VOLUME 3 - APPENDICES

JORDAN RIVER HYDRAULIC STUDY

SALT LAKE COUNTY

July 2019

BOWEN COLLINS & ASSOCIATES

APPENDIX A
COMPARISON OF MONUMENT CROSS SECTIONS
1987 VS 2018

JORDAN RIVER SURVEY MONUMENTS 2100 SOUTH TO 14600 SOUTH

SUBMITTED TO:

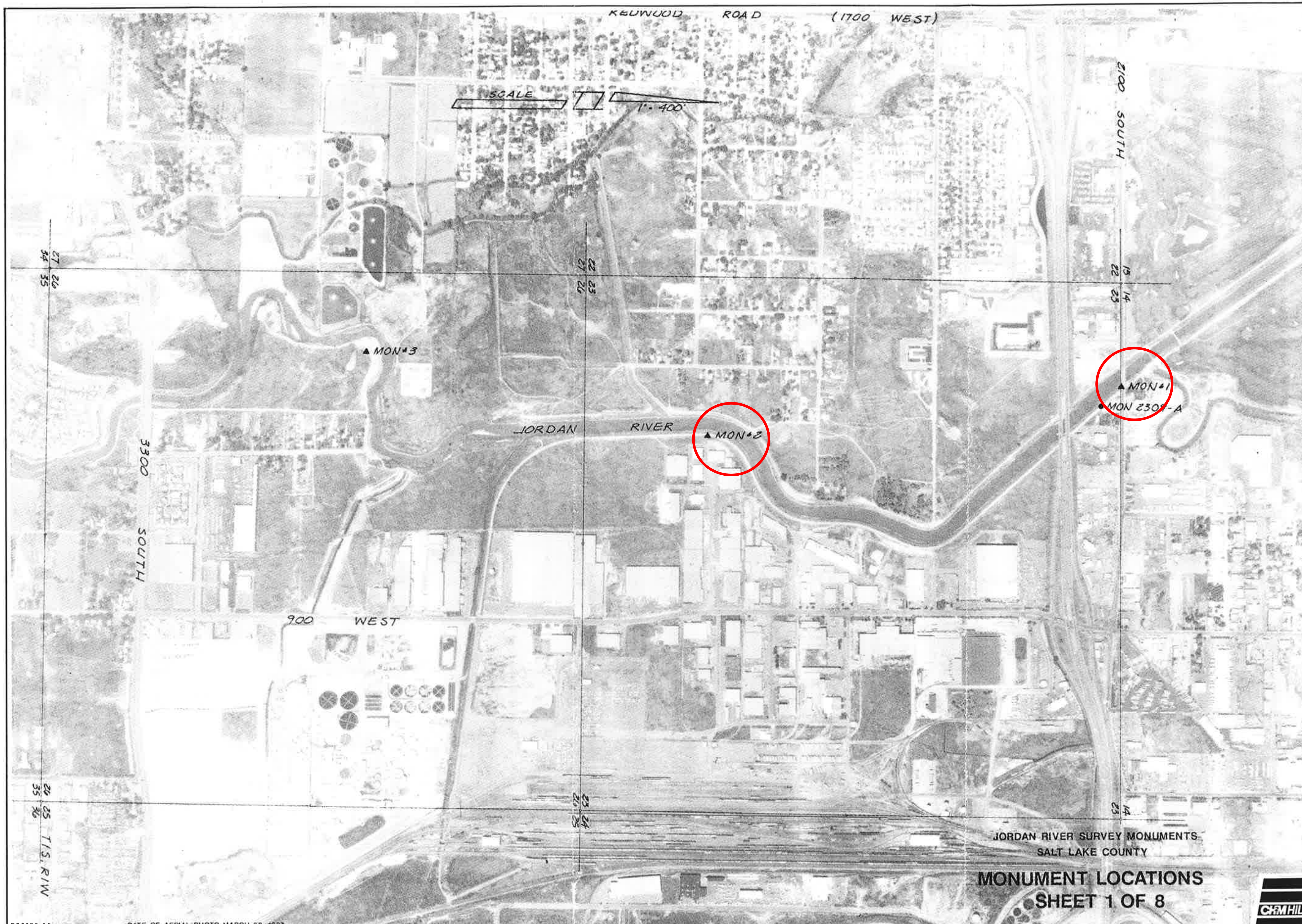
SALT LAKE COUNTY FLOOD CONTROL

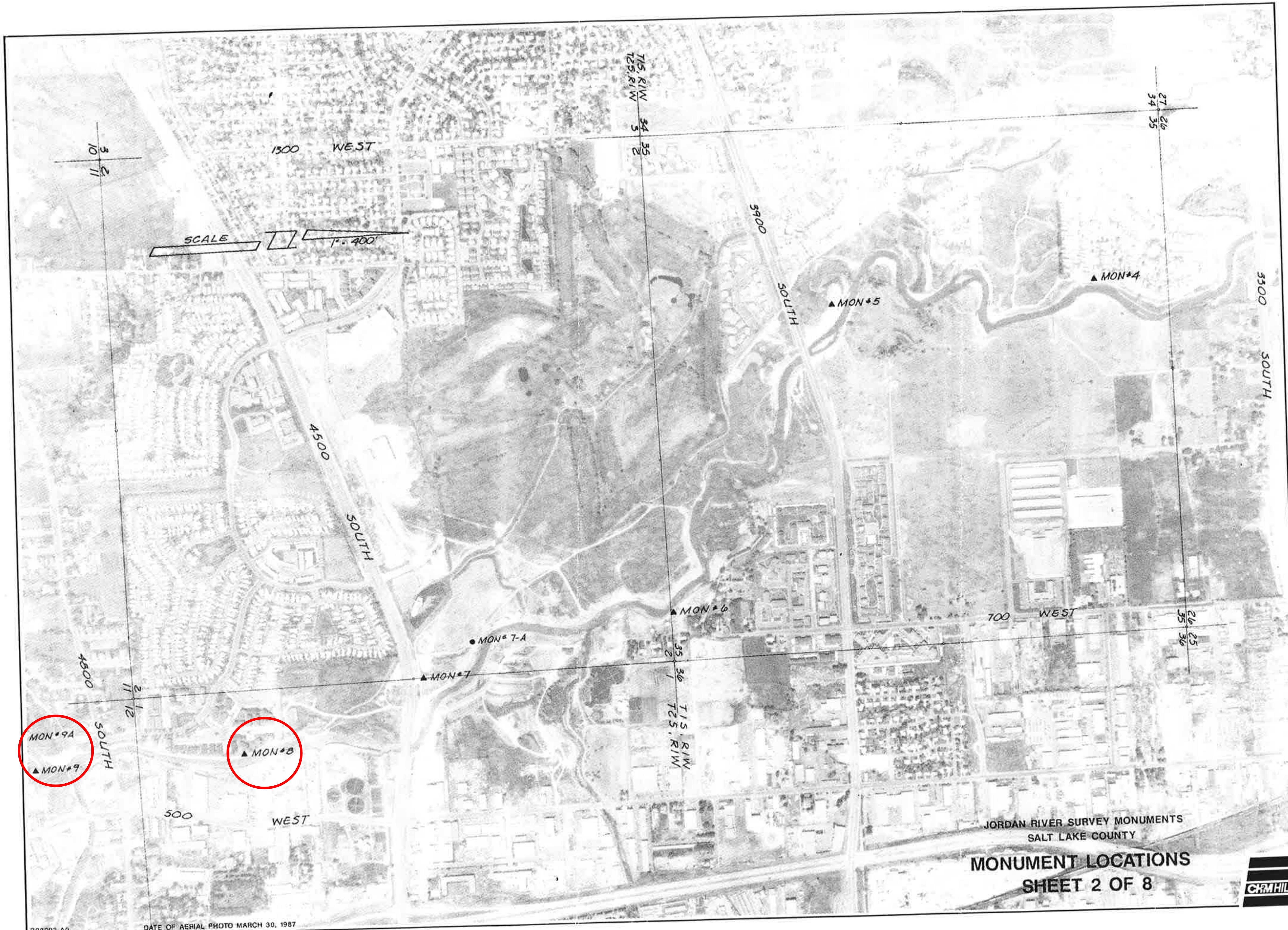
SUBMITTED BY:

CH2M HILL

SALT LAKE CITY , UTAH

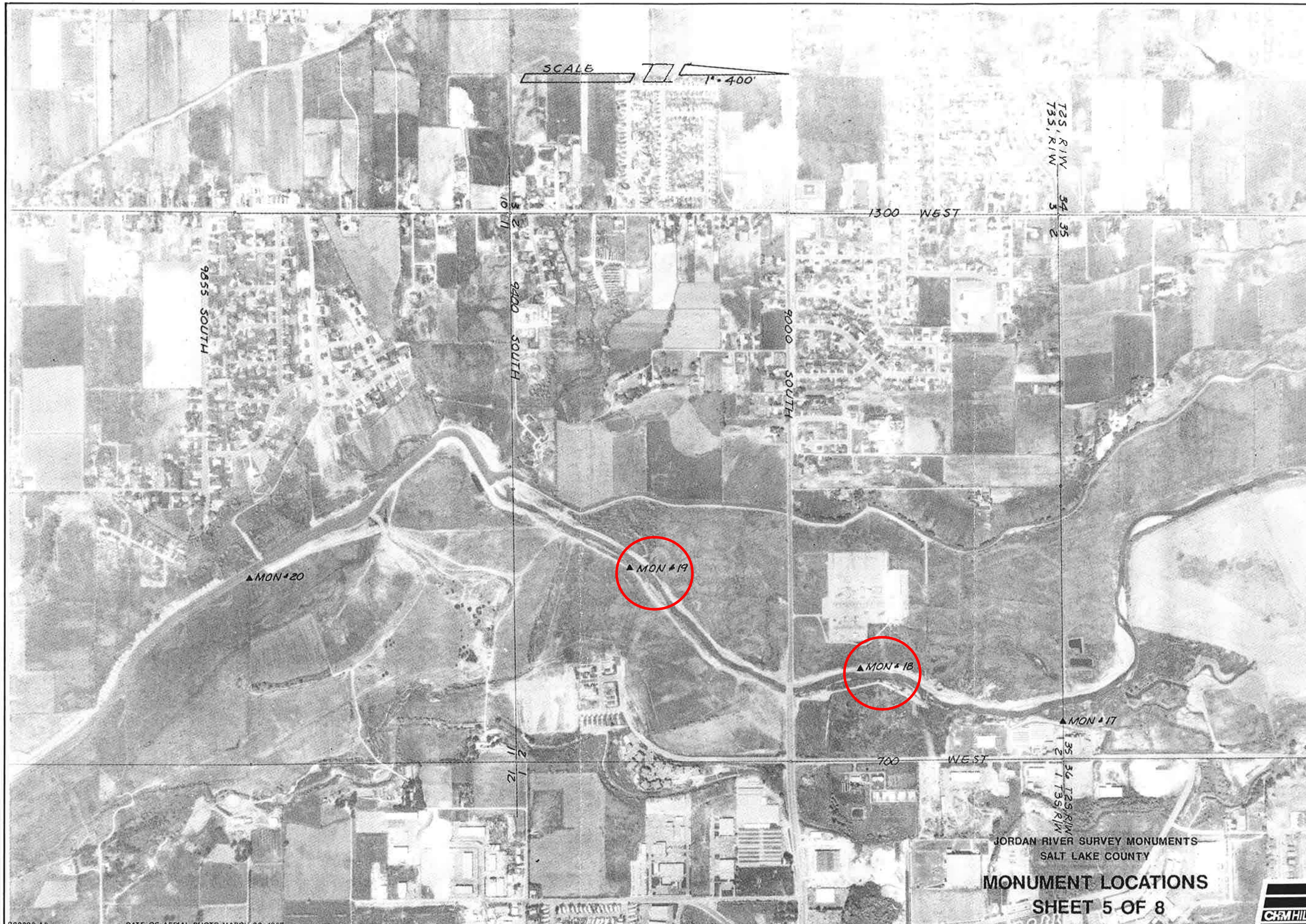
SEPTEMBER 1987

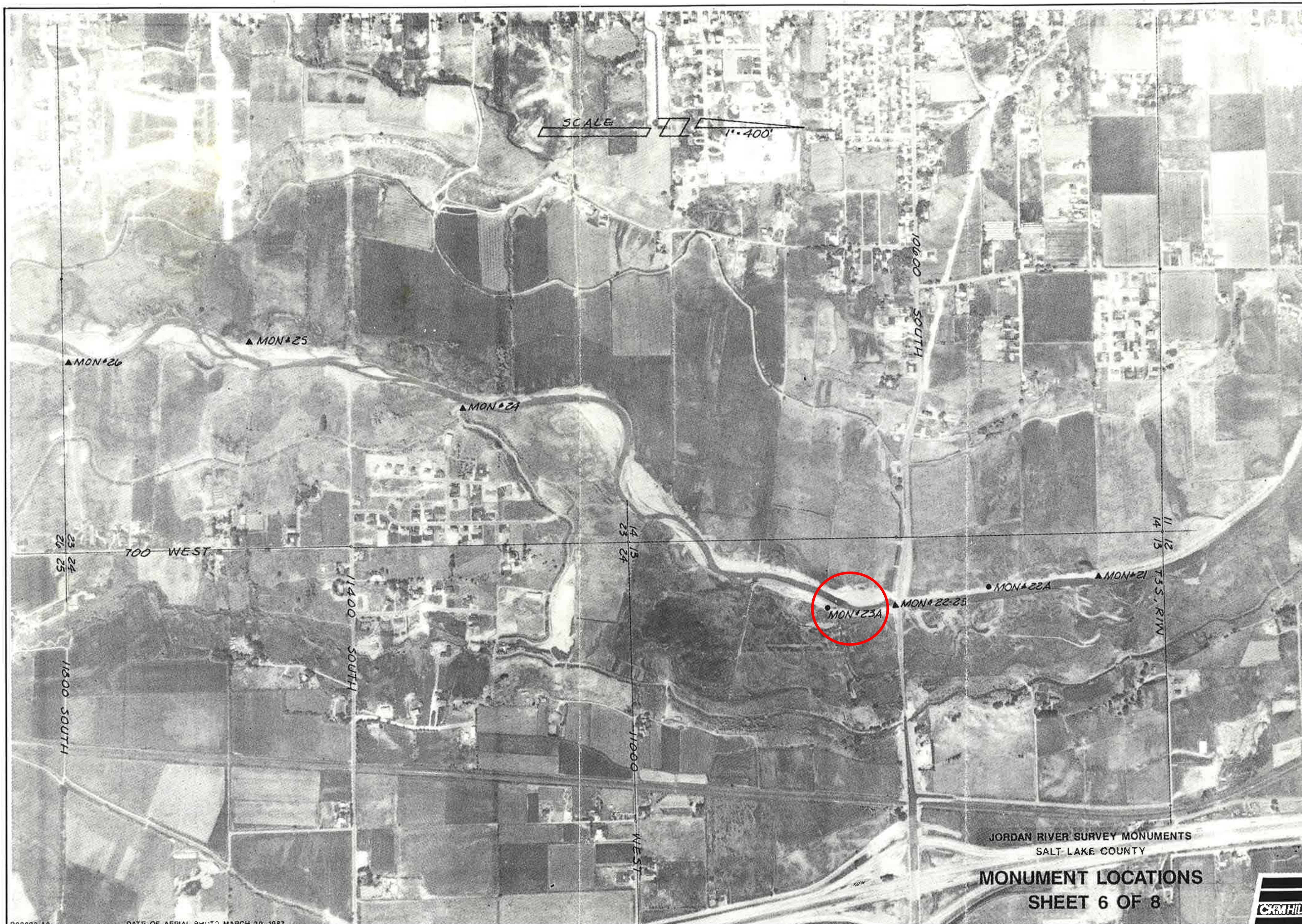

REDWOOD ROAD (1700 WEST)
SCALE 1" = 400'
2100 SOUTH
3300 SOUTH
900 WEST
JORDAN RIVER
MON #1
MON 2309-A
MON #2
MON #3
T.1S. R.1W.
JORDAN RIVER SURVEY MONUMENTS
SALT LAKE COUNTY
MONUMENT LOCATIONS
SHEET 1 OF 8
CH2M HILL
B22293.A0
DATE OF AERIAL PHOTO MARCH 30, 1987

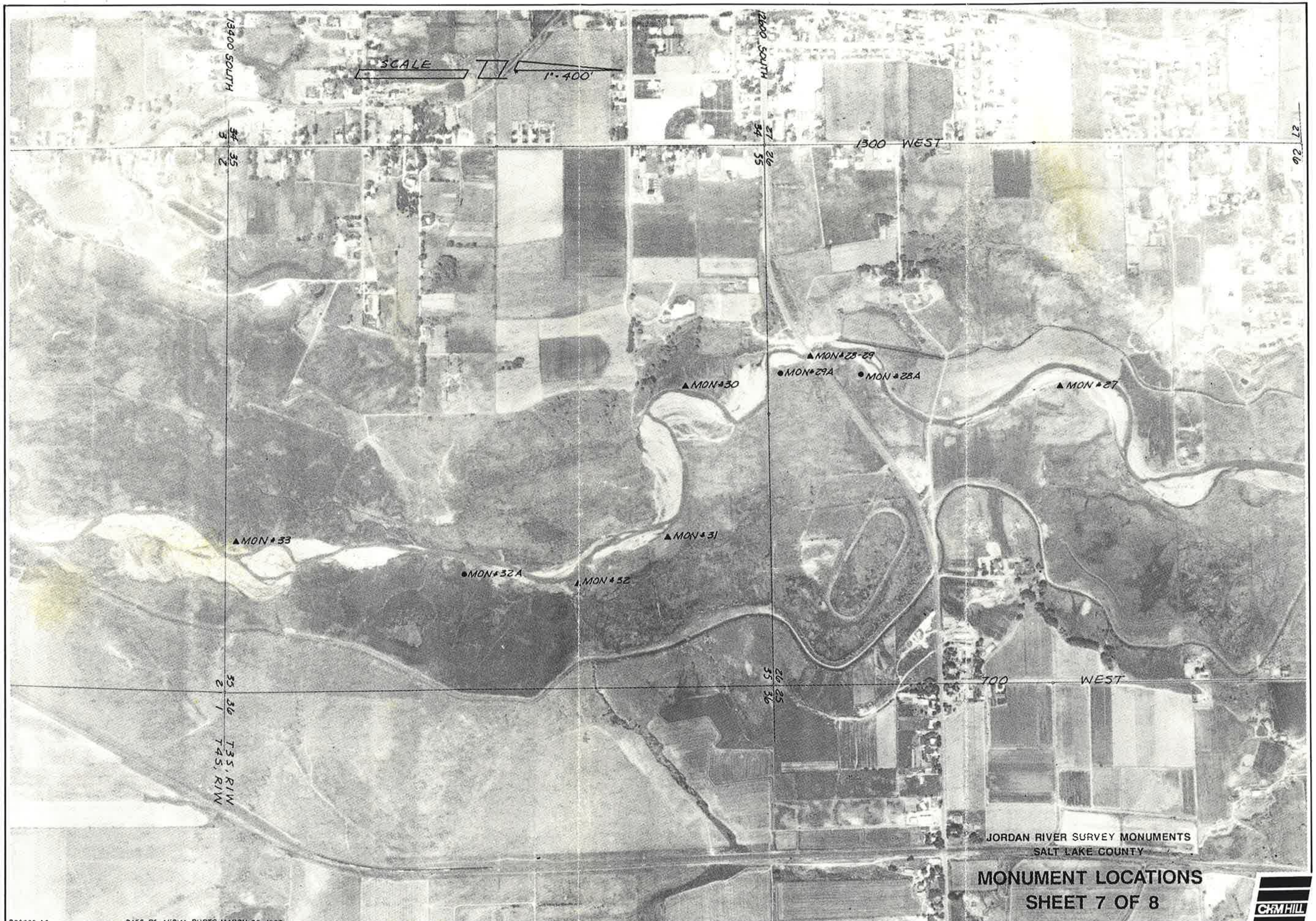

T1S, R1W
T2S, R1W
34 35
3 2
27 26
34 35
10 3
11 2
SCALE
1" = 400'
1300 WEST
3900 SOUTH
4500 SOUTH
3300 SOUTH
4800 SOUTH
700 WEST
500 WEST
MON #4
MON #5
MON #6
MON #7-A
MON #7
MON #8
MON #9A
MON #9
26 25
35 36
11 2
12 1
35 36
2 1
T1S, R1W
T2S, R1W
JORDAN RIVER SURVEY MONUMENTS
SALT LAKE COUNTY
MONUMENT LOCATIONS
SHEET 2 OF 8
CH2M HILL
B22293.A0
DATE OF AERIAL PHOTO MARCH 30, 1987


SCALE
1" = 400'
1800 WEST
15 14
22 23
10 11
15 14
3 2
10 11
MON # 11
MON # 12
MON # 12A
MON # 10
5300 SOUTH
4800 SOUTH
I-215
700 WEST
14 13
23 24
11 12
14 13
11
12
T2S, R1W
I-15
B22293.A0
DATE OF AERIAL PHOTO MARCH 30, 1987
JORDAN RIVER SURVEY MONUMENTS
SALT LAKE COUNTY
MONUMENT LOCATIONS
SHEET 3 OF 8
CH2M HILL

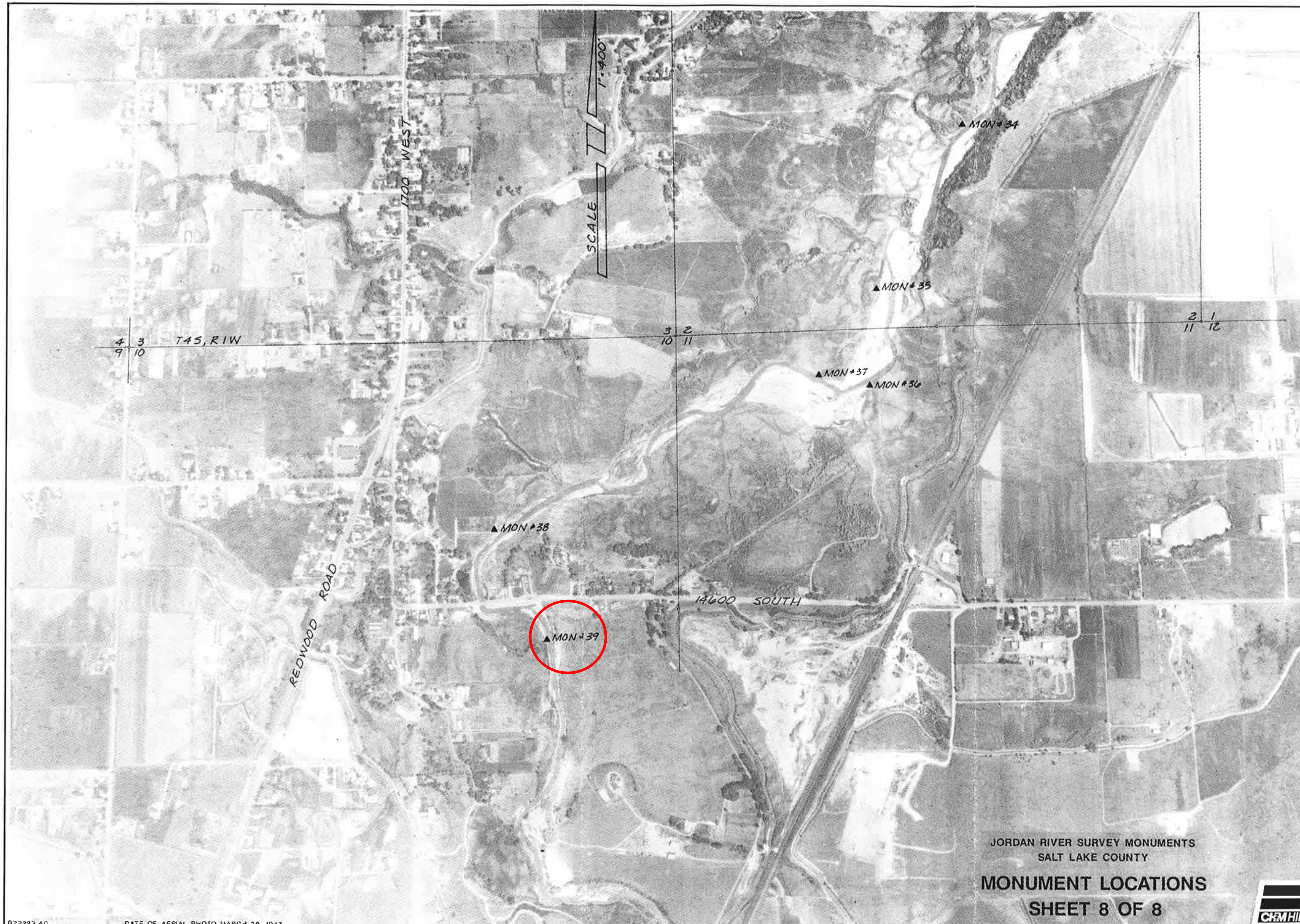
SCALE
1" = 400'
1600 SOUTH
7000 SOUTH
T2S, R1W
1300 WEST
700 WEST
MON #14A
MON #14
MON #13
MON #15
MON #15A
MON #16A
MON #16
JORDAN RIVER SURVEY MONUMENTS
SALT LAKE COUNTY
MONUMENT LOCATIONS
SHEET 4 OF 8
CH2M HILL
B22293.A0
DATE OF AERIAL PHOTO MARCH 30, 1987


SCALE
1" = 400'
T2S, R1W
T3S, R1W
1300 WEST
9855 SOUTH
9400 SOUTH
9000 SOUTH
MON # 20
MON # 19
MON # 18
MON # 17
700 WEST
T2S R1W
T3S R1W
JORDAN RIVER SURVEY MONUMENTS
SALT LAKE COUNTY
MONUMENT LOCATIONS
SHEET 5 OF 8
CH2M HILL
822293.A0
DATE OF AERIAL PHOTO MARCH 30, 1987


SCALE
1"=400'
MON#26
MON#25
MON#24
10600 SOUTH
700 WEST
22 23
25 24
14 13
23 24
14 13
11 12
11400 SOUTH
1800 SOUTH
11000 WEST
MON#23A
MON#22-23
MON#22A
MON#21
T3S, R1W
JORDAN RIVER SURVEY MONUMENTS
SALT LAKE COUNTY
MONUMENT LOCATIONS
SHEET 6 OF 8
CH2M HILL
B22293.A0
DATE OF AERIAL PHOTO MARCH 30, 1987



13400 SOUTH
12600 SOUTH
SCALE
1"=400'
1300 WEST
700 WEST
▲MON #33
●MON #32A
▲MON #32
▲MON #31
▲MON #30
●MON #29A
▲MON #28-29
●MON #28A
▲MON #27
T3S, R1W
T4S, R1W
JORDAN RIVER SURVEY MONUMENTS
SALT LAKE COUNTY
MONUMENT LOCATIONS
SHEET 7 OF 8
B22293.A0
DATE OF AERIAL PHOTO MARCH 30, 1987



JORDAN RIVER SURVEY MONUMENTS
SALT LAKE COUNTY

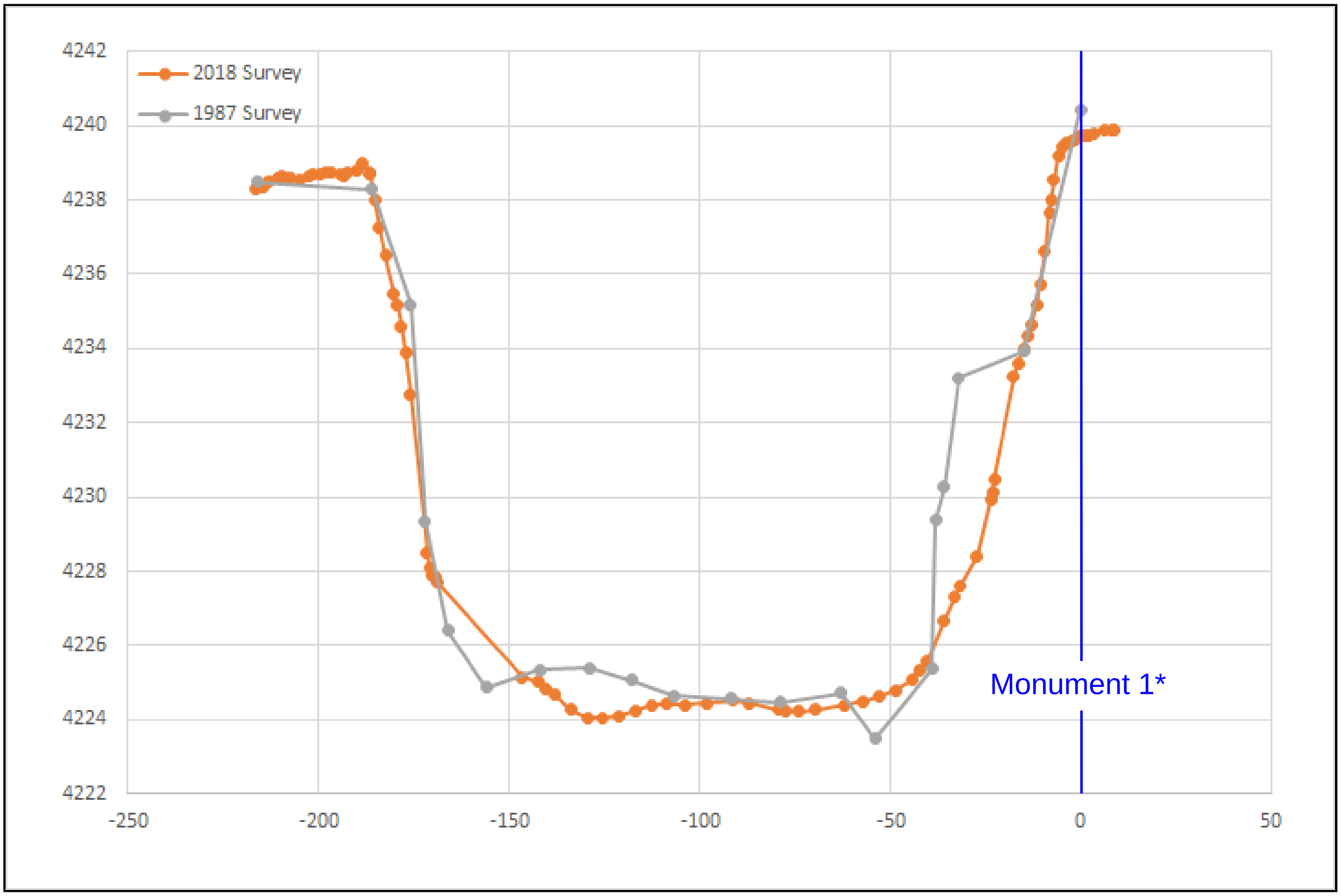
MONUMENT LOCATIONS
SHEET 8 OF 8

822293.A0

DATE OF AERIAL PHOTO MARCH 30, 1987

CH2M HILL

Monumented Cross Sections
Monument 1* (2100 South)

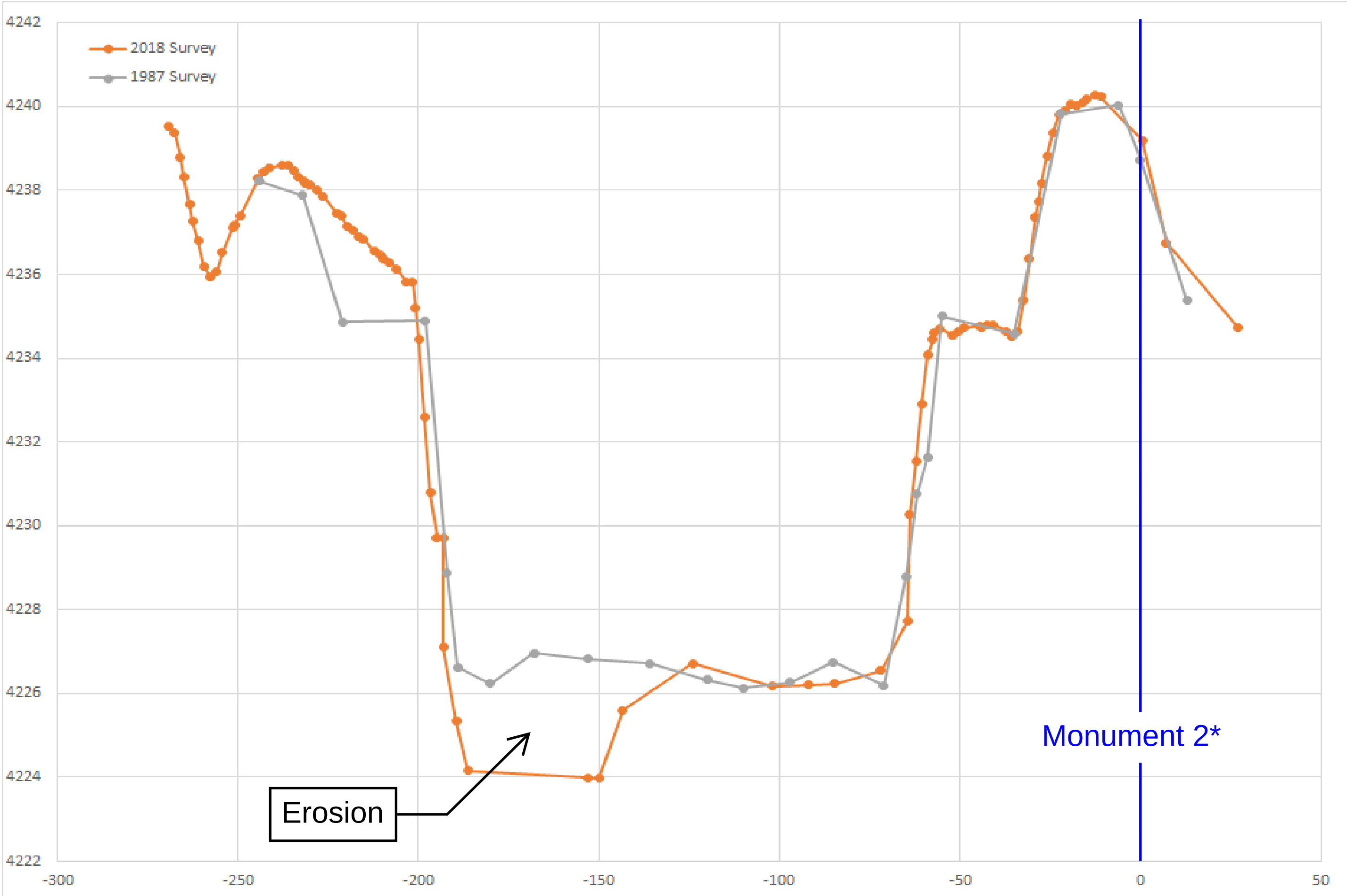


Notes:

1. Minimal changes.

*Monument was not specifically surveyed. However, the 2018 cross section is within approximately 20 feet of the original cross section.

Monumented Cross Sections
Monument 2* (2600 South)

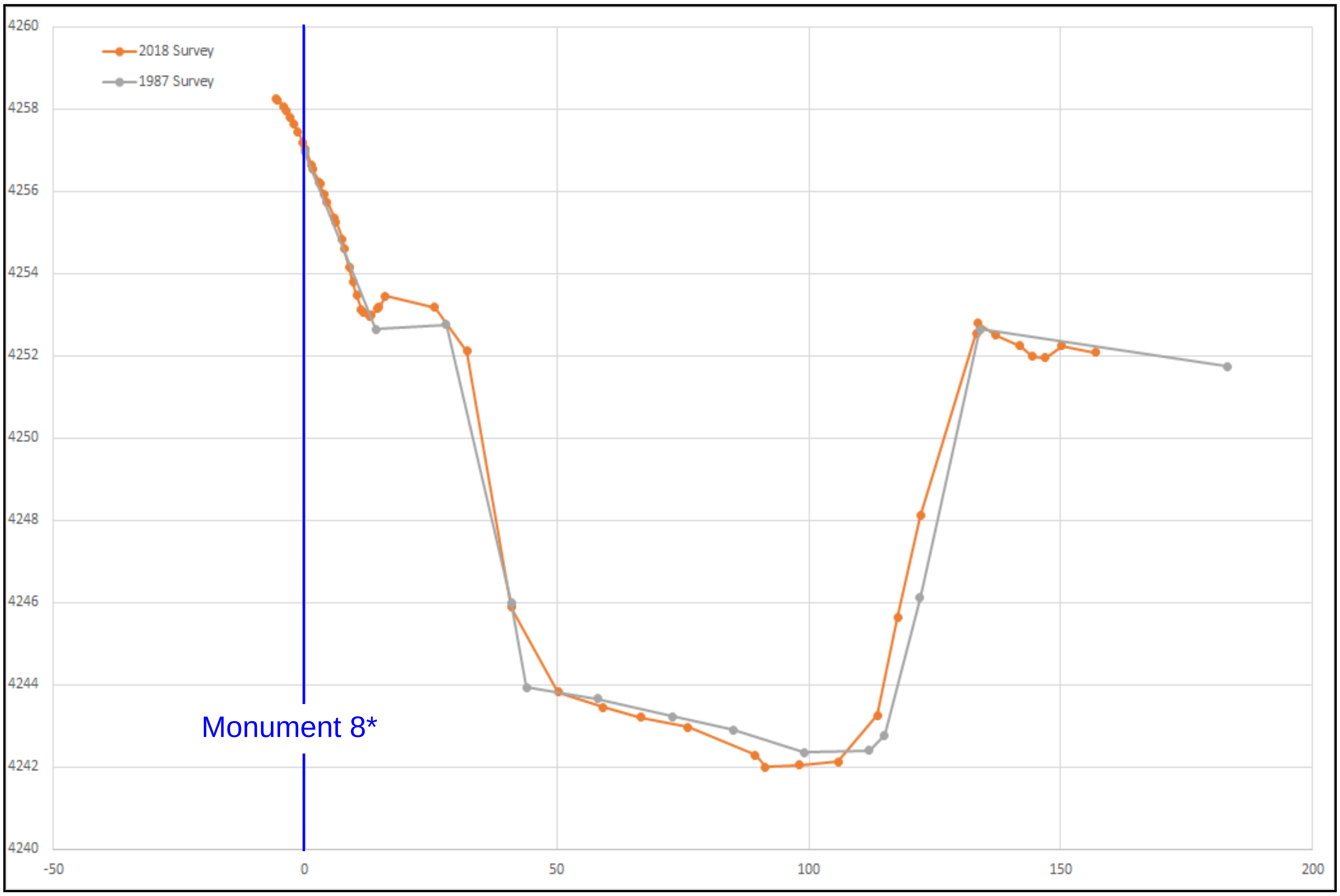


Notes:

1. Channel bottom has experienced erosion or dredging of approximately 2 feet.
2. Other changes are minimal.

*Monument was not specifically surveyed. However, the 2018 cross section is within approximately 20 feet of the original cross section.

Monumented Cross Sections
Monument 8* (4700 South)

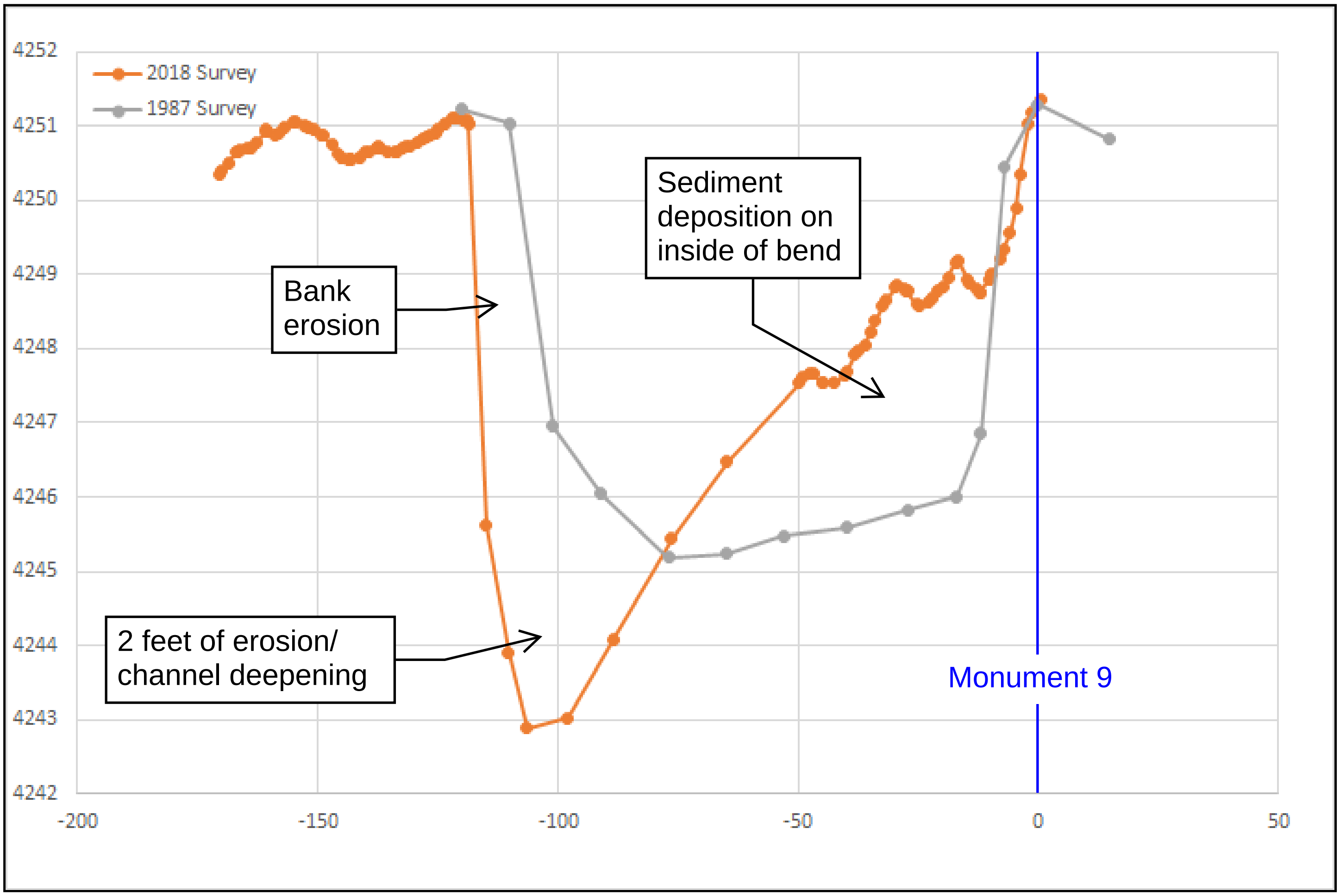


Notes:

1. Minimal changes.

*Monument was not specifically surveyed. However, the 2018 cross section is within approximately 20 feet of the original cross section.

