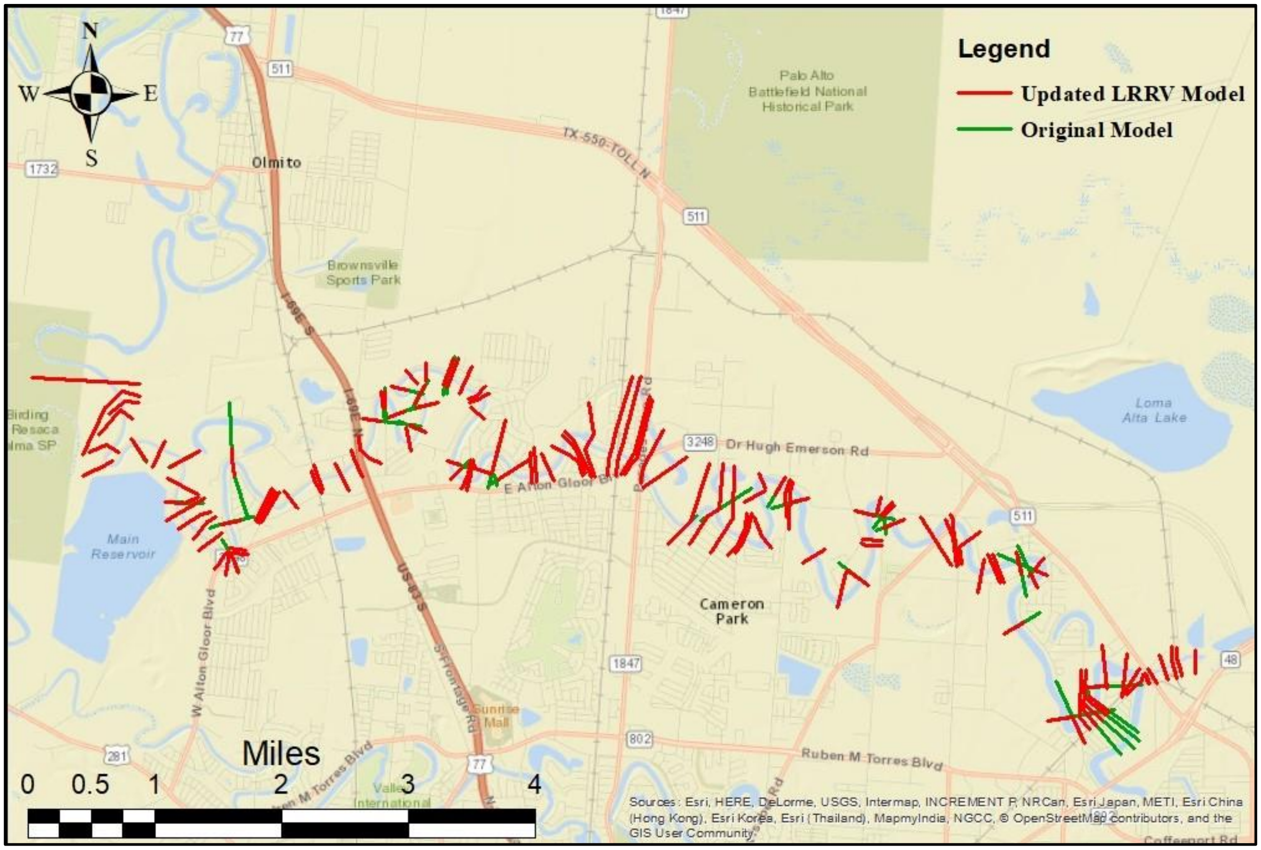

Figure E-4-5: Comparison of Updated and Previous Model Cross-sections (red colored line - Updated Model XS; green colored line - Previous Model XS)

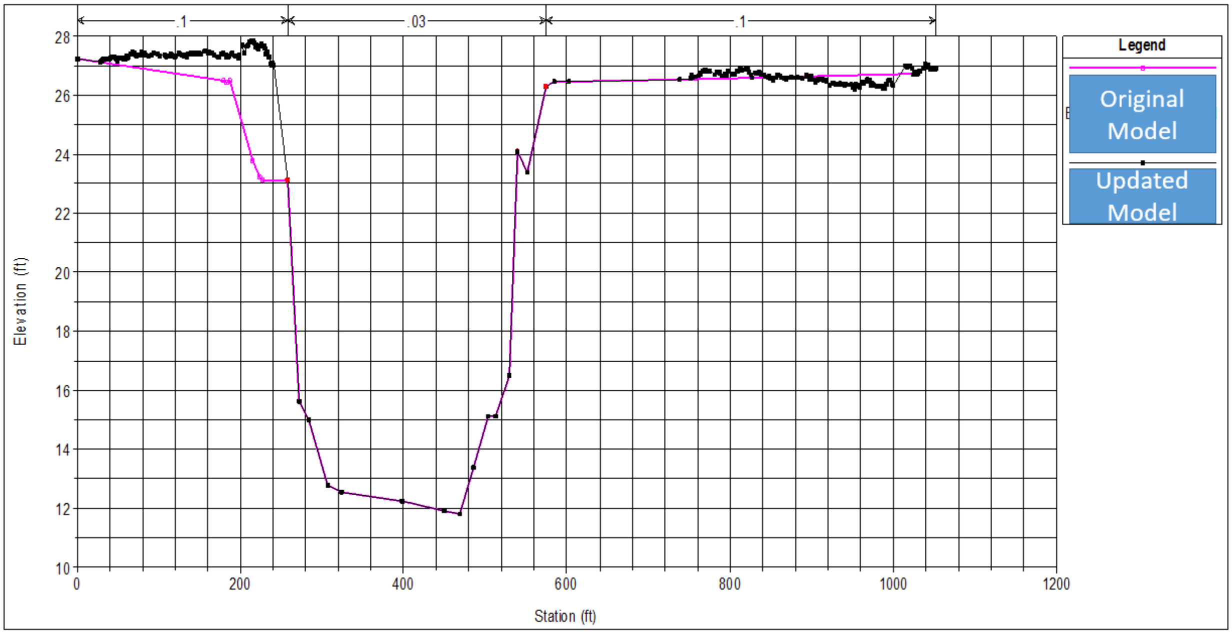

Figure E-4-6: Example of Updated Terrain Data for XS #33252.91 of Model LRRV (black line represents updated model; magenta line represents original model)