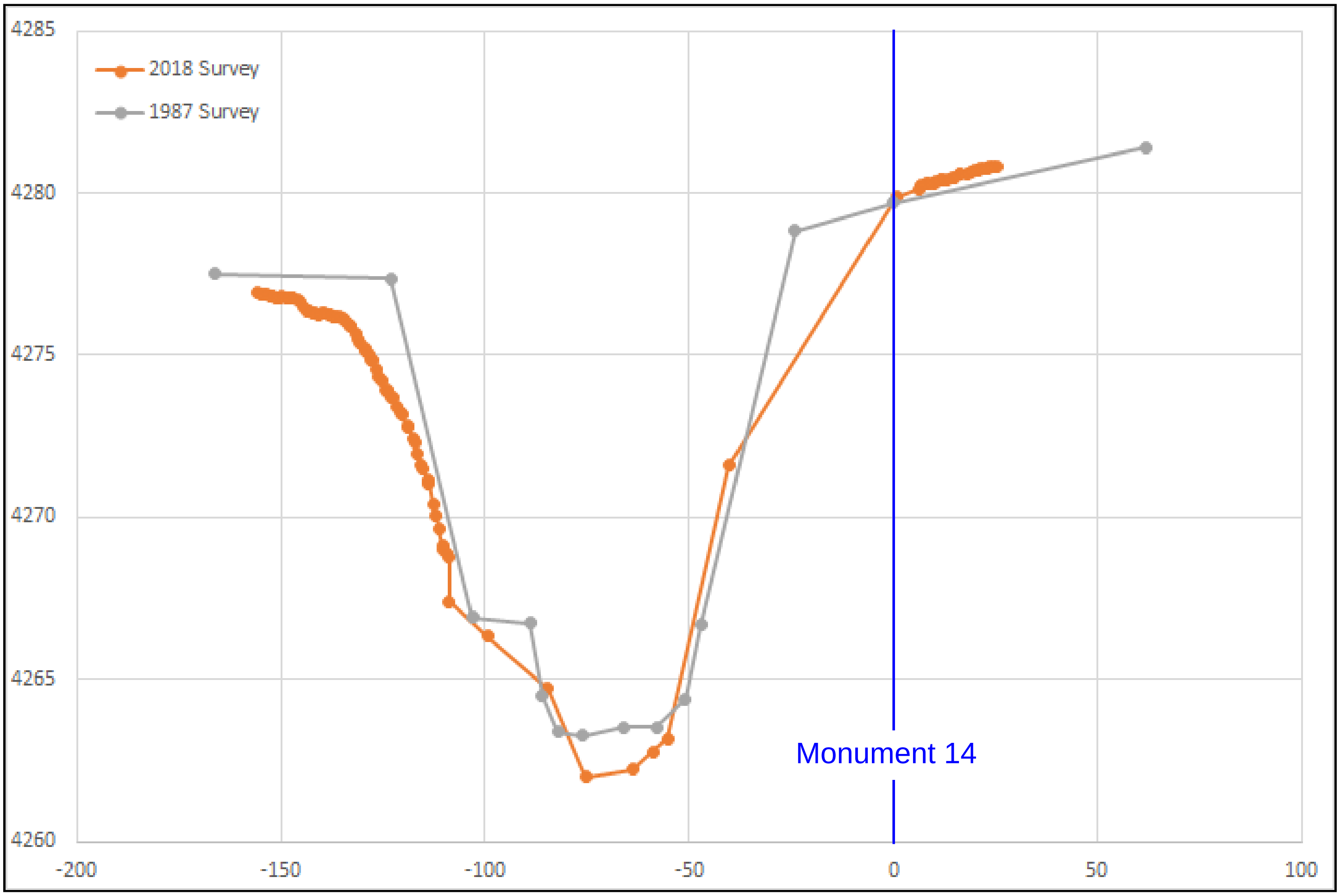
Monumented Cross Sections
Monument 9 (4900 South)



Notes:

1. West bank has shifted approximately 10 feet.
2. Area is part of a restoration site.

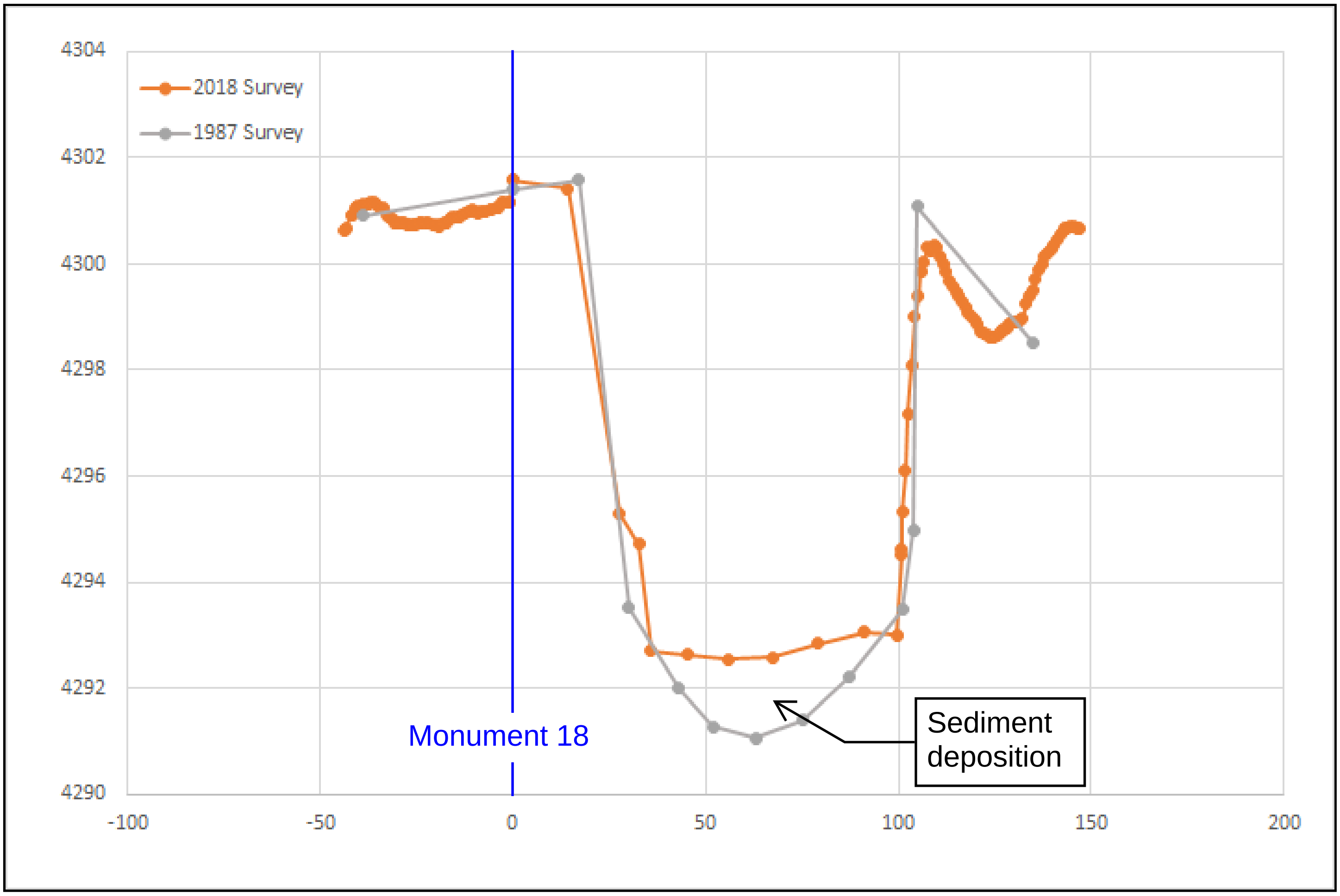
Monumented Cross Sections
Monument 14 (6400 South)



Notes:

1. Banks have been laid back slightly.
2. Channel bottom is approximately 1 foot deeper due to erosion.

Monumented Cross Sections
Monument 18 (8900 South)

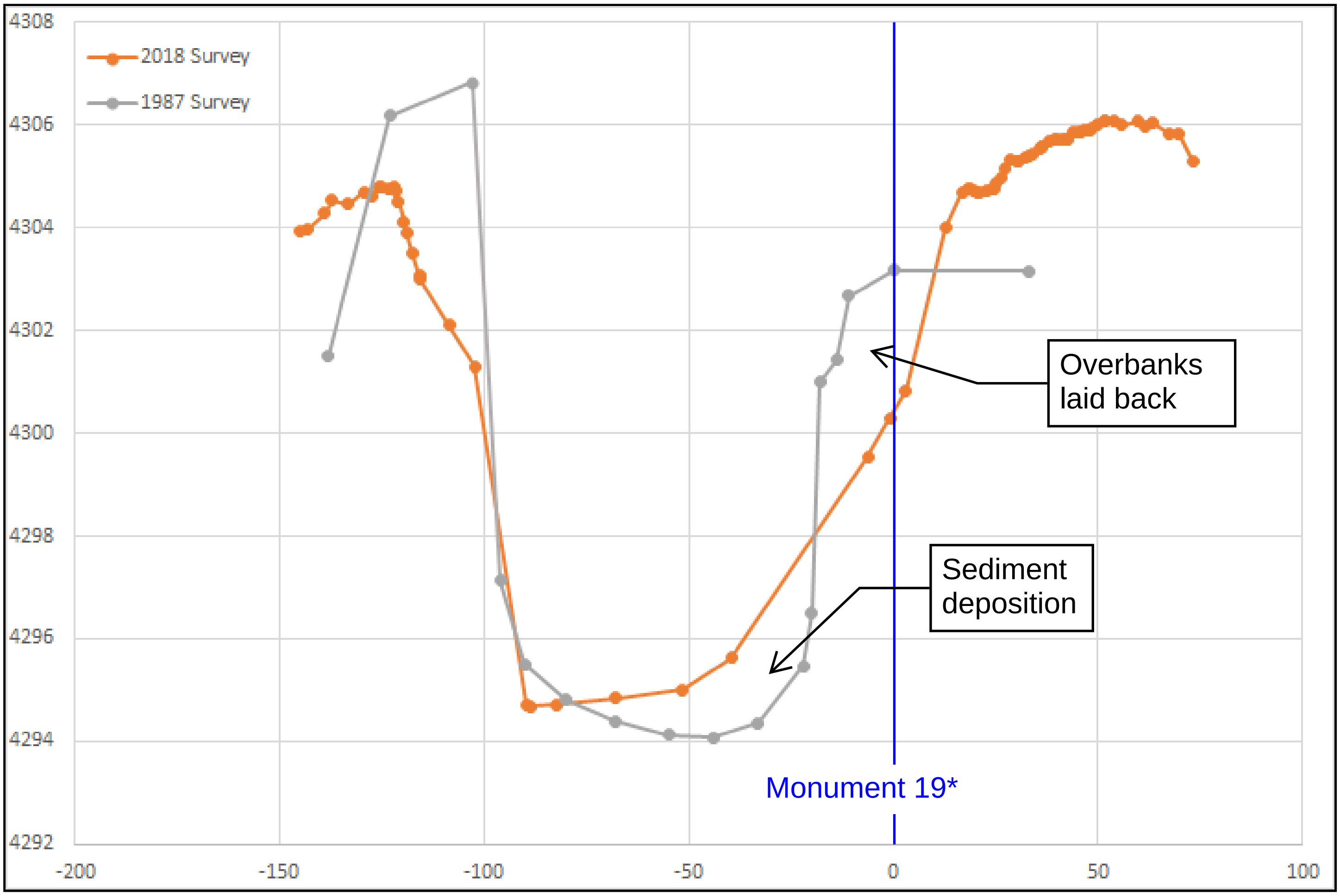


Notes:

1. Approximately 1.5 feet of sedimentation in the channel bottom.
2. Other changes are minimal.

<u>Monumented Cross Sections</u>

Monument 19* (9300 South)

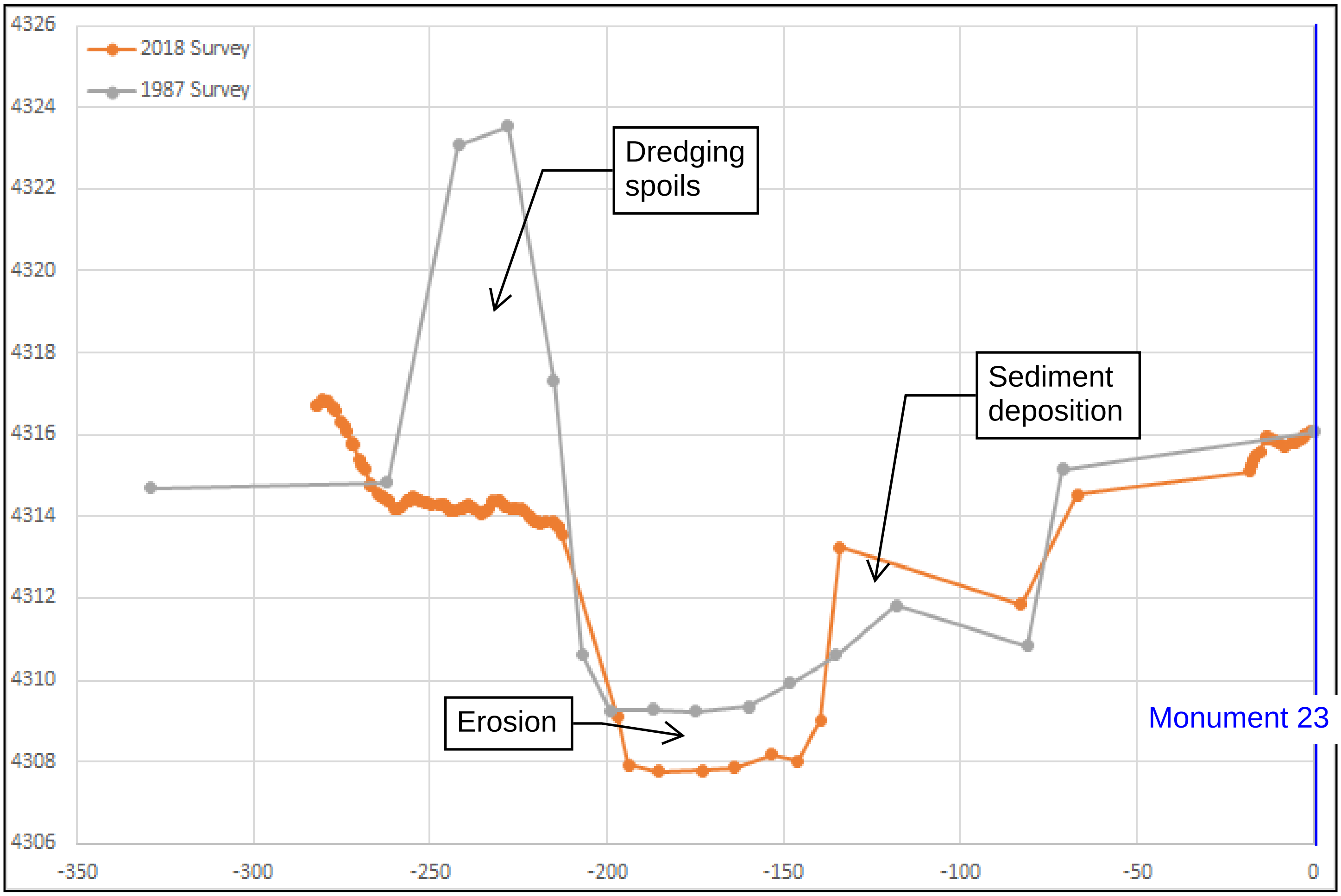


<u>Notes:</u>

1. Approximately 1 foot of sediment deposition in the channel bottom.
2. Overbanks are laid back.

*Monument was not specifically surveyed. However, the 2018 cross section is within approximately 20 feet of the original cross section.

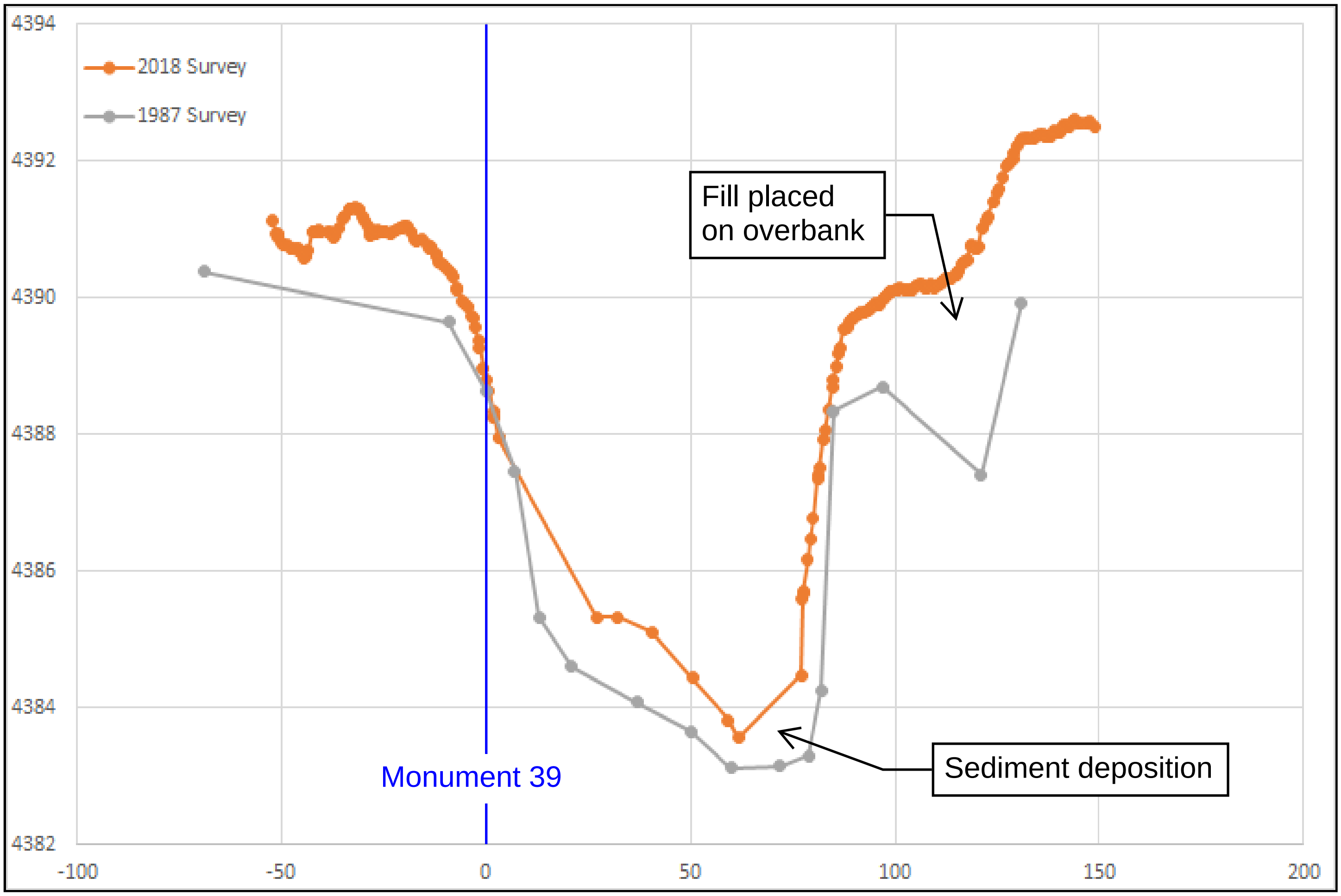
Monumented Cross Sections
Monument 23 (10700 South)



Notes:

1. Channel bottom has experienced erosion approximately 1.5 feet deep.
2. Dredging spoils from 1985 dredging have been removed.

Monumented Cross Sections
Monument 39 (14700 South)



Notes:

1. Approximately 1 foot of sedimentation in channel.
2. Fill has been placed on overbanks.

APPENDIX B
JORDAN RIVER STABILITY STUDY
(CH2M HILL)