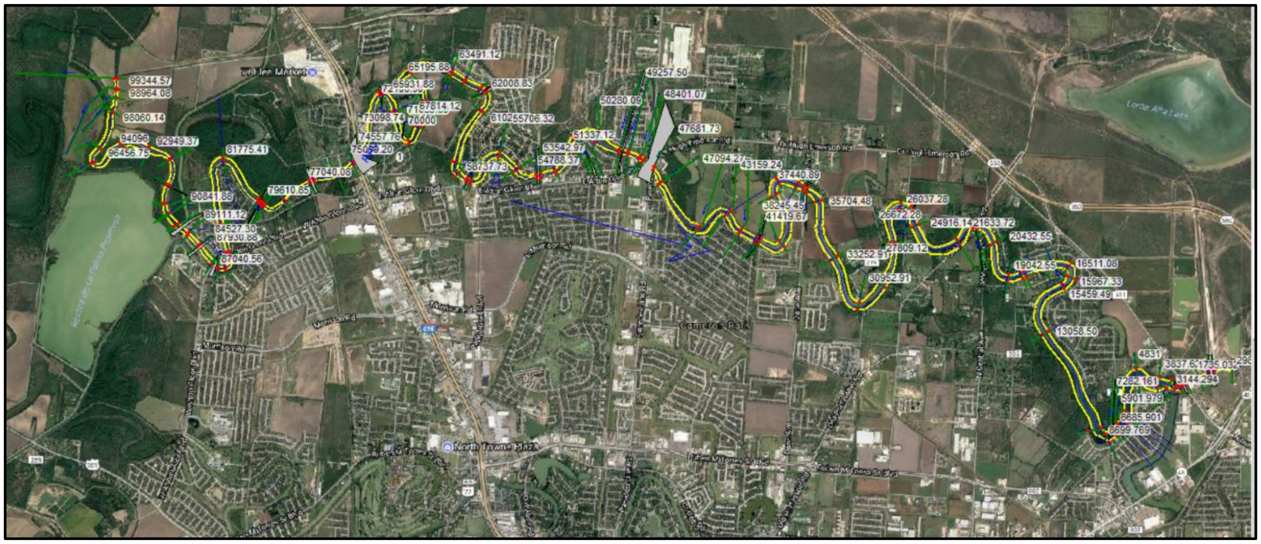

Figure E-4-7: LRRV Model Geometry

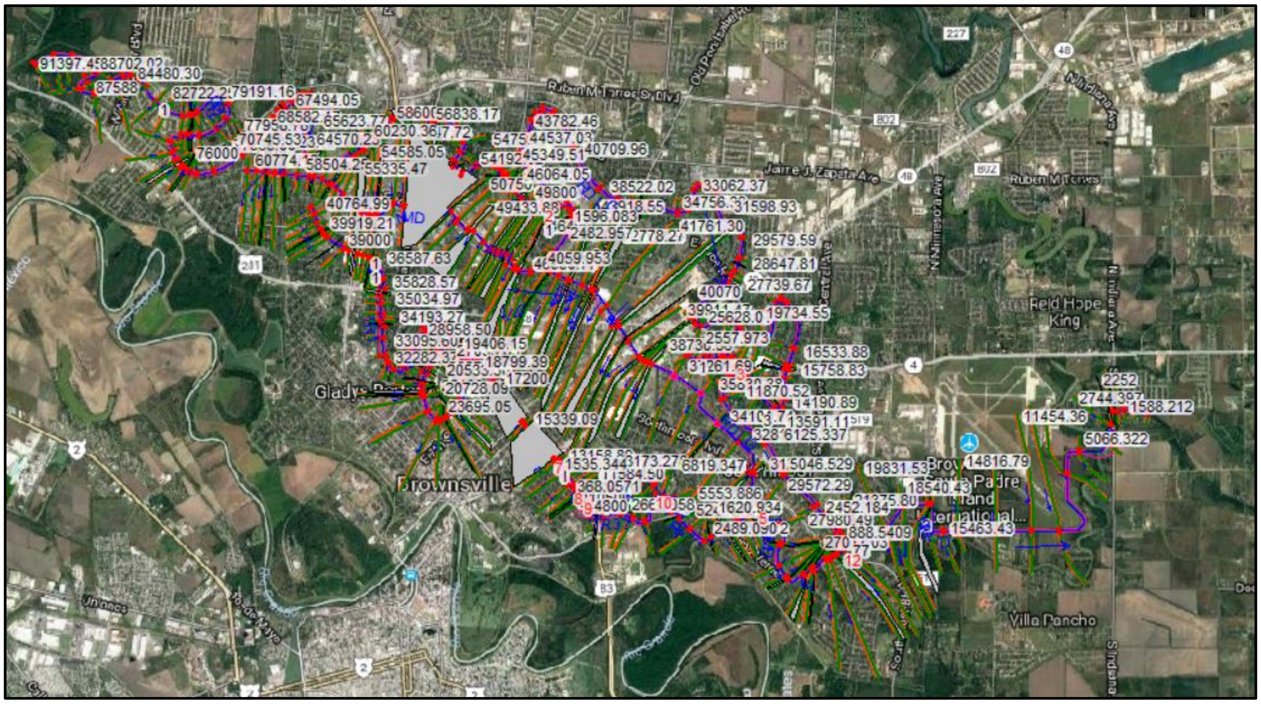

Figure E-4-8: Merged (RDLG, NMD, TR) Model Geometry

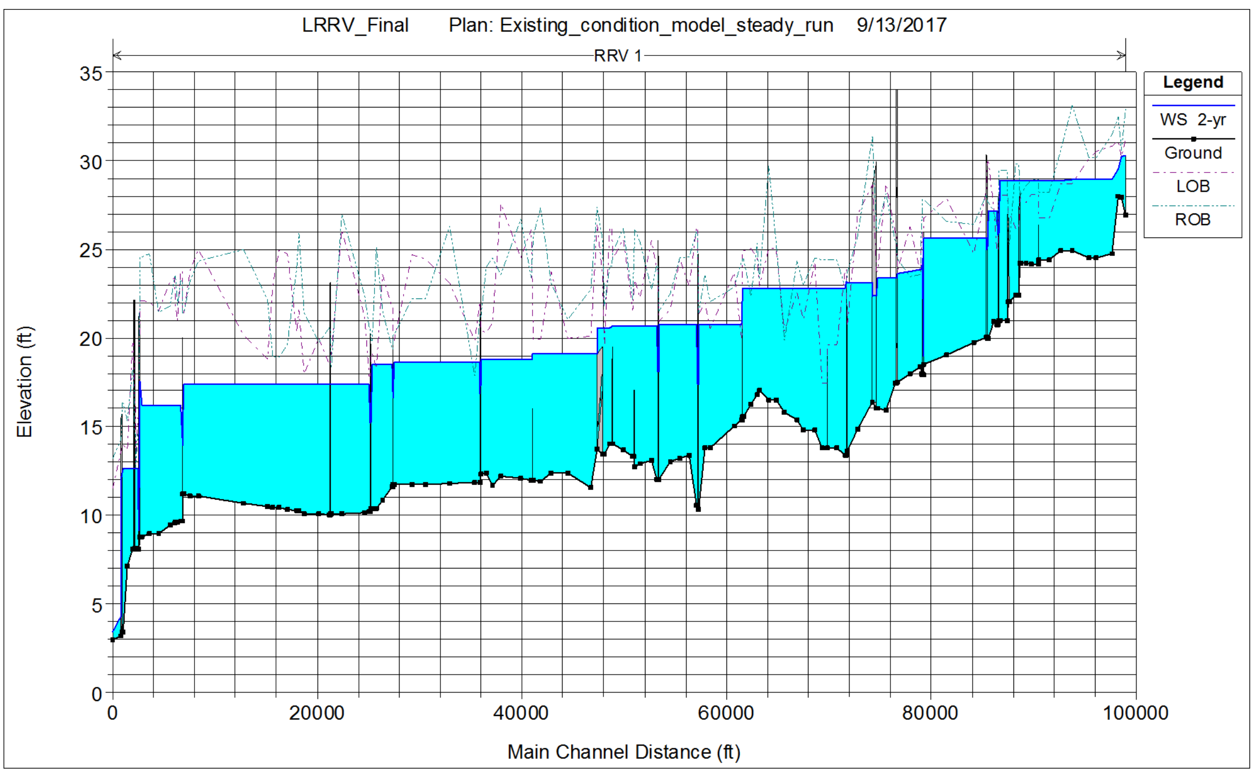

Figure E-4-9: Water Surface Elevation Profile for LRRV Model

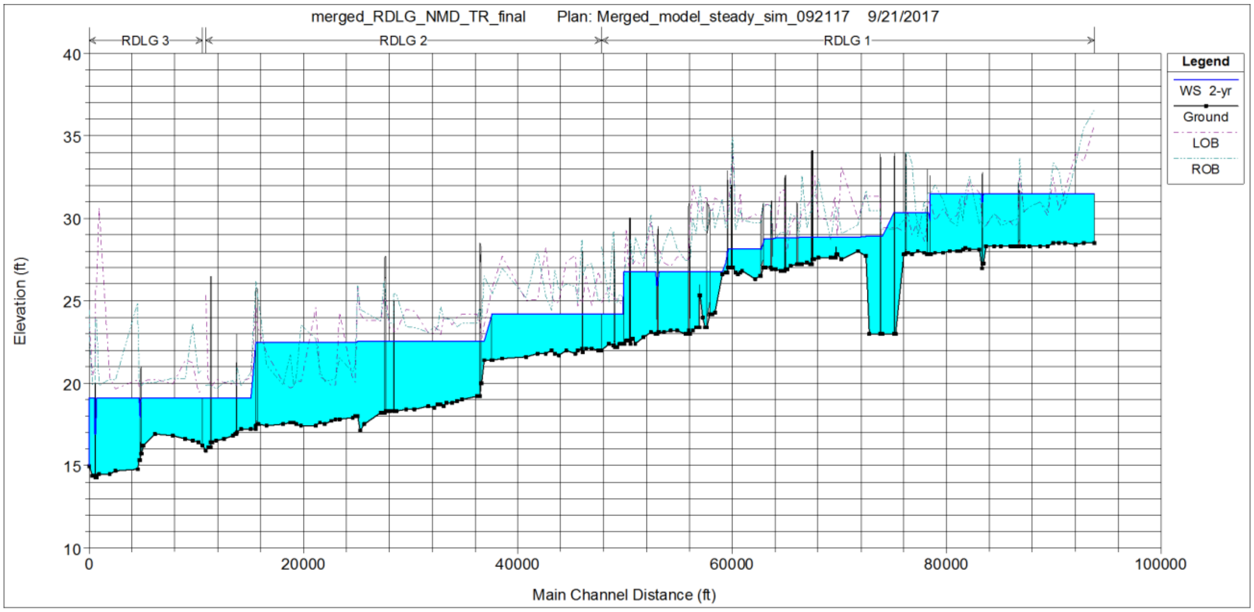

Figure E-4-10: Water Surface Elevation Profile for RDLG Model

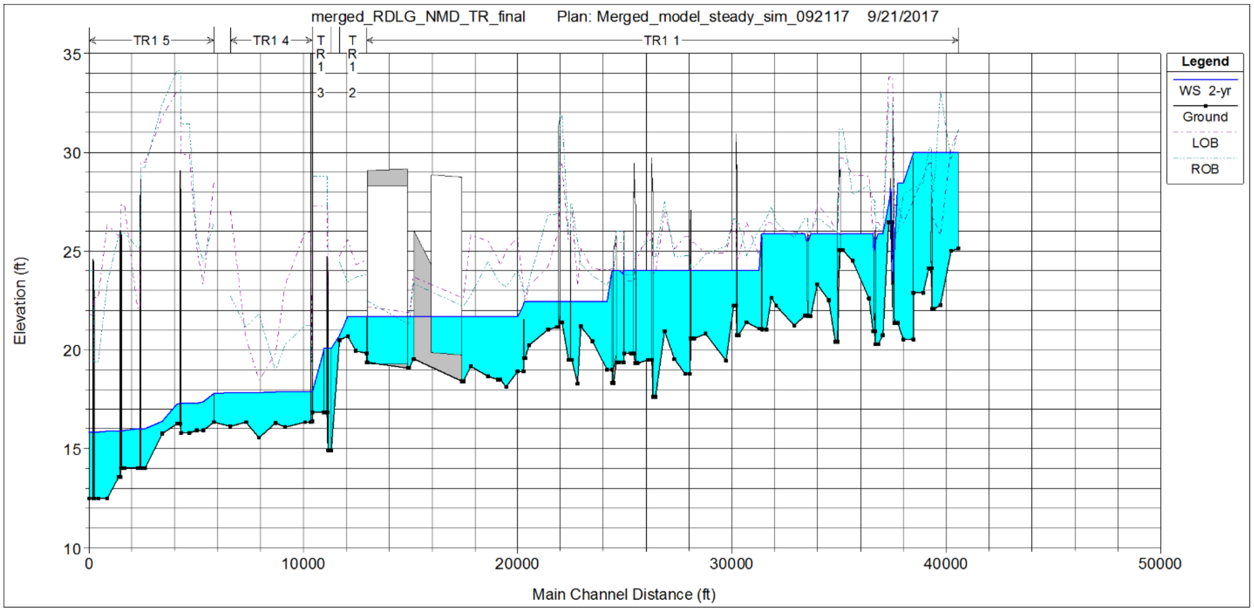

Figure E-4-11: Water Surface Elevation Profile for TR Model

Table E-4-5: LRRV Model XS Modifications

Cross-Section Station Number	Cross-section changes in the updated LRRV Model
90124.13	XS cutline is bended to avoid intersecting with XS 89609.19.
86422.92	The left flooplain portion of the XS cutline is shorten
84527.3	Both left and right side of the original XS is shorten
81775.41	Both left and right side of the original XS is shorten
73098.74	XS was shortened to prevent crossing with section 68899.12.