09-11-92

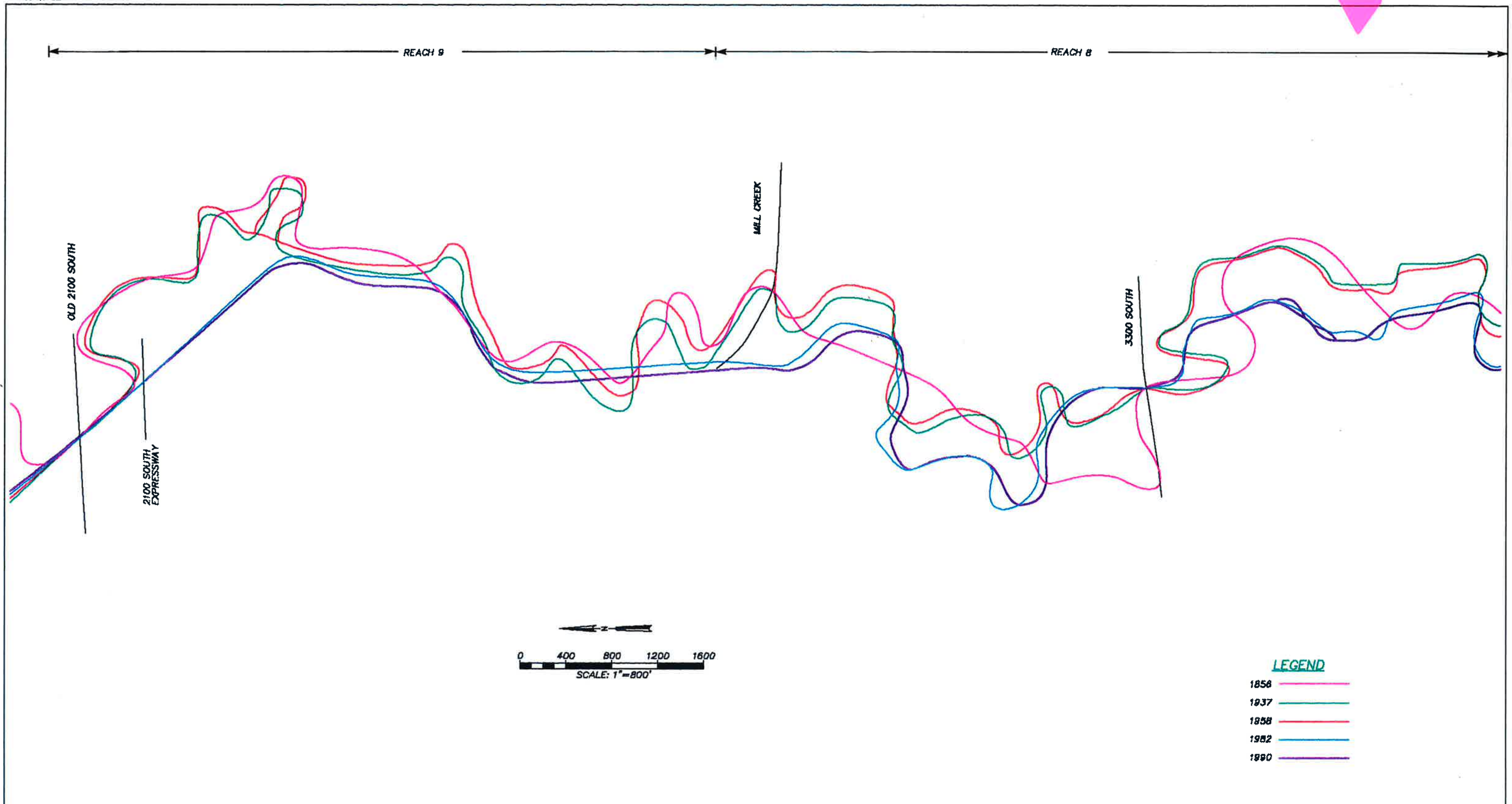


Figure 10 - 1 of 9

JORDAN RIVER CHANNEL LOCATIONS 1856-1990

JORDAN RIVER STABILITY STUDY

CH2M HILL

D:\B33516\56-90-1.DWG

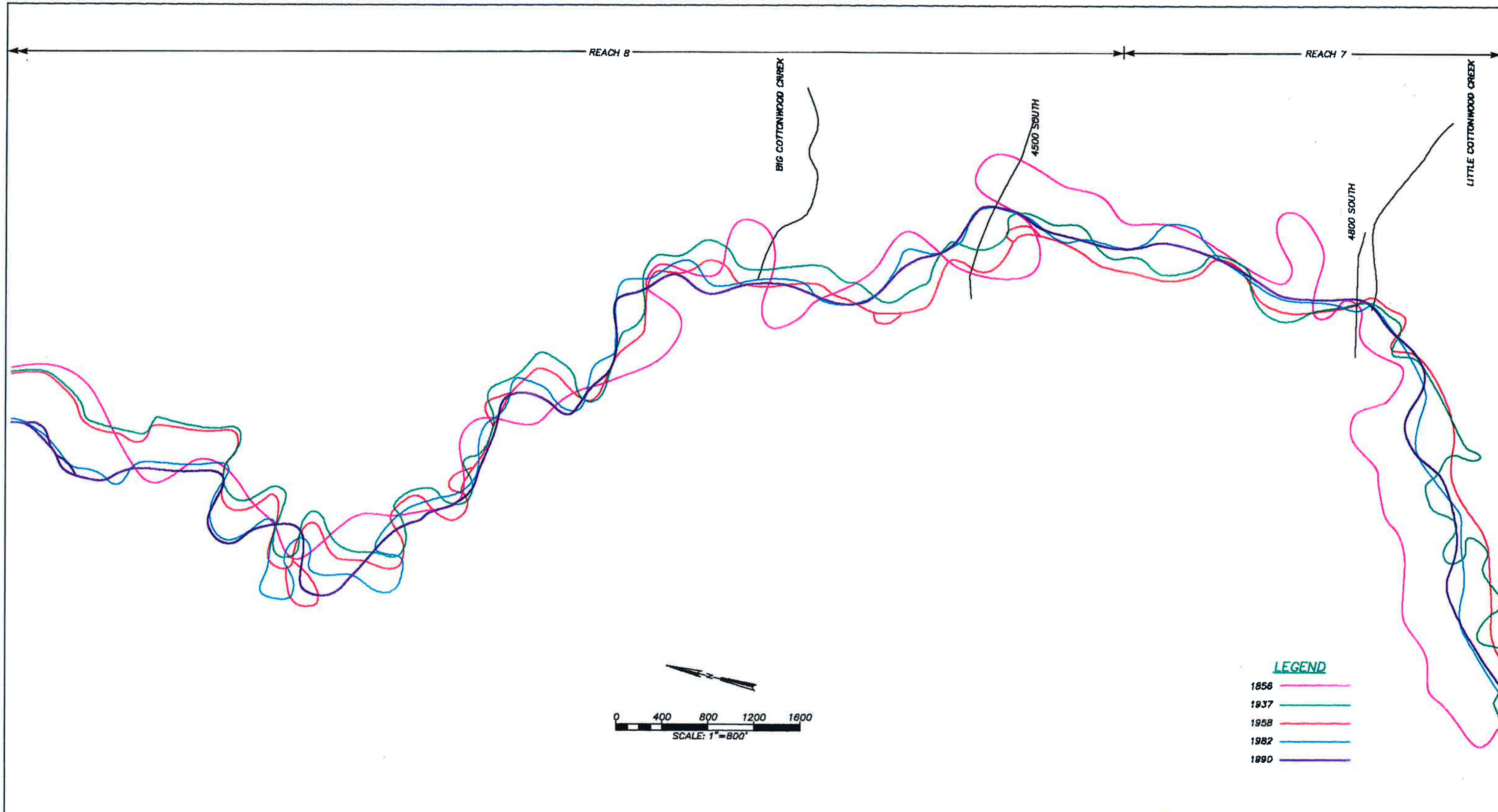


Figure 10 - 2 of 9
JORDAN RIVER CHANNEL LOCATIONS 1856-1990
JORDAN RIVER STABILITY STUDY

CH2M HILL

09-11-92

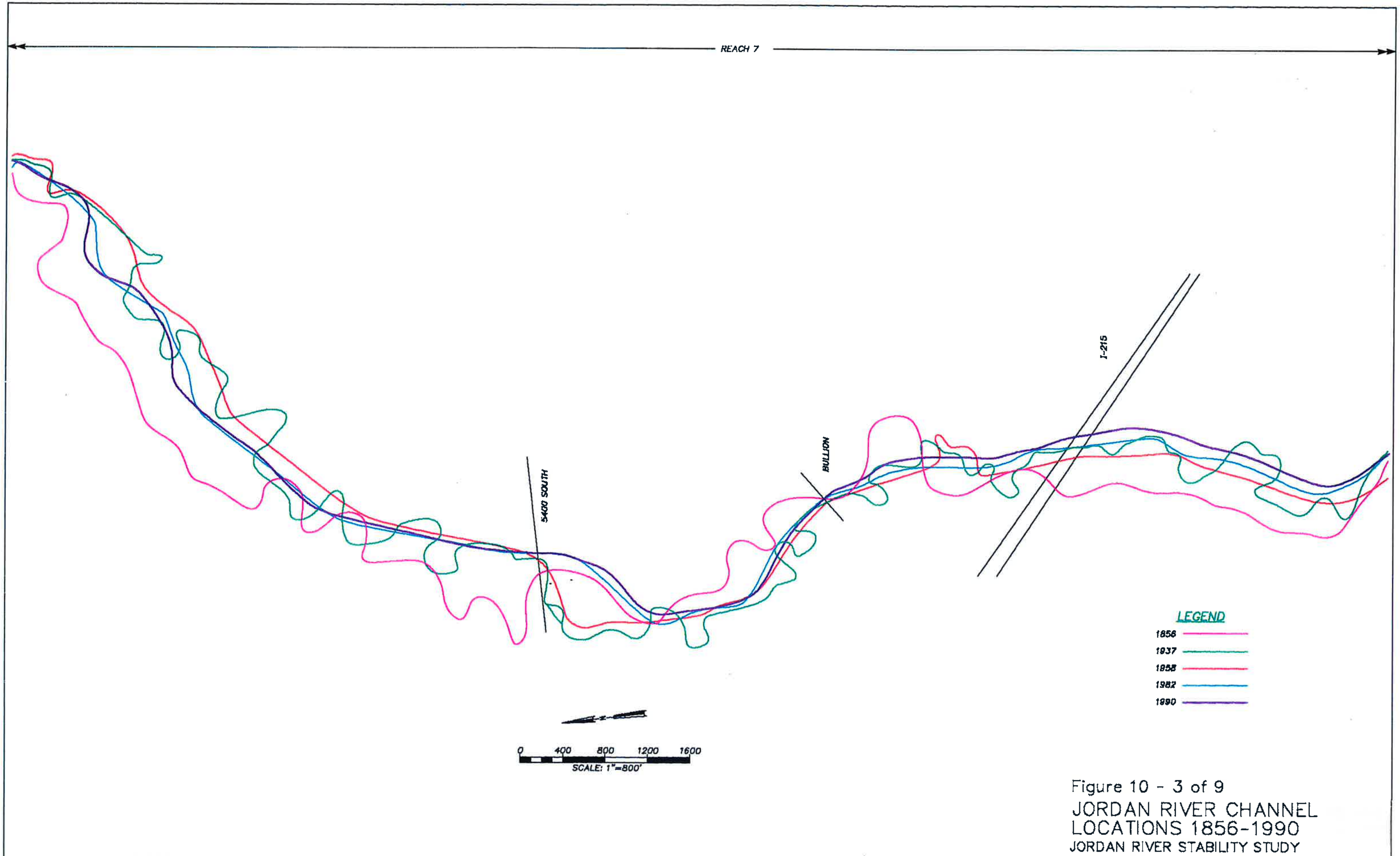


Figure 10 - 3 of 9
JORDAN RIVER CHANNEL
LOCATIONS 1856-1990
JORDAN RIVER STABILITY STUDY

D:\833818\85-90-3.DWG

09-11-92

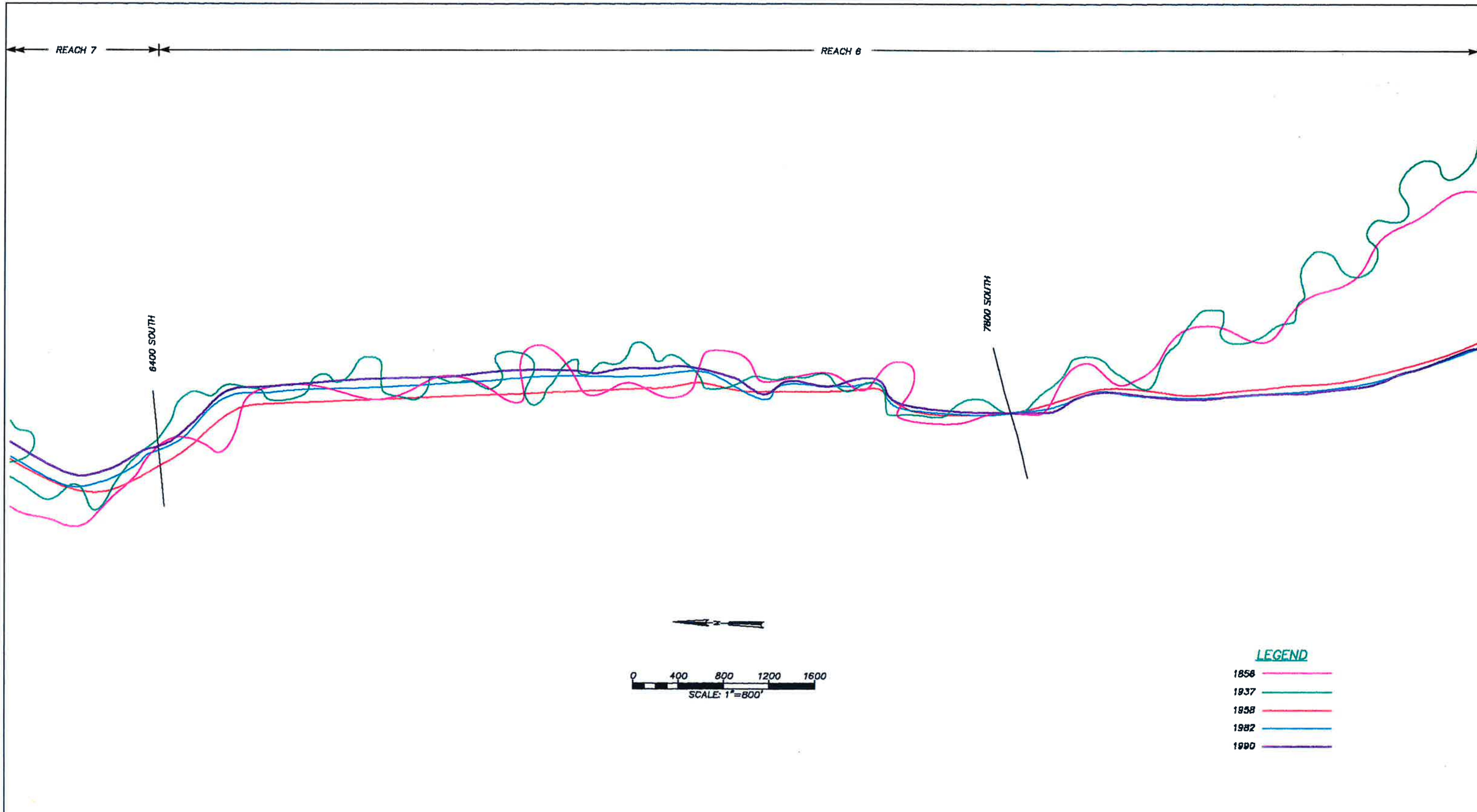


Figure 10 - 4 of 9
JORDAN RIVER CHANNEL
LOCATIONS 1856-1990
JORDAN RIVER STABILITY STUDY

D:\833815\56-90-4.DWG

09-11-92

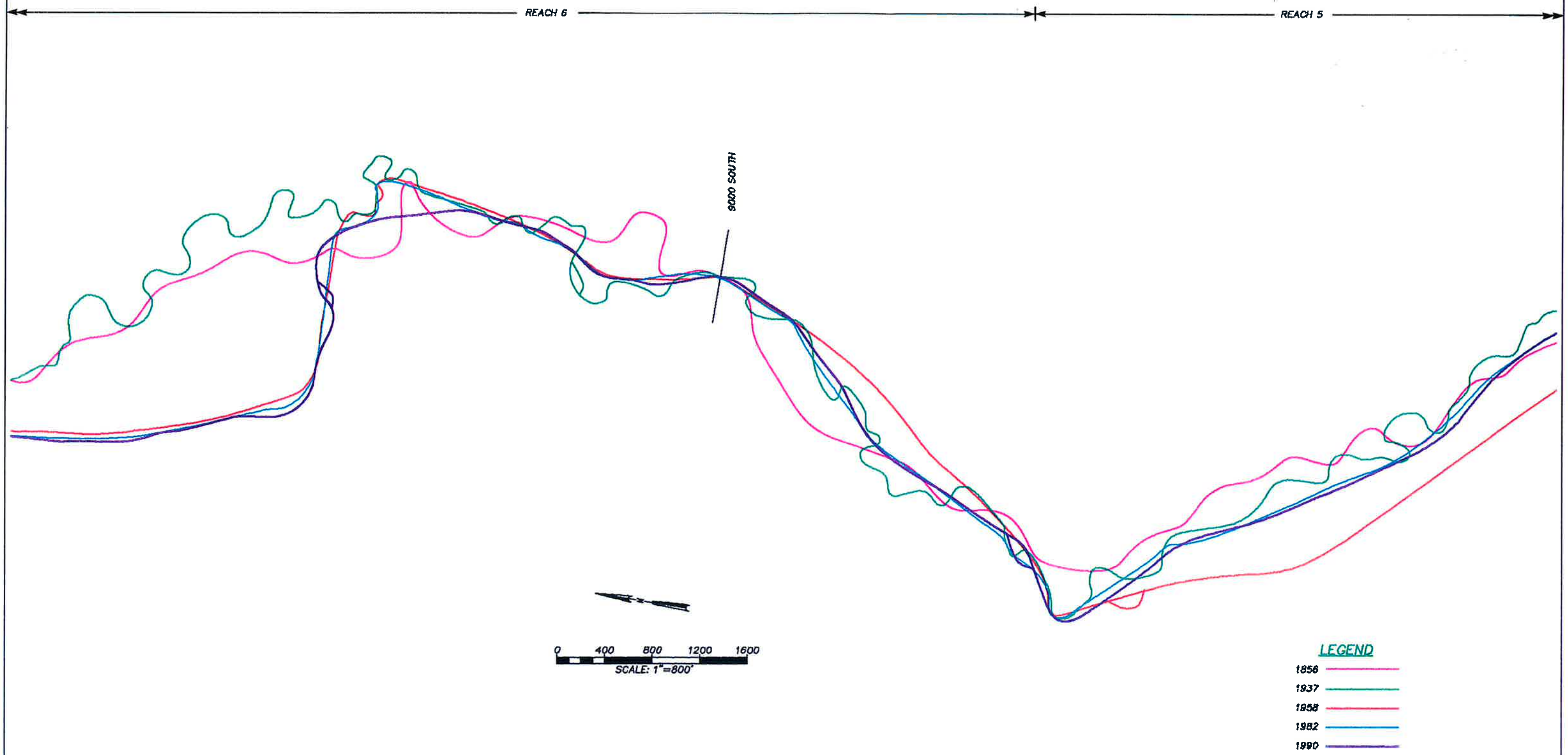


Figure 10 - 5 of 9
JORDAN RIVER CHANNEL LOCATIONS 1856-1990
JORDAN RIVER STABILITY STUDY

CH2M HILL

D:\833818\56-90-5.DWG

09-11-92

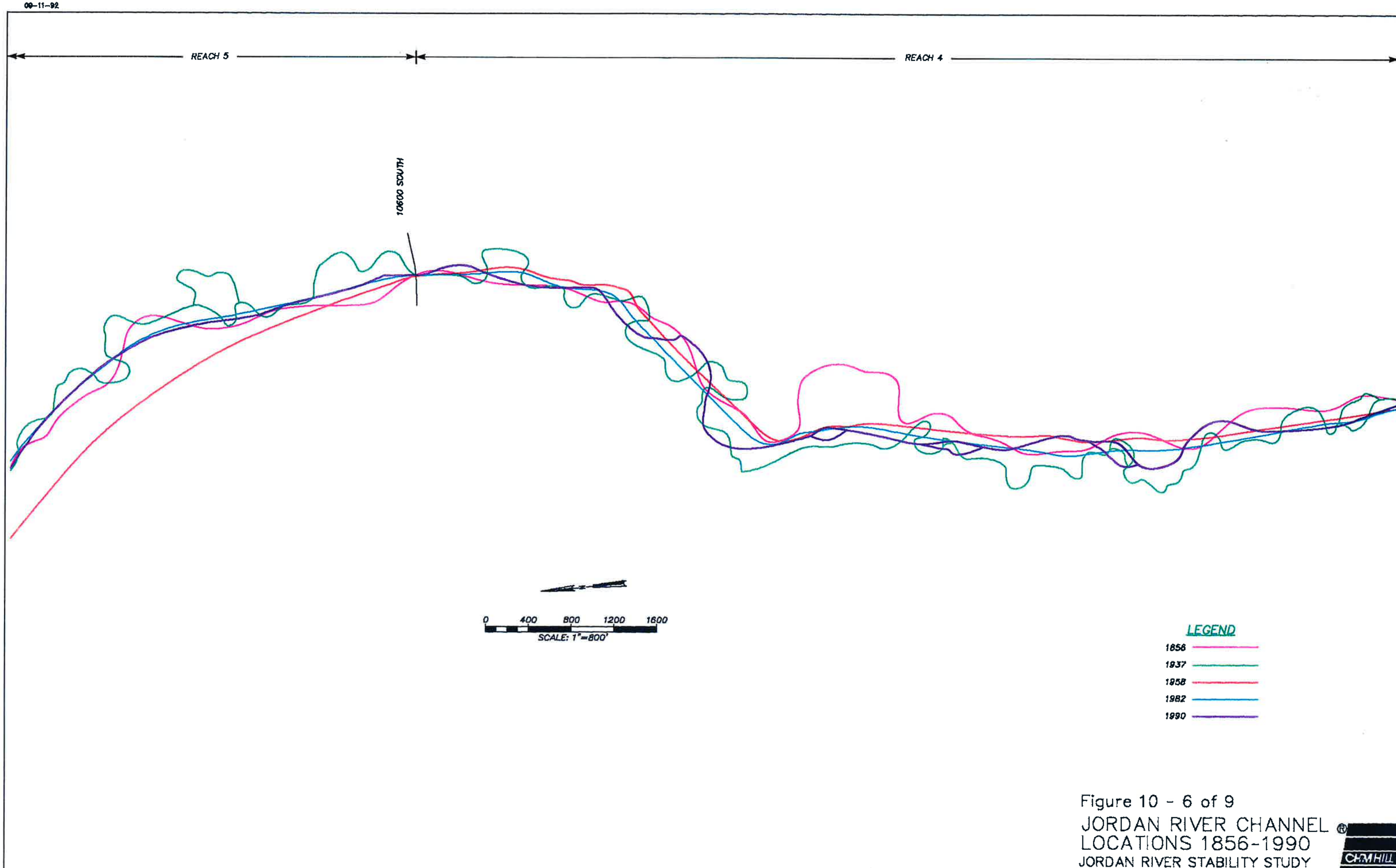


Figure 10 - 6 of 9
JORDAN RIVER CHANNEL LOCATIONS 1856-1990
JORDAN RIVER STABILITY STUDY

CH2M HILL

D:\933618\56-90-6.DWG

09-11-92

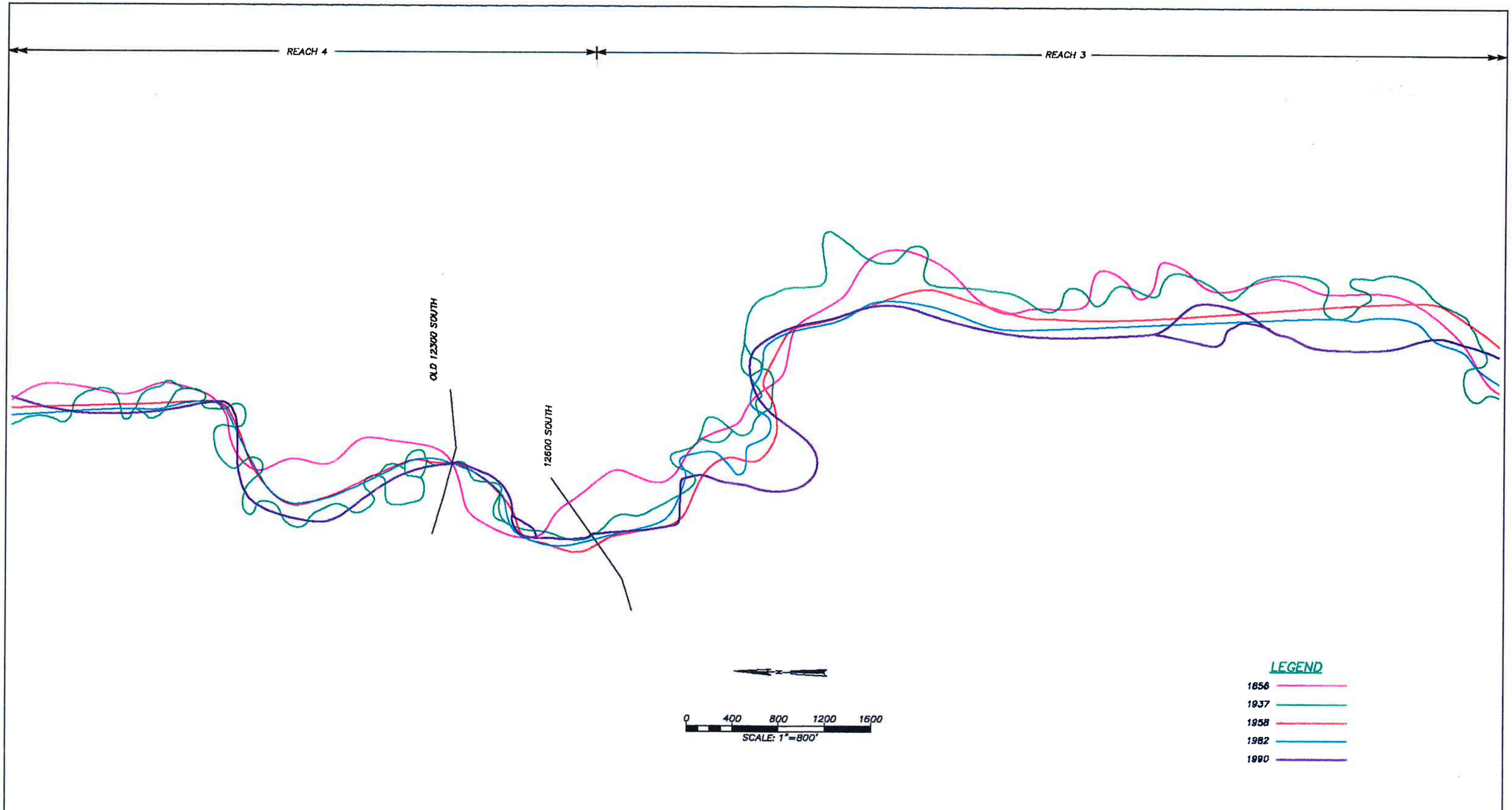


Figure 10 - 7 of 9

JORDAN RIVER CHANNEL LOCATIONS 1856-1990

JORDAN RIVER STABILITY STUDY

CH2M HILL

D:\833818\86-90-7.DWG

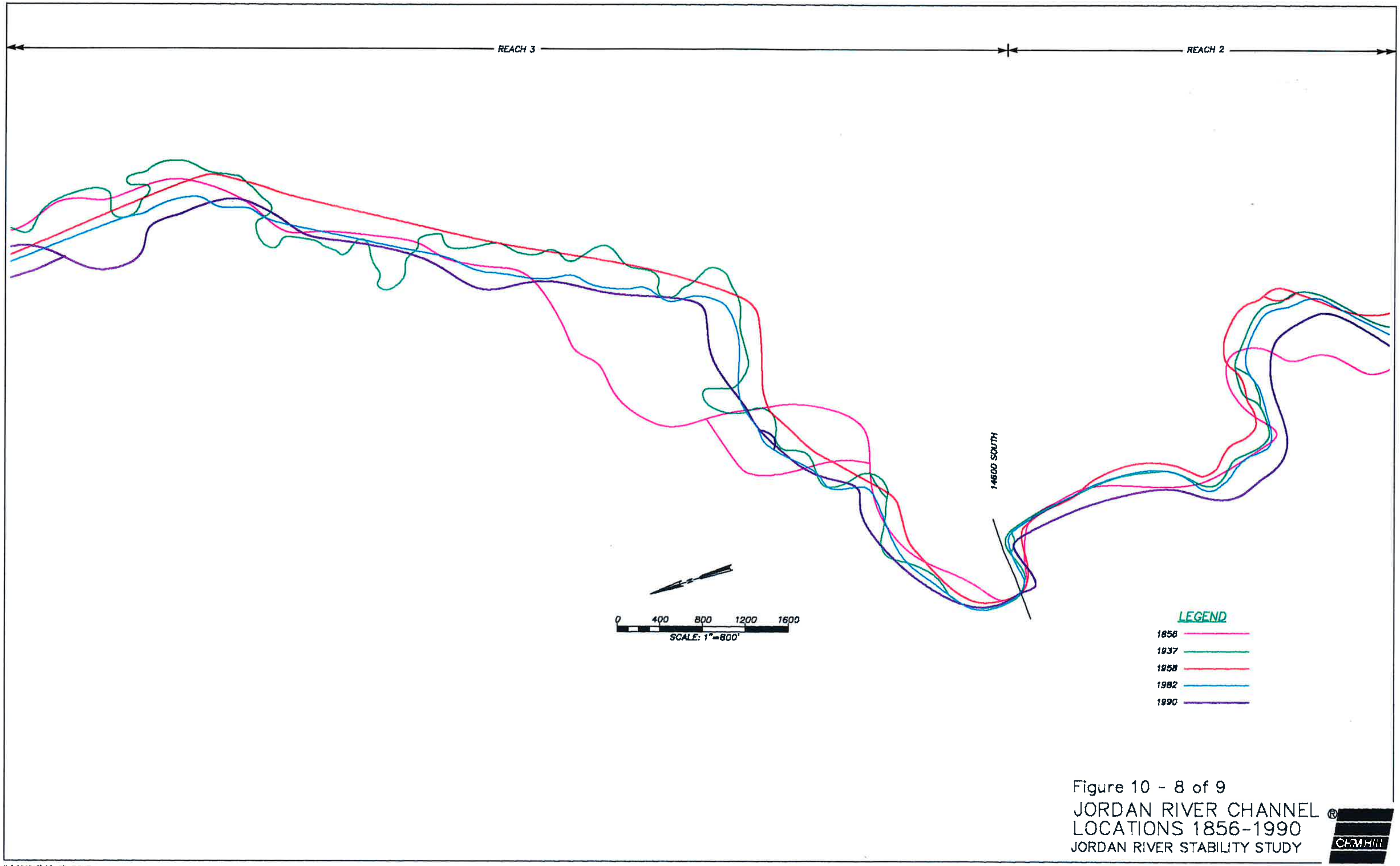


Figure 10 - 8 of 9

JORDAN RIVER CHANNEL LOCATIONS 1856-1990

JORDAN RIVER STABILITY STUDY

CH2M HILL

09-11-92

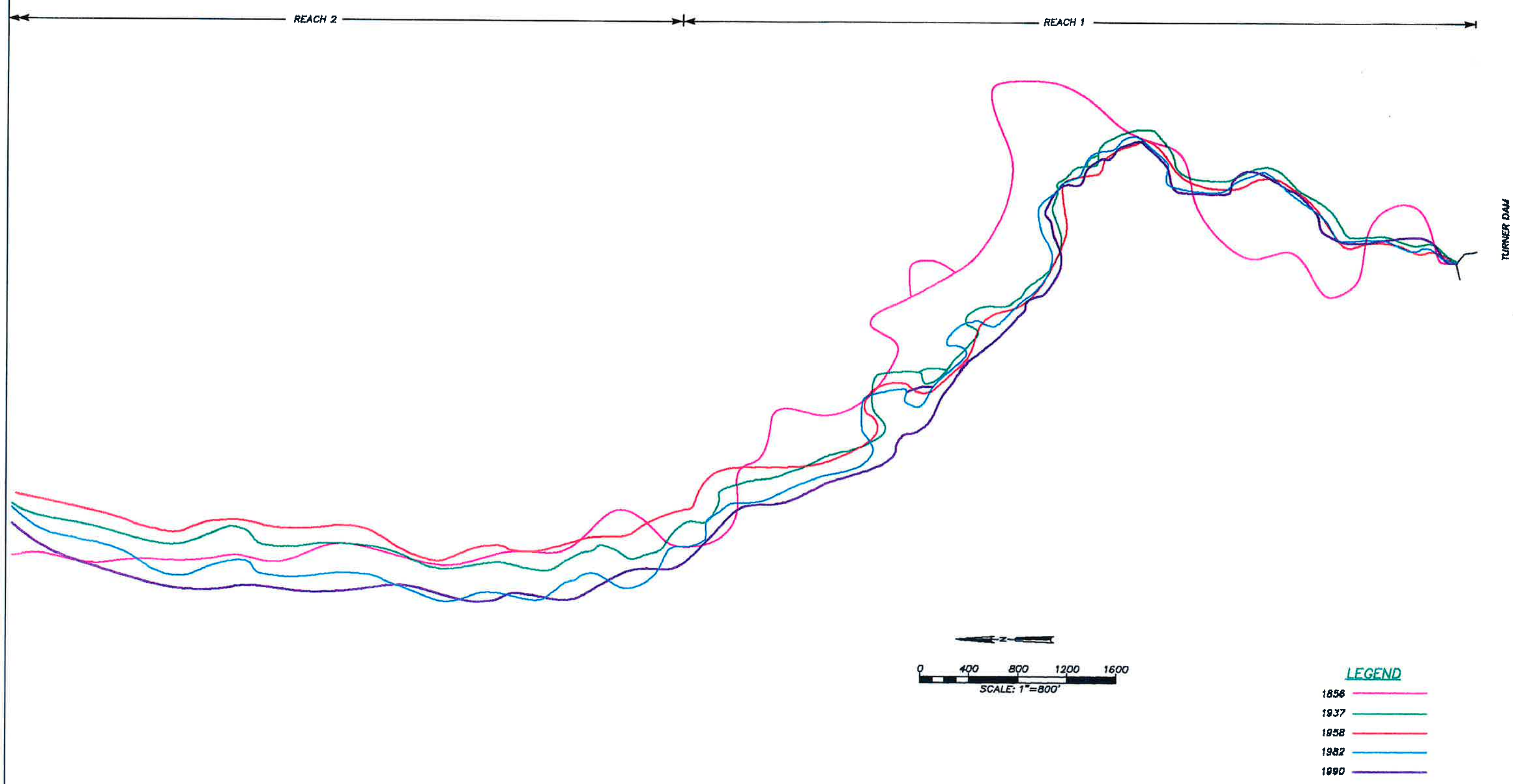
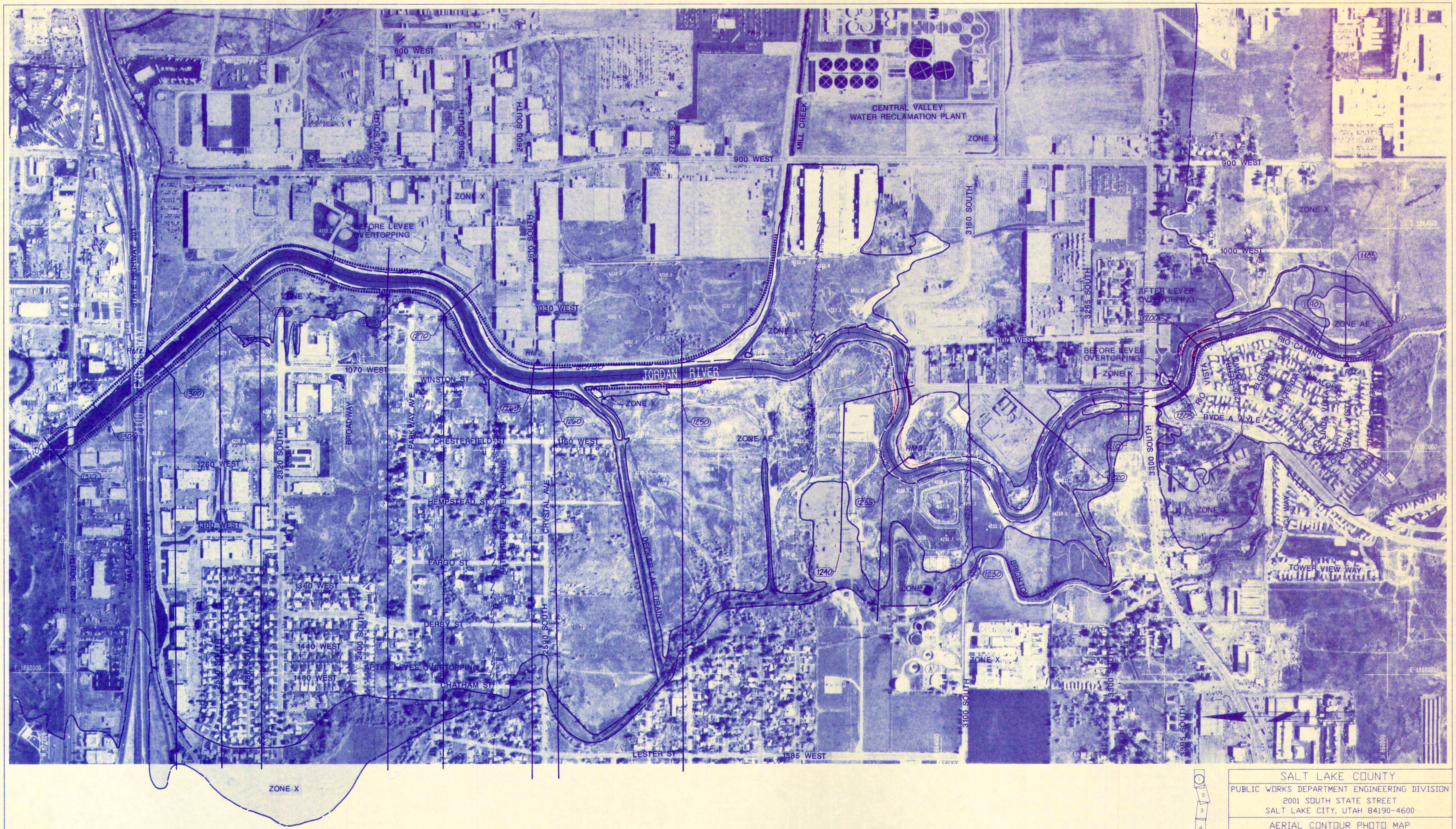


Figure 10 - 9 of 9
JORDAN RIVER CHANNEL LOCATIONS 1856-1990
JORDAN RIVER STABILITY STUDY

CH2M HILL

D:\833618\56-90-9.DWG

APPENDIX C
CURRENT EFFECTIVE FEMA WORKMAPS



OVERLAY IDENTIFICATION	COMPOSITE	1-9.A	1-9	1-9.B	
PROJ NO [redacted]	OVERLAY		1-9	1-9.B	
CONTRACT [redacted]	SCREEN				

BOI30398.A0

SHEET INDEX: 1 2 3 4 5 6 7 8 9

SALT LAKE COUNTY

PUBLIC WORKS DEPARTMENT ENGINEERING DIVISION
2001 SOUTH STATE STREET
SALT LAKE CITY, UTAH 84190-4600

AERIAL CONTOUR PHOTO MAP

JORDAN RIVER 2100 S. - UTAH COUNTY LINE

PHOTO DATE: 11-7-90

CONTOUR INTERVAL: 4' W/ 2' SUP.

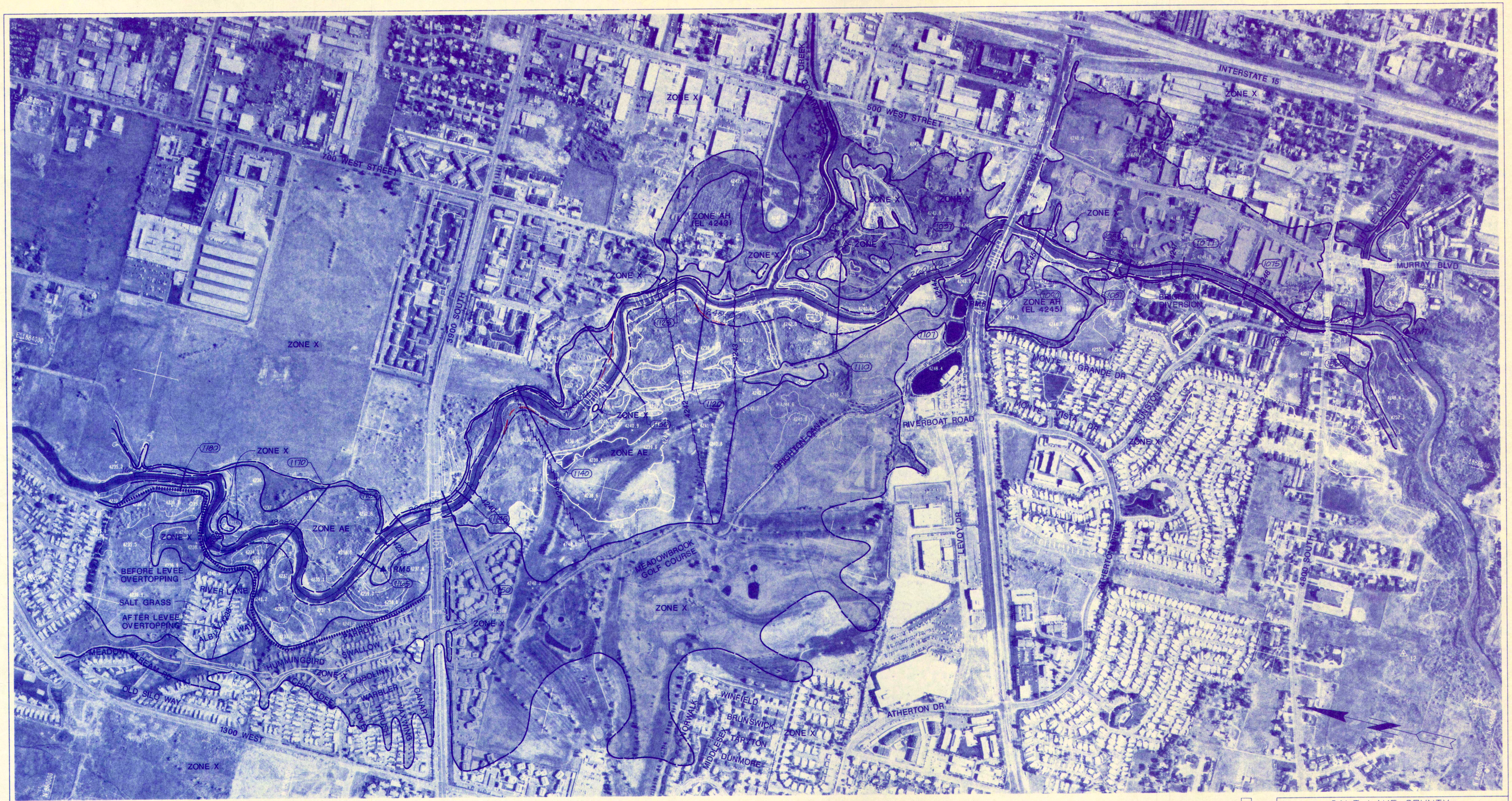
SCALE: 1" = 400'

LOCATION:

ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM
CONTROL SURVEY BY FORSGREN ASSOCIATES/P.A.
PHOTOGRAMMETRIC SERVICES BY AERO-GRAPHICS INC

PROJECT NUMBER FV 89 0120

SHEET NO 1 OF 9



OVERLAY IDENTIFICATION	COMPOSITE	2-9.A	2-9	2-9B
PROJ NO	OVERLAY		2-9	
CONTRACT	SCREEN			2-9B

SHEET INDEX: 1, 2, 3, 4, 5, 6, 7, 8, 9

SALT LAKE COUNTY

PUBLIC WORKS DEPARTMENT ENGINEERING DIVISION
2001 SOUTH STATE STREET
SALT LAKE CITY, UTAH 84190-4600

AERIAL CONTOUR PHOTO MAP

JORDAN RIVER 2100 S. - UTAH COUNTY LINE

PHOTO DATE: 11-7-90
CONTOUR INTERVAL: 4' W/ 2' SUP.
SCALE: 1" = 400'
LOCATION:

ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM
CONTROL SURVEY BY FORSGREN ASSOCIATES/P.A.
PHOTOGRAMMETRIC SERVICES BY AERO-GRAPHICS INC

PROJECT NUMBER FV 89 0120

SHEET NO 2 OF 9

BOI30398.A0

OVERLAY IDENTIFICATION	COMPOSITE	3-9.A	3-9	3-9.B
PROJ NO [redacted]	OVERLAY		3-9	3-9.B
CONTRACT [redacted]	SCREEN			

SHEET INDEX: 1, 2, 3, 4, 5, 6, 7, 8, 9

SALT LAKE COUNTY

PUBLIC WORKS DEPARTMENT ENGINEERING DIVISION
2001 SOUTH STATE STREET
SALT LAKE CITY, UTAH 84190-4600

AERIAL CONTOUR PHOTO MAP

JORDAN RIVER 2100 S. - UTAH COUNTY LINE

PHOTO DATE: 11-7-90

CONTOUR INTERVAL: 4' W/ 2' SUP.

SCALE: 1" = 400'

LOCATION:

ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM
CONTROL SURVEY BY FORSGREN ASSOCIATES/P.A.
PHOTOGRAMMETRIC SERVICES BY AERO-GRAPHICS INC

PROJECT NUMBER FV 89 0120

SHEET NO 3 OF 9

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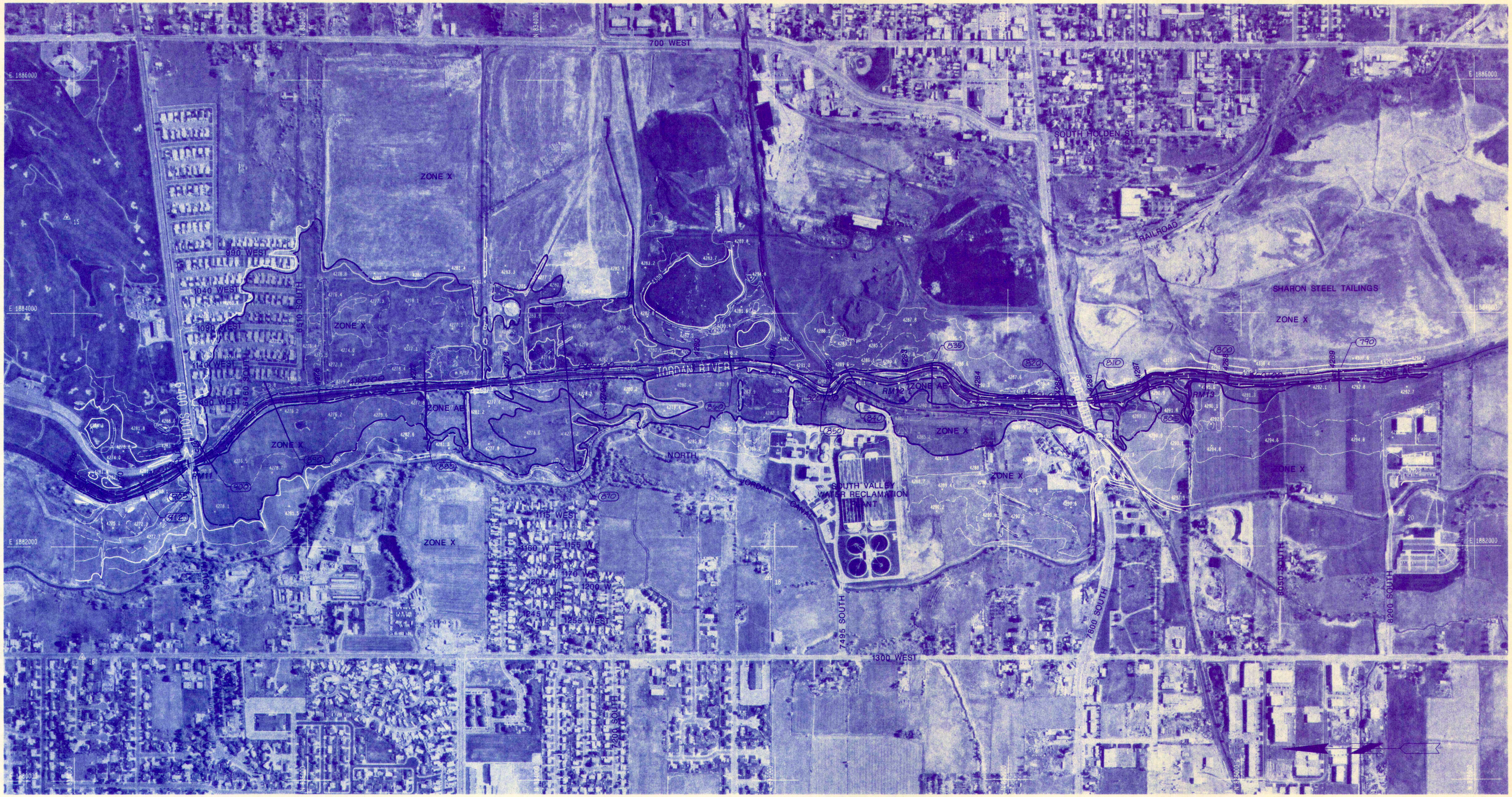


SHEET INDEX

1 2 3 4 5 6 7 8 9

SALT LAKE COUNTY

PUBLIC WORKS DEPARTMENT ENGINEERING DIVISION
2001 SOUTH STATE STREET
SALT LAKE CITY, UTAH 84190-4600

AERIAL CONTOUR PHOTO MAP

JORDAN RIVER 2100 S. - UTAH COUNTY LINE

PHOTO DATE: 11-7-90
CONTOUR INTERVAL: 4' W/ 2' SUP.
SCALE: 1" = 400'
LOCATION:

ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM
CONTROL SURVEY BY FORSGREN ASSOCIATES/P.A.
PHOTOGRAMMETRIC SERVICES BY AERO-GRAPHICS INC

PROJECT NUMBER FV 89 0120

SHEET NO 4 OF 9

BOI30398.A0

SHEET INDEX

SALT LAKE COUNTY	
PUBLIC WORKS DEPARTMENT ENGINEERING DIVISION 2001 SOUTH STATE STREET SALT LAKE CITY, UTAH 84190-4600	
AERIAL CONTOUR PHOTO MAP	
JORDAN RIVER 2100 S. - UTAH COUNTY LINE	
PHOTO DATE: 11-7-90	
CONTOUR INTERVAL: 4' W/ 2' SUP.	
SCALE: 1" = 400'	
LOCATION:	
ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM CONTROL SURVEY BY FORSGREN ASSOCIATES/P.A. PHOTOGRAMMETRIC SERVICES BY AERO-GRAPHICS INC	
PROJECT NUMBER FV 89 0120	SHEET NO 5 OF 9

BOI30398 A0

OVERLAY IDENTIFICATION	COMPOSITE	6-9.A	6-9	6-9.B	
PROJ NO	OVERLAY		6-9	6-9.B	
CONTRACT	SCREEN				

BOI30398.A0

SHEET INDEX

1 2 3 4 5 6 7 8 9

SALT LAKE COUNTY

PUBLIC WORKS DEPARTMENT ENGINEERING DIVISION
2001 SOUTH STATE STREET
SALT LAKE CITY, UTAH 84190-4600

AERIAL CONTOUR PHOTO MAP

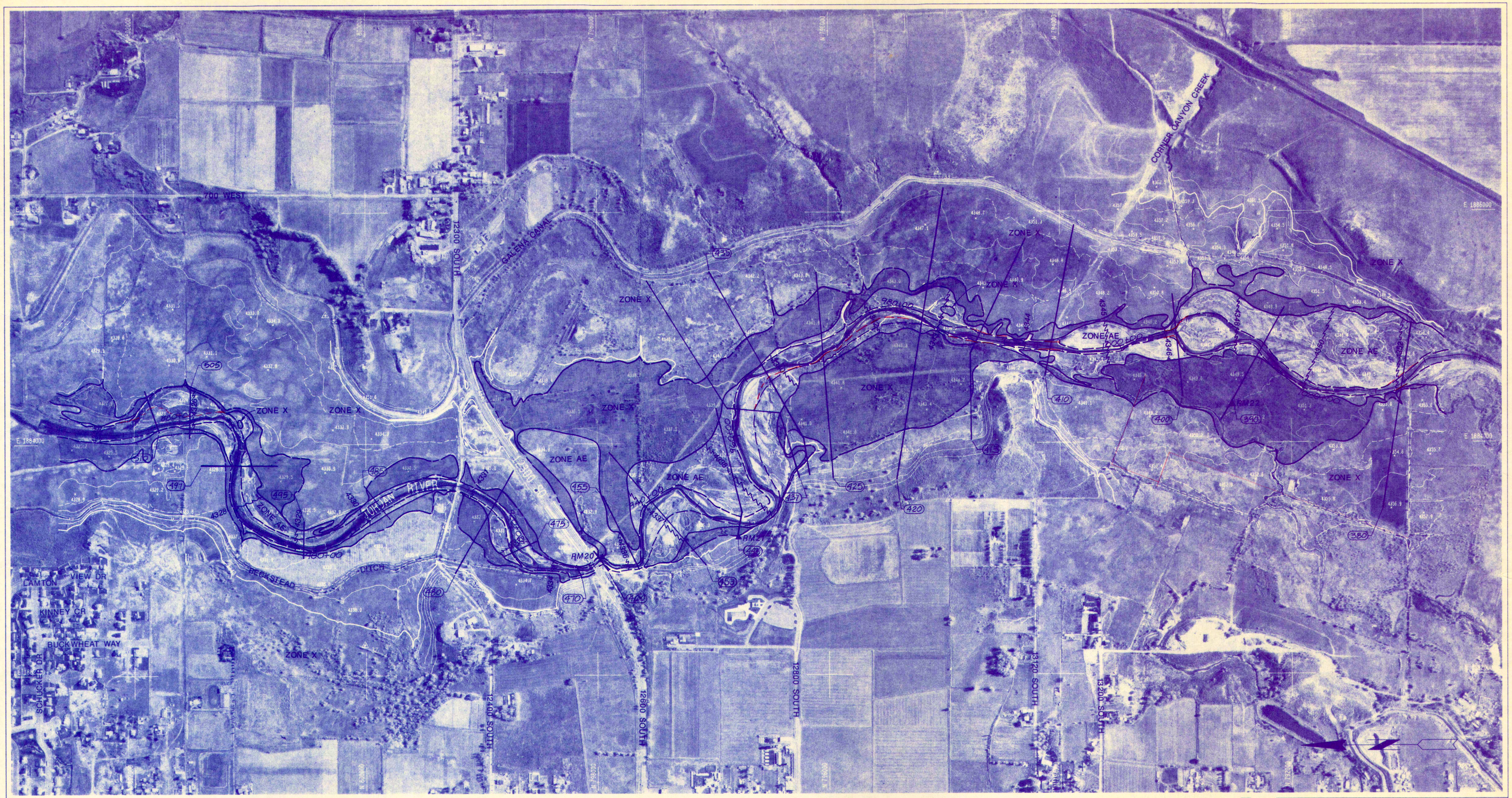
JORDAN RIVER 2100 S. - UTAH COUNTY LINE

PHOTO DATE: 11-7-90
CONTOUR INTERVAL: 4' W/ 2' SUP.
SCALE: 1" = 400'
LOCATION:

ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM
CONTROL SURVEY BY FORSGREN ASSOCIATES/P.A.
PHOTOGRAMMETRIC SERVICES BY AERO-GRAPHICS INC

PROJECT NUMBER FV 89 0120

SHEET NO 6 OF 9



OVERLAY IDENTIFICATION	COMPOSITE	7.9.A	7-9	7-9-B	
PROJ NO	[redacted]	OVERLAY		7-9	7-9.B
CONTRACT	[redacted]	SCREEN			

SHEET INDEX: 1 2 3 4 5 6 7 8 9

SALT LAKE COUNTY

PUBLIC WORKS DEPARTMENT ENGINEERING DIVISION
2001 SOUTH STATE STREET
SALT LAKE CITY, UTAH 84190-4600

AERIAL CONTOUR PHOTO MAP

JORDAN RIVER 2100 S. - UTAH COUNTY LINE

PHOTO DATE: 11-7-90
CONTOUR INTERVAL: 4' W/ 2' SUP.
SCALE: 1" = 400'
LOCATION:

ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM
CONTROL SURVEY BY FORSGREN ASSOCIATES/P.A.
PHOTOGRAMMETRIC SERVICES BY AERO-GRAPHICS INC

PROJECT NUMBER FV 89 0120

SHEET NO 7 OF 9

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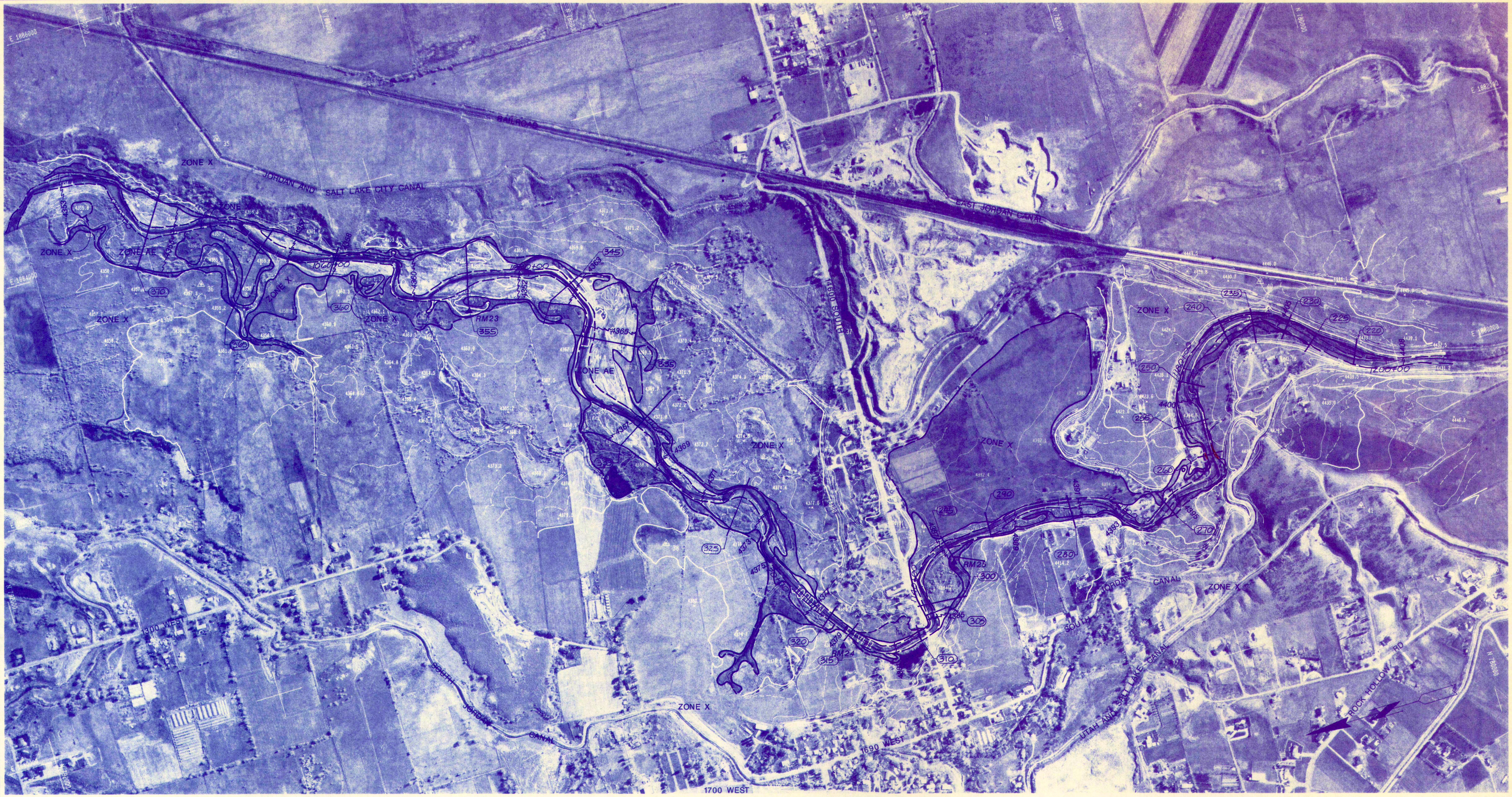
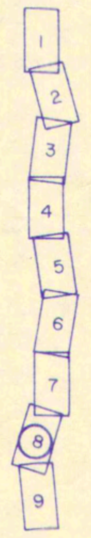




SALT LAKE COUNTY

PUBLIC WORKS DEPARTMENT ENGINEERING DIVISION
2001 SOUTH STATE STREET
SALT LAKE CITY, UTAH 84190-4600

AERIAL CONTOUR PHOTO MAP

JORDAN RIVER 2100 S. - UTAH COUNTY LINE

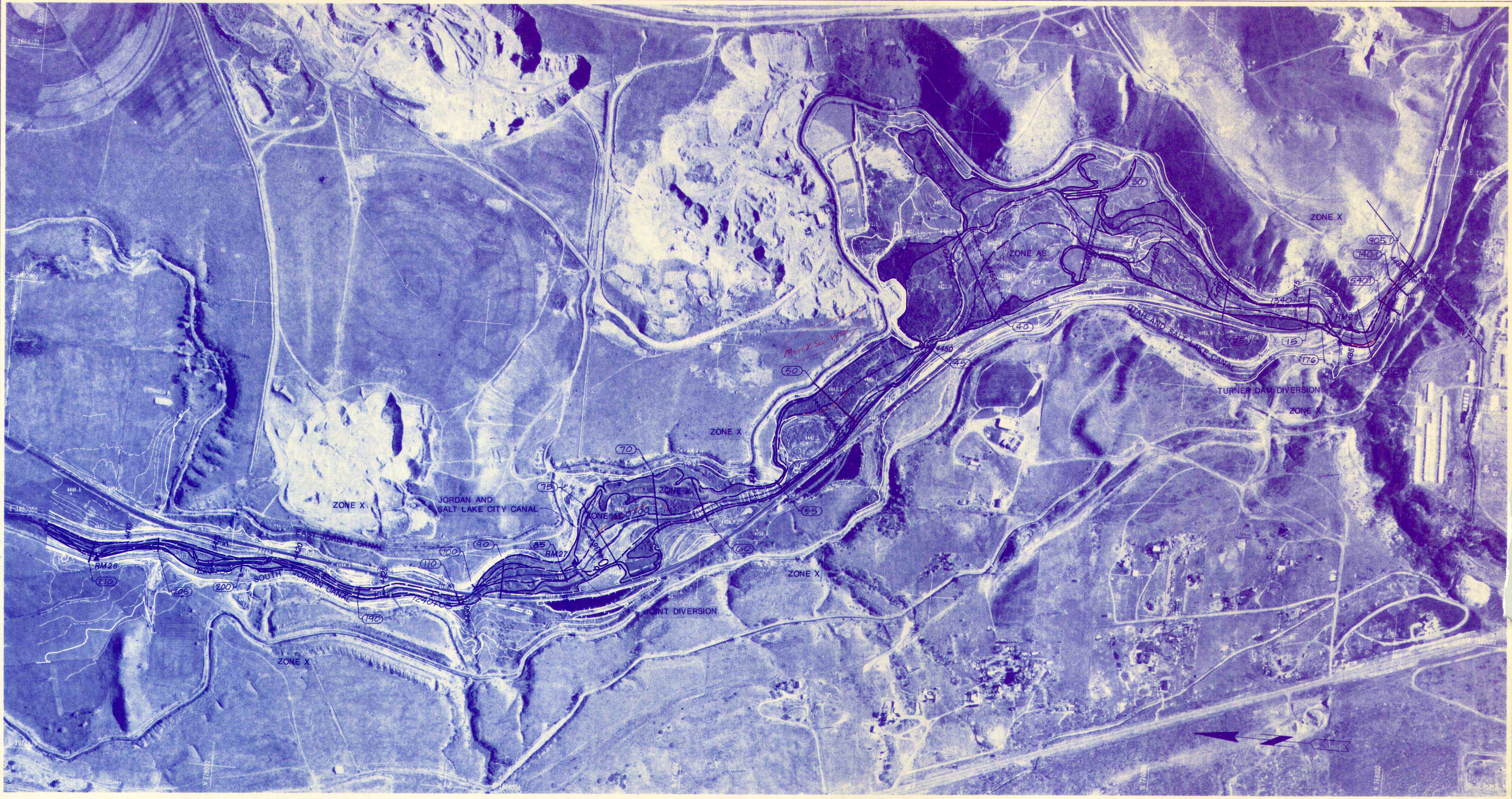
PHOTO DATE: 11-7-90
CONTOUR INTERVAL: 4' W/ 2' SUP.
SCALE: 1" = 400'
LOCATION:

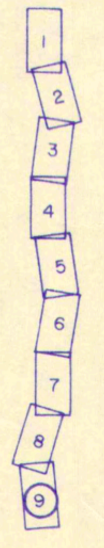
ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM
CONTROL SURVEY BY FORSGREN ASSOCIATES/P.A.
PHOTOGRAMMETRIC SERVICES BY AERO-GRAPHICS INC

PROJECT NUMBER FV 89 0120

SHEET NO 8 OF 9

B0130398 A0





SHEET INDEX

SALT LAKE COUNTY	
PUBLIC WORKS DEPARTMENT ENGINEERING DIVISION 2001 SOUTH STATE STREET SALT LAKE CITY, UTAH 84190-4600	
AERIAL CONTOUR PHOTO MAP	
JORDAN RIVER 2100 S. - UTAH COUNTY LINE	
PHOTO DATE: 11-7-90	
CONTOUR INTERVAL: 4' W/ 2' SUP.	
SCALE: 1" = 400'	
LOCATION:	
ELEVATIONS NATIONAL GEODETIC VERTICAL DATUM CONTROL SURVEY BY FORSGREN ASSOCIATES/P.A. PHOTOGRAMMETRIC SERVICES BY AERO-GRAPHICS INC	
PROJECT NUMBER FV 89 0120	SHEET NO 9 OF 9

B0130398.A0

APPENDIX D
FEMA FIS SUMMARY OF DISCHARGES

Table 8. Summary of Discharges

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges cfs[1] 10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
Big Cottonwood Creek					
At Canyon Mouth	50.0	625	880	1,230	3,800
At Fairview Drive (2200 East)	--[2]	660	880	1,100	3,000
At Highland Circle	--[2]	1,150	1,900	2,200	3,600
Below Creekside Detention Basin	--[2]	640	800	880	1,020
At 900 East Street	70.9	690	860	920	1,100
At 400 East Street	72.6	720	890	1,000	1,500
At Jordan River	78.2	760	920	1,030	1,110
Burr Fork					
At Mouth	--[2]	75	125	150	220
Corner Canyon Creek					
At Union Pacific Railroad	5.00	40	205	290	890
At 300 East Street	5.00	25	180	285	975
At I-15	6.00	25	175	315	1,040
At Denver and Rio Grande Western Railroad	7.00	25	120	240	700
Dry Creek					
At Dimple Dell Road	4.00	5	30	320	1,630
At 2300 East Street (extended)	5.00	50	90	420	1,845
At 1300 East Street	11.00	110	200	510	2,120
At 700 East Street	13.00	130	240	550	1,750
At 300 West Street (located in South Jordan)	14.00	125	195	420	750
Emigration Creek and Burr Fork					
At Canyon Mouth	19.00	75	125	150	220

[1]Reductions in flow are generally due to detention storage through roadway fills or loss of flow to shallow flooding in overbank areas.
[2]Data not available.

Table 8. Summary of Discharges (Cont'd)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges cfs[1] 10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
Emigration Creek					
At Foothill Drive (U.S. Highway 40 (US 40) and State Highway 186 (SH 186)	20.10	88	150	180	265
At 13th South Street	23.00	135	360	1,010	2,740
At 19th East Street	23.00	130	360	950	2,840
At 17th South Street	23.00	125	305	360	360
At 15th East Street	23.00	125	260	300	300
At 13th East Street (State Highway 181)	24.20	120	240	300	300
At Entrance to Conduit	24.20	220	280	315	330
Jordan River					
At Narrows	2,755.00	1,260	2,400	3,000	4,800
At 9000 South Street	2,905.00	1,170	2,230	2,790	4,465
At 5800 South Street	2,985.00	1,200	2,280	2,850	4,560
At Little Cottonwood Creek Confluence	--[2]	1,585	3,010	3,740	5,925
At Big Cottonwood Creek Confluence	--[2]	1,930	3,665	4,535	7,145
At Mill Creek Confluence	--[2]	2,000	3,800	4,700	7,400
At 2100 South Street	3,165.00[3]	2,000	3,800	4,700	7,400
At Redwood Road	140.00[4]	1,233	1,233	1,233	1,233
Downstream of Surplus Canal Diversion	4.34	235[5]	250[5]	250[5]	250[5]
At 13th South Street Extended	107.60[4]	825	920	1,010	1,145
At Union Pacific Railroad Bridge	110.20[4]	910	1,005	1,095	1,230
At Indiana Avenue	116.70[4]	1,220	1,315	1,405	1,540
At 5th South Street	116.70[4]	1,350	1,445	1,530	1,670
At 4th South Street	117.00[4]	1,370	1,485	1,585	1,785
At North Temple Street (US 40 and SH 186)	140.30[4]	1,460	1,615	1,790	2,095
At 500 North Street	140.30[4]	1,460	1,610	1,765	2,060
At 700 North Street	140.30[4]	1,285	1,325	1,370	1,475
At Rose Park Golf Course Bridge	140.30[4]	1,200	1,200	1,200	1,200

[1]Reductions in flow are generally due to detention storage through roadway fills or loss of flow to shallow flooding in overbank areas. [2]Data not available. [3]Value estimated based on published drainage area for gage at 1700 South Street. [4]Drainage area does not include tributary area upstream of the Surplus Canal diversion. [5]Includes a base flow of 200 cfs diverted from the Upper Jordan River Basin through diversion structures located at Surplus Canal.

Table 8. Summary of Discharges (Cont'd)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges cfs[1] 10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
Little Cottonwood Creek					
At Canyon Mouth	27.40	690	1,000	1,400	4,000
Near 1445 East Street	--[2]	760	1,100	1,380	2,800
At I-215	--[2]	830	1,200	1,450	2,150
At 900 East Street	42.70	790	980	1,050	1,200
At 700 East Street	44.30	790	980	1,050	1,200
At State Street	45.50	770	955	1,035	1,200
At Jordan River	46.10	780	955	1,035	1,200
Little Willow Creek					
At Canyon Mouth	--[2]	--[2]	--[2]	140	--[2]
At Pioneer Road	--[2]	--[2]	--[2]	159	--[2]
At 2000 East	--[2]	--[2]	--[2]	246	--[2]
Through Detention Basin	--[2]	--[2]	--[2]	140	--[2]
At Hidden Valley Country Club	--[2]	--[2]	--[2]	140	--[2]
Midas Creek					
Confluence with Jordan River to upstream South Jordan Canal	15.41	372	907	1,139	1,600
To upstream of the Utah and South Lake Canal	14.83	270	740	937	1,300
To upstream of the Utah Lake Distributing Canal	14.38	236	681	873	1,250
To 3600 West Street	13.91	224	660	844	1,200
At 6000 West	--[2]	--[2]	--[2]	410	--[2]
Approximately 3,000 feet upstream of Midas Vista Street	--[2]	--[2]	--[2]	503	--[2]
At Provo Reservoir Canal	--[2]	--[2]	--[2]	497	--[2]
At 4000 West	--[2]	--[2]	--[2]	495	--[2]
At 3600 West	--[2]	--[2]	--[2]	168	--[2]

[1]Reductions in flow are generally due to detention storage through roadway fills or loss of flow to shallow flooding in overbank areas.
[2]Data not available.

Table 8. Summary of Discharges (Cont'd)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges cfs[1] 10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
Mill Creek					
At Canyon Road	22.00	150	260	340	1,800
Downstream of 2700 East Street	27.00	520	620	710	1,900
At Canyon Way	28.00	790	900	1,030	2,600
Downstream of Highland Drive	31.00	370	450	540	600
At 700 East Street (upstream of South Salt Lake)	33.00	700	750	800	850
At 3300 South Street	32.00	370	380	400	460
At 400 East Street	35.40	380	650	660	670
At the Jordan River	40.80	380	580	660	900
Parleys Creek					
At Canyon Mouth	51.00	240	330	370	450
Red Butte Creek					
At Canyon Mouth	11.00	40	60	70	100
At Foothill Drive (US 40 and SH 186)	11.35	45	75	140	270
At Sunnyside Avenue	11.50	90	110	170	370
At 15th East Street	11.73	150	190	260	380
At 13th East Street	11.89	170	200	240	340
Willow Creek					
At Kathy Drive	4.00	10	25	230	1,100
At 11700 South Street	5.00	70	100	300	1,150
At 12300 South Street (west of I-15, upstream of South Jordan)	17.00	25	150	276	922
Willow Creek (East)					
At 11700 South Street (upstream of Draper)	5.00	70	100	300	1,150
At 12400 South Street (above Union Pacific Railroad)	10.00	10	25	330	1,400
Willow Creek (West)					
At I-15	13.00	15	42	60	60
At 11400 South Street	15.00	200	350	380	445

APPENDIX E
JORDAN RIVER/SURPLUS CANAL CLOMR

Bowen Collins
& Associates, Inc.
CONSULTING ENGINEERS

154 EAST 14000 SOUTH • DRAPER, UTAH 84020
TEL: (801) 495-2224 • FAX: (801) 495-2225

September 14, 2015

LOMC Clearinghouse

Subject: Request for a Hydrology Revision for the Jordan River and Surplus Canal

Dear LOMC Clearinghouse Representative:

This letter, attached forms and supporting information are respectfully submitted on behalf of Salt Lake County with the petition that the current effective hydrology for the Jordan River and Surplus Canal be revised. The attached Technical Memorandum (TM) explains that the 1985 Compromise Agreement is not accounted for in the current effective hydrology. Table 1 below indicates both the current effective and proposed discharges for the Jordan River and Surplus Canal. The proposed discharges are based on the legal requirement that discharges from Utah Lake into the Jordan River be regulated at the Utah Lake Outlet such that the peak discharge in the Jordan River at 2100 South does not exceed 3,400 cfs (and therefore in the Surplus Canal immediately downstream).