72100.9	XS cutline was shorten
71950.06	XS cutline was shorten
71089.69	XS cutline was shorten
68899.12	The left flood plain of the original XS was shorten
67814.12	XS cutline was shorten
67216.65	XS cutline was shorten
65931.88	XS cutline was shorten
63491.12	XS cutline was shorten
63333.39	XS cutline was shorten
58737.73	XS cutline was shorten
58177.73	XS cutline was shorten
56628.58	XS cutline was shorten
55706.32	XS cutline was shorten
54788.37	XS cutline was shorten
44776.27	XS cutline was shorten
36792.03	XS cutline was shorten
35704.48	XS cutline was shorten
29559.34	XS Cutline was shorten
26672.28	XS cutline was shorten
26037.28	XS cutline was shorten
25637.6	XS cutline was shorten
25334.66	XS cutline was shorten
24916.14	XS cutline was shorten
18502.34	XS cutline was extended
18337.42	XS cutline was extended
17396.08	XS cutline was shorten
16511.08	XS cutline was shorten
15967.33	XS cutline was shorten
13058.5	XS cutline was shorten
8699.769	XS cutline was shorten
7889.769	XS cutline was shorten
6685.901	XS cutline was shorten
6461.005	XS cutline was shorten
6294.25	XS cutline was shorten
5901.979	XS cutline was shorten

Table E-4-6: Merged (RDLF, NMD, TR) Model XS Modifications

River	Reach	Cross-Sections Station Number	Cross-section changes in the updated Model
RDLG	1	73033.74	Left side of the original XS was shorten
RDLG	3	255.3978	Right side of the original XS was shorten
NMD	1	29572.29	Right side of the original XS was bent to prevent crossing with section # 664.767 of River TR, Reach 1
NMD	3	2744.397	Right side of the original XS was bent
NMD	3	2084.659	Right side of the original XS was bent

Impacts From Relative Sea Level Change

Relative sea level change was assessed using the Port Isabel NOAA gage to forecast sea level change (SLC) for the project area.