Table 1
Summary of Proposed Flood Insurance Discharges for the Jordan River and Surplus Canal (cfs)

Location	10-Year	50-Year	100-Year	500-Year
At Head of Surplus Canal	1,900	(NA) 3,300	(NA) 3,300	(NA) 3,300
At 2100 South	2,000	(3,800) 3,400	(4,700) 3,400	(7,400) 3,400
At Mill Creek Confluence	2,000	(3,800) 3,400	(4,700) 3,400	(7,400) 3,400
At Big Cottonwood Creek Confluence	1,930	(3,665) 3,360	(4,535) 3,360	(7,145) 3,360
At Little Cottonwood Creek Confluence	1,585	3,010	(3,740) 3,015	(5,925) 3,015
At 5800 South	1,200	2,280	2,850	(4,560) 2,935
At 9000 South	1,170	2,230	2,790	(4,465) 2,900
At Jordan Narrows	1,260	2,400	3,000	(4,800) 3,220

Note: *Black numbers are current effective flood insurance study discharges. Red numbers are proposed discharges that have been reduced to account for the regulation of discharges from Utah Lake in accordance with the 1985 Compromise Agreement requirements to keep peak flows at 2100 South below 3,400 cfs.*

The goal of this submittal is to obtain FEMA's approval of the proposed discharges shown in Table 1. Once that is complete, Salt Lake County will begin making plans to certify the levees along the Surplus Canal. Revising discharge values is a critical component to certifying the levees as it returns the discharge values to the original levee design discharge values. The original levees were design to convey 3,300 cfs. Based on the current effective discharge of 4,700 cfs, the levees are freeboard deficient.

We understand this is a unique request and we look forward to working with you to the successful completion of this request. Your prompt attention to this request will be greatly appreciated. If you have any technical questions pertaining to this request or accompanying backup data, or if you need additional information, please contact Craig Bagley (cbagley@bowencollins.com) or Matt Stayner (mstayner@bowencollins.com).

Sincerely,

Bowen Collins & Associates, Inc.

Matthew H Stayner, P.E., C.F.M.
Project Manager

Federal Emergency Management Agency

Washington, D.C. 20472

July 5, 2016

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

The Honorable Ben McAdams
Mayor, Salt Lake County
2001 South State Street, Suite N2-100
Salt Lake City, UT 84114

IN REPLY REFER TO:
Case No.: 15-08-1395R
Community: Salt Lake County, UT
Community No.: 490102

104

Dear Mayor McAdams:

This responds to a request that the Department of Homeland Security's Federal Emergency Management Agency (FEMA) comment on the effects that revised flood hazard information would have on the effective Flood Insurance Rate Map (FIRM) and Flood Insurance Study (FIS) report for your community in accordance with Part 65 of the National Flood Insurance Program (NFIP) regulations. In a report dated September 2015, Mr. Matthew Stayner, P.E., CFM, of Bowen Collins and Associates, Inc., requested that FEMA evaluate the effects that a revised hydrologic analysis would have on the flood hazard information shown on the effective FIRM and FIS report.

All data required to complete our review of this request for a Conditional Letter of Map Revision (CLOMR) were submitted with letters from Mr. Matthew Stayner, P.E., CFM, of Bowen Collins and Associates, Inc.

Because this revision request also affects the Cities of Murray, Salt Lake City, South Salt Lake City, West Valley City, Taylorsville, Midvale, West Jordan, Sandy City, South Jordan, Draper, Riverton and Bluffdale; separate CLOMRs for those communities were issued on the same date as this CLOMR.

Information pertinent to this revision request is listed below.

Identifier:	Jordan River Surplus Canal Hydrology
Flooding Source:	Jordan River and Surplus Canal
FIRM Panels Affected:	49035C0120E, 0137E, 0139E, 0140E, 0141E, 0143E, 0280E, 0281E, 0283F, 0291G, 0293G, 0431G, 0433G, 0434G, 0441G, 0442G, 0443G, 0581G, & 0583G
FIRM Panels Affected within the Unincorporated Areas of Salt Lake County:	49035C0120E, 0137E, 0291G, 0431G & 0433G

We have completed our review of the submitted data and determined that the discharges presented in the report entitled, "Technical Support for a Hydrology LOMR for the Jordan River and the Surplus Canal" prepared by Bowen Collins and Associates, Inc., dated September 2015, are reasonable and that the effective discharges should be revised. We based this determination on the 1-percent-annual-chance discharges computed in the submitted hydrologic analysis.

Upon completion of a revised hydraulic analysis utilizing this submitted hydrologic analysis, your community must submit the data listed below and request that we make a final determination on revising the effective FIRM and FIS report. Upon completion of the revised hydraulic analysis, a revision to the FIRM and FIS report would be warranted.

- Detailed application and certification forms must be used for requesting final map revisions. Therefore, when the map revision request for the area covered by this letter is submitted, please include the following forms, which may be accessed at https://www.fema.gov/media-library/assets/documents/1343.

    - Form 1, entitled "Overview and Concurrence Form"
    - Form 2, entitled "Riverine Hydrology and Hydraulics Form" Hydraulic analyses of the base flood, the 10-percent, 2-percent, and 0.2-percent-annual-chance floods, and the regulatory floodway, must be submitted with Form 2.

- A certified topographic work map showing the revised and effective base floodplain boundaries. Please ensure that the revised information ties-in with the current effective information at the downstream and upstream ends of the revised reach.

- An annotated copy of the FIRM, at the scale of the effective FIRM, that shows the revised base floodplain boundary delineations shown on the submitted work map and how they tie-in to the base floodplain boundary delineations shown on the current effective FIRM at the downstream and upstream ends of the revised reach.

- Documentation of the individual legal notices sent to property owners who will be affected by any widening or shifting of the base floodplain or any Base Flood Elevation (BFE) establishment along the Jordan River.

FEMA's fee schedule for reviewing and processing requests for conditional and final modifications to published flood information and maps may be accessed at https://www.fema.gov/flood-map-related-fees. The fee at the time of the map revision submittal must be received before we can begin processing the request. Payment of this fee can be made through a check or money order, made payable in U.S. funds to the National Flood Insurance Program, or by credit card (Visa or MasterCard only). Please either forward the payment, along with the revision application, to the following address:

LOMC Clearinghouse
Attention: LOMR Manager
847 South Pickett Street
Alexandria, Virginia 22304-4605

or submit the LOMR using the Online LOMC portal at: https://hazards.fema.gov/femaportal/onlinelomc/signin.

After receiving appropriate documentation to show that the hydraulic analysis for Jordan River and Surplus Canal has been completed, FEMA will initiate a revision to the FIRM and FIS report.

This CLOMR is based on minimum floodplain management criteria established under the NFIP. Your community is responsible for approving all floodplain development, and for ensuring all necessary permits required by Federal or State/Commonwealth law have been received. State, county, and community officials, based on knowledge of local conditions and in the interest of safety, may set higher standards for construction in the Special Flood Hazard Area. If the State, county, or community has adopted more restrictive or comprehensive floodplain management criteria, these criteria take precedence over the minimum NFIP criteria.

If you have general questions about your request, FEMA policy, or the NFIP, please contact the FEMA Map Information eXchange (FMIX) toll free, at 1-877-FEMA MAP (1-877-336-2627). If you have specific questions concerning your request, please contact Mr. Sean McNabb, either by telephone at (303) 235-4303 or by e-mail at sean.mcnabb@fema.dhs.gov.

Sincerely,

Patrick "Rick" F. Sacbibit, P.E., Branch Chief
Engineering Services Branch
Federal Insurance and Mitigation Administration

cc: Mr. Rolen Yoshinaga
Director of Planning and Development Services
Salt Lake County

Mr. Matthew Stayner, P.E., CFM
Project Engineer
Bowen Collins and Associates, Inc.

APPENDIX F
LOWER JORDAN RIVER HYDROLOGY STUDY

LOWER JORDAN RIVER HYDROLOGY STUDY

PREPARED BY

SALT LAKE COUNTY ENGINEERING DIVISION
SALT LAKE CITY, UTAH

NOVEMBER 2010

SUMMARY

A review of observed flows on the Jordan River between North Temple and Redwood road shows that the FEMA-designated 1% annual chance flow at 5th North (1,765 cfs) is much higher than any recorded instantaneous peak flow at this location (1,000 cfs). Because of this apparent incongruity, it was determined that a statistical analysis should be prepared to estimate what a more likely 1% annual chance flow should be. The analysis was performed in accordance with Bulletin 17b, "Guidelines for Determining Flood Flow Frequency", of the Hydrology Subcommittee from the US Department of the Interior, using HEC-SSP software developed by the US Army Corps of Engineers. Using a log-Pearson type III distribution with 33 years of gage data and a historic period of 93 years, a more likely 1% annual chance flood flow on the Jordan River at 5th North was determined to be 992 cfs.

DIVERSION OF FLOWS AT THE SURPLUS CANAL

The Lower Jordan River begins at the diversion of the Surplus Canal at 21st South Street and continues downstream until it empties into the wetlands and duck clubs near the borders of the Great Salt Lake. The flows from the Upper Jordan River transition into the Surplus Canal with flows into the Lower Jordan River being diverted from the main waterway. The Lower Jordan diversion has been modified several times over its life, with the current gate configuration consisting of two 10' x 5' box culverts, each with a radial gate. Normal operation of the gates is for the gates to be partially closed to allow only enough water down the Lower Jordan River to meet irrigation water rights, typically 200 cfs or less. The gates can be completely closed during high water sending all water down the Surplus Canal. The maximum flow into the Lower Jordan River with the gates wide open is limited to approximately 500 cfs due to the current gate configuration.

There is a streamflow gage on the Lower Jordan downstream of the diversion gates that has collected streamflow records from 1943 to the present. These records are typically combined with the records of the streamflow gage on the Surplus Canal just downstream diversion to approximate the flow of the Jordan River upstream of the diversion. On their own, the gage records on the Lower Jordan side of the diversion don't provide a lot of useful information about flood flows in the Lower Jordan except to note what the flow was on a particular date at that location. A statistical analysis of the gage data in this location to determine 1% annual chance flows would not be valuable in determining 1% annual chance flows at the diversion because the flows downstream of the diversion are controlled and do not represent natural events. In addition, there is a large storm drain culvert just below the diversion, and upstream of the gage, that delivers additional storm water to the river. The current operation procedure is to limit this flow to 200 cfs during high water events, and for this analysis, the 1% annual chance flow just below the diversion at 21st South Street is considered to be 200 cfs.

5th NORTH FLOW ANALYSIS

The 1% annual chance flow on the Lower Jordan River at 5th North Street is currently listed by FEMA as 1765 cfs and is based on an FIS Hydrology Report by Rollins, Brown, and Gunnell (RB&G) in 1980. At the time of the RB&G study, the length of record from the streamflow gage at 5th North Street was insufficient to perform a meaningful statistical analysis. The flow was thus determined by summing the estimated flow capacities of the storm drain pipes between the diversion at 21st South Street and North Temple Street. Downstream of North Temple Street there are several storm drains that discharge into the Jordan River, but none of these were found to have a meaningful impact on the flow in the river. The flow capacity at North Temple was determined in the RB&G study to be 1790 cfs, and through losses and other routing parameters the flow was determined to be 1765 cfs at 5th North Street.

The gage on the downstream side of 5th North Street has a streamflow record from 1977 until the present (2009), with the exception of the year 1987 in which the gage was not in operation. Instantaneous peak flows were taken from the gage data for each of these years. In addition to the nearly continuous record from 1977 on, peak flows during the 1952 flood were recorded at this location and documented by the USGS. These provide an instantaneous peak streamflow record for 33 systematic events.

In addition to the measured flows at the 5th North gage site, there are two flood years that have been noted in historical documents for the Lower Jordan. These are the floods of 1917 and 1922. The flows for these two events at North Temple Street (a few blocks upstream of the 5th North gage location) were 1000 cfs and 940 cfs respectively, as stated in a document prepared by the Salt Lake County Engineer's Office in 1950 titled "Preliminary Report on Flood Control in the Jordan River." The 1950 County Engineer's report notes that the 1917 flood was the largest recorded flow of reliable record the Lower Jordan had experienced to that time.

Because the diversion configuration during these historical floods allowed much higher flows to enter the Lower Jordan than what the current conditions allow, the historic flood flows have been adjusted to probable current condition flows.

The Salt Lake County report referenced above states that of the 1000 cfs reported for the 1917 flood, an estimated 800 cfs came from the diversion at the Surplus Canal and 200 cfs came from inflow between the diversion and North Temple. Adjusting the flows to correlate with the configuration of the current diversion (200 cfs), the flows at North Temple would likely have been near 400 cfs.

The flood of 1922 peaked at about 940 cfs at North Temple. Of this peak flow, 590 cfs reportedly came from the diversion at the Surplus Canal and 350 cfs came from local inflow between the diversion and North Temple. Adjusting the flows to correlate with the configuration of the current diversion (200 cfs), the flows at North Temple would likely have been near 550 cfs.

Because neither of these flood flows exceed the highest peak of the systematic gage record, the flow values for the historical events were not considered in the analysis, but the historical period was adjusted to include the time from the earliest of these events (1917) to 2009, giving a historical period of 93 years. The historical events are presented with the systematic events in Table 1.

TABLE 1 – YEARLY INSTANTANEOUS PEAKS AT 5TH NORTH

Water Year	Date	Peak Discharge (cfs)
1917*	-	400*
1922*	-	550*
1952	5/5/1952	667
1977	5/16/1977	430
1978	9/18/1978	792
1979†	8/13/1979	265†
1980	1/14/1980	395
1981	5/3/1981	446
1982	5/3/1982	657
1983	6/1/1983	932
1984	6/1/1984	832
1985	10/12/1984	672
1986	8/20/1986	817
1988	4/18/1988	428
1989	5/12/1989	618
1990†	10/26/1989	276†
1991	9/8/1991	618
1992	10/27/1991	638

Water Year	Date	Peak Discharge (cfs)
1993	5/4/1993	796
1994	4/10/1994	571
1995	6/6/1995	637
1996	4/17/1996	576
1997	6/10/1997	617
1998	6/17/1998	850
1999	5/3/1999	655
2000	9/23/2000	651
2001	7/9/2001	470
2002	11/22/2001	498
2003	9/10/2003	494
2004	3/26/2004	504
2005	4/12/2005	669
2006	4/15/2006	694
2007	6/6/2007	551
2008	8/31/2008	558
2009	4/15/2009	548

*Historical events (adjusted to current values)

†Determined to be a low outlier in the analysis

A statistical analysis using the maximum annual instantaneous peaks from the gage record and using the historical period as noted was prepared using the HEC-SSP software available from the Army Corps of Engineers. No effort was made to try to adjust the systematic gage records for the effects of the upstream controls at the diversion. However, it is felt that using these peak values as-is would produce a fair and probably slightly conservative result for the 1% annual chance event. The analysis was based on a log-Pearson type III distribution and assumed a generalized skew of -0.25, as is consistent with previous hydrology studies in Salt Lake County. The results of this analysis provided the flood flow frequency curve shown in Figure 1. The calculated flow for the 1% annual chance flow is 992 cfs.

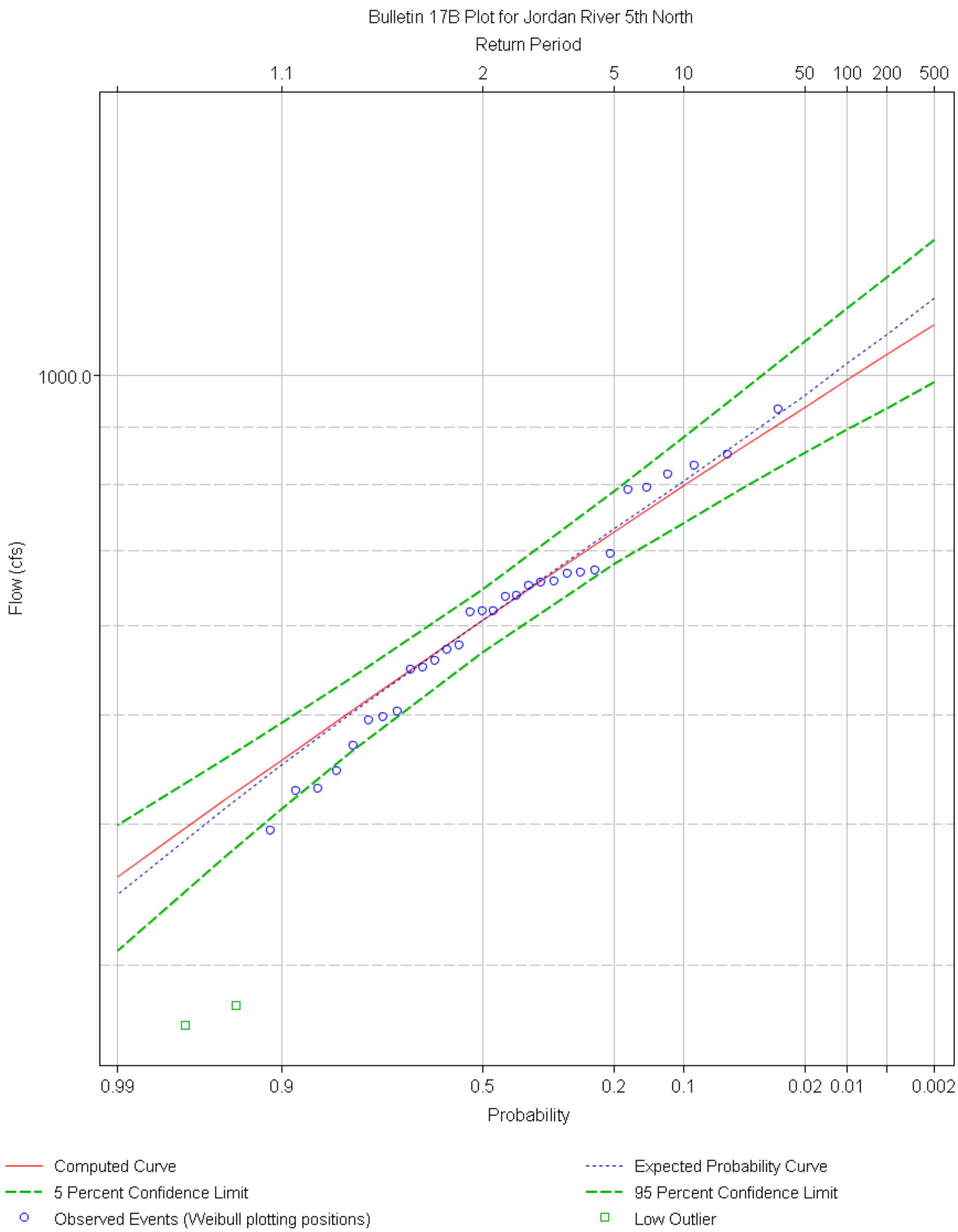


FIGURE 1 – FLOOD FLOW FREQUENCY CURVE AT 5TH NORTH

FLOWS BETWEEN THE LOWER JORDAN DIVERSION AND 5TH NORTH

The total flow at 5th North Street is made up from the flow diverted at the Surplus Canal plus various piped systems that discharge directly to the river between the diversion and North Temple Street. These include natural streams and local drainage. The piped inflows that contribute to the total flood flow at 5th North Street occur primarily at the locations listed in Table 2. If the 1% annual chance flood peak were to occur at the same time on each of these tributaries, the estimated combined flow, as determined in the 1980 RB&G FIS study, would be approximately 1790 cfs at North Temple Street. Through the gage and historical data used in this study it has been shown that these tributaries have not and likely will not peak at the same time and thus the flow on the Lower Jordan is much lower than predicted using the previous assumptions. Though the 1% annual chance flows do not peak at the same time for each tributary, it is logical that the flow distribution for the 1% annual chance flow on the Lower Jordan would be similar to the distribution proposed in the effective FIS study. This distribution is based on a detailed study of the capacity of the pipes that deliver the flows from each drainage area to the river. Using this distribution method, the percentage of flow increase at each location was used in estimating the new amount of flow between the diversion and 5th North, as shown in Table 2 (rounded to 5 cfs).

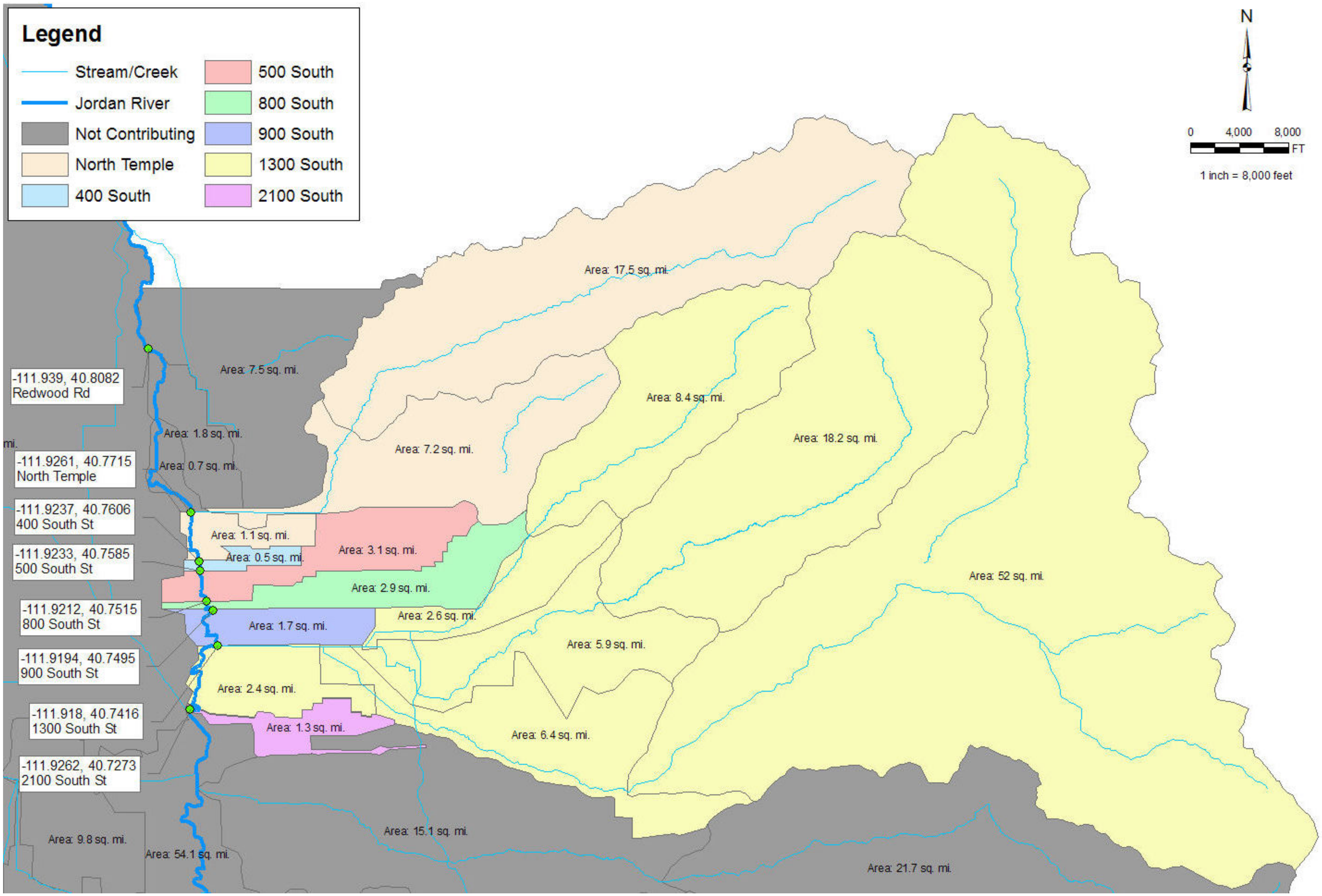
However, FEMA's technical service provider has requested that in place of the above method of distribution, the distribution of flows between the gaged sites be based on the relative drainage area size. This distribution was calculated in accordance with the methodologies described in the USGS's *Methods for Estimating Magnitude and Frequency of Peak Flows for Natural Streams in Utah* (equation 2) and is included in Table 2. Figure 2 shows the drainage basin sizes for each of the locations listed in Table 2. These drainage basin sizes do not identically match the basin sizes listed in the effective FIS study, but have been delineated more recently and are assumed to be more accurate than the basin sizes shown previously. The 1% annual chance flow from North Temple Street to the downstream end of the Lower Jordan is assumed to remain constant at 992 cfs.

As the distribution of flows based on the relative drainage area is the method that FEMA's technical service provider requested be used, it is the distribution that we will consider as the final distribution between the Lower Jordan diversion and the gage at 5th North.

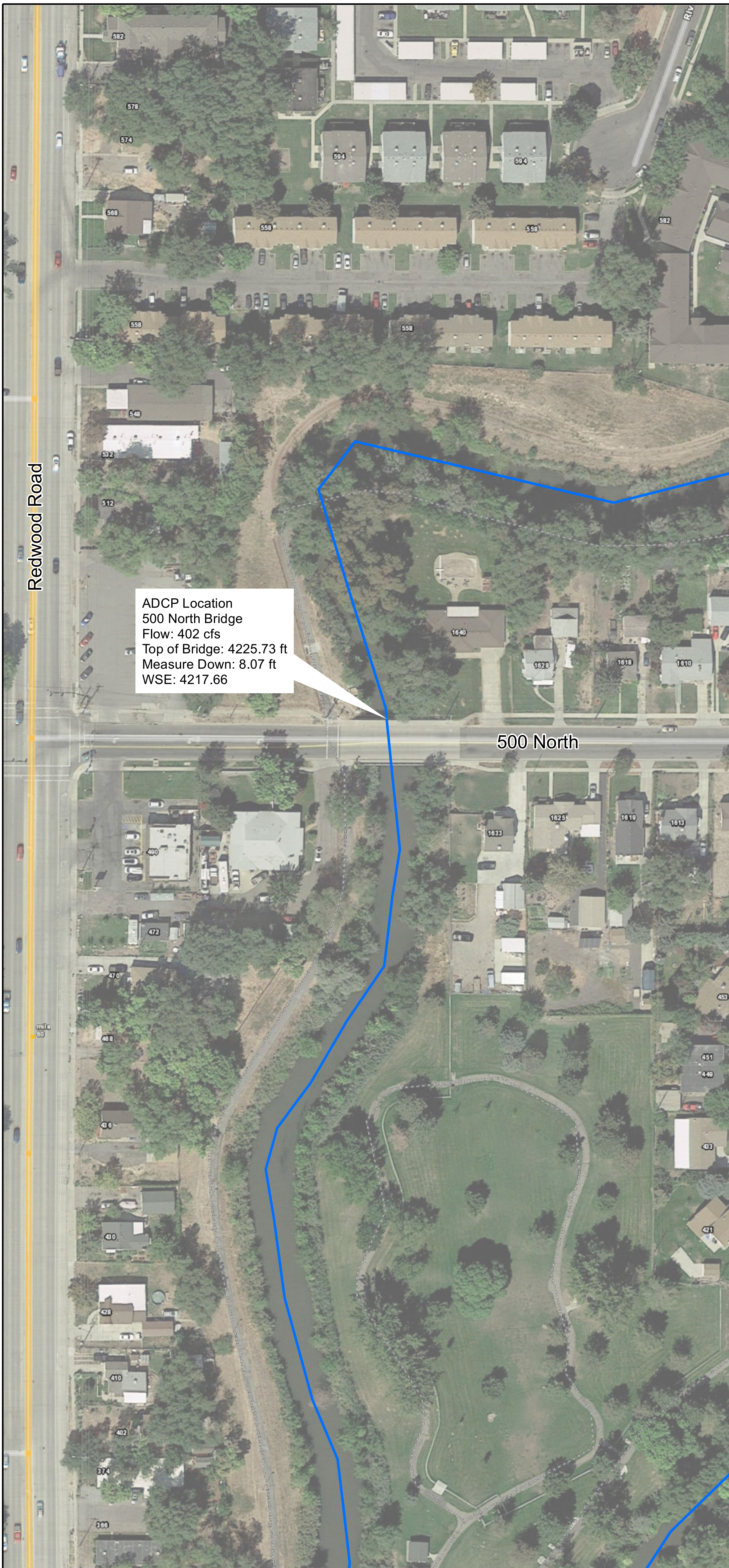
TABLE 2 –FLOW DISTRIBUTION ANALYSIS FOR 1% ANNUAL CHANCE FLOOD

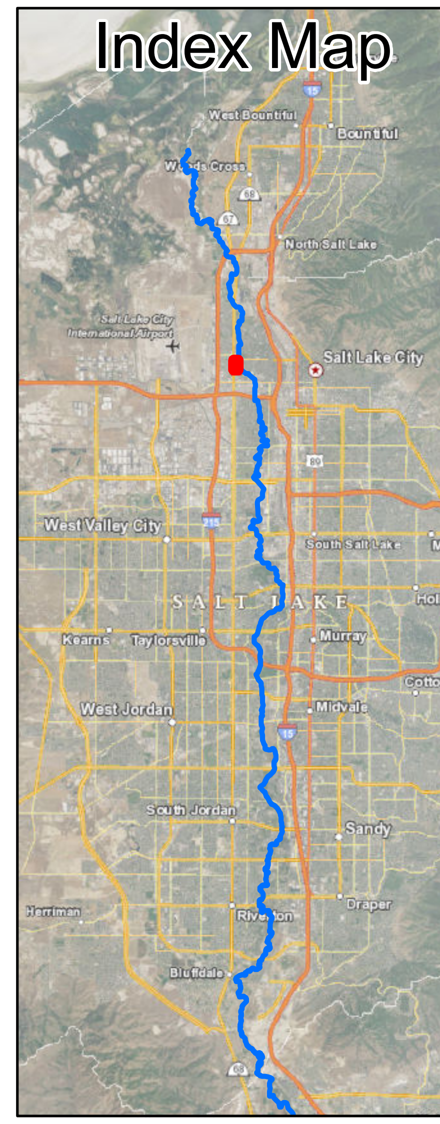
Location	Effective FIS Listed 1% Annual Chance Peak Flow (cfs)	Cumulative Percentage of Flow	New 1% Annual Chance Peak Flow Based on % of Tributary Conveyance Capacity (cfs)	Effective FIS Listed Cumulative Drainage Area (sq. mi.)	New Cumulative Drainage Area (sq. mi.)	New 1% Annual Chance Peak Flow Based on Drainage Area (cfs)
Lower Jordan Diversion	200	-	200	-	-	200
2100 South Street	250	3.1%	225	4.34	1.3	208
1300 South Street	1010	50.9%	605	107.6	97.1	787
900 South Street (UP Bridge)	1095	56.3%	645	110.2	98.8	797
800 South Street (Indiana Ave.)	1405	75.8%	800	116.7	101.6	814
500 South Street	1530	83.6%	860	116.7	104.7	833
400 South Street	1585	87.1%	890	117	105.2	836
North Temple Street	1790	100.0%	992	140.3	131.0	992
Total	1790		992			992

FIGURE 2 – DRAINAGE AREAS



APPENDIX G
FLOW MEASUREMENT DATA COLLECTION





LEGEND

Jordan River

NORTH:

NORTH

SCALE:

0 50 100 Feet

FLOW MEASUREMENT LOCATIONS - 500 NORTH

SALT LAKE COUNTY

JORDAN RIVER HYDRAULIC STUDY

BOWEN COLLINS & ASSOCIATES Celebrating 20 Years

FIGURE NO.

1

P:\Salt Lake County\2017 Jordan River Hydraulic Study\4.0 GIS\4.1 Projects\500 North.mxd bkirk 6/18/2019

Station Number: 500 N
Station Name: Jordan River 500 North

Meas. No: 0
Date: 04/16/2019

Party: BK, SC
Boat/Motor:
Gage Height: 0.00 ft

Width: 60.4 ft
Area: 242 ft²
G.H.Change: 0.000 ft

Processed by: SC
Mean Velocity: 1.66 ft/s
Discharge: 402 ft³/s

Area Method: Avg. Course
Nav. Method: Bottom Track
MagVar Method: None (0.0°)
Depth: Composite (BT)
Discharge Method: None
% Correction: 0.00

ADCP Depth: 0.250 ft
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 ft/s
Adj.Mean Vel: 0.00 ft/s
Rated Area: 0.000 ft²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 0.33 ft/s
WT Error Vel.: 1.15 ft/s
BT Up Vel.: 1.00 ft/s
WT Up Vel.: 3.00 ft/s
Use Weighted Mean Depth: YES

Max. Vel.: 3.77 ft/s
Max. Depth: 5.28 ft
Mean Depth: 4.00 ft
% Meas.: 72.50
Water Temp.: None
ADCP Temp.: 50.2 °F

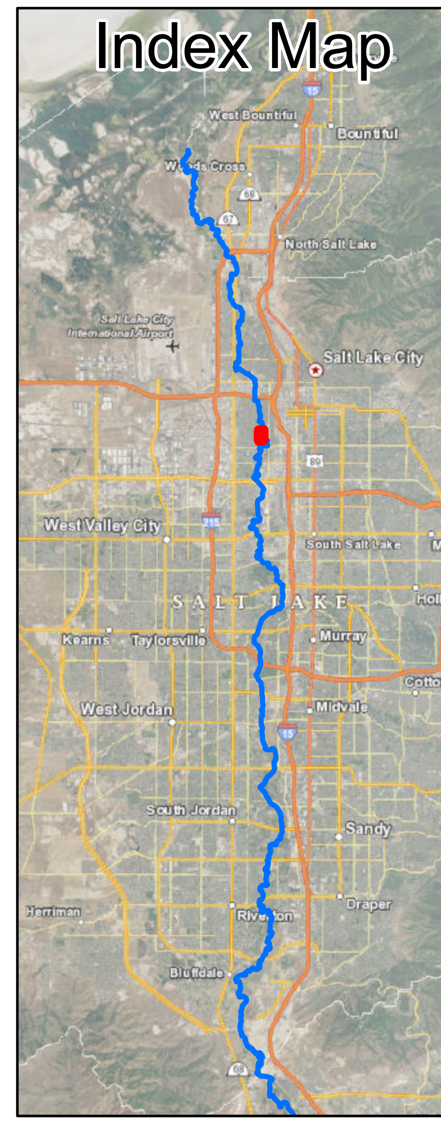
ADCP:
Type/Freq.: StreamPro / 2000 kHz
Serial #: 1996 Firmware: 31.16
Bin Size: 6 cm Blank: 3 cm
BT Mode: 10 BT Pings: 2
WT Mode: 12 WT Pings: 6

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: Upstream side of 500 N Bridge

Project Name: 500 N 04162019_0.mmt
Software: 2.20

Tr.#		Edge Distance L	Edge Distance R	#Ens.	Discharge Top	Discharge Middle	Discharge Bottom	Discharge Left	Discharge Right	Discharge Total	Width	Area	Time Start	Time End	Mean Vel. Boat	Mean Vel. Water	% Bad Ens.	% Bad Bins
000	L	5	3	177	53.5	289	48.5	7.42	2.05	401	59	237	16:22	16:26	0.27	1.69	3	0
001	R	5	3	182	56.6	299	50.9	6.64	1.73	415	63	247	16:26	16:30	0.28	1.68	7	1
002	L	5	3	164	52.8	288	44.8	6.29	2.30	394	60	241	16:30	16:33	0.29	1.63	1	1
003	R	5	3	170	53.4	289	46.5	6.75	1.70	397	60	241	16:33	16:37	0.27	1.65	2	1
Mean		5	3	173	54.0	291	47.7	6.77	1.94	402	60	242	**Total**	00:15	0.28	1.66	3	1
SDev		0	0	8	1.71	5.35	2.61	0.472	0.284	9.30	1.5	4.4			0.01	0.03		
SD/M		0.0%	0.0%	4.6%	3.2%	1.8%	5.5%	7.0%	14.6%	2.3%	2.5%	1.8%			3.1%	1.7%		

Remarks:



LEGEND

Jordan River

NORTH:

NORTH

SCALE:

0 50 100 Feet

FLOW MEASUREMENT LOCATIONS - 1050 SOUTH

SALT LAKE COUNTY

JORDAN RIVER HYDRAULIC STUDY

BOWEN COLLINS & ASSOCIATES

Celebrating 20 Years

FIGURE NO.

2

P:\Salt Lake County\2017 Jordan River Hydraulic Study\4.0 GIS\4.1 Projects\1050 South.mxd bkirk 6/18/2019

Station Number: Peace Gardens
Station Name: Jordan River 1100 S

Meas. No: 0
Date: 04/16/2019

Party:
Boat/Motor:
Gage Height: 0.00 ft

Width: 54.4 ft
Area: 189 ft²
G.H.Change: 0.000 ft

Processed by:
Mean Velocity: 1.17 ft/s
Discharge: 221 ft³/s

Area Method: Avg. Course
Nav. Method: Bottom Track
MagVar Method: None (0.0°)
Depth: Composite (BT)
Discharge Method: Proportional
% Correction: 0.10

ADCP Depth: 0.250 ft
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 ft/s
Adj.Mean Vel: 0.00 ft/s
Rated Area: 0.000 ft²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 0.33 ft/s
WT Error Vel.: 0.98 ft/s
BT Up Vel.: 1.00 ft/s
WT Up Vel.: 2.00 ft/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.74 ft/s
Max. Depth: 4.69 ft
Mean Depth: 3.47 ft
% Meas.: 68.41
Water Temp.: None
ADCP Temp.: 50.3 °F

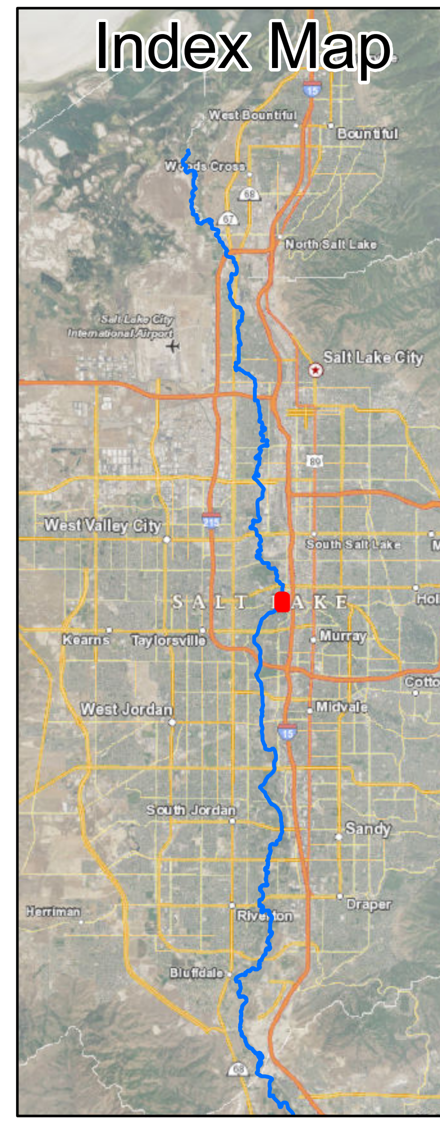
ADCP:
Type/Freq.: StreamPro / 2000 kHz
Serial #: 1996
Firmware: 31.16
Bin Size: 8 cm
Blank: 50 cm
BT Mode: 0
BT Pings: 1
WT Mode: 12
WT Pings: 6

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location:

Project Name: Peace Gardens 04162019_0.
Software: 2.20

Tr.#		Edge Distance		#Ens.	MBT Corrected Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	6	4	178	32.3	153	26.9	10.5	1.59	225	54	191	15:09	15:13	0.23	1.18	0	1
001	L	6	4	172	33.0	154	27.4	9.85	1.41	226	54	187	15:13	15:17	0.24	1.21	0	1
002	R	6	4	176	31.4	149	26.3	8.86	1.02	216	54	189	15:17	15:21	0.23	1.15	0	0
004	L	6	4	182	32.1	148	27.6	7.91	0.848	216	55	189	15:27	15:31	0.22	1.14	0	0
Mean		6	4	177	32.2	151	27.0	9.29	1.22	221	54	189	**Total**	00:21	0.23	1.17	0	1
SDev		0	0	4	0.639	3.37	0.596	1.14	0.342	5.35	0.6	1.4			0.01	0.03		
SD/M		0.0%	0.0%	2.4%	2.0%	2.2%	2.2%	12.3%	28.1%	2.4%	1.1%	0.7%			2.4%	2.6%		

Remarks:



LEGEND

Jordan River

NORTH:

SCALE: 0 50 100 Feet

FLOW MEASUREMENT LOCATIONS - 4700 SOUTH

SALT LAKE COUNTY
JORDAN RIVER HYDRAULIC STUDY

BOWEN COLLINS & ASSOCIATES
Celebrating 20 Years

FIGURE NO.
3

P:\Salt Lake County\2017 Jordan River Hydraulic Study\4.0 GIS\4.1 Projects\4800 South.mxd bkirk 6/18/2019

Station Number: 4800 S
Meas. No: 0

Station Name: Jordan River 4800 S
Date: 04/16/2019

Party: BK, SC
Width: 58.6 ft
Processed by: SC

Boat/Motor:
Area: 275 ft²
Mean Velocity: 2.70 ft/s

Gage Height: 0.00 ft
G.H.Change: 0.000 ft
Discharge: 739 ft³/s

Area Method: Avg. Course
ADCP Depth: 0.250 ft

Nav. Method: Bottom Track
Shore Ens.:10

MagVar Method: None (0.0°)
Bottom Est: Power (0.1667)

Depth: Composite (BT)
Top Est: Power (0.1667)

Discharge Method: Proportional

% Correction: 0.94

Index Vel.: 0.00 ft/s
Rating No.: 1

Adj.Mean Vel: 0.00 ft/s
Qm Rating: U

Rated Area: 0.000 ft²
Diff.: 0.000%

Control1: Unspecified

Control2: Unspecified

Control3: Unspecified

Screening Thresholds:

BT 3-Beam Solution: YES

WT 3-Beam Solution: YES

BT Error Vel.: 0.33 ft/s

WT Error Vel.: 1.25 ft/s

BT Up Vel.: 1.00 ft/s

WT Up Vel.: 3.00 ft/s

Use Weighted Mean Depth: YES

Max. Vel.: 5.98 ft/s

Max. Depth: 7.84 ft

Mean Depth: 4.71 ft

% Meas.: 71.24

Water Temp.: None

ADCP Temp.: 52.0 °F

ADCP:

Type/Freq.: StreamPro / 2000 kHz

Serial #: 1996
Firmware: 31.16

Bin Size: 5 cm
Blank: 3 cm

BT Mode: 10
BT Pings: 2

WT Mode: 12
WT Pings: 6

Performed Diag. Test: NO

Performed Moving Bed Test: YES

Performed Compass Calibration: YES   Evaluation: YES

Meas. Location: Arrowhead Park Foot Bridge

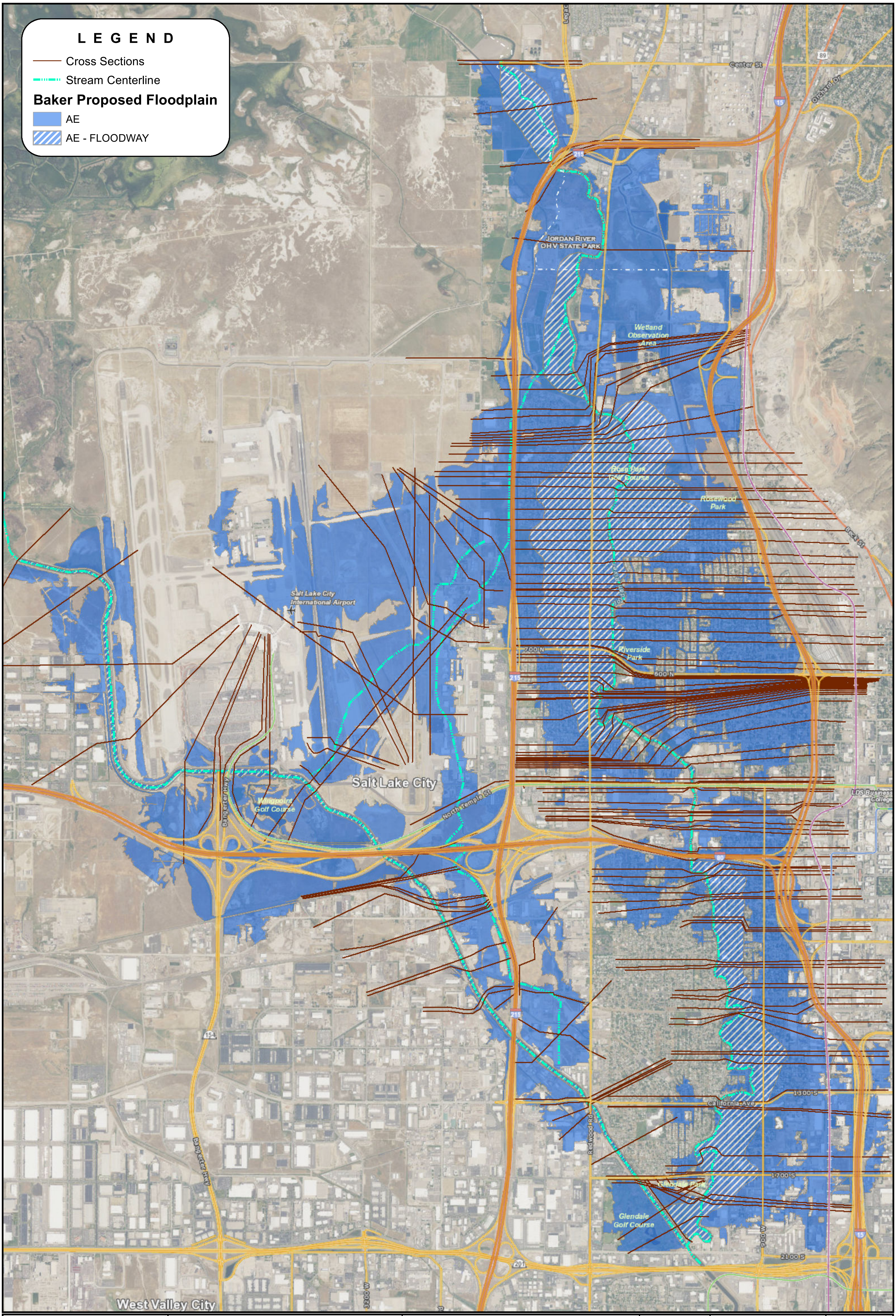
Project Name: Station 4800 S 04162019_0.mm

Software: 2.20

Tr.#		Edge Distance		#Ens.	MBT Corrected Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	4	6	207	72.4	507	129	3.96	7.84	720	53	257	13:50	13:54	0.31	2.81	7	1
001	L	4	6	192	79.2	548	129	4.27	1.62	763	67	305	13:54	13:58	0.35	2.50	10	2
002	R	4	6	188	74.4	529	134	5.05	1.84	744	53	254	13:59	14:02	0.29	2.93	4	1
003	L	4	6	163	74.4	522	129	4.73	-0.989	729	62	284	14:03	14:06	0.36	2.57	7	1
Mean		4	6	187	75.1	527	130	4.50	2.58	739	59	275	**Total**	00:16	0.32	2.70	7	1
SDev		0	0	18	2.89	17.2	2.40	0.485	3.74	18.5	7.1	24.2			0.04	0.20		
SD/M		0.0%	0.0%	9.8%	3.8%	3.3%	1.8%	10.8%	144.9%	2.5%	12.1%	8.8%			10.9%	7.4%		

Remarks:

APPENDIX H
VALLEY ANALYSIS STUDY
(MICHAEL BAKER INTERNATIONAL, INC.)