The Port Isabel NOAA gage is located about 20 miles east of the project area and is the nearest gage that assesses long term climate change. The historical sea level change with the 95 percent confidence interval is shown in Figure E-4-12.

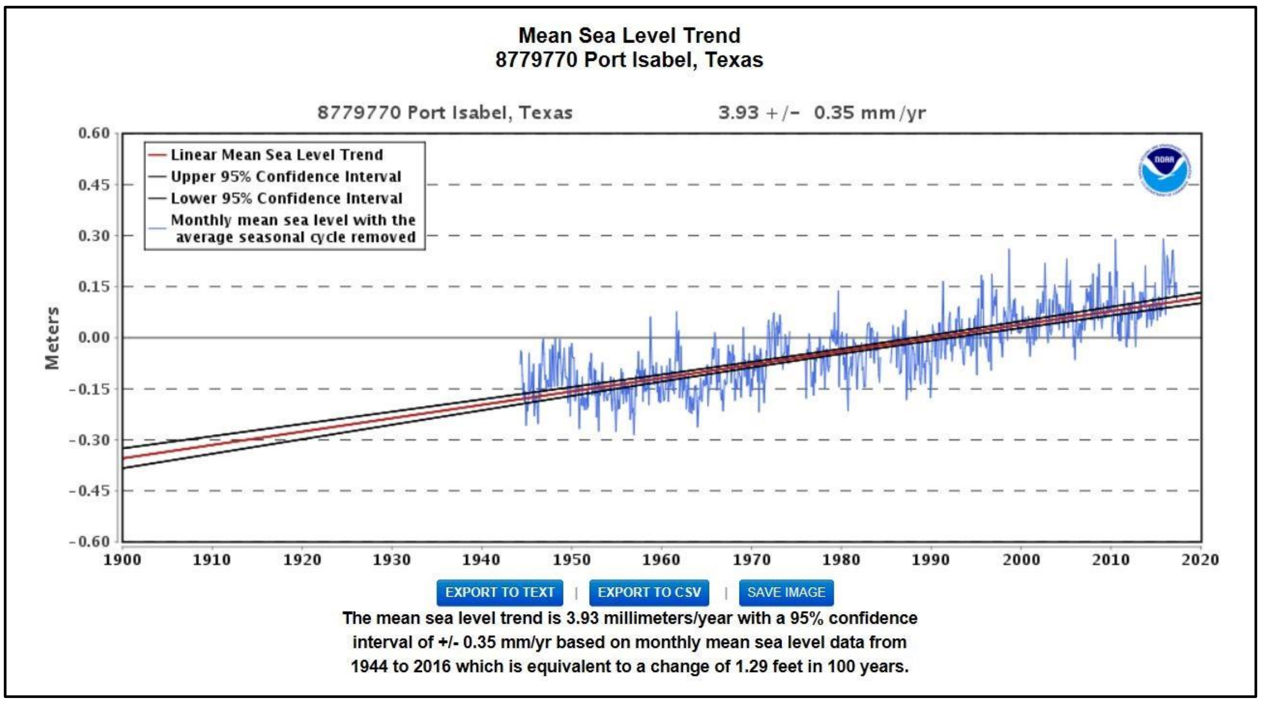

Figure E-4-12: Historical Sea Level Trend for Port Isabel, Texas Gage

This graph shows a change of 1.29 feet in relative sea level rise over the course of 72 years with a trend of 0.013 ft/yr.

Using the USACE guidance on SLC ER 1100-2-8162, “Incorporating Sea Level Change in Civil Works Programs” and the data provided from the NOAA gage an estimation of the high, intermediate, and low sea level change vulnerability assessment were developed (Figure E-4-13).