SALT LAKE COUNTY
JORDAN RIVER
HYDRAULIC ANALYSIS

2012 BAKER FLOODPLAIN

NORTH:

SCALE: 0 1,500 3,000 Feet

FIGURE NO. 1

BOWEN COLLINS & ASSOCIATES

P:\Salt Lake County\2017 Jordan River Hydraulic Study\4.0 GIS\4.1 Projects\Baker Floodplain.mxd bkirk 3/15/2019

APPENDIX I
LOWER JORDAN RIVER LEVEE EVALUATION
(CH2M HILL)

Final Report

Lower Jordan River Levee Evaluation

Prepared for

Salt Lake County Public Works

2001 South State Street, N4100
Salt Lake City, Utah 84190-3050

Prepared by

CH2MHILL

215 S. State Street, Suite 1000
Salt Lake City, Utah 84111

November 2009

Final Report

Lower Jordan River Levee Evaluation

Prepared for

Salt Lake County

November 2009

CH2MHILL

Executive Summary

The effective Federal Emergency Management Agency's (FEMA's) flood insurance rate maps for Salt Lake County, Utah currently recognize a levee located along the lower Jordan River as providing protection for the 100-year flood event. Per FEMA guidelines, Salt Lake County began work in 2008 to locate documentation of certification of the levee along the west bank of the river between North Temple Drive and Redwood Road. The County was unable to locate the required documentation and thus initiated the study described herein in April 2009. The objective of this study was to evaluate the existing levee system and identify improvements required for certification of this levee system.

Levee Condition

The existing levee is an earthen embankment located immediately adjacent to the river channel. Whereas the levee is an engineered structure built explicitly for the purpose of flood control, the levee appears to not have been consistently inspected and maintained since its construction. CH2M HILL completed a review of available information, a site visit to visually evaluate the levee, and a limited geotechnical exploration of soils in and below the levee to evaluate the levee's present condition. The present condition of the levee was determined to be unacceptable per current United States Corps of Engineers (USACE) guidelines and rating system. Primary reasons for this rating are as follows:

- The levee does not provide the minimum required freeboard of 3 feet for much of its length.
- Numerous trees and other vegetation are growing upon the levee and within the vegetation exclusion zone prescribed by the USACE and FEMA.
- In numerous locations structures have encroached upon the levee that may affect the stability of the levee as well as impede levee inspections and flood fighting operations.
- A geotechnical evaluation of the levee found extensive river bank erosion and that, as a result, existing levee slopes are over-steep and unstable.
- The levee was observed to have been significantly impacted by burrowing animals.
- An active levee Operations and Maintenance plan or program is not in place.

Evaluation of Alternatives

Guiding principles were defined to guide the development of alternative physical improvements that would be required for the levee to be certified, such as the following:

1. The improvements must meet FEMA guidelines for design and construction of a flood control levee.
2. The improvements should minimize impacts to existing right-of-way (ROW), use, and structures.

3. The improvements should minimize impacts to existing trees and riverbank.
4. The improvements should be consistent with existing planning documents for the Jordan River corridor.

The following two alternatives for physical improvements were identified that consisted of variations of both new earthen embankment and new floodwall:

- Alternative No. 1 primarily sought to maintain the existing levee alignment to use existing ROW and address the other guiding principles as much as possible (see Appendix E for figures). This alternative uses predominantly an earthen embankment along the existing alignment using a riprap buttress to provide slope stability for the levee and river bank and limited use of floodwalls to minimize impacts to trees and structures. The estimated total cost (including ROW acquisition and engineering) for this alternative is $13,843,000.
- Alternative No. 2 primarily sought to use available open space to minimize impacts to trees and riverbank habitat (see **Appendix F** for figures). This alternative sought to use an earthen embankment set back away from the river where possible and floodwalls to minimize impacts to the riverbank and trees while addressing the other guiding principles as much as possible. The estimated total cost (including ROW acquisition and engineering) for this alternative is $13,391,000.

As previously described, the existing levee does not meet current FEMA guidelines. Thus, the existing levee is not certifiable. It is very likely that FEMA will remove the levee from the effective flood insurance rate maps and designate the structures currently shown as protected by the levee as within the 100-year floodplain. Property owners within the designated 100-year floodplain will be required by FEMA to obtain flood insurance. Preliminary estimates indicate that approximately 1,600 structures exist within this floodplain.

Recommendations

Preliminary discussions between the County and Salt Lake City have centered on concerns regarding the financial burden the purchase of flood insurance will have on this community if improvements are not implemented and the impact construction and maintenance of the levee improvements will have on existing habitat along the river corridor. CH2M HILL recommends that Alternative No. 2 be carried forward in a public process that better defines the public's concerns and vision for this corridor; identifies permitting requirements, opportunities for enhancing this corridor, and funding options; and incorporates these into a reasonable, implementable, and sustainable solution. Construction of a levee in an urban river environment requires careful consideration of how these flood control facilities can best be incorporated into the community's vision for the river corridor.

These improvements to the levee system will establish the physical barrier required for flood control; however, management considerations must also be implemented for the levee system to be certified. CH2M HILL also recommends that the County develop and implement a formal operations and maintenance plan for the levee system. This plan, as well as an evaluation of required environmental mitigation and potential interior drainage concerns, is best addressed as part of the design of the levee system improvements.

Contents

Tables

Figures

Appendices

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Acronyms and Abbreviations

ASTM	American Society of Testing and Materials
CFR	*Code of Federal Regulations*
cfs	cubic feet per second
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
GPS	global positioning system
H&H	hydrology and hydraulic
LIDAR	Light Detection and Ranging
LOMA	Letter of Map Amendment
NFIP	National Flood Insurance Program
NGVD29	National Geodetic Vertical Datum of 1929
PVC	polyvinyl chloride
ROW	right-of-way
USACE	United States Army Corps of Engineers
WOH	weight of hammer
WOR	weight of rod

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1.0 Introduction

This report was prepared as part of a project authorized by Salt Lake County in an agreement with CH2M HILL, Inc. (CH2M HILL) for the lower Jordan River Levee Improvements project, dated April 23, 2009 (County Contract No. PP09100C). This study entails an evaluation of and recommendation for improvements to the existing levee located along the west bank of the lower Jordan River, between North Temple Drive and Redwood Road. This study is Phase I of the following three planned phases for the project:

- Phase I - Feasibility Study
- Phase II - Design
- Phase III - Construction

The central objective for Phase I is to evaluate the current condition and recommend improvements to the existing levee that, when implemented, will allow the levee to be certified by the Federal Emergency Management Agency (FEMA).

1.1 Project Objectives and Purpose

Salt Lake County's objective is to evaluate the existing levee system and identify, and then implement, improvements required for certification of the levee system within the project limits. Improvements will be implemented as soon as practicable and as funding is made available.

The purpose of this report is to document the results of Phase I—namely, CH2M HILL's evaluation of the existing levee and proposed alternative improvements—and to summarize recommended actions for the County to implement. Design and construction of possible improvements will follow in subsequent phases of this project.

1.1.1 Guiding Principles

The following guiding principles were identified that informed the evaluation of alternative improvements:

1. The existing levee was constructed first and foremost as a flood control structure. Up to 1,600 structures currently rely upon the levee for flood protection (Nick Kryger, personal communication, September 2, 2009). The final improved levee system must meet current FEMA guidelines for a certifiable levee for this area to continue with its current status in the National Flood Insurance Program (NFIP).

2. This reach of the Jordan River is located within a developed, urban corridor. Improvements to the levee should be within existing right-of-way (ROW) and minimize impacts to existing permanent structures (that is, homes, apartment buildings, and bridges) and uses while still meeting FEMA guidelines for required setbacks.

3. A significant number of trees and other vegetation have grown along the river bank and levee since the levee's construction in 1982. FEMA guidelines do not allow woody

vegetation within a defined corridor centered on the levee; therefore, a significant number of trees will have to be removed to bring the levee into compliance. Improvements to the levee should attempt to minimize impacts to existing trees and associated habitat.

4. Proposed improvements should be consistent with goals identified in planning documents previously prepared for the Jordan River corridor (such as Blueprint Jordan River [Envision Utah, 2008] and Water Quality Stewardship Plan [Salt Lake County, 2009]).

1.2 Scope of Work

The scope of work for this evaluation phase included the following components:

1. Collect available data describing the design and construction of the existing levee, hydrology and hydraulics for the Jordan River, geology of study area, and drainage facilities for the landward side of levee
2. Complete the required field investigations to observe, document, and investigate the existing condition of the levee:
   - A 1-day field visit was conducted to walk the existing levee, document visible features and condition, and identify possible issues that will need to be addressed. Observations are summarized in *Summary of Site Visit Lower Jordan River Levee Evaluation* (CH2M HILL, 2009a) (see **Appendix A**).
   - A geotechnical exploration was completed to obtain pertinent subsurface information to evaluate the existing levee. Boring logs and data results are summarized in *Geotechnical Data Report – Phase I, Jordan River Levee Project – North Temple to Redwood Road* (CH2M HILL, 2009b) (see **Appendix B**).
3. Coordinate as required with Salt Lake City and Salt Lake County personnel for access, review of observations, and discussion of alternatives
4. Conduct geotechnical analyses to evaluate the stability of the existing levee slopes and provide recommendations for required improvements
5. Provide a summary of the estimated costs for proposed improvements to the levee

1.3 Study Limits

The study reach of the Jordan River is located northwest of downtown Salt Lake City, Utah (**Figure 1**). The levee segment included in this study runs along the west bank of the Jordan River from the downstream side of the North Temple Road bridge to the upstream face of the Redwood Road bridge. For the purposes of this study, the levee was divided into five reaches based on the location of existing bridges across the river (**Figure 2**). A summary of each reach is given in the following paragraphs. A full description of each reach can be found in **Appendix A**.

- **Reach 1** starts at the bridge at the Redwood Road crossing of the Jordan River and ends at the Rose Park Golf Course bridge. This reach of the levee is approximately 4,200 feet long and consists of a new asphalt paved trail. Approximately 600 feet at the downstream end of the levee is adjacent to a residential area, with the remainder of the levee adjacent to the Rose Park Golf Course. An irrigation pump station is located riverward of the levee at the beginning of this reach.
- **Reach 2** begins at the Rose Park Golf Course bridge and ends at the 1000 North Street bridge. This reach of the levee is approximately 3,350 feet long and consists primarily of a dirt road and trail. The majority of the trail is adjacent to the Rose Park and Jordan River Par 3 Golf Courses.
- **Reach 3** begins at the 1000 North Street bridge and ends at the 700 North Street bridge. This reach of the levee is approximately 2,650 feet long and consists of a bark and dirt path and road. Approximately 850 feet of this reach is adjacent to a City library, while the remainder of the levee runs adjacent to Riverside Drive and a residential neighborhood. A pedestrian bridge crosses the Jordan River along this reach and two abandoned irrigation pump stations are located riverward of the levee.
- **Reach 4** begins at the 700 North Street bridge and ends at the 500 North Street bridge. This reach of the levee is approximately 2,225 feet long and consists of a bark and dirt path and road for the majority of the levee, with the last 825 feet of the levee being offset from the trail. This reach runs adjacent to a commercial building and apartment complexes. A pedestrian bridge crosses the Jordan River along this reach and two abandoned irrigation pump stations are located riverward of the levee.
- **Reach 5** begins at the 500 North Street bridge and ends at North Temple Road bridge. This reach of the levee is approximately 5,552 feet long, and consists of paved trails, grass-covered levee, and dirt paths. The reach runs adjacent to residential neighborhoods, State office buildings, a park, and a mobile home park. Four pedestrian bridges cross the Jordan River along this reach.

1.4 Project History and Planning Context

The existing levee on the west bank of the Jordan River is the product of several studies and phases of construction throughout the 1970s and 1980s. Several studies were completed over the years by the United States Corps of Engineers (USACE), private developers, FEMA, and Salt Lake County. Each study focused on the need to reduce the risk of the Jordan River flooding the area west of the channel and provided recommendations for improvements that addressed regulatory requirements. Only some of the studies resulted in actual physical improvements. Construction efforts included an initial effort to fill in low spots along the river bank, realignment of a segment of the river channel, dredging of the channel, construction of the existing levee, and emergency improvements of the levee during the floods of 1983 and 1984. All of these efforts shaped the levee as it exists today.

1.4.1 Federal Insurance Administration Flood Hazard Boundary Maps

Flood studies for the study area go back to the early 1970s. The Federal Insurance Administration initially published flood insurance maps for the area in 1974. These original maps identified the corridor along the Jordan River and a significant area west of the river and north of 700 North Street as a special flood hazard area.

1.4.2 United States Corps of Engineers Flood Control Studies

The USACE completed work in 1976 to study alternatives for the development of a flood control project for the lower Jordan River that incorporated parkway concepts. These reports, *Lower Jordan River, Utah – Feasibility Report for Water Resources Development* (USACE, 1976a) and *Revised Draft – Environmental Statement – Lower Jordan River, Utah* (USACE, 1976b), established 100-year flood flows, mapped 100-year flood plains, and presented important concepts for controlling flooding and developing a parkway along this reach of the river. These reports, however, did not result in federal funds for construction of flood control facilities or a parkway.

1.4.3 Ivory and Company Reports

Proposals in the late 1970s to develop available tracts of land in this area required the flood hazard area to be addressed. FEMA required a developer, Ivory and Company, to reduce the flood hazard before flood insurance could be provided for a proposed development just west of the Jordan River. Ivory and Company and its consultants completed three studies to investigate what would be necessary to mitigate flooding in this area. Two reports—*Flood Plain and Parkway Analysis of the Lower Jordan River for Ivory and Company* (Bingham, 1980a) and *Flood Plain Analysis of the Lower Jordan River for Ivory and Company* (Bingham, 1980b)—were completed to examine the routing of a revised flood hydrograph through this reach of the river, document the elevations of the top of the west bank of the river, and consider how the river channel might be improved to better convey flood flows. A third report, prepared by Bingham in December 1980 (Bingham, 1980c), documented the investigation of soils along the west bank levee and how low areas might be raised to address flooding concerns.

Of note is that the Ivory and Company reports imply that a levee may have been in existence prior to the 1980 studies. Record drawings from the County's levee project in 1981 and 1982, described as follows, confirm that most of this reach had an earthen berm along the river prior to 1981. Ivory and Company subsequently did fill in low areas in 1980 in locations near the fairgrounds foot bridge (Reach 5), upstream and downstream of 1000 North (Reaches 2 and 3), and upstream of the current Golf Course bridge (Reach 2). These improvements in the end were not able to address FEMA's requirements.

1.4.4 Flood Control Developments

Ongoing deliberations between Salt Lake County, Salt Lake City, Ivory and Company, FEMA, and USACE resulted in a number of actions in 1980, including the following:

- FEMA began a new Flood Insurance Study (FIS) for the lower Jordan River.
- The USACE accepted new hydrology that reduced the 100-year flow from 2,700 to 1,828 cubic feet per second (cfs).
- Plans were initiated to build a new levee on the west bank of the lower Jordan River.

- Request was made to FEMA for Letter of Map Amendment (LOMA) to remove the proposed Ivory and Company development from the flood hazard area based on the proposed improvements.

FEMA denied the County's request for a LOMA to address Ivory and Company's development in 1981 but agreed that a LOMA would be approved if a levee was constructed with 3 feet of freeboard from North Temple Drive to Redwood Road. The County's and City's intent was to remove an area, including the proposed Ivory and Company development, from the flood hazard area, thus negating the requirement for flood insurance in this area.

With agreement from FEMA, Salt Lake County initiated a levee project in the fall of 1981, referred to as the Lower Jordan River Interim Levee Project, to initially provide 2 feet of freeboard along the river from North Temple Drive to Redwood Road for the 100-year flood event, relocate a portion of the river channel in Reach 5 (**see Figure 2**), and dredge the channel from North Temple to Redwood Road to increase the channel's flow capacity. The agreement also stipulated that the County would then raise the levee to provide 3 feet of freeboard along this same reach by June 30, 1983. FEMA accepted as-built drawings for the Interim Levee Project in 1982 and revised the flood hazard area mapping in 1982 to achieve this objective.

Salt Lake County initiated studies in 1982 (CH2M HILL, 1982) to investigate improvements required to raise the levee to provide 3 feet of freeboard for the 100-year flood event. These studies were completed to address the 100-year water surface profile included in FEMA's new FIS and to address new FEMA policies for levees. While the studies and final design to raise the entire levee to 3 feet of freeboard from North Temple Drive to Redwood Road were finalized in 1984, construction of the proposed improvements did not occur.

Historical documents discuss emergency improvements to the levee during the floods of 1983 and 1984 but the location of this work is unknown. It should be noted that the floods of 1983 and 1984 resulted in a peak flow of 932, substantially less than FEMA's current estimate for the 100-year flood flow of 1,823. Subsequent construction of bridge improvements, development and redevelopment of adjoining properties, construction of trail improvements, and natural recruitment and growth of trees have all shaped the levee to the levee that exists today.

1.4.5 FEMA Flood Insurance Study

FEMA completed its Flood Insurance Study for the lower Jordan River in 1983. Due to the agreements and work previously discussed, the FIS incorporated the existing levee on the west bank of the lower Jordan River from North Temple Drive to Redwood Road and identified the floodplain behind the levee as Zone X (see **Figure 3**). Of note, is that much of the riverbank between North Temple Drive to 700 North appears to have been of an elevation adequate to contain the 100-year flood without a levee in place at the time the FIS was completed. This is something that should be verified in future phases of this project. The recent update to the Salt Lake County FIS, dated September 25, 2009, identified this area as Zone X and it remains so at the time this report was published.

1.5 Need for this Study

FEMA guidelines for modernization of flood plain maps require all levees to be certified and then accredited by FEMA. Certification is a process whereby the owner of the levee system documents the condition and performance of the levee, develops and implements operations and maintenance protocol, maintains records of inspections and repairs, and certifies to FEMA that the levee meets FEMA levee guidelines and will operate as intended. A review of Salt Lake County's files could not identify prior certification of the levee in the study area. Therefore, Salt Lake County must provide certification of the levee for it to be recognized by FEMA in flood insurance evaluations. If the levee is not certified, the properties currently located in the zone behind the levee will be required to purchase flood insurance.

Salt Lake County completed initial investigations in January 2009 to determine if the existing levee provided adequate freeboard. These investigations identified approximately $1 million in improvements to simply raise the levee 6 to 18 inches to meet freeboard requirements. Further investigation into the requirements for certification determined the need for this study. These requirements include developing an appropriate levee geometry, adequate setbacks from trees and structures, maintenance of vegetation and control of burrowing animals, access to the levee during flood events, erosion protection, and proper engineering of penetrations through the levees.

1.6 Organization of this Report

This report is organized as follows:

- **Section 1.0 – Introduction** specifies the underlying objective for the project and principles that guided the completion of the evaluations described in this report, summarizes the scope of work and limits for this study, summarizes the history of the development of flood control facilities for the study area, defines the need for this study, and outlines the organization of this report.
- **Section 2.0 – FEMA Certification Requirements for Levee Systems** provides a summary of the design standards and documentation required by FEMA.
- **Section 3.0 – Investigation of the Levee Condition** provides a summary of CH2M HILL's investigation of the existing levee system.
- **Section 4.0 – Assessment of Levee Conditions** provides a summary of the levee conditions based on CH2M HILL's observations and evaluations.
- **Section 5.0 – Recommendations and Proposed Alternatives** provides a summary of the recommendations.

2.0 FEMA Certification Requirements for Levee Systems

Levee systems are an important mechanism for mitigating flood hazards in urban areas and, when implemented per FEMA guidelines, are relevant to the determination of flood insurance requirements under the NFIP. FEMA's guidelines for design, maintenance, and operation of levee systems have changed somewhat over time but, more importantly, have not been consistently implemented. The tragic results of failed levees and flood walls in New Orleans during Hurricane Katrina highlighted many of these problems and served as the impetus for a comprehensive review of levee policy by FEMA and numerous other state and federal agencies. While some design criteria are still in development, one element of this policy has not changed and is currently being enforced – the identification and certification of all levee systems.

As the owner of the levee system along the lower Jordan River, Salt Lake County must provide FEMA with documentation required for certification of the levee system along the study area. This section provides a summary of the design standards and documentation required by FEMA.

2.1 Levee Certification

The certification of levees by FEMA is governed by the 44 *Code of Federal Regulations* (CFR) 65.10, which requires that flood protection levees be certified by registered professional engineers and public officials who are responsible for the design, maintenance, and operation of the levee system. Certification states that the levee system meets minimum design, operation, and maintenance standards as specified in 44 CFR 65.10. While the design and construction of a levee system is a significant component of certification, certification does not end with construction. Long-term operation and maintenance of the levee system is also a critical element for certification. As such, FEMA is considering policy revisions that will require documentation and reporting of operation, maintenance, and levee conditions for levee recertification on a recurring basis.

Certification requirements generally fall into the following three categories:

1. Design Criteria
2. Operations and Maintenance
3. Interior Drainage

The components of a levee certification submittal are summarized in the following sections. FEMA's form MT-2 Form 3, "Riverine Structures Form" should be submitted along with a cover letter and supporting documentation to FEMA for their review of the levee certification.

2.1.1 Design Criteria

FEMA has established minimum design standards for certifiable levee systems but is working with other state and federal agencies to improve and update these standards. Minimum design criteria are based on the levee providing flood protection behind the levee for the design base flood event. The base flood refers to a flood that has a 1 percent chance of being exceeded annually, which results in an average return period of once every 100 years. Note that this does not suggest that a flood of this level occurs exactly every 100 years, but that on average, when taken over a very long period of time, a flood of this size occurs once every 100 years. The following sections summarize the design criteria defined by FEMA for levees. Copies of planning and design documents and record drawings of the constructed facilities should be submitted to FEMA as part of the certification process.

Guidance Documents

FEMA references several USACE manuals for the evaluation and design of levee systems, including the following:

- USACE EM 1110-2-1913 *Design and Construction of Levees* (April 2000)
- USACE *Levee Owner's Manual for Non-Federal Flood Control Works* (March 2006)
- USACE EM 1110-1-1904 *Settlement Analyses* (September 1990)
- USACE EM 1110-2-1413 *Hydrologic Analysis of Interior Drainage Areas* (January 1987)
- USACE EM 1110-2-2502 *Retaining and Flood Walls* (September 1989)
- USACE EM 1110-2-1906 *Laboratory Soils Testing* (August 1986)
- ~~USACE EM 1110-2-301 *Guidelines for Landscape Planting and Vegetation Management at Floodwalls, Levees, and Embankment Dams* (January 2000)~~ (this has been superseded by USACE ETL 1110-2-571 *Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures* [April 2009])
- USACE EM 1110-2-2705 *Structural Design of Closure Structures for Local Flood Protection Projects* (March 1994)

The following additional references have been used in the evaluation of the levee systems for this project:

- USACE EM 1110-2-1601 *Hydraulic Design of Flood Control Structures* (June 1991, updated in June 1994)
- FEMA 473 *Technical Manual for Dam Owners Impacts of Animals on Earthen Dams* (September 2005)
- USACE ETL 1110-2-570 *Certification of Levee Systems for the National Flood Insurance Program (NFIP)* (Draft September, 2007)

Freeboard

FEMA requires a minimum of 3 feet of freeboard above the base flood elevation. A minimum freeboard of 4 feet is required within 100 feet of either side of bridges or other structures that are located riverward of the levee and may constrict river flow. Three and a half feet of freeboard is required at the upstream end of the levee, tapering to 3.0 feet at the downstream end of the levee. This freeboard is generally considered to account for uncertainty in the hydrology and hydraulic (H&H) modeling of the flood, wave actions, changes in the urban hydrology, as well as uncertainty in the structural performance of the levee. The uncertainty in levee performance most commonly includes the uncertainty in stability analyses, but also include the likelihood of excessive seepage, internal erosion and piping through the levee embankment and its foundation, and erosion of the levee during flood events.

FEMA and USACE have been developing new criteria that would allow the levee owner to potentially reduce the design freeboard from the default freeboard of 3.0 feet. To reduce the freeboard, the levee owner is required to perform detailed H&H engineering analyses that more accurately define the base flood level. These additional H&H analyses were initially considered by the County; however, due to the challenges in redefining the hydrology for the Jordan River, these analyses were not included in the scope of work for this particular project. The County did obtain new surveyed cross-sections of the river channel and developed a new HEC-RAS model of the study reach using existing hydrology. This model did not indicate any significant change in the 100-year water surface elevation from what is published in the effective FIS (Salt Lake County 2009).

FEMA's standard minimum freeboard requirements, as summarized in **Table 1**, were used herein.

TABLE 1
FEMA (2002) Freeboard Requirements

Location	FEMA-Required Freeboard above the 100-year Base Flood Elevation (feet)
Normal Levee	3.0
Within 100 feet of any structures riverward of the levee (e.g., bridges)	4.0
Upstream end of the levee	3.5

Penetrations

Penetrations are structural elements such as utilities that cross through a levee and may present a risk of seepage and internal erosion to the levee system. It is required that leakage from or infiltration into any pipe crossing under, through, or over a levee be prevented. Existing penetrations that go through the levee or levee foundation are allowed, but need special consideration that may or may not have been addressed during their installation. However, for existing pipelines, the USACE (2000) requires the following:

- Penetrations must have adequate strength and flexibility to accommodate levee loading.

- Existing penetrations need to be confirmed they are in good condition.
- It is recommended that pressure pipelines be relocated to cross over the levee. However, if they are left in place, they must be confirmed to have a means of rapid closure in case of leakage or rupture. Pressurized pipelines are often constructed through a levee with secondary containment to minimize the risk of a leak.
- Gravity discharge pipelines require flap gates or a slide-type gate on the riverside of the levee. In addition, for flap gates, emergency closer devices should also be included in the event of an inoperative flap gate. The slide gates must be located such that they can be operated during the design flood event.
- The backfill material around the pipe must be pervious under the landside third of the levee to minimize the potential for piping.

The same considerations are required for new pipelines that will be constructed under, through, or over the levee, and it is preferable that all new pressurized pipelines cross over the levee.

For pipelines no longer in service, it is recommended that the pipelines be removed during clearing and grubbing operations. If the pipeline is not removed, it still needs to meet the previously listed requirements, as well as be completely filled with concrete.

Closures

The design, certification, and accreditation of levees considers all elements of the levee system (including the levee itself), closure structures, and drainage devices as one system, providing protection against the design flood. Therefore, any openings, such as bridges, need to be evaluated as a location that could potentially compromise the integrity of the levee system.

All openings in the levee that do not meet the freeboard requirements must be provided with closure devices that are structural parts of the system. Based on the guidelines that the minimum freeboard within 100 feet of any structure located riverward of the levee shall be 4 feet, a closure structure is required if the elevation of the bridge crossing is less than 4 feet above the 100-year flood level. Note that closure structures could be a steel or concrete hydraulic control structure, or could be sandbags or stop logs (ETL 1110-2-570, USACE 2007). If sandbags are to be used, they must be stockpiled and readily deployable during a flood, and be specifically addressed in the Operation and Maintenance Manual. Sandbags must not be used for cases where more than about 3 feet of height is required, when the levee is used to protect against flash flooding, or used during extended durations.

Embankment Protection

Protection of the river channel and levee slope against erosion is required to maintain levee stability and integrity during the 100-year base flood event. Using the guidelines provided by the USACE (1994), the maximum permissible velocities for different soil types to prevent erosion are listed in **Table 2**. If the stream channel velocity during the 100-year flood exceeds these velocities, erosion control measures are required to protect the levee.

Historical documents indicate that the existing levee was constructed with a minimum 3H:1V riverward side slope to the bottom of the river channel. Observations documented in *Summary of Site Visit Lower Jordan River Levee Evaluation* (CH2M HILL, 2009a) note that many of the existing levee slopes are over steepened on the riverward side indicating that erosion of the channel banks and levee has been an issue.

Based on FEMA's current hydraulic model, the mean channel velocities along this reach of the Jordan River vary from 1.9 to 4.6 feet per second, with the velocities generally higher near the upstream reaches, and adjacent to bridge crossings. In general, the soils for the foundation of the existing levee consist of silts and sands, with some locations of clay. The maximum permissible stream velocity for an unprotected channel would therefore be around 2 to 6 feet per second, with the majority of the soils being silts with maximum tolerable velocities of 2 feet per second. This confirms observations in the field that erosion is an issue and erosion control measures will likely have to be implemented. However, if the levee is setback a sufficient distance from the riverbank, erosion protection may not be required, given that monitoring of erosion and appropriate maintenance of the riverbank and levee is conducted to maintain levee stability. The setback distance is discussed in **Section 4.0**, but in summary, the levee needs to be setback beyond a 3(H):1(V) slope from the toe of the riverbank.

TABLE 2
Maximum Channel Velocity to Minimize Channel Erosion
(after USACE, 1994)

Soil Material	Mean Channel Velocity (feet per second)
Clay	6.0
Silty Clay	3.5
Sandy Silt	2.0
Fine Sand	2.0
Coarse Sand	4.0
Fine Gravel	6.0

Embankment and Foundation Seepage

Seepage analyses are required to estimate the quantity of seepage and, more importantly, the phreatic surface of the seepage profile through the levee embankment. The results of the seepage analyses are to be used in the stability analyses. If the phreatic surface daylight on the landward levee slope, appropriate measures (such as chimney, blanket, and toe drains) shall be implemented to collect and discharge this seepage without compromising the internal stability of the embankment.

Embankment and Foundation Stability

The levee embankment and foundation shall be analyzed to meet minimum slope stability requirements. The USACE (2000) lists four conditions that are to be analyzed: (1) end-of-construction, (2) sudden (also called rapid) drawdown, (3) steady-state seepage at full flood stage, and (4) earthquake. **Table 3** lists acceptable factors of safety against slope stability failure for these conditions.

TABLE 3
Minimum Factors of Safety – Levee Slope Stability (after USACE, 2000)

Condition	Minimum Slope Stability Factor of Safety
1. End-of-Construction	1.3
2. Sudden Drawdown	1.0 to 1.2[a]
3. Steady-State Seepage	1.4
4. Earthquake	–[b]

NOTES:
[a]A factor of safety of 1.0 applies to cases where the water levels are unlikely to persist for a long period of time. A factor of safety of 1.2 applies to cases where the water levees are likely to persist for a long period of time.
[b]No earthquake criteria is provided, as earthquake loading is generally not considered during periods of high water given the low probability of both events occurring at the same time. However, earthquake damage will require maintenance to repair the levee to pre-earthquake conditions.

The levee and foundation shall be analyzed for settlement, and the levee shall meet the freeboard requirements after settlement has occurred.

Vegetation

The USACE (2009) provides guidance on the location and types of vegetation allowed on levees. In general, vegetation (except for perennial grasses) is not allowed on the levee or within a 15-foot buffer. Vegetation is not allowed in the levee section as it inhibits flood-fighting capabilities, as well as poses concerns regarding levee stability. Trees and root balls can become unstable during design storm events, and if they fail, a large portion of the levee can be removed during failure, potentially leading to failure of the levee. In addition, when trees die, their roots may decay and result in seepage paths through the levee. For these reasons, the USACE has developed guidelines as to the minimum location of vegetation in relation to the levee (ETL 1110-2-571, USACE, 2009). These guidelines are illustrated in **Figure 4**, as applicable to the levee systems evaluated for this project.

Only grass, riprap, or engineered surfaces are allowed in the vegetation free zone. For all trees larger than 2 inches in diameter in the vegetation free zone, the USACE requires the following:

1. Excavation and complete removal of trunks, stumps, root balls, and all roots larger than ½ inch in diameter within 15 feet of the levee
2. Removal of all organic debris from the void
3. Filling and compaction of replacement soil in the resulting void

Trees and shrubs smaller than 2 inches in diameter should be mowed as part of the periodic maintenance of the levee

Animal Impacts

FEMA (2005) provides guidance on the impacts and necessary repairs of burrows and preventive measures of animals on embankments. Based on the same intent as for vegetation, animal burrows shall be repaired within the levee. FEMA includes the following two methods to repair animal burrows: (1) fill with a flowable cement/soil mixture or (2) excavate and fill and compact soil in the resulting void.

As preventive measures, FEMA includes both design mitigation methods, as well as methods for eliminating the animals from the area. Mitigation methods to prevent burrowing by animals and that may be applicable to this project include the following:

1. Erosion protection methods (such as riprap) placed on the riverward slope to minimize the ability of animals to burrow into the slope
2. Wire netting on riverward slopes that do not require riprap for erosion protection
3. Hardening of the levee crest with concrete, asphalt, or compacted gravel
4. Removal of problematic animals through trapping, poisoning, frightening, repelling, or shooting

2.1.2 Operations and Maintenance

A significant factor in the failure of many levees is a lack of planning for and implementation of operations and maintenance procedures. FEMA requires the community to prepare, submit, and then maintain various operations and maintenance documents for the levee system. The required documents are described as follows. Preparation of these plans was not included in the scope of work for Phase I of this project.

Operations

An officially adopted Operations Manual must be submitted to FEMA as part of the levee certification package. Operation of the levee system must be under the jurisdiction of an NFIP community that assumes ultimate responsibility for operation of the levee system. The Operations Manual must document the use of a flood warning system, triggering emergency operation activities and demonstrate that there is adequate warning time for operation of system components. The Operations Manual must identify all closure structures and include a formal plan of operations during an emergency, but the plan must also cover testing, inspection, and training. Responsibilities and actions for the operation of closure structures should be defined and assigned to specific individuals. The Operations Manual must also identify all interior drainage facilities and include a formal plan of operation during an emergency including testing, inspection, and training. Responsibilities and actions for the operation of interior drainage systems should be defined and assigned to specific individuals. Inspection of all facilities should occur at least once a year.

Maintenance

An officially adopted Maintenance Manual must be submitted to FEMA as part of the levee certification package. Maintenance of the levee system must be under the jurisdiction of an NFIP community that assumes ultimate responsibility for maintenance of the levee system. The Maintenance Manual must specify maintenance activities to be performed (inspections, vegetation control, etc.), frequency of those activities, and specific individuals responsible for maintenance. The objective is to preserve the integrity of the levee system. Copies of all maintenance and inspection records should be kept, including records that document how deficiencies were addressed. Inspection of all facilities should occur at least once a year.

Performance Assessment

While not required by FEMA, a routine assessment of levee condition and performance during flood events is a useful tool for reviewing the long-term adequacy of levee systems. The assessment may take place after a significant flood event and areas of erosion, seepage, ponding behind the levee, sedimentation, and structural damage to the system should be noted. The assessment may also note how closures and interior drainage systems performed, any flooding that occurred, and any other pertinent information relevant to the levee's performance.

2.1.3 Interior Drainage Analysis

FEMA requires that the internal drainage of the protected area be analyzed to confirm that the levee system does not result in significant internal flooding of the protected areas. The analysis should identify the source(s) of such flooding, the extent of the flooded area, and the water-surface elevation if the flooding is expected to exceed 1 foot in depth. The analysis must be based upon the joint probability of interior and exterior flooding.

Interior drainage analysis was not included in the scope of work for Phase I of this project. However, areas of potential ponding of stormwater were identified during field investigations conducted in Phase I.

3.0 Investigation of Levee Condition

A key element of Phase I was to investigate the existing levee system and collect the information required to assess its condition. CH2M HILL conducted a three-part investigation of the existing levee system to obtain the information required for this evaluation, including the following:

1. Literature review
2. Site inspection
3. Field exploration

This section summarizes the results of these investigations.

3.1 Literature Review

A literature review was conducted to obtain historic documentation of the existing levee available from Salt Lake County, identify the timeline of construction of the existing levee, and review design documents, as-built drawings, and geotechnical studies of the existing levee and nearby structures.

Salt Lake County provided extensive documentation of the levee system from their archives. As noted in **Section 1.0**, CH2M HILL developed a conceptual and final design for improvements to the levee in 1984 to address new FEMA levee policies and a new FIS that included updated hydrology and hydraulic information. CH2M HILL's archives from this project were also reviewed. This information is largely summarized in the history of the levee system provided in **Section 1.0** (see **Project History** and **Planning Context**) but highlights relevant to the levee's condition follow.

Until 1982, the levee system was a patchwork of improvements to the west bank of the river to control flooding. Documents point to various efforts to fill in low areas and build an earthen berm along the west bank to control flooding. Some of these efforts were engineered designs, whereas most of the improvements likely were not. One can also surmise from topographic information that some areas of the floodplain were filled in over time, perhaps for improvements for agriculture and development, but also for flood control. An important conclusion from this information is that the soils that comprise the existing levee embankment and foundation materials may not be engineered or represent native soils. Soils along the levee alignment could vary and significant variations may not be captured in the geotechnical explorations conducted as part of this study.

3.1.1 Design/Construction of Existing Levee

As described in **Section 1.0**, Salt Lake County undertook an extensive flood control project in 1981 to address some of the flooding concerns along the study area. Improvements included the realignment of a reach of the channel immediately to the south of the 500 South bridge crossing, construction of a levee embankment on the west side of the channel, and dredging of the river channel.

Levee/Channel Improvements

The County's "Interim Levee Project," also known as Phase I, was started in October 1981 to address specific concerns identified by FEMA regarding potential flooding hazards in the area. FEMA would not approve a proposed flood plain map amendment until a levee was constructed along the entire length of this reach of river. The project was limited to the river reach between North Temple Drive and Redwood Road.

The County retained CH2M HILL in September 1981 to design levee improvements that would provide 3 feet of freeboard using FEMA's new hydraulic profile of the river. However, since a levee needed to be in place by early 1982, the County could not wait for completion of the final FIS or levee design. Construction of the "Interim Levee Project" was started in October 1981 in cooperation with FEMA and was finished in July 1982. The objective of this project was to build a new levee that provided a minimum of 2 feet of freeboard with the condition that the levee would be raised to a final 3 feet of freeboard in a subsequent phase of the project. The second phase of the project would be built per FEMA's final hydraulic profile for the river.

Levee improvements in Phase I of the project included removal of vegetation and organic matter from the proposed levee location and subsequent compaction of the native materials. Clay material was imported for construction of the levee, placed in 8- to 12-inch lifts and compacted to 95.0 percent (the American Society of Testing and Materials [ASTM] standard for relative compaction was not noted, but is assumed to be ASTM D698). Compaction results and "as-built drawings" were provided to FEMA in August 1982.

The new levee generally had side slopes of 3H:1V extending to the toe of the river bank. The channel was also widened to provide additional flow capacity. See **Figure 5** for a typical cross-section of the new "interim" levee and channel. There is no indication from as-built drawings that erosion control measures, such as riprap, were placed on the new levee as part of this project.

Channel Realignment

Approximately 800 lineal feet of the river channel immediately south of the 500 South bridge crossing was moved an average of 30 feet to the east to provide adequate ROW for subsequent construction of a levee on the west side of the river channel. The need for this work was identified during construction of the Interim Levee Project in November 1981. Work was completed in 1982. The realignment project included construction of a levee embankment on the west bank with a landward side slope of 4H:1V and riverward side slope of 2H:1V. Sketches of the improvements indicate that the levee crest was approximately 10 feet wide. Clean gravel fill (that is, "sewer rock") was used for construction of the new, west river bank below the normal water surface elevation of 4,213 feet. An imported clay material was used for construction of the river bank and levee above the normal water surface elevation.

3.1.2 Subsequent Modifications to Levee

As described in **Section 1.0**, no record of specific improvements to the levee after construction of the Interim Levee Project in 1982 exists. The improvements to the levee identified for Phase II of the project were never built. There is mention of emergency improvements to the levee made during the floods of 1983; however, no details were provided. No documentation of operations, maintenance, or inspections since 1982 has been located. The preponderance of trees on the existing levee indicates that maintenance of the levee per FEMA guidelines may not have occurred.

As a result, it is assumed that the existing levee system that exists today is largely the same levee that was built in 1982. Ongoing development and redevelopment along the river corridor, erosion of the levee by the river, and construction and maintenance of a recreational trail on the levee may have modified the levee to various extents; however, none of these modifications appear to be documented.

3.1.3 Available Geotechnical Information

Jordan River Levee

Bingham Engineering (1980c) excavated nine test pits along the levee alignment to log the upper subsurface materials and to measure the density of the existing levee fill. The fill was noted as generally sandy silt to clayey silt, with an average of about 75 percent relative density. It was noted that the existing levee at that time was built on top of the existing ground without stripping, and that a layer of organics was present between the levee and native soils, but that this layer was relatively compact and was considered relatively impervious.

Bridges and Other Nearby Projects

A number of existing geotechnical reports exist that document the conditions for structures located within, adjacent to, or near the levee system. Six reports have been identified, dating from 1960 to 1981, for the design of bridges and a sewer line. These are documented and copies of them are available in the *Geotechnical Data Report* for this project contained in **Appendix B** (CH2M HILL, 2009b).

3.1.4 Available Survey Information

Salt Lake County surveyed new cross-sections of the lower Jordan River in the study area in 2008. The objective of this effort was to define the freeboard the existing levee provides. Cross-sections were obtained generally every 400 feet along the river channel and used to develop an initial profile of the levee crest for use in comparison to the river's hydraulic profile. This survey work was completed using the National Geodetic Vertical Datum of 1929 (NGVD29) vertical datum and a horizontal coordinate system unique to this project. Salt Lake County's work is documented in a preliminary report completed in 2009. The findings were that the existing levee does not meet FEMA's freeboard requirements for certification and accreditation.

Salt Lake City provided CH2M HILL with available Light Detection and Ranging (LIDAR) data developed by the State of Utah for the study area. This data was converted from metric units to English units and converted to the NGVD29 datum for use in this project. A comparison between the LIDAR and the County's ground survey indicates that they are more or less consistent, but that the LIDAR survey generally indicates an elevation about 6 inches lower than the ground survey. It should also be noted that no available survey data is available documenting the improvements made in Reach 1 for the new recreation trail. The trail project appears to have widened the levee but not raised the levee.

The LIDAR data was used for the purposes of this study as it provided a consistent topographical map of the levee, river bank, and surrounding area. A more detailed ground survey will be required for preliminary and final design.

3.2 Site Investigation

CH2M HILL conducted a site visit to the study reach on June 1 and 2, 2009, to document visible features and the condition of the levee and to identify potential issues that need to be addressed as part of this project. The site visit and inspection in general followed the guidelines provided by the USACE (2006) in the *Levee Owner's Manual for Non-Federal Flood Control Works.*

Observations were noted on hard-copy aerial photographs and notepads. Features were mapped using a Trimble GeoXT to define quantities and approximate locations of features. Only trees in excess of 6 inches were mapped by global positioning system (GPS) but trees observed to be greater than 2 inches in diameter were counted. Absolute accuracy of feature locations is estimated at ±10 feet and tree counts to be within ±10 percent in the areas surveyed. Note that trees outside of the existing levee easement were only surveyed if easily accessed.