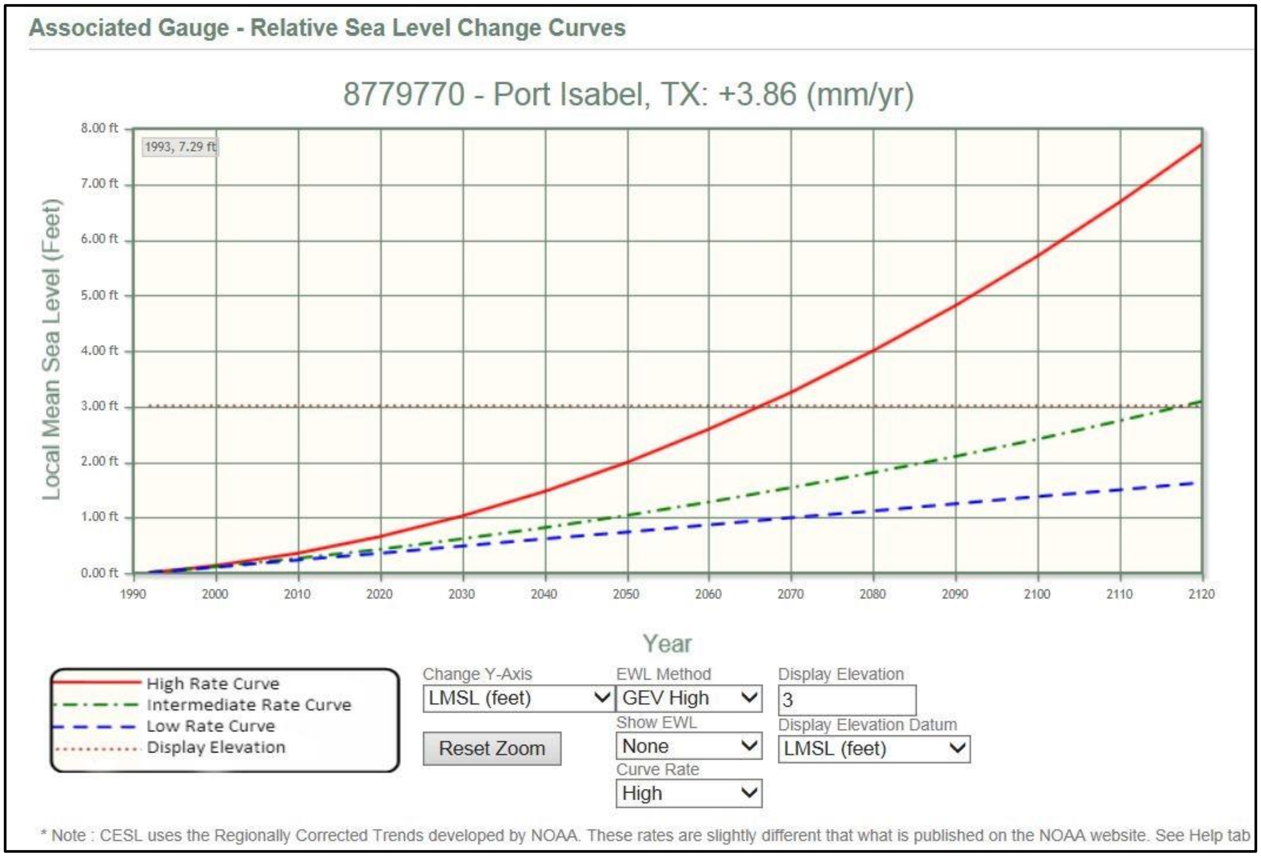

Figure E-4-13: Relative Sea Level Change Curves at Port Isabel, Texas Gage

Table E-4-7: Relative Sea Level Change Impacts at the Resacas with respect to the Port Isabel, Texas Gage

	75-Year Planning Horizon	
Controlling Tidal Gauge Rate Curve	**Impacted at 2095?**	**Level of Consequential Impacts**
High	No	N/A
Intermediate	No	N/A
Low	No	N/A

The intermediate rate of sea level rise rate was used to assess the impacts of the SLC on the project. The data above was taken from the Comprehensive Evaluation of Projects with Respect to Sea Level Change (CESL) web-based tool which assesses the vulnerability that the project area has to SLC over the lifetime of the project. The period of analysis for this ecosystem restoration project is 75 years. At 2095, there are no impacts to the project from sea level rise at the high, intermediate or low rates (Table E-4-7). Since this project will experience no impacts due to SLC, no additional analyses of SLC impacts to alternatives were conducted. This project will likely not experience impacts due to SLC over the life of the project for the low and intermediate expected SLC and should have no effect on the design or operation of the project.

Impact to Hydrology due to Project Climate Change

This section is in compliance with Engineering and Construction Bulletin (ECB) 2016-25 “Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects”. Average annual temperature in South Texas, which includes the Brownsville area, is anticipated to increase by 6-8 degrees F by 2100, with stronger warming in the summer (Norwine and John, eds., (2007) “The Changing Climate of South Texas 1900-2100”). While total annual precipitation is anticipated to remain unchanged, precipitation events, including hurricanes, are likely to be more intense, and separated by longer dry spells (Norwine and John, eds. 2013). The primary projected impacts of these changes is an estimated 25 percent reduction in Rio Grande water supplies accompanied by an estimated 12.5 percent increase in evaporation and rising water demand (U.S. Bureau of Reclamation (2013), “Lower Rio Grande Basin Study”). These hydrologic changes could have an impact to the performance and sustainability of the proposed NER plan.

The vulnerability of the project area to these changes was investigated using the USACE Vulnerability Assessment Tool, which provides a qualitative assessment of parameters that could impact the performance and sustainability of the project. Figure E-4-14 and Figure E-4-15show the projected change in low flow reduction, precipitation runoff, and drought severity, respectively for the driest (lowest runoff) 50 percent of model outputs for the region. Use of just the lowest runoff models in this analysis is justified because the primary anticipated impacts to the project relate to water supply, the primary source for which is the Rio Grande. The shades of red indicate increased vulnerability for that parameter and shades of green represent decreased vulnerability. Analyses of the annual maximum flow series and nonstationarities in annual maximum flow, as required by ECB 2016-25, could not be performed due to the absence of long-term stream gage data for the Rio Grande below Falcon Reservoir, and the highly regulated nature of releases from this reservoir.