It should be noted that observations were made only from the top of the levee and not from the water. Vegetation obscured much of the levee from view, thus the true extent of some of the issues could not be assessed. Areas with high vegetation incidence that were spot checked revealed many stumps of trees that had been previously cut down and signs of erosion and rodent damage that were obscured from view from the top of the levee. Additionally, areas where levee grass had been mowed revealed more erosion and rodent damage than areas with extensive vegetation. While this highlights the hindrance that vegetation posed to the levee inspection, general observations could still be made and overall trends could still be identified.

Observations documented for each reach are summarized in CH2M HILL (2009a) *Technical Memorandum – Summary of Site Visit – Lower Jordan River Levee Evaluation.*

In summary, the following key issues were identified from the site visit:

- A significant amount of unacceptable vegetation covers the existing levee. Tall grasses, brush, and small trees obscured much of the levee and prevented a thorough assessment of the levee's condition. Several hundred trees (defined as greater than 2 inches in diameter) were observed within the levee's vegetation-free zone. It should be noted that while some of these trees were planted, most of these trees appear to have been recruited on their own. These trees should not have been planted nor allowed to recruit and grow and should have been removed as part of an ongoing levee maintenance program.

- Significant lengths of the levee were excessively steep with side slopes on the riverward side in excess of 3H:1V for the majority of the levee, and steeper than 1H:1V in some locations. The existing levee was built with side slopes of 3H:1V as part of the Interim

Levee Project. The fact that the majority of the riverward side slope of the existing levee is now steeper than 1H:1V indicates active bank erosion and slope instability.

- Numerous cases of encroachment of the levee were observed. Many of these features, such as storage sheds and recreational vehicles, can be moved with some minimal effort; however, many other features such as irrigation pump stations, utilities, mobile homes, buildings, and fences will require significant coordination and effort to relocate. These structures restrict emergency response and in some cases may have detrimental impacts to the stability of the levee.
- Several levee penetrations were observed; however, they were relatively few in number. Three storm drain outfalls were identified that did not have flap gates or other backflow prevention measures. One flowing spring was identified in Reach 5 indicating saturated conditions. Three other small-diameter (less than 4 inches) pipelines that appeared to be abandoned were observed. Existing irrigation pump stations are assumed to include pipelines that also penetrate the levee.
- Signs of rodent activity were observed throughout the study reach. Beaver activity was pronounced in Reaches 3 and 5 but was observed in all reaches. Observations made from the water by others indicate that beaver and muskrat are prevalent throughout the study reach. While the beaver activity was mainly in the river bank itself (which is often an integral part of the levee), indications of smaller rodents in the upper earthen levee section were also observed.

Each reach was assigned one of the following ratings according the USACE (2006) rating system:

- **Acceptable:** The rated item is in satisfactory, acceptable condition and will function as designed and intended during the next flood event.
- **Minimally Acceptable:** The rated item has a minor deficiency that needs to be corrected. The minor deficiency will not seriously impair the functioning of the item during the next flood event. The overall reliability of the project will be lowered because of the minor deficiency.
- **Unacceptable:** The rated item is unsatisfactory. The deficiency is so serious that the item will not adequately function in the next flood event, compromising the project's ability to provide reliable flood protection.

The overall project rating for entire levee system is equal to the lowest rating for an individual reach.

Based on the site investigation, all five reaches were assigned an Unacceptable rating, with the overall levee also receiving an Unacceptable rating. The primary reason for the Unacceptable rating was the overabundance of vegetation on the levee and encroachments into the levee section, as well as the steep slopes, penetrations, erosion, and rodent activity.

3.3 Geotechnical Exploration

A geotechnical exploration was conducted to get a general idea of the geotechnical conditions of the existing levee embankment and the levee foundation. Sixteen borings were advanced as part of this exploration (**Figure 2**), with 14 borings to a depth of 20 feet and two borings to a depth of 100 feet. The borings were spaced on average 1,000 feet apart, which is not adequate for detailed design, but gives a general understanding of the subsurface conditions along the levee.

The geotechnical exploration indicated that the existing levee, where present and where the borings were advanced, consisted of sandy silt material, and contained some organics, gravel, and clays.

Beneath the existing fill was recent alluvium and Lake Bonneville deposits to the maximum depth of the borings. This material was found to be very discontinuous, and consisted of varying thicknesses of silt, silty clay, clay, organics, and fine to medium sand. The material was also noted to be relatively soft/loose, with standard penetration test values generally less than 10 blows per foot, and in many cases, the blowcount was zero with the observations of *weight of rod (WOR)* and *weight of hammer (WOH)*. These results indicate that the material is weak, and may not be able to maintain stable embankment conditions over the long term.

The ground water table within the levee was not measured, but given the close proximity of the Jordan River, it is assumed to be close to the same elevation as the river.

Details and the results of the geotechnical exploration are contained in **Appendix B** in the *Geotechnical Data Report - Phase I - Jordan River Levee Project North Temple to Redwood Road* (CH2M HILL, 2009b). The data report also includes a summary of the geotechnical work conducted for the nearby structures and summarizes the regional geology.

4.0 Assessment of Levee Condition

Based on the levee reconnaissance and field investigation, several issues were identified regarding the existing levees, including the following:

- Freeboard requirements and required levee crest raise
- Bridge crossings
- Vegetation
- Encroachments and easements
- Levee access
- Penetrations
- Riverside erosion and erosion protection
- River bank and levee geotechnical stability
- Animals

These are discussed in detail in the following sections, with a summary of the impact for each reach. **Figure C1** in **Appendix C** shows the existing conditions encountered during the levee assessment. Note that the assessment within this section is based solely on the information obtained from the levee survey and the conditions observed in the site investigation and geotechnical exploration. It should be anticipated that due to the vegetation and access difficulties to portions of the levee that there may be additional existing conditions not documented herein.

4.1.1 Freeboard Requirements and Required Levee Crest Raise

As documented by Salt Lake County (2009), the majority of the existing levee crest varies from zero to a maximum of 3 feet below the required levee crest elevation (see **Figure C2** in **Appendix C**), with the average levee raises required shown in **Table 4** for each Reach.

Generally, the following two options are available for the levee system to meet the freeboard requirements:

1. Raise or build a new levee with an earthen embankment or floodwall structure to meet the freeboard requirements. In general, to meet the 100-year flood requirements and using a 3-foot minimum freeboard, the levee needs to be raised by about 1 foot. The highest raise is approximately 3 feet just south of the 700 North Street bridge.
2. Update the H&H models by performing an additional study to evaluate the uncertainty of the models and to develop a better-defined 1 percent chance of exceedance flood. The minimum freeboard, even with the refined analyses, is 2 feet. Performing additional H&H studies was not within the scope of this project.

TABLE 4
Average Levee Raise by Reach

Reach	Average Raise Required (ft)
1	0.3[a]
2	0.7
3	1.3
4	1.4
5	1.0

NOTES:
[a] The raise requirement for Reach 1 is unknown, as a recent trail was constructed on the levee after the ground and LIDAR surveys were conducted. However, based on the pre-trail survey, an average levee raise of 0.3 foot would be required along this reach if the new trail maintains the same grade as the old trail.

4.1.2 Bridge Crossings

As discussed previously in the report, the levee must be evaluated as a continuous levee system and bridge crossing are discontinuities in the system that need to be addressed in regards to closures. The freeboard requirements at the bridge crossings are summarized **Table 5**. Note that these evaluations are based on the LIDAR survey data and uses the NGVD29 datum. The abutment elevations are considered to be approximately the elevations of the sidewalk on the abutment at the centerline of the levee. All elevations should be verified by field survey during design.

TABLE 5
Bridge Crossing Summary

Bridge	Abutment Elevation (feet)[a]	100-year Flood Elevation (feet)	Required Abutment Elevation for Flood Protection (feet)[b]	Raise Required (feet)
North Redwood Road	4,218.0	4,215.1	4,219.1	±1.0
Rose Park Golf Course	4,218.1	4,215.9	4,219.9	±2.0
1000 North Street	4,218.4	4,216.8	4,220.8	±2.5
Pedestrian Bridge, STA 93+00	4,218.4	4,217.5	4,221.5	±3.0
700 North Street	4,218.7	4,217.8	4,221.8	±3.0
Pedestrian Bridge, STA 120+30	Levee is offset ±50 feet from the bridge abutment and path.			
500 North Street	4,221.3	4,218.5	4,222.5	±1.0
Pedestrian Bridge, STA 135+70	4,221.1	4,219.1	4,223.1	±2.0
Pedestrian Bridge, STA 146+30	Levee is offset ±50 feet from the bridge abutment.			
Pedestrian Bridge, STA 172+00	4,220.5	4,220.2	4,224.2	±3.5
Pedestrian Bridge, STA 176+60	Levee is offset ±40 feet from the bridge abutment.			
North Temple Road	4,222.2	4,220.7	4,224.7	±2.5

NOTES:
[a]The elevation shown is on the levee alignment where the road or path crosses the levee. The elevation shown is on the edge of the road, assuming that this is the critical location if water was to bypass the levee during a flood.
[b]Based on a 4-foot freeboard required within 100 feet of the bridge.

For the bridges that require a raise, this could be accomplished by raising the bridge approach by the amount shown, or providing a closure with a height as indicated for the raise. In addition, for bridges with camber, it may be possible to tie in the levee alignment farther riverward to be able to account for the camber elevation rise.

For the Golf Course and other pedestrian bridges, the abutment could likely be incorporated into the levee. For the road bridges, the raising of the abutment may be more difficult. The concrete curb and railings of the bridges will need to be surveyed and may provide the necessary closure if the levee section is tied into the bridge curb/railing with a closure concrete wall. Other options may also be available, and each bridge will have to be surveyed and evaluated individually. In addition, the use of sandbags may be an option for the smaller raises, provided they are meeting the requirements for a closure and are included in the Operation and Maintenance Manual.

Note that it is recognized that these are small raises, and the accuracy of the LIDAR survey data may not be accurate enough to accurately capture the need for raises at the bridge crossings. It is recommended that ground surveys be conducted to accompany this data and confirm the abutment elevations.

4.1.3 Vegetation

Significant vegetation is present within the levee system for the entire levee alignment. Almost 1,200 trees larger than 2 inches in diameter were observed along the levee alignment (**Table 6**); in addition, numerous smaller trees and brush were present, and in locations that did not have trees, the levee was generally obscured by tall grass. Approximately four trees larger than 4 feet in diameter were noted. Following the USACE guidelines, all trees should be removed from the levee, which includes 15 feet either side of the levee toe (see **Figure 4**).

TABLE 6
Summary of Trees along the Levee Reaches

Reach	Approximate Number of Trees Larger than		Notable Trees Larger than 3-feet in Diameter
	2-inch diameter	6-inch diameter	
1	271	219	Two ±4-foot Cottonwood trees on landward side of levee.
2	319	212	One ±6-foot Cottonwood tree on landward side of levee.
3	166	162	One ±8-foot Cottonwood tree on levee.
4	144	144	None observed.
5	361	361	None observed.

4.1.4 Encroachments and Easements

Numerous encroachments were noted along the levee reaches. These encroachments, when located within 15 feet of the levee, will need to be removed to meet the USACE guidelines for levees. **Table 7** summarizes the encroachments observed along each reach.

Some of these encroachments are the results of narrow easements. Based on the Salt Lake City parcel mapping, the easement along much of the levee is too narrow to support a full-width levee section. For example, the apartment building located along Reach 4 is setback approximately 25 feet from the top of the river bank. At this location, the base flood is elevation 4,218.1 feet. With a 3-foot required freeboard, the required levee crest is elevation 4,221.1 feet. The measured ground/levee surface in this vicinity is elevation 4,219.5 to 4,221.0 feet. This indicates a required levee improvements of around zero to 1.5 feet of fill. Even a small levee of this height would require a levee section minimum width of 36 feet (12-foot crest, 3:1 side slopes, 1.5 feet high, and a 15-foot offset, assuming the waterside toe of the levee is right at the river bank crest). Other locations of tight easements include the section along Reach 2 adjacent to Riverside Drive and Reach 5 adjacent to the mobile home park.

TABLE 7
Encroachment Summary

Reach	Encroachments
1	An abandoned irrigation pump stations riverward of the levee. Fences are located on the golf course side of the levee. Retaining walls landward of the levee at residences near North Redwood Road. Retaining walls landward of the levee surround trees along Golf Course.
2	Utility poles near 1000 North Street. Debris disposal piles adjacent to Golf Course. Fence located on riverside of the levee adjacent to the Par 3 Golf Course.
3	Portions of the library and sculptures may be encroaching on the landward side of the levee. Compost bins and a small shed on the landward side of the levee. Two abandoned irrigation pump stations riverward of the levee. Utility poles located landward of the levee. Fire hydrants located landward of the levee. Sprinkler system.
4	Two abandoned irrigation pump stations riverward of the levee. A retaining wall and concrete pad of unknown use located riverward of the levee. An active flow gauging station located riverward of the levee adjacent to 500 North Street. Utility poles located on and landward of the levee. An apartment building located within the landward toe of the levee. Residential sheds and structures located landward of the levee. Fences located landward of the levee.
5	An abandoned irrigation pump station riverward of the levee. Irrigation piping within and riverward of the levee. A well with a 2-inch polyvinyl chloride (PVC) discharge into the river located riverward of the levee. Small retaining walls located landward and within the landward toe of the levee. A parking lot. Fencing located landward of the levee. Approximately 26 storage sheds were located within the levee toe or landward of the levee. Two to three fixed mobile homes were located landward of the levee. Utility poles are located on and landward of the levee.

NOTE:
All items described here are noted to be within the levee (for example, within 15 feet of the levee toe). Uncertainty in regards to the levee toe exists in some instances, so there is may be some uncertainty regarding whether some of these are encroachments.

4.1.5 Levee Access

To facilitate periodic inspections and to allow for flood fighting efforts, access should be provided to the crest and landward side of the levee. In general, most of the levee currently has good access, with the following exeptions:

- **Reach 1**: Vehicular access at the north end of Reach 1 is obstructed by removable pylons in the levee crest. This does not hinder access, provided that the County has access to unlock the pylons. A locked gate is located at 1000 North Street that blocks both inspection and vehicular access to the levee. Access can be obtained along the central section of Reach 1 by accessing through the golf courses. Fences run along the northern portion of this reach that encroach in the levee section and hinder access and inspection. These fences should be removed from the levee section.
- **Reach 2**: A fence also runs along the southern portion of this reach that encroaches in the levee section and hinders access and inspection. These fences should be removed from the levee section.
- **Reach 5**: A locked gate prevents inspection and vehicular access at North Temple Road. Permanent pylons in the crest of the levee are present approximately 700 feet north of North Temple. Good access exists to the middle and north end of the levee. Fences also run along the southern portion of this reach that encroach in the levee section and hinder access and inspection. These fences should be removed from the levee section.

These noted obstructions should be removed to provide access to inspect the levee and for flood fighting. The obstructions at Reach 1 can be resolved by obtaining keys to unlock the obstructions as needed. The permanent pylons at Reach 5 should be replaced with removable pylons, and keys obtained to the gate to gain access to the southern section of Reach 5.

4.1.6 Penetrations

Several penetrations exist through the levee or levee foundation. Some of these penetrations are intakes or outlets into the river, while others continue across the river. The levee penetrations that discharge into the river should be sealed with flap gates to prevent backflow into a drainage system. Intake lines (for example, pipeline at the abandoned irrigation pump stations) should be investigated to confirm that the line would not allow unhindered flow back through the levee during a design flood event. This may require removing or sealing the intakes. The backfill for penetrations that cross the river also needs to be evaluated to confirm that the backfill is adequate to minimize seepage along the outside of the pipe.

Table 8 summarizes the penetrations that were observed in the levee or river bank; it is likely that additional penetrations exist that were not observed due to high water, or were obscured by the tall grass, brush, and trees.

TABLE 8
Penetration Summary

Reach	Penetrations
1	A petroleum pipeline penetrates the levee at North Redwood Road. A sewer pipeline penetrates the levee at North Redwood Road. A water pipeline penetrates the levee at North Redwood Road. It is probable that a water pipeline penetrates the levee at the abandoned pump station. A 36-inch corrugated metal pipe storm sewer transitioning to a 24-inch pipe penetrates the levee near the Golf Course bridge. Several PVC pipes drain into the Jordan River from the golf course.
2	A storm sewer penetrates the levee under 1000 North Road and Bridge.
3	A storm sewer is shown on the City's utility mapping to penetrate the levee at the location of the irrigation pump station along Riverside Drive. Need to confirm that this is a storm sewer or part of the abandoned irrigation pump station.
4	It is probable that water pipelines penetrate the levee at the abandoned pump station locations. It is unknown if there is a penetration at the unknown retaining wall and concrete pad. A 2-inch pipeline penetrates the levee. A 12-inch corrugated metal pipe penetrates the levee without a flap gate.
5	It was not observed, but the City's utility mapping indicates an 18-inch reinforced-concrete pipe storm sewer pipe discharging into the river at 500 North Street. It is probable that a water pipeline penetrates the levee at the abandoned pump station location. A 2-inch discharge appears to originate from a well and discharge into the Jordan River. A drainage tile extends into the Jordan River, and it is unknown if the drain tile penetrates the levee foundation.

4.1.7 Riverside Erosion and Erosion Protection

Erosion of the river bank was noted in portions of all reaches. The erosion noted was generally surficial sloughing on steep slopes, often in areas where the slopes were steeper than 1H:1V.

In general, no erosion protection is present along the riverward side of the levee except for native grasses and shrubs, with the following exceptions:

- **Reach 1**: A 300-foot section of the reach is lined with riprap. It appears as though this was placed during construction of the new trail along the levee crest.
- **Reach 5**: A portion of the levee through a park between the State office buildings is well-identified and has a well-established stand of grass and is well maintained.

It is estimated that during flood stage, the river will have velocities of 1.9 to 4.6 feet per second or larger over most of this section of the Jordan River. Given these velocities, the fact that the levee and foundation soils were identified as clays, sands, and silts, and the recommendations of the USACE regarding erosion stability of soils (**Table 1**), it is recommended that this entire reach of levee be protected from erosion by covering the slope with riprap or other engineered means.

As an initial estimate, for the majority of the levee the average flows are 5 feet per second or less, with a resulting mean grain size (D_{50}) for riprap of around 2 inches. In isolated areas and around structures larger velocities may be encountered. For velocities of 10 feet per second the D_{50} needs to be around 8 inches. The actual riprap size will need to be determined during design based on actual channel velocities, and incorporating sufficient margins of safety into the designs.

4.1.8 River Bank and Levee Geotechnical Stability

Geotechnical analyses of the river bank and levee are very much dependant on the site-specific soil conditions at each location. Given that the borings were relatively widely spaced, generalized parameters were used to evaluate typical slope stability based on the types of soil encountered and their estimated strengths.

Stability analyses were conducted on a generalized section. Static steady-state and sudden drawdown slope stability analyses indicated that slopes steeper than 3(H):1(V) do not include adequate factors of safety against slope stability during the design flood event. The analyses included both the river bank and the levee section, though given that the levee section is only a few feet high in most locations, the levee itself does not control the geotechnical stability. In many cases, the stability of the river bank is what controlled. If the levee is located adjacent to a riverbank that is steeper than 3(H):1(V), the riverbank must be stabilized to provide an adequate factor of safety against slope stability of the levee/riverbank section.

Note that these were generalized analyses and that during final design, analyses will be required to evaluate specific levee sections. In some locations, flatter slopes may be required, or steeper slopes may be permissible, depending on the results of the reach-specific analyses.

The LIDAR data was used to estimate the riverbank slopes along the levee, and the results are shown in **Appendix D**. The yellow color indicates slopes that are steeper than 3:1, and the red color indicates slopes that are steeper than 1:1. No color indicates that the slopes are flatter than 3:1. Note that the majority of the river bank has slopes steeper than 3:1, and numerous locations exist for which the slopes are steeper than 1:1.

In locations of over-steepened riverbank slopes (for example, steeper than 3:1), the slope should either be buttressed, the levee set back, or the slope trimmed back to a 3:1 slope or flatter (**Figure 5**).

A preponderance of loose, sandy soils is present within the levee foundation. Based on analyses of the soils, they are predicted to liquefy during an event that has a 50 percent probability of being exceeded in 50 years (approximately 75-year motion). This is a relatively frequent event, and in general, structures are designed to withstand the 10 percent probability of being exceeded in 50 years (approximately 475-year motion) motion or larger. Given that these soils are prone to seismically induced liquefaction during a relatively frequent event, the seismic performance needs to be included in the Operation and Maintenance Manual. Although it is not recommended that the earthquake scenario be assumed to occur during the design flood, damage to the levee system during an earthquake would be a maintenance issue that needs to be addressed before a flood does occur.

Stability analyses were conducted using an assumed liquefied soil strength, and indicate that significant portions of the levee/riverbank would fail or undergo large deformations during a seismic event that would induce liquefaction of the foundation soils. It is anticipated that this event would require rebuilding the majority of the levee. Alternatively, soil improvement could be conducted to improve the soils and minimize liquefaction of the foundation soils, though this would be a relatively large cost. The seismic damage would occur for the current levee location, or in most cases, even if the levee is setback from the riverbank.

4.1.9 Animals

Small rodent burrows were noted along the majority of the levee. In addition, beaver and muskrat activity was noted, primarily in Reaches 3 and 5, but it is assumed that their habitat extends along the entire project area. Numerous collapsed beaver dens were observed in the river bank and toe of the levee that penetrate the levee. It is assumed that visible beaver damage indicates that there are numerous other dens penetrating the levee. These burrowing animals will need to be controlled for safe levee operation.

4.1.10 Seepage

Given that the levee is relatively short in height and that in many cases the 100-year flood is not expected to crest above the existing river bank, seepage through the levee is of minimal concern. Layers of sand were noted in the geotechnical exploration, but these layers appeared to be discontinuous, and are not considered to pose a significant seepage concern.

4.1.11 Summary

Based on this assessment of the levee, significant work will be required to raise the levee to the required freeboard and to meet the requirements for certification and accreditation. The removal of vegetation and rodent burrows will require significant excavations into the foundation soils, and during stripping and grubbing of the grasses and brush most of the existing levee will be removed. The levee could be rebuilt in place, though doing so would require stabilizing the river bank in the many locations that the bank is steeper than 3:1, or the levee could be built offset from the riverbank. The offset levee has many advantages, and could minimize the removal of riparian vegetation; however, this option is limited by the easement allowance along the levee, and may not be possible in many locations due to the tight easement.

5.0 Proposed Alternatives and Recommendations

5.1 Guiding Principles for Improvements

As discussed in **Section 1.0**, the following five guiding principles were used to evaluate alternative improvements:

1. The existing levee was constructed first and foremost as a flood-control structure. Up to 1,600 structures currently rely on the levee for flood protection (Nick Kryger, personal communication, September 2, 2009). The final improved levee system must meet current FEMA guidelines for a certifiable levee for this area to continue with its current status in the NFIP.
2. This reach of the Jordan River is located within a developed, urban corridor. Improvements to the levee should be within existing ROW and minimize impacts to existing permanent structures (that is, homes, apartment buildings, and bridges) and uses while still meeting FEMA guidelines for required setbacks.
3. A significant number of trees and other vegetation have grown along the river bank and levee since the levee's construction in 1982. FEMA guidelines do not allow woody vegetation within a defined corridor centered on the levee; therefore, a significant number of trees will have to be removed to bring the levee into compliance. Improvements to the levee should attempt to minimize impacts to existing trees and associated habitat.
4. Proposed improvements should be consistent with goals identified in planning documents previously prepared for the Jordan River corridor (such as Blueprint Jordan River [Envision Utah, 2008] and Water Quality Stewardship Plan [Salt Lake County, 2009]).

Some of these principles are mutually exclusive, and it is not possible to meet all of these principles with a single levee design and alignment. Given this limitation, several levee design and alignments were evaluated, each alternative satisfying different measures of each principle.

5.2 Types of Levee

The following two types of levees are recommended for consideration: (1) an earth embankment and (2) a floodwall. These types of levees are recommended as the best alternatives to meet the previously noted principles. The specific levee type used was based on the assessment of the levee conditions.

In general, the earth embankment is the least expensive option and it can be planted with grass and covered with a gravel or paved surfacing for a trail. However, given the width of an earth embankment, it impacts a larger area and requires a larger vegetation-free buffer (see **Figure 4**). A floodwall, being a narrower structure, minimizes the required vegetation-free buffer, but it is a structural element and is more expensive than an earth embankment.

Both of these are levee types are discussed in more detail in the following sections.

5.2.1 Earth Embankment

In areas with adequate easement and limited concern about impact to trees or other structures or encroachments, an earthen embankment levee is the least expensive option. Two generalized earth embankment options are shown in **Figure 6**—one where the existing levee is raised adjacent to the river bank (**Figure 6A**) and another where the levee is set back away from the river bank (**Figure 6B**).

The design criteria of the earth embankment levee include the following:

1. The levee crest will be 12 feet wide to allow for ease of construction, maintenance, and flood-fighting ability. In constricted areas, if there is benefit, the crest width may be decreased to a minimum of 10 feet. The levee crest may also be widened if required.
2. Based on the results of slope stability analyses for the typical levee materials (for example, clays and silts), the side slopes on the riverward and landward sides of the levee will be 3(H):1(V).
3. This option requires a significant vegetation-free zone that extends 15 feet on either side of the levee toe. Depending on the levee height, this vegetation-free zone could be 50 feet or more. The vegetation-free zone for the earth embankment option is shown schematically on **Figure 6**.
4. Construction of an earth embankment would consist of locating a borrow source that contains sufficient quantities of earth fill required, meets specifications for levee fill (in general, this would be any type of silty or clayey material), and is located a reasonable distance from the levee.

Note that these design criteria are based on generalized conditions observed during the field explorations. Final design will require more detailed analyses and properties to confirm these criteria, and it should be anticipated that the criteria may vary from those previously noted.

The construction sequence for an earth embankment levee section would consist of the following:

1. Stripping the grasses and grubbing the trees and shrubs from the levee section
2. Grub and remove the root balls for all trees larger then 2 inches in diameter within the vegetation free zone
3. Scale the tree excavations to remove loose material and to create excavation slopes no steeper than 3H:1V
4. Backfill the removed tree excavations with compacted fill
5. Clean up the river bank and place the buttress or toe protection riprap

6. Place the levee fill lifts and compact
7. Plant new trees outside the vegetation-free zone if desired
8. Place the surfacing for a path or road on the levee crest and seed the levee slope and all disturbed ground

Given the number of trees (and associated root systems) and impacts of burrowing animals within the existing levee, the new levee will largely be a replacement of the existing levee.

Raise Earth Embankment Levee Option (Figure 6A)

In general, the existing levee was constructed adjacent to the riverbank, with the riverbank being an extension of the riverward levee slope. In some locations, it is not possible to distinguish the levee slope from the riverbank slope. The raise-levee option is based on maintaining the existing levee location to minimize impacts on adjacent structures and ROW and raising the levee to the required levee elevation.

Given the steep riverbank along much of the river (see **Appendix D**), the existing riverbank does not meet acceptable factors of safety for slope stability. If the levee is to remain adjacent to the riverbank, it will be necessary to stabilize the riverbank. **Figure 6A** shows a riprap buttress placed on the river bank, with the size of this buttress based on the need to stabilize the riverbank to acceptable slope stability factors of safety (see **Table 3**). This is a significant riprap buttress, and the actual size of it will vary depending on the specific section geometry and soil properties; however, a buttress of approximately this size will be required to raise the levee when located next to riverbank steeper than approximately 3(H):1(V).

Offset Earth Embankment Levee Option (Figure 6B)

If adequate ROW exists to set the levee back from the riverbank beyond approximately a 3(H):1(V) slope from the toe of the riverbank (see **Figure 6B**), then the levee could be constructed using minimal riprap, only as needed to provide for erosion protection. This option provides the added benefit of potentially minimizing impacts to the river channel, riverbank, and existing trees along the riverbank. A riprap buttress would not be required to stabilize the riverbank slope. Erosion, sloughing, and slope failures should be expected as the riverbank is not stabilized with this option; however, these failures should not impact the levee section as long as the toe of the riverbank slope is protection from erosion. If erosion and sloughing of the slope is observed, inspections should be undertaken as necessary to confirm that the levee stability is not in jeopardy and to maintain stability of the levee section.

5.2.2 Floodwall

In areas for which limited easement exists, or to minimize disturbance to trees or other structures, a floodwall levee option is recommended. By using a floodwall option, the levee section is narrower and the overall vegetation-free zone is minimized. Two generalized floodwall levee options are shown in **Figure 7**, one being a floodwall located on the riverward side of the existing levee (**Figure 7A**) and one located landside of the existing levee (**Figure 7B**).

A multitude of floodwall options are available, consisting of concrete walls, sheetpile walls, etc. For this project, a sheetpile wall with a concrete cap is considered the most economically reasonable type. However, in specific locations along this levee, during final design, alternative floodwall types may be considered for special cases.

The design criteria of the floodwall levee include the following:

1. A vertical sheetpile wall will be used. The sheetpiles will be pressed or driven into place. Based on sheetpile wall and seepage analyses, the required sheetpile length is estimated to be around 12 feet.

2. The sheetpile will be driven to be approximately at existing grade and a concrete cap will be cast on top of the wall. The concrete cap is estimated to be about 1 foot wide and generally 2 to 3 feet high.

3. The stability and supporting seepage analyses indicate that the maximum height of retained soil is approximately 2.5 feet. Therefore, for the waterside location, the wall must be located set back from the 3(H):1(V) slope so that if this slope fails there is a maximum of 2.5 feet of exposed wall (see **Figure 7A**).

4. The maximum height of water to be retained by the considered floodwall is about 4 feet if the ground surface on both sides of the floodwall is level. If the landside soil surface slopes at 3(H):1(V) (as in **Figure 7B**), the maximum retained water height is about 2 feet. An alternative, more robust floodwall will have to be designed to retain larger water heights.

5. The floodwall option requires a minimal vegetation-free zone that extends 15 feet to either side of the floodwall. With a 1-foot-wide wall, this vegetation-free zone is approximately 31 feet at the maximum. With the floodwall located on the riverside, the vegetation-free zone is minimized, though the vegetation along the riverbank will have to be removed. The vegetation-free zone for the earth embankment option is shown schematically on **Figure 7**.

Note that these design criteria are based on generalized conditions observed during the field explorations. Final design will require more detailed analyses and properties to confirm these criteria, and it should be anticipated that the criteria may vary than those previously noted.

The construction sequence for a floodwall levee section would consist of the following:

1. Stripping the grasses and grubbing the trees and shrubs along the levee alignment

2. Grub and remove the root balls for all trees larger than 2 inches in diameter within the vegetation-free zone

3. Scale the tree excavations to remove loose material and to create excavation slopes no steeper than 3H:1V

4. Backfill the removed tree excavations with compacted fill

5. Clean up the river bank and place the toe protection riprap

6. Install the sheetpile wall

7. Form, pour, and finish the concrete cap
8. Plant new trees outside the vegetation free zone, if desired
9. Place the surfacing for a path or road and seed all disturbed ground

Riverward Floodwall Levee Option (Figure 7A)

In areas that the levee ROW is narrow, this is the preferred alternative as it requires a minimal levee section. This option is shown with riprap that is only used as erosion protection. However, in some locations where the riverbank is overly steep, and a desire exists to have the floodwall located closer to the riverbank than allowed by the 2.5-foot maximum exposed height, a riprap buttress could be placed similar to the earth embankment raise option (**Figure 6A**). This buttress would stabilize the slope and allow the floodwall to be right at the edge of the river bank, minimizing the total vegetation-free zone to about 16 feet.

Landward Floodwall Levee Option (Figure 7B)

In areas that there is a desire to maintain the existing trees along the riverbank, this is the preferred alternative, as it is possible to minimize the impact to trees along the riverbank, while still maintaining a relatively narrow ROW. As long as the floodwall was outside the 3(H):1(V) zone from the riverbank toe, there would be minimal need stabilize the riverbank, with only erosion protection riprap recommended to minimize riverbank erosion.

5.3 Alignment Alternatives

The following two alignment alternatives were considered for this evaluation: (1) the existing alignment and (2) an offset alignment to minimize impacts. Both alternatives use both earthen embankments and floodwalls to achieve the objectives defined in the guiding principles.

5.3.1 Alternative No. 1 – Keep Existing Alignment

The objective of this alternative was to maintain the existing levee alignment as much as possible to minimize impacts to existing ROW. This alternative consists primarily of an earth embankment levee with some use of a floodwall. An effort was made to shift the levee landward if there was adequate ROW to both minimize vegetation impacts along the riverbank, as well as to minimize the need for riprap buttressing. In areas that limited ROW exists, or to minimize disturbance to large trees, a floodwall option was used. **Appendix E** shows the plan and profile for the alternative. Shown on the plan and profile are the levee type, the centerline, the levee section, and the 15-foot vegetation-free buffer.

An approximate summary of this alternative is shown in **Table 9**. Note that the number of trees impacted is approximate, as not all the trees within the levee corridor were surveyed.

TABLE 9
Alignment Alternative No. 1 Summary

Item	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Total
Number of 6-inch or larger trees to be removed	206	193	95	85	202	781
Length of earth embankment levee (feet)	3,780	3,350	940	1,580	4,030	13,680
Length of floodwall levee (feet)	240	0	1,720	530	1,500	3,990
Volume of earth fill required (cubic yards)	4,480	4,660	1,270	3,870	5,890	20,170
Volume of riprap required (cubic yards)	23,540	19,600	1,990	4,480	`5,420	49,610
Private ROW Acquisition (acre)	0.0	0.0	0.0	0.4	0.1	0.5
Public ROW Acquisition (acre)	0.4	1.6	1.8	2.1	6.4	12.2
Golf Course ROW Acquisition (acre)	2.7	2.5	0.0	0.0	0.0	5.2

5.3.2 Alternative No. 2 – Offset Alignment to Minimize Impacts

The objective of this alternative was to minimize the impacts to the riverbank and trees by shifting the levee as necessary to minimize these impacts. The primary change occurs in Reaches 1 and 2, where the levee alignment is shifted into the golf courses. In addition, the levee is shifted onto adjacent vacant properties in Reach 3 south of the library and in Reach 4 south of 700 North. This option used the floodwall for a much longer length, which resulted in significantly fewer trees being impacted. In addition, due to shifting the levee away from the riverbank, much less riprap is required to stability the slope. **Appendix F** shows the plan and profile for this alternative. Shown on the plan and profile are the levee type, the centerline, the levee section, and the 15-foot vegetation-free buffer.

An approximate summary of this alternative is show in **Table 10**. Note that the number of trees impacted is approximate, as not all the trees within the levee corridor were surveyed.

TABLE 10
Alignment Alternative No. 2 Summary

Item	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Total
Number of 6-inch or larger trees to be removed	62	24	43	35	147	311
Length of earth embankment levee (feet)	3,580	3,400	910	1,330	2,490	11,710
Length of floodwall levee (feet)	200	0	1,740	840	3,050	5,830
Volume of earth fill required (cubic yards)	18,310	18,030	2,810	4,940	3,090	47,180
Volume of riprap required (cubic yards)	2,840	2,550	1,980	1,620	4,160	8,990
Private ROW Acquisition (acre)	0.0	0.0	0.0	0.3	0.0	0.3
Public ROW Acquisition (acre)	0.4	0.2	2.1	2.0	4.1	8.8
Golf Course ROW Acquisition (acre)	5.3	5.3	0.0	0.0	0.0	10.6

5.3.3 Cost Estimate

A cost estimate was conducted for both alignment alternatives. The cost estimate was based on the generalized sections shown in **Figures** 6 and 7, the plans and profiles shown in **Appendices** E and F, and the quantities shown in **Tables** 9 and 10. Some of the key assumptions for the cost estimate not previously listed include the following:

- General conditions, contractor's profit, bonds/insurance, and mobilization/demobilization are combined 20 percent of the total contract.
- Trees to be removed are an average of 10 inches in diameter. It is assumed that the trees will be cut down and the stumps will be removed with an excavator.
- For every one tree removed, three trees will be planted outside of the vegetation free zone.
- The stripping removed during site preparation for the earth embankment options will be reused as topsoil for the new embankment levee.
- The earth fill required for the new earth embankment levee will be purchased, imported, and placed with a dozer and compacted in lifts with a sheepsfoot or padfoot roller.
- The riprap materials will be purchased and hauled to the site and placed with an excavator.
- The crest of the earth embankment and the trail adjacent to the floodwall will be finished with asphalt surfacing. Grass located on golf course properties will be replaced with sod, whereas seed will be used elsewhere.
- It was assumed that 5 percent of the total construction cost would be used for environmental mitigation.
- It was assumed that the golf course reconstruction would include the construction of two new tee boxes.
- A 4.75 percent sales tax was applied.
- The cost estimate includes a 30 percent contingency to account for items unknown at this early stage in design.
- Cost of project administration and engineering was estimated at 15 percent of the capital costs.
- While a cost to purchase ROW from both public and private entities is included, the County will assume for their budgeting purposes that public ROW, including ROW along the golf course, will be provided by others to the County at no cost.

The cost estimate has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on actual labor and material costs, competitive market conditions, final project scope, implementation schedule, and other variable factors. As a result, the final project costs will vary from the estimates presented herein. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help provide proper project evaluation and adequate funding.

Table 11 summarizes the unit rates used in the analyses. **Tables 12** and **13** summarize the cost estimates for each alignment option.

TABLE 11
Cost Estimate Unit Rate Summary

Item	Unit Rate
Existing tree: tree and stump removal and disposal offsite (assume 10-inch-diameter average tree)	$302/each
New tree: purchasing and planting (8- to 10-foot tree)	$200/each
Site clearing	$825/acre
Golf Course mitigation	$32,500/tee box
Earth fill: purchase, haul to site, place, and compact imported earth fill for earth embankment levee	$20/cubic yard
Riprap: purchase, haul to site, and place riprap (assume a 5-mile haul each way)	$50/cubic yard
Asphalt surfacing for levee crest trail and road	$25/linear foot
Floodwall: steel sheetpile wall	$20/square foot
Floodwall: concrete cap	$500/cubic yard
Private ROW acquisition	$196,020/acre
Public and Golf Course ROW acquisition	$163,350/acre

TABLE 12
Alignment Alternative No. 1 Summary

Item	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Total
Tree Removal and New Tree Planting	$186,000	$174,000	$86,000	$77,000	$182,000	$704,000
Site Stripping and Preparation	$11,000	$10,000	$5,000	$5,000	$12,000	$44,000
Earth Embankment Levee	$130,000	$128,000	$30,000	$88,000	$133,000	$508,000
Floodwall Levee	$75,000	$0	$530,000	$162,000	$462,000	$1,230,000
Riprap	$1,177,000	$980,000	$100,000	$224,000	$271,000	$2,752,000
Asphalt Recreational Trail	$94,000	$84,000	$23,000	$40,000	$101,000	$342,000
Mitigation of Environmental Impacts	$84,000	$69,000	$39,000	$30,000	$58,000	$279,000
Golf Course Improvements	$0	$0	$0	$0	$0	$0
Subtotal	$1,758,000	$1,445,000	$813,000	$625,000	$1,219,000	$5,860,000
General Conditions (20 percent)	$352,000	$289,000	$163,000	$125,000	$244,000	$1,172,000
Sales tax (4.75 percent)	$100,000	$82,000	$46,000	$36,000	$69,000	$334,000
Contingency (30 percent)	$633,000	$520,000	$293,000	$225,000	$439,000	$2,110,000
Engineering and Administration (15 percent)	$426,000	$351,000	$197,000	$152,000	$296,000	$1,421,000
Subtotal	$1,511,000	$1,242,000	$699,000	$537,000	$1,048,000	$5,037,000
Construction Cost	**$3,268,000**	**$2,688,000**	**$1,512,000**	**$1,163,000**	**$2,267,000**	**$10,897,000**
Private ROW Acquisition	$0	$0	$0	$73,000	$26,000	$99,000
Public ROW Acquisition	$63,000	$255,000	$295,000	$343,000	$1,041,000	$1,997,000
Golf Course ROW Acquisition	$438,000	$412,000	$0	$0	$0	$850,000
ROW Acquisition Cost	**$500,000**	**$668,000**	**$295,000**	**$416,000**	**$1,066,000**	**$2,946,000**
TOTAL	**$3,769,000**	**$3,355,000**	**$1,807,000**	**$1,579,000**	**$3,333,000**	**$13,843,000**

TABLE 13
Alignment Alternative No. 2 Summary

Item	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Total
Tree Removal and New Tree Planting	$56,000	$22,000	$39,000	$32,000	$133,000	$281,000
Site Stripping and Preparation	$11,000	$9,000	$4,000	$3,000	$9,000	$36,000
Earth Embankment Levee	$384,000	$378,000	$62,000	$105,000	$72,000	$1,001,000
Floodwall Levee	$62,000	$0	$535,000	$259,000	$942,000	$1,798,000
Riprap	$142,000	$127,000	$99,000	$81,000	$208,000	$658,000
Asphalt Recreational Trail	$90,000	$85,000	$23,000	$33,000	$62,000	$293,000
Mitigation of Environmental Impacts	$37,000	$31,000	$38,000	$26,000	$71,000	$203,000
Golf Course Improvements	$1,200,000	$0	$0	$0	$0	$1,200,000
Subtotal	$1,981,000	$652,000	$799,000	$539,000	$1,497,000	$5,469,000
General Conditions (20 percent)	$396,000	$130,000	$160,000	$108,000	$299,000	$1,094,000
Sales tax (4.75 percent)	$113,000	$37,000	$46,000	$31,000	$85,000	$312,000
Contingency (30 percent)	$713,000	$235,000	$288,000	$194,000	$539,000	$1,969,000
Engineering and Administration (15 percent)	$481,000	$158,000	$194,000	$131,000	$363,000	$1,326,000
Subtotal	$1,703,000	$560,000	$687,000	$464,000	$1,287,000	$4,701,000
Construction Cost	**$3,684,000**	**$1,212,000**	**$1,486,000**	**$1,003,000**	**$2,784,000**	**$10,170,000**
Private ROW Acquisition	$0	$0	$0	$64,000	$0	$64,000
Public ROW Acquisition	$63,000	$35,000	$335,000	$328,000	$670,000	$1,431,000
Golf Course ROW Acquisition	$863,000	$864,000	$0	$0	$0	$1,726,000
ROW Acquisition Cost	**$925,000**	**$898,000**	**$335,000**	**$392,000**	**$670,000**	**$3,221,000**
TOTAL	**$4,610,000**	**$2,110,000**	**$1,822,000**	**$1,395,000**	**$3,454,000**	**$13,391,000**

5.4 No Action Alternative

While the objective of this study was to identify and evaluate alternatives to improve the existing levee system to FEMA standards, it is also important to consider the no action alternative.

The current effective flood insurance rate map (FEMA, September 25, 2009) identifies a floodplain west of the Jordan River (that is, behind or landward of the levee) associated with the 100-year flood event (**Figure 3**). The FEMA Insurance Rate Maps currently designate this as an area that is protected from the 100-year flood event by the existing levee (that is, Zone X). Thus flood insurance is not compulsory in this area and the property owners are eligible to purchase discounted flood insurance at rates for a Moderate-to-Low Risk Area. A residential property owner electing to purchase flood insurance for coverage for a $250,000 building and $100,000 for building contents could pay between $350 to $1,500 per year depending upon qualifications (policy rates for 2008 obtained from http://www.floodsmart.gov/floodsmart/pages/residential_coverage/policy_rates.jsp).

If the levee is not certified and accredited by FEMA, the floodplain will likely be redesignated as a Zone A, thus reclassifying it as a high risk area. Residential property owners with mortgages obtained through a federally regulated or insured lender will now be required to purchase a flood insurance policy. Flood insurance rates for coverage for a similar $250,000 building and $100,000 for building contents are approximately $2,650 per year.

Salt Lake City has estimated that there are approximately 1,600 structures within the current Zone X floodplain. If this floodplain is redesignated by FEMA as a Zone A floodplain because the levee is not certified, any structures with mortgages obtained through a federally regulated or insured lender will be required to purchase flood insurance. Assuming that only 1,000 structures will be required to obtain flood insurance and assuming that the average policy rate is $2,000 per year, this community could be required to pay up to $2,000,000 per year for flood insurance.

5.5 Summary of Alternatives

Two alternatives for improving the existing levee system and a no action alternative have been previously defined. **Table 14** provides a brief summary of each of the alternatives for comparison purposes.

TABLE 14
Summary of Improvement Options
Lower Jordan River Levee Evaluation

Option	1. Raise levee in existing alignment	2. Offset levee/floodwall	3. Do nothing
Objectives	1. Meet FEMA requirements for certification 2. Stay primarily within existing ROW 3. Minimize impacts to existing structures 4. Minimize impacts to existing trail	1. Meet FEMA requirements for certification 2. Minimize impacts to existing structures 3. Minimize impacts to trees and habitat 4. Minimize impacts to existing trail	No impacts to existing trees, habitat or ROW
Key differentiators	Riprap used to stabilize riverbank and maintain existing levee alignment, requires removal of trees along riverbank	Uses floodwall to minimize impacts to trees/ROW, offset levee in existing open space	No change from existing condition
Figures to reference	Figure 6A, Figure 7A and 7B, Appendix E	Figure 6B, Figure 7A and 7B, Appendix F	
Does this option meet FEMA design requirements for certification?	Yes	Yes	No
Will option <u>require</u> purchase of flood insurance by those who currently do not have it?	No, if levee is certified	No, if levee is certified	Yes
Approximate number of 6-inch or larger trees to be removed	781	311	0
Length of earth embankment levee (feet)	13,680	11,710	0
Length of floodwall levee (feet)	3,990	5,830	0
Volume of earth fill required (cubic yards)	20,170	47,180	0
Volume of riprap required (cubic yards)	49,610	8,990	0
How is riprap used?	Used as buttress for levee	Used as toe protection for levee	

TABLE 14
Summary of Improvement Options
Lower Jordan River Levee Evaluation

Option	1. Raise levee in existing alignment	2. Offset levee/floodwall	3. Do nothing
Estimated construction cost (without ROW and angr/admin)	$9,476,000	$8,443,000	0
Cost for ROW	$2,946,000	$3,221,000	0
Total Cost	**$13,843,000**	**$13,391,000**	

NOTES:
(1) If the levee is not certified, the levee will not meet FEMA's requirements for the NFIP and flood insurance will be required for structures currently located behind the levee in the Zone X.