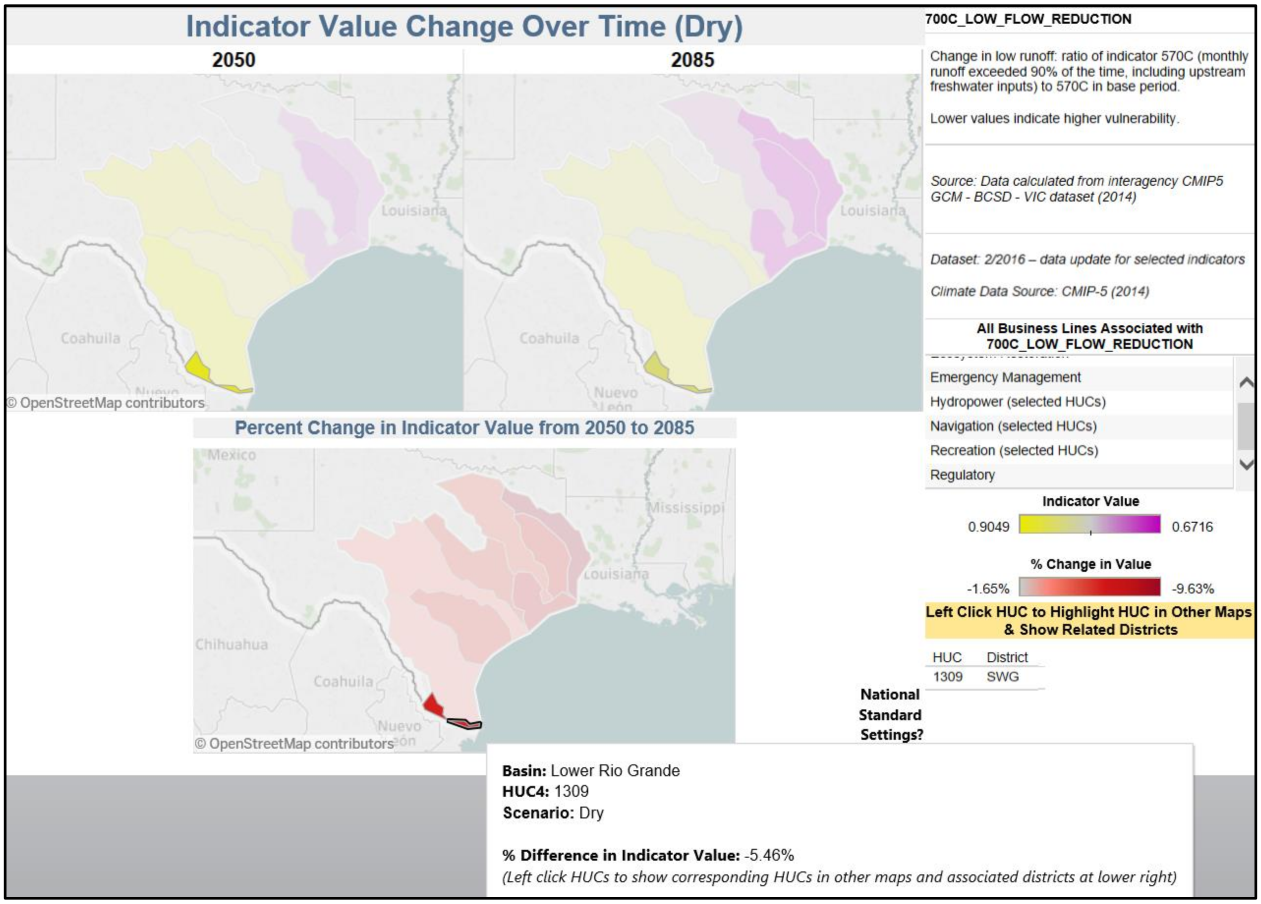

Figure E-4-14: Projected Change in Low Flow Reduction (2050-2085)

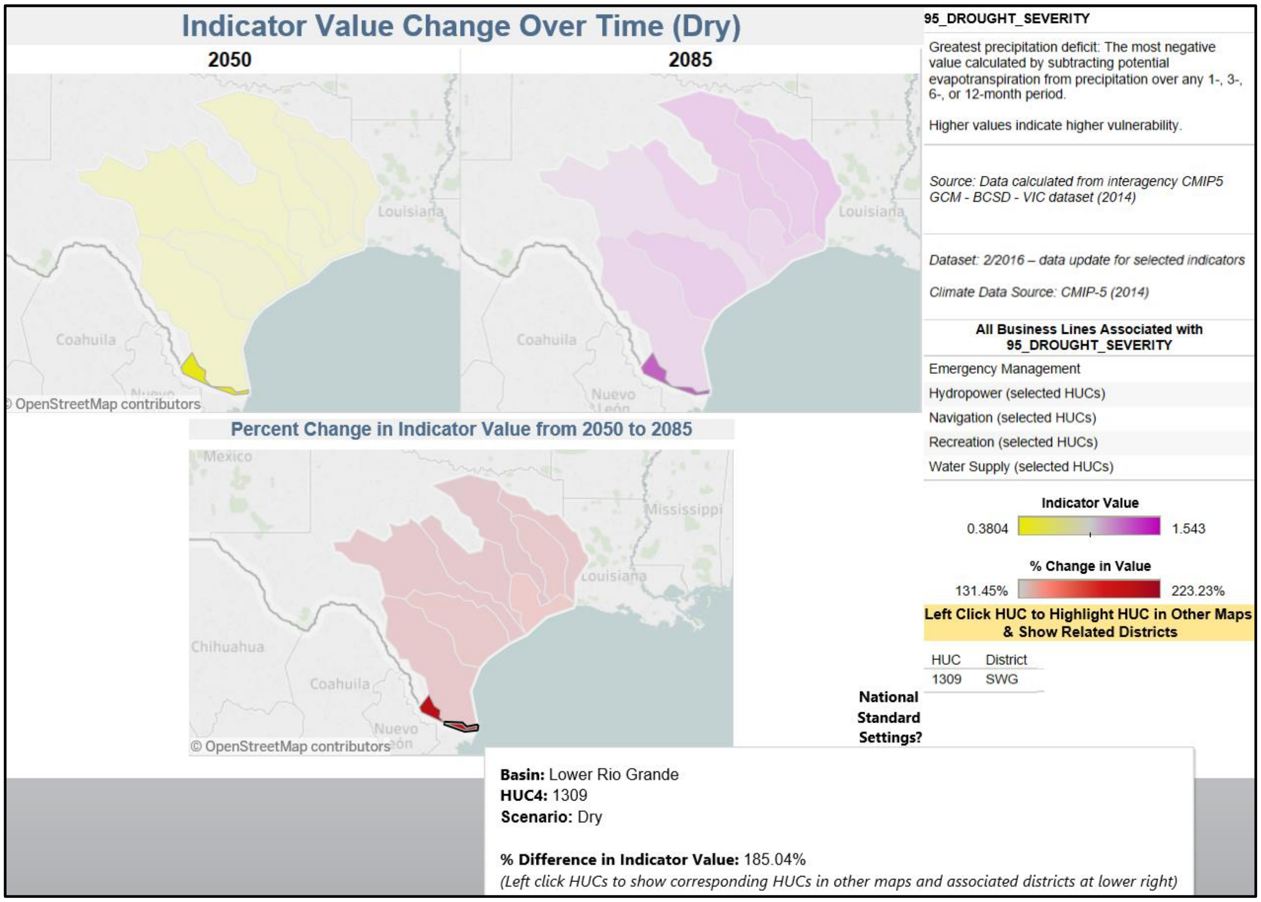

Figure E-4-15: Projected Change in Drought Severity (2050-2085)

The figures above show that the Lower Rio Grande (HUC 1309) can expect significantly more severe droughts during the life cycle of this project (Figure E-4-15). This would cause lower runoff during rain events due to dry soil conditions. Also, air temperature is expected to increase which could increase evaporation in reservoirs upstream that control flow rates in river, as well as evaporation of water in the restored resacas. The reduced low flow conditions (Figure E-4-14) could present challenges for the project since most of the raw water used to manage the resacas system comes from the Rio Grande. These projections are in agreement with the “Lower Rio Grande Basin Study” published by the U.S. Bureau of Reclamation in 2013. Finally, the Vulnerability Assessment tool shows significant regional vulnerability for ecosystem restoration projects generally due to the projected reduction in water availability in aquatic and riparian areas (data not shown).

However, the anticipated reduction in water availability in the project area is unlikely to significantly impact the project since the sponsor has secure water rights that can be used to meet project needs. BPUB recently published a report entitled “BPUB Water Conservation and Drought Contingency Plan” in May 2014. This report shows that

BPUB currently has rights to 40,215 acre-feet of municipal water plus an additional 40,000 acre-feet of water from the Rio Grande River, when excess water is available. Table E-4-8, below, compares the available amount of raw water with the amount of material to be removed from the project area. It is recognized that the projected-year 2060 water demands of 90,584 ac-ft per year, exceed the raw water supply, however the BPUB continues their efforts “to secure additional raw water supplies, [develop] water reuse as an alternative to potable supply needs, [plan] a regional seawater desalination plant, and [implement] measures to reduce water demands.”

Table E-4-8: Volume of Dredge/Excavation Material Compared to Available Water Supply

	Volume
Total amount of material to be dredged/excavated	946 ac-feet (1,527,000 feet^3)
Total amount of available raw water (2013)	80,215 ac-feet (40,000 ac-feet from Rio Grande River, when available)
Projected raw water demand (2060)	90,584 ac-feet
Percentage of volume to be removed from resacas system	1.1 percent (total), 2.2 percent (if no water available from Rio Grande River)

From the information gathered, the amount of material to be removed by the NER plan would be insignificant (<2.2 percent) to the total amount of water available for use by BPUB. It is also important to note that the resacas would need to be operated at lower levels than current conditions for several reasons discussed in the next section. This would lower the amount of water needed to regulate the resacas systems.

The estimated amount of additional water necessary to regulate the resacas system under the NER plan should not require a significant amount of additional water. However, there are still concerns about the availability of water from the Rio Grande and nearby reservoirs during severe droughts. This could reduce the desired water levels in the resacas and affect the resiliency of the proposed project. BPUB is actively pursuing additional sources and implementing new water conservations plans.

In addition, resacas now and historically have experienced extremely low water levels, or have completely dried up during droughts. The ecosystem is adapted to this variability. Currently, when water in a resaca is extremely low and stagnant, the resaca is allowed to dry out and then refilled or flushed out. It is a fairly routine occurrence currently and will almost certainly continue to happen in the future. It is anticipated that the restored resaca ecosystem will continue to be resilient to such drought episodes.

Based on the information available, there is a risk of reduced performance and sustainability of the NER plan due to projected climate changes. Although there is not a current water supply issue, there is a risk that water availability may be reduced in the future. The sponsor is actively working to mitigate that risk. Consequently, the risk of climate change to the project is considered “low” at this time.

Summary of H&H Analysis

The H&H analyses conducted during this phase of the study were completed in order to obtain enough information to make sound engineering decisions about the sustainability and resiliency of the NER plan. After reviewing all of the available information, there is no reason to believe that the NER plan would not be sustainable and resilient, from an H&H perspective, for the entire lifespan of the project. The NER plan was not modeled in this phase of the study, however there are some key constraints that need to be followed in order for the NER plan to function properly:

The water levels for each segment of the resacas need to be lowered in order to:

1. Create flow conditions that will allow riparian areas to thrive,
2. Mitigate any risk of induced flooding due to increased overbank roughness caused by riparian areas,
3. Offset water supply needed to replenish volume removed by dredge material.

Recommendations/Future Analyses

- New hydrologic and hydraulic models for the project area. This would include full calibration, frequency analysis, future conditions analysis, and alternative analysis. The current models are not detailed enough for design requirements.
- New bathymetric data for resacas within NER plan extents
- Perform more detailed climate change analysis, including quantitative inland hydrology and salt water intrusion analysis.
- Development of new water management plan for resacas system. This would include operational guidelines for existing and new water control structures, flood and drought contingency plans, and operation and maintenance manual.