6.0 Recommendations

Salt Lake County's objective for this project was to evaluate the existing levee system and identify improvements required for certification of the levee system within the project limits. Guiding principles were defined for the development of alternatives (see **Sections 1.0** and 5.0) and two alternatives were defined to address these principles using different approaches. A third alternative, a no action alternative, was also discussed to place the cost of improvements in context. Given the realities of today's economy, it is important that the path forward carefully balance the cost of implementation, available funds, and the very real cost of flood insurance for the affected community. Construction of any improvements to the levee in this urban environment will also require careful consideration of how these flood control facilities can best be incorporated into the community's vision for the river corridor and potential impacts to the environment. This section provides a recommendation for levee system improvements and a recommended path forward for implementation of the improvements.

6.1 Recommended Alternative

Initial discussions between Salt Lake City and Salt Lake County centered upon concerns regarding the financial burden the purchase of flood insurance will have on this community if improvements are not implemented and the impact construction and maintenance of the levee improvements will have upon existing habitat along the river corridor if they are implemented. Alternative No. 2 is the lower cost alternative and more directly addresses concerns regarding vegetation, habitat, and the uses of the Jordan River corridor. Thus, CH2M HILL recommends that Alternative No. 2 be carried forward in a public process that better defines the public's concerns and vision for this corridor, identifies permitting requirements, opportunities for enhancing this corridor, and funding options—and incorporates these into a reasonable, implementable, and sustainable solution. This alternative should be designed and constructed for the levee system to be certified.

Salt Lake County should also move forward with the completion of an evaluation of interior drainage patterns on the landward side of the levee. This is a FEMA requirement for certification of a levee system. The objective of this effort is to determine if and what improvements may be required to prevent the levee from causing flooding to occur on the landward side of the levee. Levees often restrict free drainage into the river, thus facilities should be provided to prevent interior drainage from being retained by the levee and flooding those structures the levee is protecting from river flooding.

Salt Lake County should also move forward with the development of a comprehensive operations and maintenance plan. This is a FEMA requirement for certification of a levee system. The objective for this effort is to clearly specify how the levee system will be operated and maintained and identify the resources required for implementation.

6.2 Recommended Approach

The objective of this first phase of the project was to evaluate the condition of the existing levee system and identify and evaluate alternatives for improvements. This phase of the project did not define permitting and mitigation requirements, it did not include a public involvement process nor did it address potential funding sources for the improvements. These elements were not included in the scope of this initial phase as the condition and scope of required improvements was unknown when the project began. Now that the need and scope of improvements is known, it is essential that these elements be addressed proactively for the improvements to be implemented successfully. CH2M HILL recommends an approach to design that addresses these issues in a deliberate manner that facilitates collaboration and flexibility. It is recommended that Phase II – Design, as described in **Section 1**, be instead delivered as two sub-phases that build upon each other—preliminary design and final design. Phase III – Construction can then be implemented in a more cost-effective manner.

6.2.1 Preliminary Design Phase

The objective of the preliminary design phase would be to clearly define the issues that the final design must address, reassess project costs, and define a flexible and realistic implementation schedule for the improvements.

A collaborative approach with the public and interested agencies will help define site-specific issues and concerns along the alignment, identify opportunities for collaboration with other agencies and potential incorporation of their objectives, and define the final alignment for the levee. Clear definition of these elements will then allow for the development of a preliminary design that addresses the pertinent issues and more importantly will be able to be successfully built. A preliminary design that is endorsed by key stakeholders will then set the basis for an updated estimate of cost for construction, a plan for obtaining project funding, and schedule for implementation. This approach will streamline final design as it will focus efforts to address clearly defined objectives with confidence that the improvements can be successfully permitted and implemented.

The following specific tasks would be included in this preliminary design phase:

1. Site survey and mapping of ROW
2. Geotechnical exploration
3. Public involvement
4. Preliminary design
5. Coordination with regulatory agencies

6.2.2 Final Design Phase

The objective of the final design phase will be to focus efforts to design levee improvements per the objectives defined in the previous phase and per the schedule that funding affords. Final design efforts will carry forward the alignment defined in the preliminary design and resolve detailed design issues required for construction and operation of the levee system. The final design phase will include public involvement to verify the design prior to construction, permitting to allow for construction, and development of final construction contract documents.

The following specific tasks would be included in this final design phase:

1. Final design
2. Public involvement
3. Permitting
4. Bidding services

Each task could be scaled depending on funding that is available for construction.

6.2.3 Summary

The present condition of the levee system presents the County with significant challenges but also significant opportunities. Potentially significant concerns will need to be addressed. The benefit of the proposed collaborative approach is that those concerns can be defined and addressed early on in the design process. The concerns can be turned into ideas that benefit the County's goal of flood control but that also address the vision and goals of the community. Final design efforts can then be focused on proven concepts and on elements that pertain to a schedule that can be afforded.

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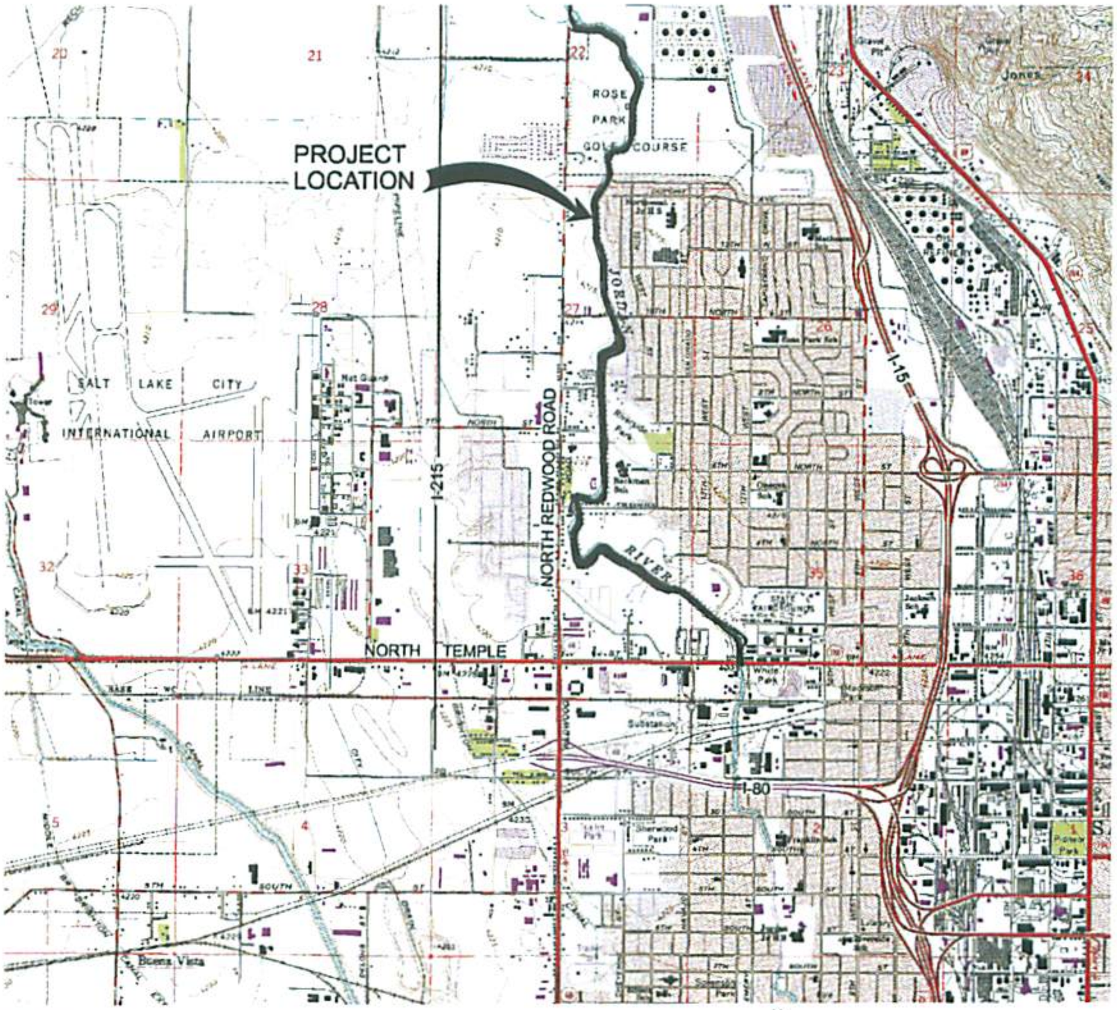
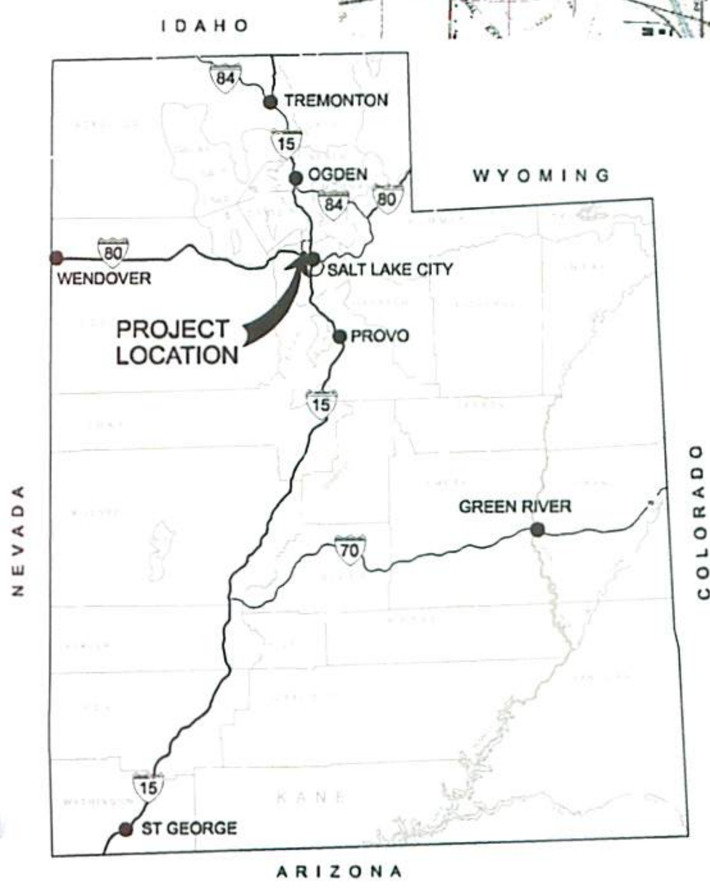
Figures



LOCATION PLAN
NTS

N



VICINITY MAP
NTS

FIGURE 1
LOCATION PLAN AND VICINITY MAP

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL

Fig1-VicinityMap_390358.dgn 11/4/2009 3:02:55 PM

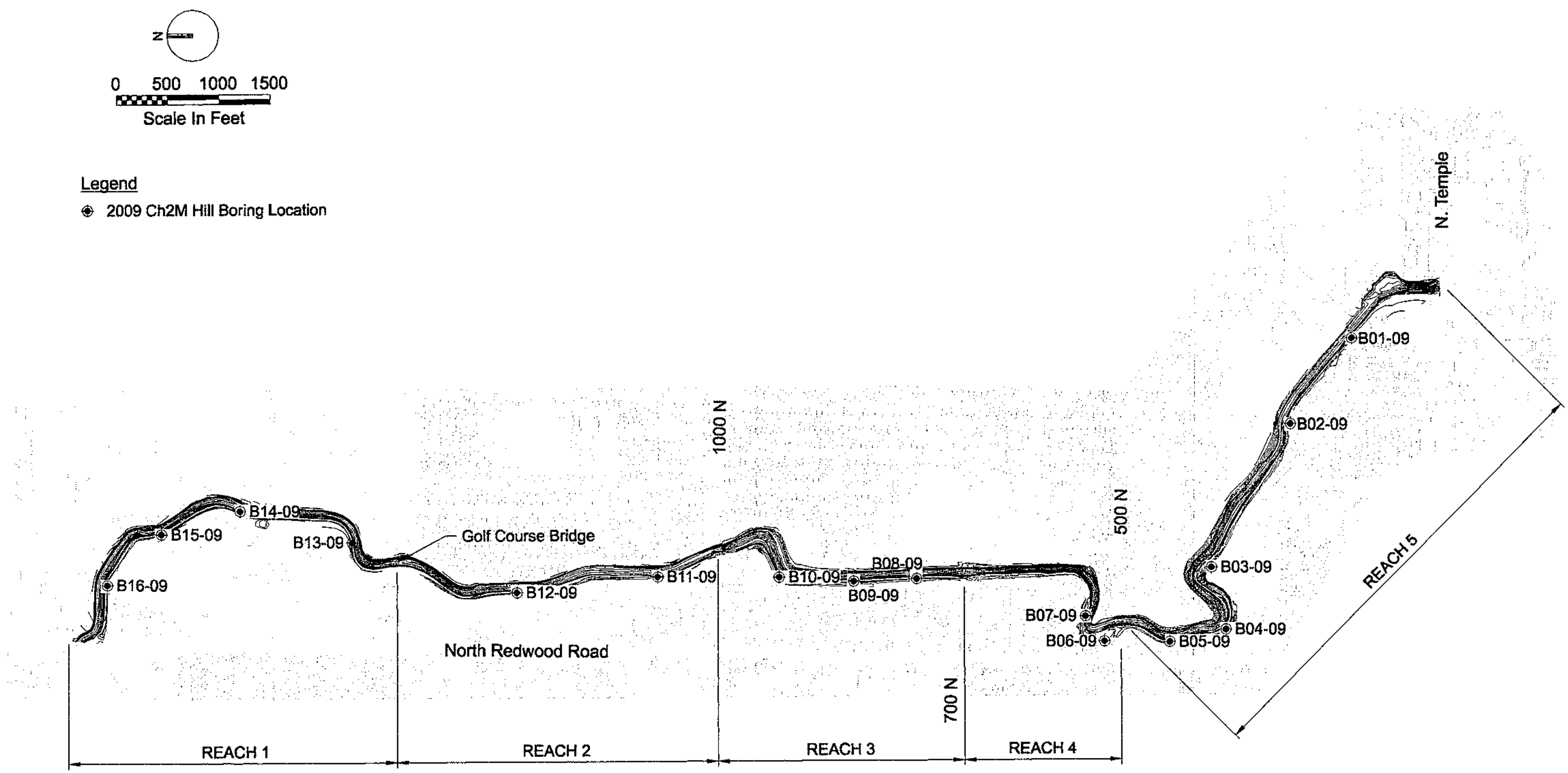


FIGURE 2
LOCATION PLAN

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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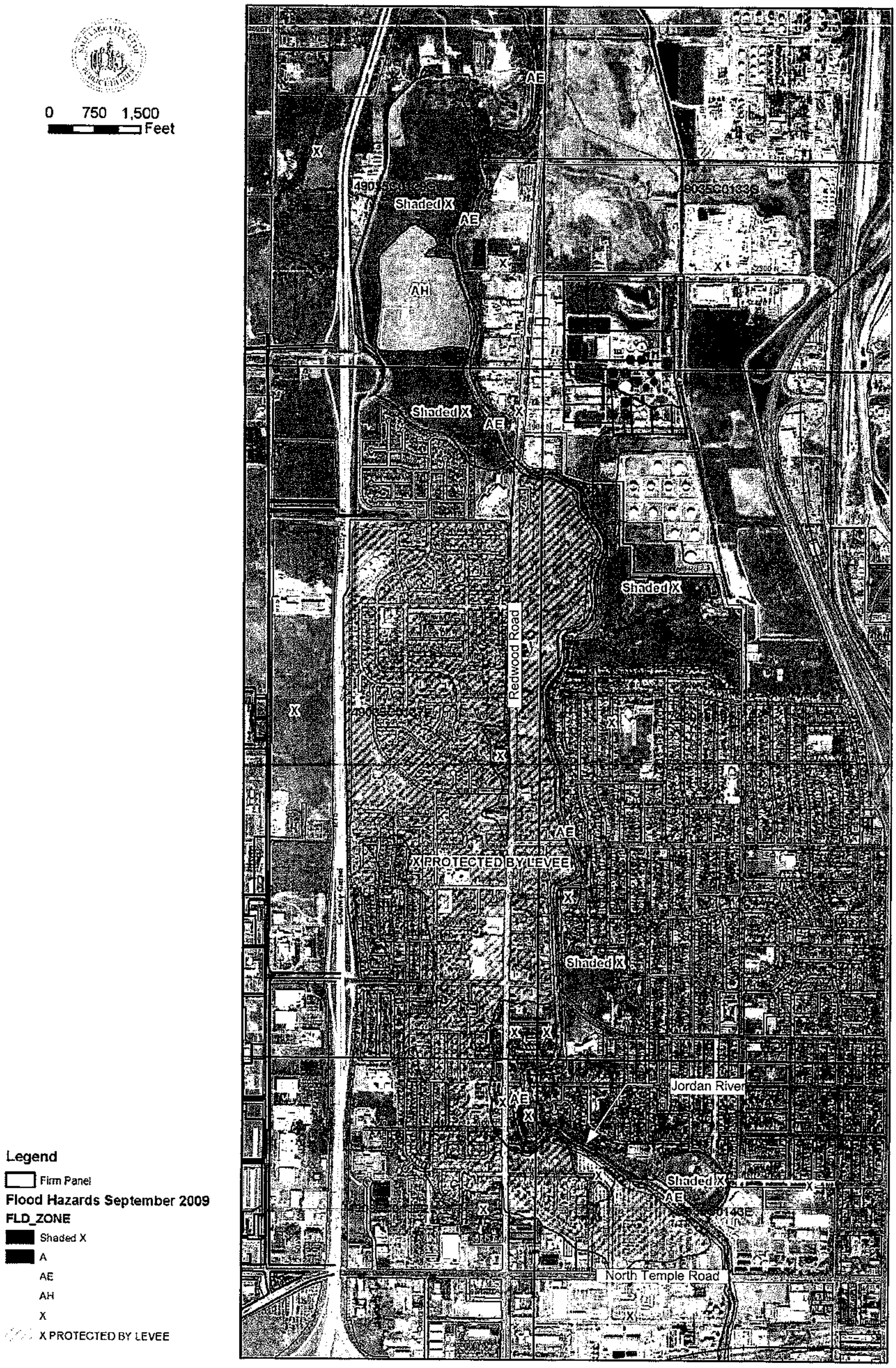

FIGURE 3
AREA PROTECTED BY LEVEE

Map provided by Salt Lake City Department of Public Utilities

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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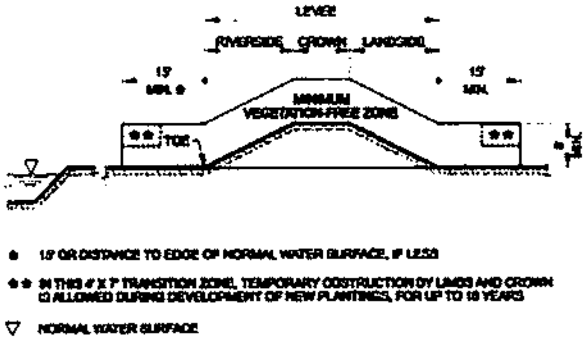
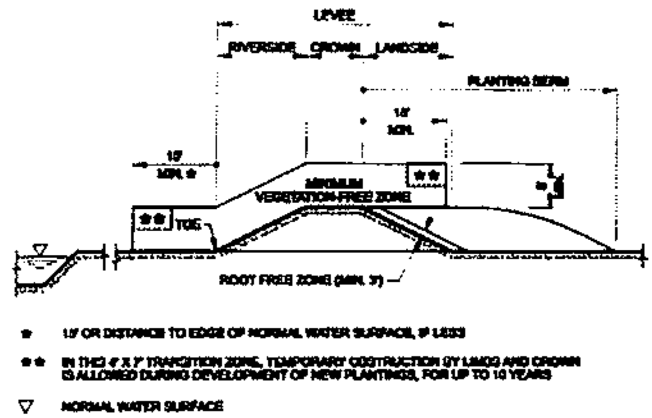
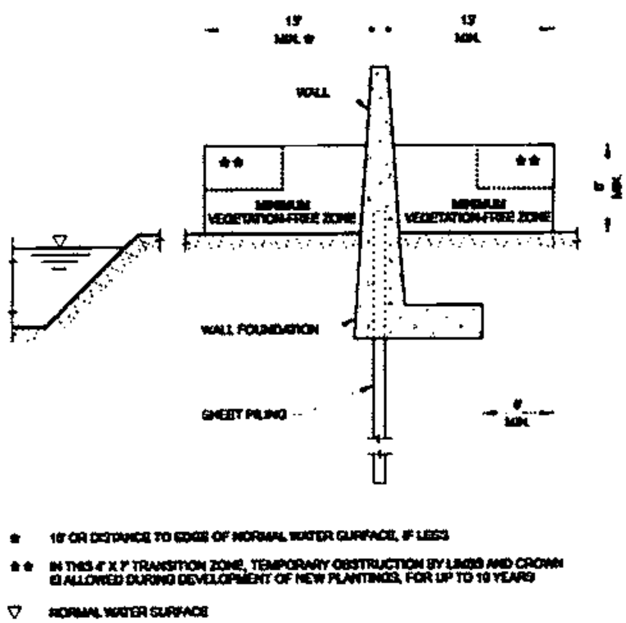


a) Earth Embankment Levee



b) Earth Embankment Levee with Planting Berm



c) Floodwall Levee

FIGURE 4
VEGETATION GUIDANCE (AFTER USACE, 2009)

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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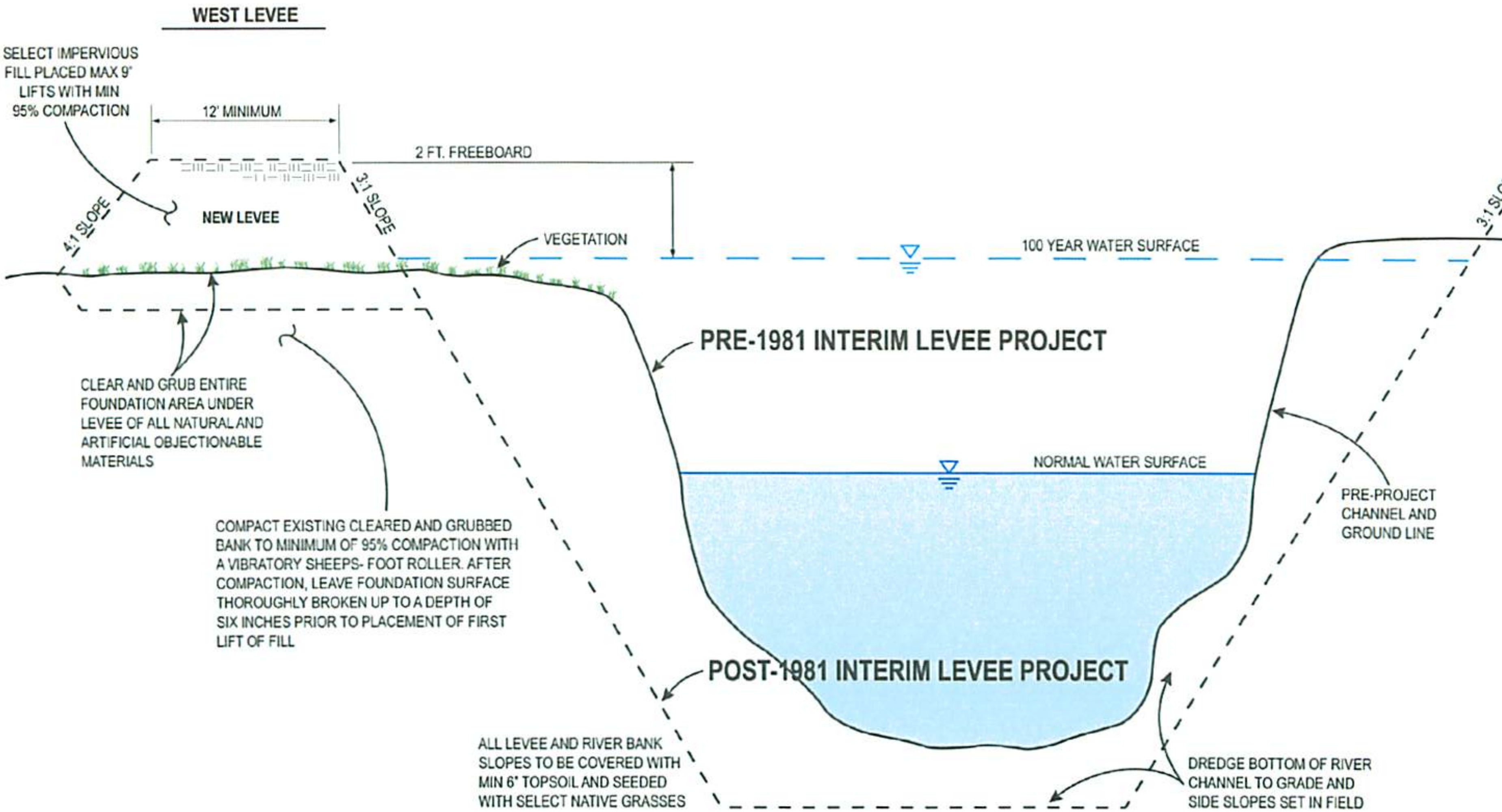

FIGURE 5
1981 "INTERIM LEVEE PROJECT" DESIGN

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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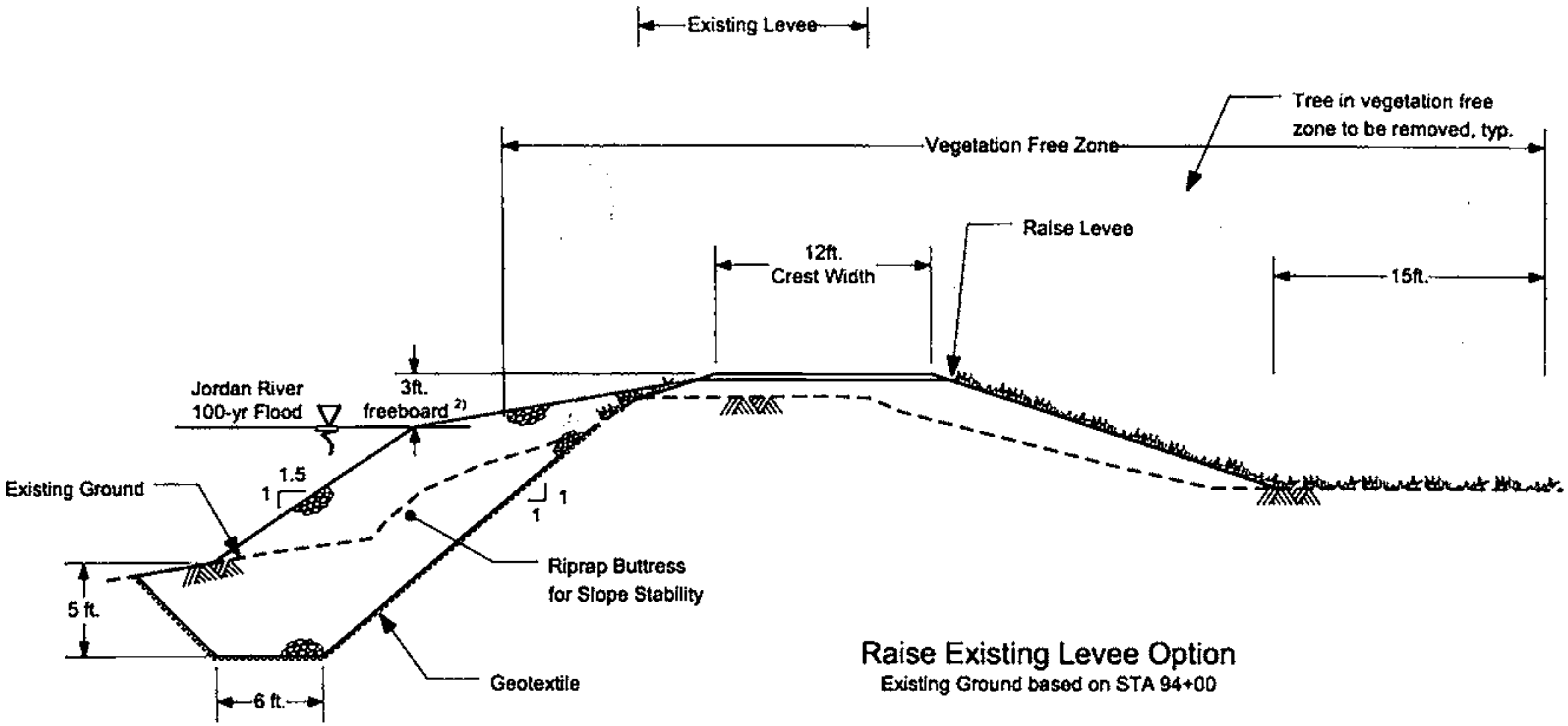

Raise Existing Levee Option
Existing Ground based on STA 94+00

Notes:

1) Trees and section shown are schematic only, and though the ground surface is based on a specific station, the section shown is general and does not represent a specific location.
2) 4 feet of freeboard is required within 100 feet of bridges or other structures located riverward of the levee.
3) A riprap buttress will be required to provide adequate factors of safety for riverbank and levee stability if there is inadequate right-of-way to offset the levee. The buttress geometry and dimensions shown are approximate, and will need to be defined during final design.

FIGURE 6A
EARTH EMBANKMENT LEVEE
RAISE LEVEE OPTION

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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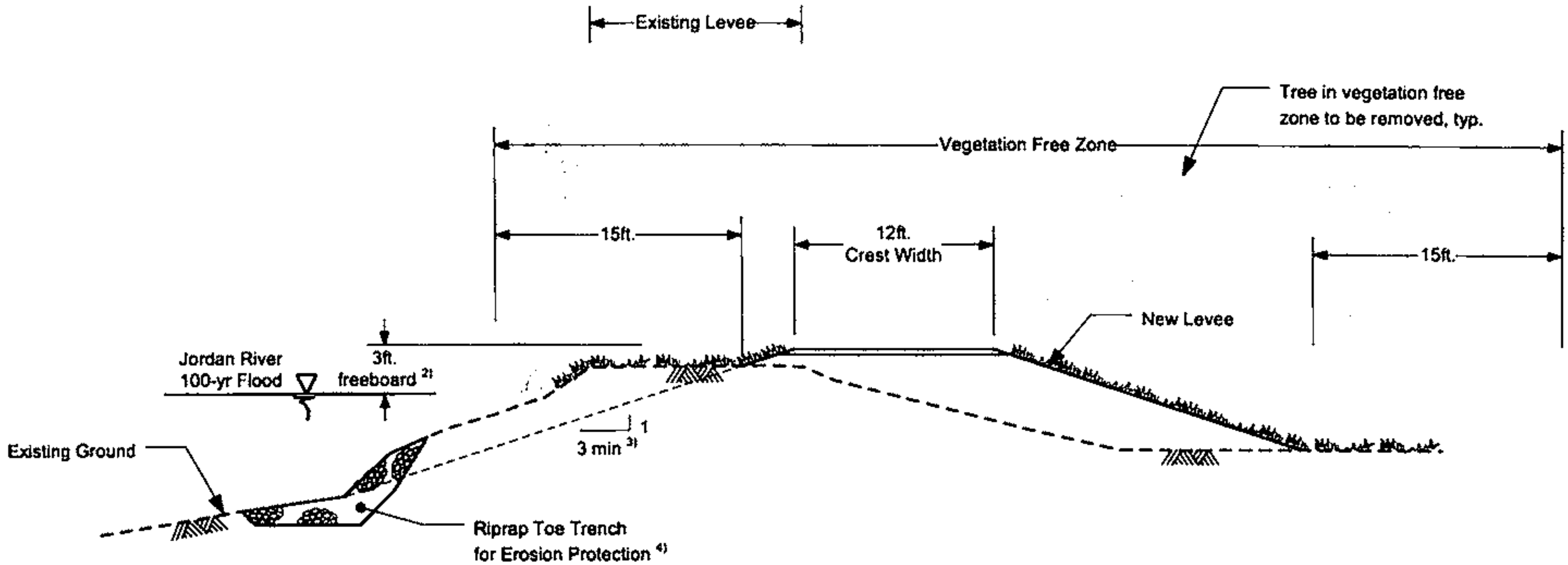


Offset Levee Option

Existing Ground based on STA 94+00

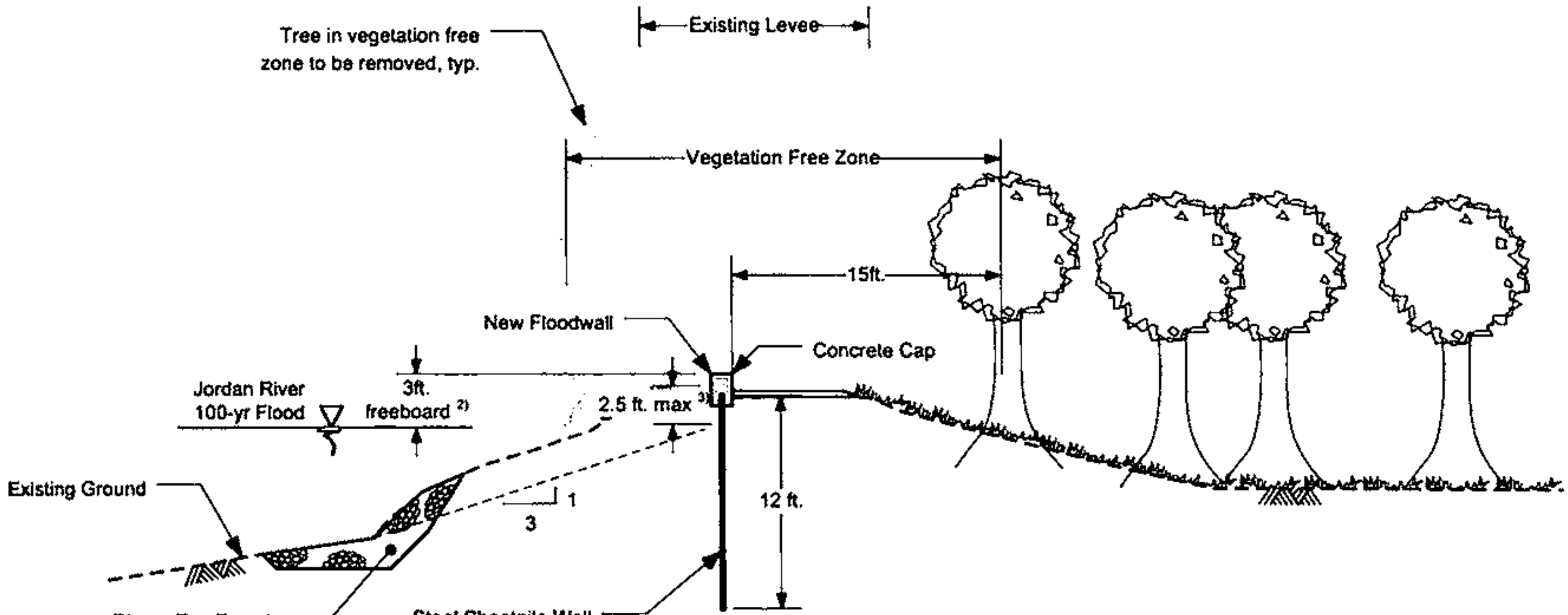
Notes:

1) Trees and section shown are schematic only, and though the ground surface is based on a specific station, the section shown is general and does not represent a specific location.
2) 4 feet of freeboard is required within 100 feet of bridges or other structures located riverward of the levee.
3) The slope defines the minimum offset required to maintain acceptable factors of safety for riverbank and levee stability. The offset could be greater if adequate right of way is available.
4) The toe trench is for erosion protection of the riverbank toe and slope. The geometry and dimensions shown are approximate and will need to be defined during final design.

FIGURE 6B
EARTH EMBANKMENT LEVEE
OFFSET LEVEE OPTION

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL



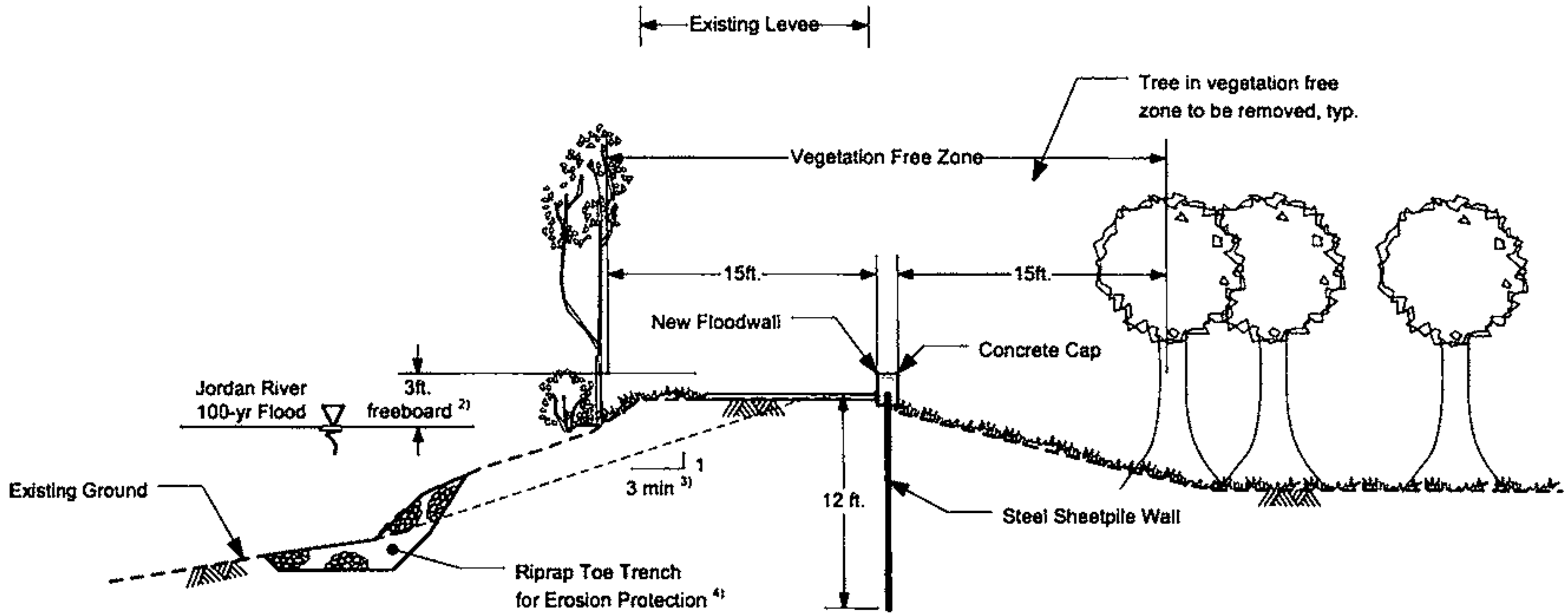
Riverward Floodwall Option
Existing Ground based on STA 94+00

Notes:
1) Trees and section shown are schematic only, and though the ground surface is based on a specific station, the section shown is general and does not represent a specific location.
2) 4 feet of freeboard is required within 100 feet of bridges or other structures located riverward of the levee.
3) Locate the wall so that the maximum wall height above the 3:1 slope from the toe of the riverbank is 2.5 ft.
4) The toe trench is for erosion protection of the riverbank toe and slope. Riprap toe protection may not be required if the floodwall is set back beyond a 3:1 slope from the riverbank toe. The geometry and dimensions shown are approximate and will need to be defined during final design.

FIGURE 7A
FLOODWALL LEVEE
RIVERWARD FLOODWALL OPTION

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL



Landward Floodwall Option

Existing Ground based on STA 94+00

Notes:

1) Trees and section shown are schematic only, and though the ground surface is based on a specific station, the section shown is general and does not represent a specific location.
2) 4 feet of freeboard is required within 100 feet of bridges or other structures located riverward of the levee.
3) This option requires that the wall be set back beyond the 3:1 slope. For the locations where the wall is closer to the river use the Riverward Floodwall Option.
4) The toe trench is for erosion protection of the riverbank toe and slope. Riprap toe protection may not be required if the floodwall is set back well beyond a 3:1 slope from the riverbank toe. The geometry and dimensions shown are approximate and will need to be defined during final design.

FIGURE 7B
FLOODWALL LEVEE
LANDWARD FLOODWALL OPTION

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL

APPENDIX A

Summary of Site Visit Lower Jordan River Levee Evaluation (CH2M HILL, 2009a)

Summary of Site Visit
Lower Jordan River Levee Evaluation

PREPARED FOR: Salt Lake County Public Works

PREPARED BY: CH2M HILL

COPIES: Salt Lake City Department of Public Utilities

DATE: June 18, 2009

As part of the Lower Jordan River Levee Evaluation project, CH2M HILL was tasked (Task 2.2) to complete a site visit to the study reach to (1) document visible features and conditions and (2) identify potential issues that will need to be addressed as part of the project. The site visit was completed by Jaco Esterhuizen, Nason McCullough, and Jeff DenBleyker. The visit was started on Monday, June 1, and concluded the morning of Tuesday, June 2, 2009.

The study reach was subdivided into five reaches, as follows (see also Figure 1):

Reach 1 .... Redwood Road Bridge to Golf Course Bridge
Reach 2 .... Golf Course Bridge to 1000 North Bridge
Reach 3 .... 1000 North Bridge to 700 North Bridge
Reach 4 .... 700 North Bridge to 500 North Bridge
Reach 5 .... 500 North Bridge to North Temple Bridge

CH2M HILL first performed a relatively rapid walkthrough along the entire study reach to identify general characteristics and trends. Scott Baird and Shane Ellis from Salt Lake County joined in the walk along Reaches 1 and 2 on Monday. CH2M HILL then walked the entire reach again, carefully mapping features and noting observations. Observations were noted on hard-copy aerial photographs and notepads. Features were mapped using a Trimble GeoXT to define quantities and approximate locations of features. Only trees in excess of 6 inches in diameter were mapped by GPS but trees observed to be greater than 2 inches in diameter were counted. Accuracy of feature locations is estimated at +/- 10 feet.

It should be noted that observations were made only from the top of the levee and not from the water. Vegetation obscured much of the levee from view, thus the true extent of some of the issues could not be assessed. Areas with high vegetation that were spot checked revealed many stumps of trees that were previously cut down and signs of erosion and rodent damage that were obscured from view from the top of the levee. Additionally, areas where levee grass had been mowed revealed more erosion and rodent damage than areas with extensive vegetation. While this highlights the hindrance that vegetation posed to the levee inspection, general observations could still be made and overall trends could still be identified. This memorandum summarizes these observations and identifies key issues and challenges for raising the levee protection system.

FIGURE 1
Location of Project Reaches
Lower Jordan River Levee Evaluation

Key Observations

Below is a summary of key observations made along each reach. More detailed observations are noted in project files. Action items are identified in bold.

Reach 1

- Numerous utilities cross the river at the Redwood Road Bridge.
- Irrigation pump house located at Redwood Road. **Need to identify whether it is active or not.**
- Pedestrian access is available from Redwood Road. Access for vehicles will require coordination with the City to unlock pylons that block vehicle access. The levee in this reach may also be accessed from the golf course club house.
- Levee is clearly defined along the entire reach.
- A new trail was constructed along Reach 1 during the spring of 2009 (see Photo 1). The trail includes an approximately 10-foot wide paved section with 5- to 8-foot gravel shoulders. Average width of the improvements was estimated to be 20 feet. It appears the levee may have been raised and widened as part of the project. **Need to locate drawings and design criteria for the path, if available.**
- A new fence was located along the majority of the length on the landward side of the levee crest (6 to 12 feet tall, see Photo 2). This fence was located on the levee crest.
- Short (less than 4 feet tall) retention walls were observed on the landward levee toe near Redwood Road in the backyards of residences (visible on the right in Photo 1).
- Short (less than 4 feet tall) retaining walls were also observed around large trees on the landward side (approximately seven walls observed, see Photo 2). These walls were located within the landward levee slope.
- Trees were more prevalent on riverward side of levee (approximately 230 on riverward side versus approximately 30 on landward side). Tall grass and vegetation was prevalent along riverward side of levee. The landward side of levee was bare in areas of new construction or covered with tall or well-maintained grass. Two very large cottonwood tress (more than 4 feet in diameter) were along this reach. Numerous stumps of trees that had been removed were noted along the riverward toe of the levee.
- Some rutting was observed along the shoulder of the paved trail.
- Oversteepened slopes on riverward side of levee were observed in the middle to south end of the reach. The northern end of the reach was less steep but more heavily vegetated, some sloughing and erosion was observed along steep areas.
- One section (towards the center of the reach) contained newly placed riprap on the riverward side of the levee. The riprap section was roughly 300 feet long.
- One 36-inch corrugated metal pipe (CMP) was observed penetrating the levee near the Golf Course Bridge. The CMP is heavily corroded and buckling. It extends through the

levee to the west where it transitions to a 24-inch steel pipeline. **Need to determine who owns and operates the CMP and associated piping.**

- Previous observations made by Jeff DenBleyker while floating the river noted a couple of miscellaneous PVC drainage pipes extending into the Jordan River from the golf course. **Need to confirm how drainage from golf course is managed.**

Options

- A new offset levee is possible but will impact golf course layout and some trees within the golf course. May consider a levee on the west side of the golf course as an alternative for evaluation.

Summary

The United States Army Corps of Engineers (USACE) has established guidelines for inspection of non-federal-owned levees (USACE, 2006). The USACE identifies rating levels as follows:

- Acceptable: No issues are identified
- Minimally Acceptable: Some issues are identified that could easily be corrected
- Unacceptable: Significant issues that need to be addressed

This reach of the Jordan River was rated as "Unacceptable" per USACE guidelines due to the following:

- Preponderance of unacceptable vegetation
- Oversteepened slope along riverward side of levee and the resulting sloughing and erosion that was observed
- Encroachments by utilities and fencing

PHOTO 1
Paved Path on Levee Crest (river on the left)

PHOTO 2
Fence, Trees, and Retaining Walls in the, and on the, Levee (river on the left)

Reach 2

- The levee along this reach was often not well defined. The ground often gently sloped up to the levee crest from the landward side. The golf course fairways and facilities often extended onto the levee crest. The levee crest undulated up to 2 feet in the middle region. The levee crest was a dirt road on the north end and maintained grass toward the south end along the golf fairways (see Photo 3) and a dirt path as the levee approached 1000 North.
- The riverward side was generally oversteepened and heavily vegetated (see Photo 3). Some bank erosion and sloughing was observed in the oversteepened riverward side of the levee.
- Considerable vegetation was located throughout this reach. The northern end of the reach had considerable numbers of Russian olive trees on both sides of the levee (see Photo 4). Approximately 250 trees were observed on the riverward side and 120 trees on the landward side (some are very large cottonwood trees). Areas where the river bank could be observed indicated some stumps of trees that had previously been removed.
- Piles of disposed leaves were located on the levee crest (see Photo 5). A few utility poles were observed. There was a tall fence located along the driving range on the north end of this reach and along a fairway at the south end of this reach (see Photo 3). A fence and locked gate was located at the levee crest adjacent to 1000 North.
- Rodent activity was prevalent throughout this reach. There was some sign of beaver activity along the river bank and ground squirrels along the levee crest (see Photo 6).
- The locked gate prevented access to the levee from 1000 North. The levee in this reach could be accessed from the club house of each of the two golf courses.

Options

- Over certain portions of the reach, a new offset levee is possible but will impact golf course layout and several large trees within the golf course.

Summary

This reach of the Jordan River was rated as "Unacceptable" per USACE guidelines due to the following:

- Preponderance of unacceptable vegetation
- Oversteepened slope along riverward side of levee and the resulting sloughing and erosion that was observed
- Encroachments by utilities and fencing

PHOTO 3
Fairway is Part of Levee, Fence on the Levee Crest (river on the right)

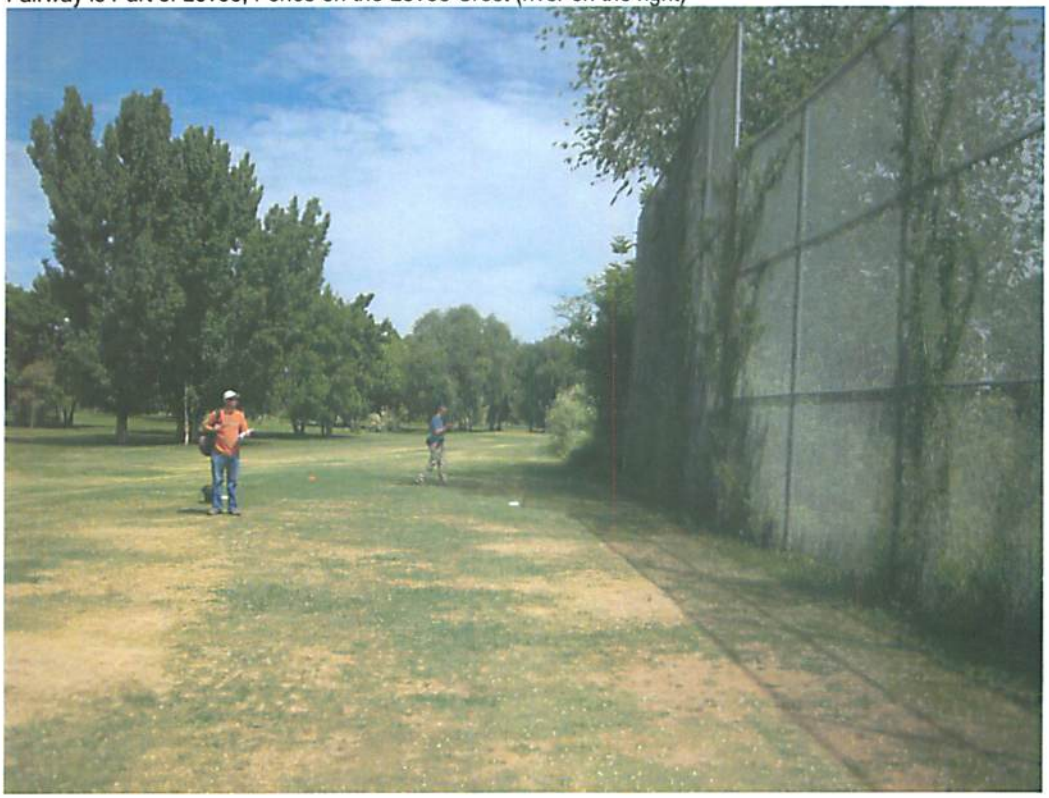


PHOTO 4
Dirt Road on Crest, Trees Growing on the Levee (river on the left)

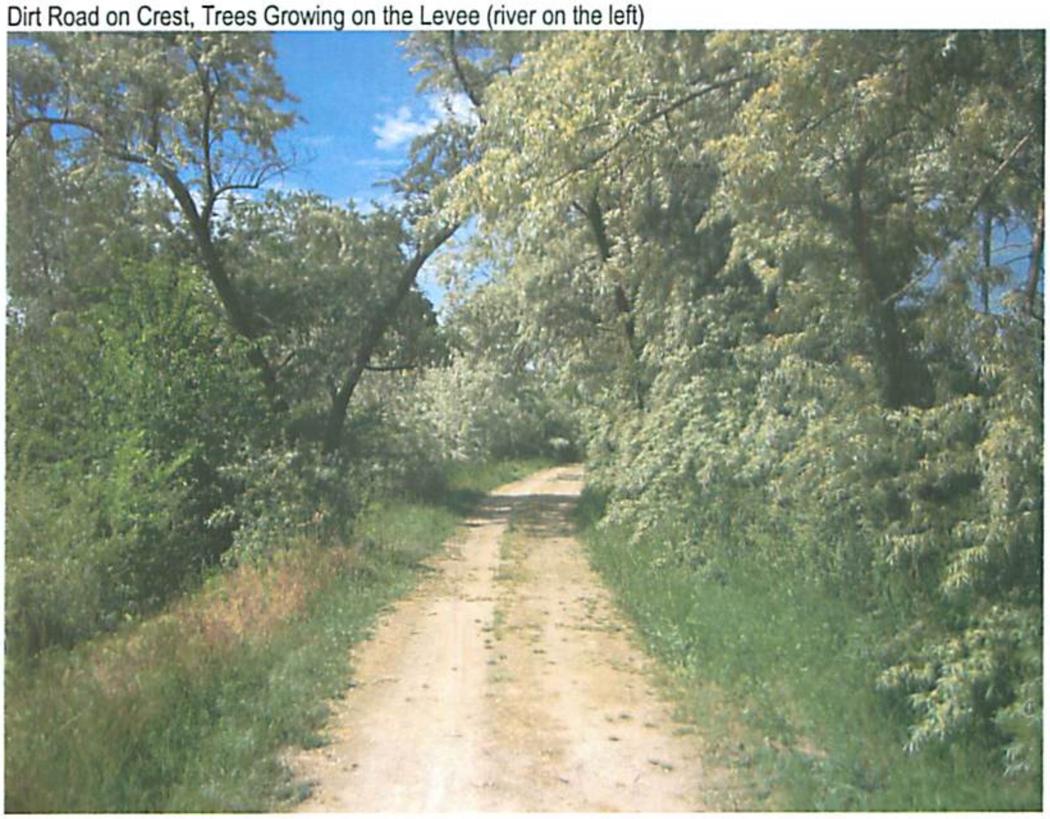


PHOTO 5
Leaf Debris Piles on the Levee Crest (river on the left)

PHOTO 6
Small Rodent Holes

Reach 3 – 1000 North Bridge to 700 North Bridge

- The Rose Park Library at 1000 North appears to be constructed at the same elevation as the levee crest. The levee became more pronounced south of the library as it became parallel to Riverside Drive and was very well defined for the remaining distance to 700 North. The levee was tightly restricted in width by the river and Riverside Drive for much of this reach (see Photo 7).
- An informal recreational trail is along the crest of the trail. Trail cover was a mix of grass, dirt, and bark. There was a concrete sidewalk at the toe of the landward side of the levee along Riverside Drive. There was one pedestrian bridge across the river along this reach.
- This reach of the levee is easily accessed along its entire length, primarily from Riverside Drive, as well as from 1000 North and 700 North.
- The condition of the levee near the library appears acceptable, except for vegetation and some encroachments. The levee in this section was set back from the river and does not appear to be oversteepened.
- The riverward side of the levee along Riverside Drive was oversteepened with areas of sloughing, surface cracking, and erosion. Deep ruts were identified at some locations along the crest of the levee (see Photo 8).
- Catch basins located along Riverside Drive appear to be placed to collect and convey interior drainage to the west away from the Jordan River. One location along Riverside Drive near 700 North does not have a catch basin and will likely have shallow ponding. **Further review of interior drainage should be completed in this area.**
- A number of encroachments were observed along this reach. The levee section adjacent to the library will need to be confirmed to verify whether the library structure and appurtenances are encroaching on the levee (see Photo 9). South of the library, compost piles and tool shed were encroaching on the levee. Various utility poles, fire hydrants, and a sprinkler system were identified as encroaching upon the levee section. A 4-inch pipeline was observed penetrating the levee but was not connected to anything on the landward or riverward site. There were two irrigation pump stations identified that appear to be abandoned (**need to verify**) but were located within the levee (see Photo 10).
- Numerous trees and heavy vegetation are on the riverward side (approximately 100) and some on the landward side (approximately 30) of the levee that encroach upon the levee (see Photos 7 through 10). The grass on the landward side of the levee was generally well maintained. Numerous stumps of trees that had previously been removed are in the riverward side of the levee.
- Numerous planted poplar trees are along the crest of the levee along Riverside Drive protected from beaver by fencing (see Photo 12 of one tree where beaver was able to cut tree down through the fencing).

- Two very large willow trees are located near the library on the riverward side of the levee. One very large, approximately 8-foot-diameter, cottonwood tree is located on the crest of the levee (see Photo 7).
- This reach had pronounced beaver and muskrat activity. One beaver and one muskrat were observed in the water. Several collapsed beaver dens were identified near the library as well as one active den (see Photo 11). Beaver damage was observed as well as several access points along the river bank. Small rodent damage was observed on the landward side of the levee.

Options

- No space is available for a new offset levee along Riverside Drive, and it will be challenging to raise the levee and flatten the slopes along this reach. Floodwall structures may have to be considered along certain portions of the reach.

Summary

This reach of the Jordan River was rated as "Unacceptable" per USACE guidelines due to the following:

- Preponderance of unacceptable vegetation
- Oversteepened slope along riverward side of levee and the resulting sloughing and erosion that was observed
- High likelihood of rodent damage to the riverward toe of the levee
- Encroachments by irrigation pump stations and utilities, and possible the library and other small structures

PHOTO 7
Large-diameter Cottonwood on the Crest (river on the right)

PHOTO 8
Oversteepened Bank, Trees on the Levee (river on the left)

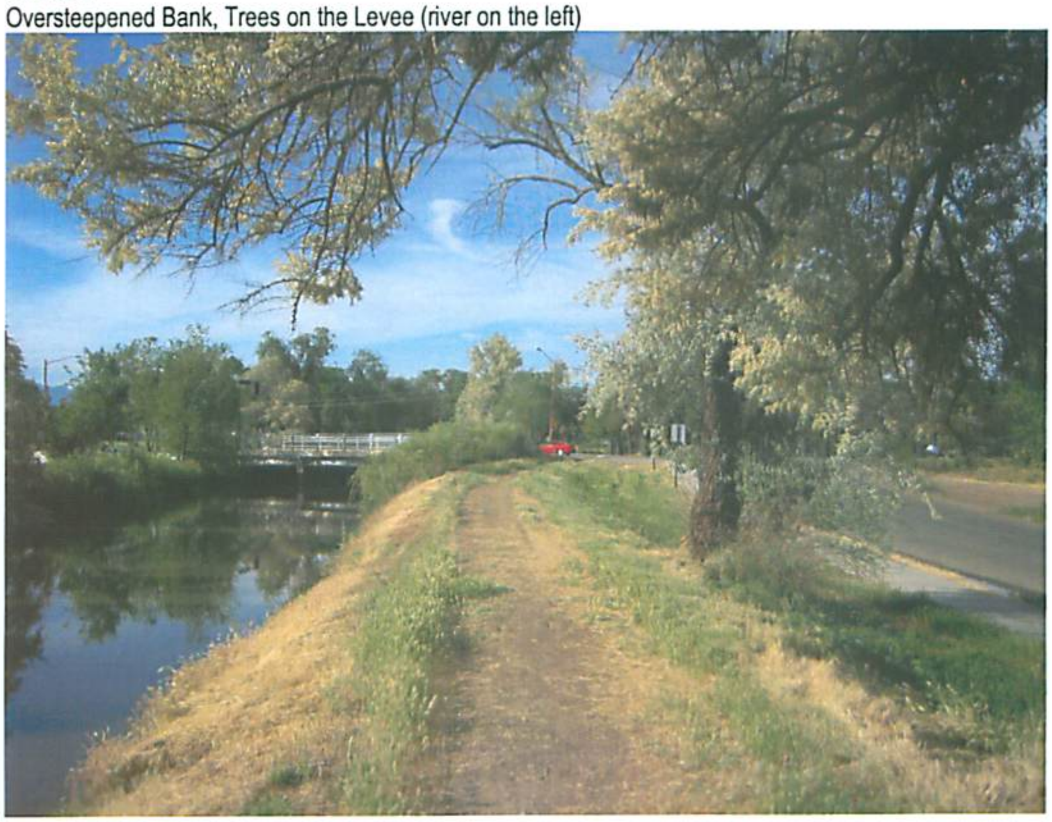
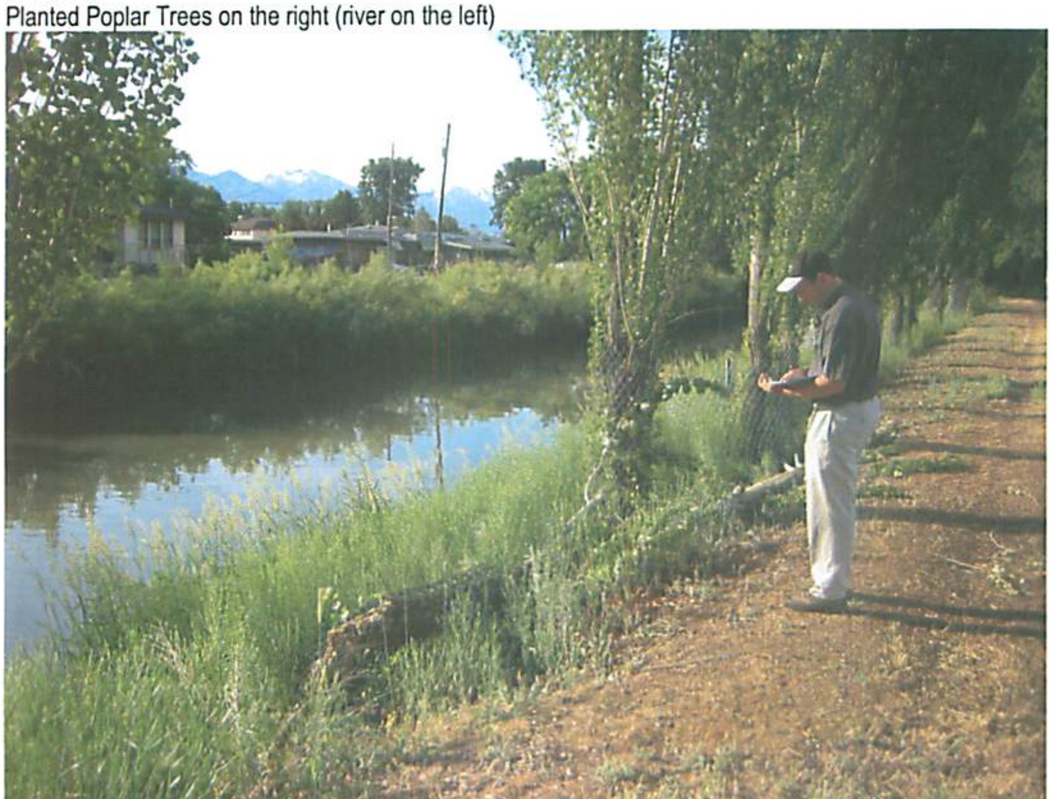


PHOTO 9
Bark path with the Library on the right (river on the left)

PHOTO 10
Irrigation Pump Station (river on the left)

PHOTO 11
Beaver Den (river on the right)

PHOTO 12
Planted Poplar Trees on the right (river on the left)



Reach 4 – 700 North Bridge to 500 North Bridge

- The levee was well defined in this reach. The northern part of this reach had a relatively wide right-of-way landward of the levee that was open space. There was a severe encroachment by an apartment building mid-point along the reach (see Photo 13).
- The levee along the southern part of this reach was set back away from the river channel. The right-of-way along the southern part of this reach also appears to be fairly wide.
- The northern part of the levee had an oversteepened riverward slope with sloughing, surface cracking and erosion observed (see Photos 14 and 15). The landward side of the northern part of the levee appeared to be maintained, but contained some trees and fence encroachments.
- The condition of the riverward slope of the southern part of the levee was maintained, though there were areas of tall grass on the levee. However, the landward slope was encroached upon by fences, trees, and structures that prevented access and inspection (see Photo 16).
- The trail was paved for approximately 300 feet starting at 500 North and extending north to a pedestrian bridge across the river (see Photo 16). The remaining part of this reach had an informal trail of dirt or bark located on the riverward side or on the crest of the levee (see Photo 13). Much of the dirt road on the crest was rutted and not maintained at grade. The levee in this reach could was easily accessed from 700 North or 500 North.
- Numerous encroachments are along this reach, including two irrigation pump stations (**need to verify whether these are abandoned**), a retaining wall and concrete pad (purpose unknown), an active flow gauging station at 500 North, a 2-inch pipeline penetration (**abandoned?**), a 12-inch CMP without flap gate (**confirm purpose**), numerous utility poles that may be abandoned (**confirm**) (see Photo 17), an apartment building, various private structures, and fencing along the southern part of the reach.
- Numerous trees are on the riverward side (approximately 60) and landward side (approximately 70) of the levee (see Photos 14 and 17). Trees along the riverbank in the southern part of the reach may be acceptable as many of them are located more than 15 feet from the riverward toe of the levee (that is, the levee is set back from the river).
- Some beaver activity was observed. Small rodent activity was observed in mowed areas.

Options

- Along the southern portion of the reach the levee is set back. It appears as if enough space is available to reshape the existing levee and to minimize tree removal along this portion of the riverbank. Further north, the space is limited and many trees will likely have to be removed. Floodwalls may have to be considered for some portions.

Summary

This reach of the Jordan River was rated as "Unacceptable" per USACE guidelines due to the following:

- Preponderance of unacceptable vegetation
- Oversteepened slope along riverward side of levee and the resulting sloughing and erosion that was observed
- Numerous encroachments

PHOTO 13
Apartment Building Encroachment (river on the right)

PHOTO 14
Oversteepened River Bank at Toe of Levee (river on the right)

PHOTO 15
Shallow Sloughing Failure or River Bank (river on the right)

PHOTO 16
Wide Easement, Levee to the Left of the Field (river on the right)

PHOTO 17
Utility Poles and Trees on Levee, Rutting of Dirt Road (river on the right)

Reach 5 – 500 North Bridge to North Temple Bridge

- The levee along this reach was subdivided into three general areas: north, middle, and south. The northern and southern areas of this reach had a well-defined levee. The levee was not easily discerned in the middle area near the state buildings. The right-of-way appeared to be very narrow in the southern area. The trail along the levee in this reach was paved, dirt, or non-existent. One pedestrian bridge was located along each area (total of three bridges).

- The levee along the northern area was set back from the river and generally appeared to be in good condition (see Photo 18). The riverbank was heavily vegetated so was not readily inspected. Areas that were visible exhibited erosion. One reach near the northern pedestrian bridge had severe bank erosion (sprinkler pipes observed hanging from riverbank). Heavy grass is along this area on both sides of the levee.
- The levee along the middle area was not easily discerned as this area has been contoured as part of a park (see Photos 19 and 20). The grass is very well maintained and irrigated. The top of riverbank in this area was lower than observed in other reaches.
- The riverward side of the southern area was oversteepened with sloughing and erosion observed (see Photo 21). Rutting was observed in the crest of the levee.
- It appears that pedestrians and vehicles could readily access this reach of the levee from 500 North, along the middle reach and through locked pylons near North Temple. The parking lot at North Temple is locked at North Temple. The parking lot would need to be accessible to access the levee from the south.
- Numerous encroachments were observed. Fencing and some private structures were located on the landward side of the levee in the northern area. One irrigation pump station was identified (**confirm if abandoned**), park irrigation piping, and one apparent well with 2-inch PVC discharge to the river was observed in the northern area (**confirm ownership of this piping**). Various utilities, landscaping retaining walls, sprinklers, and a parking lot were located in the middle area. A trailer park directly abuts the levee in the south area. Numerous storage sheds (26), fixed mobile homes (2 to 3), and numerous recreational vehicles directly abut a fence located on the levee (see Photo 22). A small corral and three large utility poles are located on the levee directly across the river from the fairgrounds. This area across from the fairgrounds is a paved parking lot.
- A spring, or water flowing from a drainage tile, was observed near the river bend near the state agricultural building.
- Extensive vegetation was observed in this reach along the levee (see Photos 18-22). Numerous trees are on the riverward side (approximately 220) and landward side (approximately 60) of the levee. The location of the effective levee in the middle area will affect the number of trees that actually impact the levee.
- Beaver activity was observed (see Photo 23). Several pronounced collapsed dens were observed in the middle area of the reach. Some small rodent activity was observed in the southern area.

Summary

This reach of the Jordan River was rated as "Unacceptable" per USACE guidelines due to the following:

- Preponderance of unacceptable vegetation
- Over-steepened slope along riverward side of levee and the resulting sloughing and erosion that was observed
- Numerous encroachments

PHOTO 18
Paved Path on Northern Section (river on the right)

PHOTO 19
Landscaped Park in Middle Section (river on the left)

PHOTO 20
Landscaping in the Middle Section (river on the right)

PHOTO 21
Dirt Path, Oversteepened Bank, Trees in Levee Section (river on the right)

PHOTO 22
Building Encroachments on Levee Toe (river on the right)

PHOTO 23
Beaver Den (river on the right)

Key Issues

The entire study reach from the Redwood Road Bridge to the North Temple Bridge would be rated as "Unacceptable" per USACE levee guidelines. Key issues are summarized as follows:

1. It is understood, as documented by Salt Lake County 2009, that the existing levee does not meet Federal Emergency Management Agency's (FEMA's) freeboard requirements for certification and accreditation.

2. A significant amount of unacceptable vegetation covers the existing levee. Tall grasses and brush obscured much of the levee and prevented a thorough assessment of the levee's condition. Several hundred trees (defined as greater than 2 inches in diameter) were observed within the levee's vegetation exclusion zone (zone extends 15 feet away from the toe of the levee in both the riverward and landward directions). Many of these trees were very large with one tree having a diameter of about 8 feet. These trees restrict access and inspection along the levee, create a potential debris and scour hazard if they fall into the river channel, could potentially destabilize or facilitate seepage if the tree and rootball are torn from the levee, and create a long term seepage and internal erosion hazard as roots die and decay.

3. Significant lengths of the levee were excessively steep with side slopes on the riverward side in excess of 1:1. These reaches were commonly found immediately adjacent to the river channel. Surface cracking along the crest of the levee and sloughing of the levee/river bank were commonly observed. While not an immediate structural threat to the levee, it is indicative of a long-term trend of bank erosion and potential channel migration. These oversteepened banks could also pose a serious threat to levee integrity during a flood event.

4. Numerous cases of encroachment of the levee were observed. Many of these features, such as storage sheds and recreational vehicles, could be moved with minimal effort; however, other features such as irrigation pump stations, utilities, mobile homes, buildings, and fences will require significant coordination and effort to relocate. The presence of these encroachments restricts access, visual inspection, and possible flood fighting measures. It is probably not practical to move some of the encroachments, such as the apartment building, so other alternatives to an earthen levee, such as using a floodwall structure, may need to be considered.

5. Several levee penetrations were observed, however they were relatively few in number. The three storm drain outfalls that were identified did not have flap gates or other backflow prevention measures. One flowing spring was identified in Reach 5 indicating saturated conditions. Three other small diameter (less than 4 inches) pipelines that appeared to be abandoned were observed. Each of the existing irrigation pump stations are assumed to include pipelines penetrating the levee to the west.

6. Signs of rodent activity were observed throughout the study reach. Beaver activity was pronounced in Reaches 3 and 5 but was observed in all reaches. Active and collapsed beaver dens were observed in the river bank in Reaches 3 and 5. Collapsed dens appeared to most consistently be found under large trees located on the riverbank where

the riverbank was less than 3 feet in height. This could be a function of areas beaver favor or simply areas where their dens more commonly fail. Observations made from the water by others indicate that beaver and muskrat are prevalent throughout the study reach and frequently locate their dens under trees located on the riverbank. While the beaver activity was mainly in the river bank itself, there were also indications of smaller rodents in the earthen levee section.

Key Challenge

The goal of the levee is to protect life and property on the west side of the Jordan River in the event of a flood with a 100-year recurrence interval. If FEMA does not accredit the levee, the community protected by the levee stands to pay substantial annual fees to purchase flood insurance for their homes and businesses.

The objective of this project is to evaluate the existing levee and identify what must be accomplished for the levee to be certified and accredited by FEMA. The community also has other interests for the levee corridor including providing for recreation, open space, and environmental conservation. It is noted that a plan was recently prepared to establish a vision for development along the Jordan River corridor (Envision Utah 2008).

The key challenge of this project will be to successfully address the objective of flood control while striking a successful balance with the community's other objectives. A levee or flood wall can be readily engineered; however, the improvements will need to comply with federal, state, and local regulations; address existing right-of-way limitations; as well as integrate with the community's vision for this area.

Initial alternatives and possible impacts were identified for consideration. These alternatives will likely change as the analysis proceeds.

Reach 1

Raise and rebuild the existing levee as required. This will likely require removal of most of the trees along the west bank of the river as well as removal or relocation of the fence separating the trail from the golf course. Some impacts may also occur to areas where homes and golf course features encroach on the levee.

Alternatively, an alignment could be identified for the levee through the golf course. This will require close coordination with the golf course to address right-of-way and minimize impacts to trees and golf course function, but would minimize the removal of trees along the river bank.

Another alternative would be to build a levee on the west side of the golf course (providing there is enough space).

Reach 2

Raise and rebuild existing levee as required. This will likely require removal of most of the trees along the west bank of the river as well as removal of the fences separating the river from the driving range and golf course. Some impacts may also occur to areas where golf course features encroach on the levee.

Alternatively, an alignment could be identified for the levee through the golf courses. This will require close coordination with the golf courses to address right-of-way and minimize impacts to trees and golf course function.

Another alternative would be to build a levee on the west side of the golf course (providing there is enough space).

Reach 3

Raise and rebuild existing levee as required. This will likely require removal of most of the trees in this reach. The effective levee section will need to be defined near the library to avoid encroachment by the library. A floodwall option could also be explored if an adequate levee will not fit in the existing right-of-way.

Reach 4

Raise and rebuild existing levee as required. This will likely require removal of many trees and relocating the levee in the right-of-way to minimize encroachments by existing buildings and minimize the removal of trees. The levee could be set back in the northern area to minimize impacts to the river. A flood wall may be required in the middle section near the apartment building. There appears to be plenty of right-of-way in the southern area, which could be used to minimize impacts to trees, river channel, and buildings.

Reach 5

Raise and rebuild existing levee as required. This will likely require removal of many trees (limited by narrow right-of-way) and acquisition of right-of-way in the southern area. The effective levee in the middle area could be defined to minimize impacts to the trees along the river. A floodwall may be required in the narrow right-of-way in the southern area of the reach.

Next Steps

CH2M HILL will be completing the required geotechnical evaluation of the existing levee. CH2M HILL will also begin identification and evaluation of alternatives for levee improvements. It is understood that coordination with stakeholders will begin after alternatives are defined.

References

2006. United States Army Corps of Engineers. Levee Owner's Manual for Non-Federal Flood Control Works. March. 176 pp.

2008. Envision Utah. Blueprint Jordan River. 57pp.

2009. Salt Lake County Public Works. Lower Jordan River Levee Study. January 8. 22pp.

APPENDIX B

Geotechnical Data Report Phase I, Jordan River Levee Project North Temple to Redwood Road (CH2M HILL, 2009b)

Geotechnical Data Report-Phase I

Jordan River Levee Project North Temple to Redwood Road

Prepared for

Salt Lake County

2001 South State Street
Salt Lake City, Utah 84190

July 2009

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Geotechnical Data Report-Phase I

Jordan River Levee Project North Temple to Redwood Road

Submitted to

Salt Lake County

July 2009

Contents

Figures

Introduction

CH2M HILL has been contracted by Salt Lake County (County) to provide geotechnical design services for the Jordan River Levee Project. This report presents the results of a geotechnical field exploration program, laboratory data, and summaries of subsurface conditions at the project site.

Purpose and Scope

CH2M HILL has prepared a Scope of Work for the County for the development of construction documents for improvements to the existing levee located on the west side of the Jordan River from North Temple to Redwood Road. The County's objective is to make required improvements to the levee so that it may be certified by the Federal Emergency Management Agency (FEMA). The County has requested that the project be completed in the following three phases:

- Phase I - Preliminary Study
- Phase II - Design
- Phase III - Services During Construction

This *Geotechnical Data Report* serves to document the field exploration and subsequent laboratory testing conducted for Phase I Task 2.0 of the Jordan River Levee Project.

Background

The section of the Jordan River Levee discussed in this report parallels the Jordan River between North Temple and Redwood Road in Salt Lake City, Utah. The levee is founded on the west bank of the Jordan River. This section is approximately 3.4 miles in length and passes through predominantly residential suburbs of Salt Lake City. Portions of the existing levee were constructed in the early 1980s. There were some segments of the levee in place prior to the work in the early 1980s, and the age of that existing levee is not known. The height of the existing levee varies from approximately zero to 6 feet above the adjacent ground surface. The Jordan River flows northward from Utah Lake to the south, and terminating at its confluence with the Great Salt Lake to the north.

Where intact, the existing levee provides additional freeboard and flood protection for residences and businesses located west of the river. However, portions of the levee do not meet the current FEMA requirements for flood control structures. Salt Lake County seeks to have the Jordan River Levee certified by FEMA. This geotechnical investigation collects data to support a geotechnical evaluation of the existing levee and for use in the preliminary design of levee modifications to meet FEMA certification.

Site Location and Description

The project site is located in Salt Lake City, Utah, immediately west of the Jordan River, Figure 1. The levee through this section is approximately 3.4 miles in length. The southern limit of the project is North Temple (40.77161°N Latitude, 111.92636°W Longitude); the northern limit of the project is Redwood Road (40.80773°N Latitude, 111.93896°W Longitude). The project is divided into 5 reaches, as shown in Figure 2 and summarized in Table 1.

TABLE 1
Levee Reach Description

Reach No.	Northern Limit	Southern Limit	Approximate Length (mi)
1	N Redwood Road	Rose Park Golf Course Bridge	0.76
2	Rose Park Golf Course Bridge	1000 N	0.63
3	1000 N	700 N	0.50
4	700 N	500 N	0.40
5	500 N	North Temple	1.06

Reach 1

This reach begins where the Jordan River crosses N. Redwood Road and extends to the Rose Park Golf Course bridge over the Jordan River, approximately 0.76 miles upstream (Figure 3A). The levee passes behind a residential area on Earnshaw Drive for the first 0.1-mile, then traverses the edge of the Rose Park Golf Course. The existing levee is topped with asphalt concrete for the entirety of Reach 1 as it coincides with the Jordan River Parkway Trail. The trail in this section is separated from the golf course by vinyl-coated chain link fencing 6 to 12 feet tall. In places the landward side of the levee is retained laterally by short segmental block retaining walls (typically less than 4 feet in height). Trees and shrubs generally line the riverbank; riprap was observed as a riverbank stabilization measure in at least one location for several hundred feet.

Reach 2

This reach begins at the Rose Park Golf Course bridge and extends to 1000 N, approximately 0.63-mile upstream (Figure 3B). The paved Jordan River Parkway Trail crosses to the east side of the river at the golf course bridge. The levee crest is a dirt road where it is adjacent to the Rose Park driving range and the practice area for the adjacent Jordan River Par Three Golf Course (approximately 0.3-mile). Trees and shrubs border the levee on both sides. The levee loses prominence where it is adjacent to the Jordan River Par Three Golf Course. Through this section, the levee blends with the maintained grass of the golf course. Trees and shrubs line the river bank through this section. The last 150 feet of the levee is adjacent to a vacant lot with trees and shrubs before it reaches a gated entrance at 1000 N.

Reach 3

This reach begins at the 1000 N bridge over the Jordan River and extends to the 700 N bridge over the Jordan River, approximately 0.50-mile upstream (Figure 3C). The levee crest is a dirt road along the entirety of this section. For the first 300 feet, the levee is adjacent to a local library, community garden, and park area. Trees and shrubs line the riverbank through this section. The remainder of the levee through this section is paralleled by Riverside Drive and a concrete sidewalk at the landward toe until the levee intersects with 700 N. Trees and shrubs line the riverbank here as well, with many large trees growing on and near the levee. Several relic irrigation pump stations are built into the levee in this section. The land west of Riverside Drive through this section is residential.

Reach 4

This reach begins at the 700 N bridge over the Jordan River and extends to the 500 N bridge over the Jordan River, approximately 0.40-mile upstream (Figure 3D). The levee crest consists of a dirt road for this reach. The last 250 feet of levee are paralleled by a paved asphalt path, and the levee swings about 100 feet away from the river (west). Note that the asphalt path is not on the levee, and the levee crest is not paved along any sections of this reach. The levee passes a small shopping center, church parking lot, several apartment buildings and a defensive driving school.

Reach 5

This reach begins at the 500 N bridge over the Jordan River and extends to North Temple, approximately 1.06 miles upstream (Figures 3D and 3E). The levee follows a sinuous path as it parallels a large meander in the Jordan River. The levee crest is paved for the first 0.25-mile as it passes between houses and the Jordan River. The levee in this section is maintained grass with adjacent trees and shrubs.

From about 0.20- to 0.42-mile upstream of 500 N, the levee passes by the Utah State Agriculture Building and a large maintained park area. The levee is discontinuous through this section. The paved path forks and leaves the levee crest, with the levee crest in this area consisting of well-maintained grass. This section of the levee is mostly open, with intermittent trees.

From about 0.42- to 0.60-mile upstream of 500 N, the levee passes the Utah State Medical Building and parking lot. The levee crest in this section is a dirt road. Many trees line the riverbank and levee through this section.

From 0.60- to 0.93-mile upstream of 500 N, the levee is adjacent to a recreational vehicle (RV) and mobile home park. Many of the RV spaces and mobile home lots in this section extend to the landward toe of the levee. In several locations, portions of the levee toe have been excavated to provide more space for the RV and mobile home lots. Many large trees and shrubs line both sides of the levee through this section. The last 0.11-mile of the levee passes a large parking lot for the Utah State Fairpark. The levee loses prominence through this section, and the levee crest transitions to a concrete sidewalk that continues to North Temple. Some shrubs and tall grass line the riverbank in this section.

Limitations

This report has been prepared for the exclusive use of Salt Lake County and CH2M HILL, for specific application to the Jordan River Levee improvements project. It has been prepared in accordance with generally accepted geotechnical engineering practice. No other warranty, express or implied, is made.

The data and descriptions presented in this report are based on the information obtained from the field exploration performed between June 15 and June 19, 2009, and the associated laboratory testing. Exploration data indicate soil and groundwater conditions only at specific locations and times, and only to the depths penetrated. Subsurface conditions and water levels may differ from conditions occurring at these explored locations. Also, the passage of time may result in a change in conditions at these locations.

CH2M HILL is not responsible for any claims, damages, or liability associated with the interpretation of subsurface data or for reuse of subsurface data without CH2M HILL's express written authorization.

Appendix A contains additional information on the geotechnical data report.

Geotechnical Explorations

Existing Geotechnical Information

Several geotechnical reports from engineering projects in the vicinity of the Jordan River Levee study were obtained. Some of the data contained in these reports may be applicable to the current project. These reports are summarized in Table 2 and are included in Appendix B.

TABLE 2
Previous Geotechnical Reports

Author	Project	Contents	Date	No. Borings/Depths
Dames and Moore	Proposed sewer trunk line near Redwood Road	Soils report, boring logs, location plan, lab data	May, 1960	18/25 ft to 35 ft
Meissner Engineers, Inc.	I-215 Salt Lake City Belt Route	Boring logs, location plan, laboratory data	Oct, 1961	4/60 ft to 112 ft
Utah State Dept. of Highways	Foundations Report for I-215 bridge over the Jordan River	Foundation Report, boring logs, location plan, laboratory data	Apr, 1962	2/100 ft, 115 ft
Utah State Dept. of Highways	4th South Street Bridge over Jordan River	Geotechnical recommendations, boring logs, location plan, laboratory data	Apr, 1963	4/102 ft to 111 ft
Utah State Dept. of Highways	North Temple Structure over Jordan River	Foundation recommendations, boring logs (some), location plan, laboratory data	May, 1967	4/145 ft[1]
CH2M HILL, Inc.	500 North/Jordan River Bridge	Foundation report, boring logs, location plan, laboratory data	Aug, 1981	2/39 ft, 102 ft

[1] Three boring logs are missing because of the nature of the report reprographics.

Geotechnical Exploration

Sixteen borings (B01-09 to B16-09) were advanced along the Jordan River Levee alignment between June 15 and June 19, 2009. ConeTec, Inc. of Salt Lake City, Utah was subcontracted by CH2M HILL for drilling, sampling, and abandonment of the soil borings. The locations of the soil borings are listed in Table 3.

Borings B2-09 and B12-09 were advanced to a depth of 100 feet using a high-mobility rubber track-mounted Fraste Multidrill-XL drill rig with mud-rotary drilling techniques. Standard penetration testing (SPT) was performed on 2.5-foot intervals in the upper 20 feet, at 5-foot intervals from 20 to 50 feet, and at 10-foot intervals from 50 to 100 feet with an automatic trip hammer. Relatively undisturbed Shelby tube samples, where taken, were collected in suitable fine-grained materials.

A 2-inch inside-diameter Schedule 40 threaded polyvinyl chloride (PVC) casing manufactured by Environmental Manufacturing, Inc. of Manhattan, Kansas was installed in B2-09 and B12-09 to a depth of 100 feet. This installed casing may be used for seismic shear wave velocity profiling at a later date. The annular space between the casing and the borehole walls was tremie-backfilled with high-solids bentonite grout. The surface completion was an 8-inch-diameter flush-mount manhole.

All other borings were advanced to a depth of 20 feet using a high-mobility rubber-track-mounted Rhino drill rig with hollow-stem auger drilling techniques. SPT was performed on 2.5-foot intervals with an automatic trip hammer. Relatively undisturbed Shelby tube samples were collected in suitable fine-grained materials. Borings were backfilled to the ground surface with bentonite chips and hydrated. Photos of the Fraste Multidrill-XL and the Rhino drill rig are shown in Figure 4.

SPTs were performed in general accordance with American Society for Testing and Materials (ASTM) D 1586, and relatively disturbed samples of materials were obtained using the standard 2-inch outside-diameter split-spoon sampler during the tests. SPT results can be used to characterize the consistency or density of in-place soil by measuring the penetration resistance expressed as "blow-counts." The blow count is the number of blows required to advance the standard split-spoon sampler 6 inches using a 140- pound hammer falling 30 inches. The sampler was driven 18 or 24 inches, and the blow count was recorded for each 6-inch increment. The sum of the blows for the second and third increments is referred to as the SPT N-value. Low N-values indicate soft or loose deposits, while high N-values are evidence of hard or dense materials. After the sampler was driven and the blow counts recorded, the sampler was withdrawn from the boring to recover a disturbed sample. A plot indicating the range of N-values versus depth is included in Figure 5.

Representative portions of each sample were placed in sealed plastic bags and taken to the laboratory for verification of field classifications and to perform index testing. The soil boring details are summarized in Table 3 with detailed soil boring logs included in Appendix C.

TABLE 3
Boring Summary

Boring No.	Reach	Latitude (deg N)	Longitude (deg W)	Ground Surface Elev (ft)	Date Completed	Completion Depth (ft)
B01-09	5	40.77401	-111.92801	4,225.3	6/19/2009	20
B02-09	5	40.77566	-111.93103	4,224.6	6/16/2009	100
B03-09	5	40.77776	-111.93609	4,226.4	6/19/2009	20
B04-09	5	40.77736	-111.93828	4,223.4	6/19/2009	20
B05-09	5	40.77887	-111.93873	4,222.6	6/19/2009	20
B06-09	4	40.78064	-111.93873	4,223.1	6/18/2009	20
B07-09	4	40.78116	-111.93785	4,220.8	6/18/2009	20
B08-09	3	40.78570	-111.93656	4,218.8	6/18/2009	20
B09-09	3	40.78740	-111.93686	4,222.3	6/18/2009	20
B10-09	3	40.78939	-111.93653	4,221.0	6/18/2009	20
B11-09A	2	40.79270	-111.93654	4,221.8	6/17/2009	15
B11-09B	2	40.79270	-111.93654	4,221.8	6/18/2009	20
B12-09	2	40.79647	-111.93713	4,219.5	6/15/2009	100
B13-09	1	40.80091	-111.93540	4,219.5	6/17/2009	20
B14-09	1	40.80396	-111.93432	4,220.6	6/17/2009	20
B15-09	1	40.80605	-111.93516	4,219.1	6/17/2009	20
B16-09	1	40.80750	-111.93696	4,220.4	6/17/2009	20

Latitude and longitude coordinates for each boring location were measured using a Trimble GeoXT Global Positioning System (GPS) unit. Ground surface elevations were interpolated from a 1-meter resolution LIDAR grid prepared by Salt Lake County, using the latitude and longitude coordinates from the GPS unit.

Geotechnical Laboratory Testing

Intermountain Geo-Environmental Services, Inc. (IGES) of Salt Lake City, Utah performed laboratory testing services on selected samples of soil under subcontract to CH2M HILL. The objective of the lab testing program was to confirm field classifications of soil and to measure index soil properties for engineering purposes. The laboratory testing program performed by IGES included the following tests:

- ASTM D 422, Standard Test Method for Particle Size Analysis of Soils
- ASTM D 1140, Standard Test Method for Amount of Soils Finer than No. 200 (75 micrometer [μm]) Sieve.
- ASTM D 2216, Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock.

- ASTM D 4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

Figure 6 presents the range of laboratory-determined natural water content vs. depth. Figure 7 presents the range of Atterberg limit values obtained for the soils at the site vs. depths. Figure 8 presents the percent fines measured in the soils sampled at the project site vs. depth. Figure 9 presents the results of particle size analyses of soils greater than the No. 200 (75 µm) sieve.

Complete laboratory test results are included in Appendix D.

Subsurface Conditions

Regional Geology

Salt Lake City is located in North Central Utah and is situated on a deep, sediment-filled basin that represents the extreme eastern extent of the Basin and Range geologic province (Lund, 1990). The city is bordered to the east by the Wasatch Mountains and to the west by the Oquirrh Mountains. The city is also located near the intersection of two of western North America's most prominent and persistent structural elements: the Wasatch Line, and the Uinta Arch (Lund, 1990). The northward-trending Wasatch Fault, an active zone of normal faulting, forms the eastern border of the city where it meets the Wasatch Front. The locations of these features are depicted in Figure 10.

The near-surface and surficial geology of the Salt Lake Valley is dominated by Quaternary materials deposited within the last 30,000 years by Lake Bonneville (Lund, 1990). Alluvial and flood plain deposits (Qa) and flood-plain/delta deposits (Qfpd) cover a large portion of the Salt Lake Valley. Floodplain deposits exist along the Jordan River and several of its tributaries, where the streams have incised Lake Bonneville Sediments (Lund, 1990). The extensive floodplain and delta complex in the vicinity of the project site consists chiefly of fine-grained sediments deposited by the Jordan River (Lund, 1990). The area is generally marshy owing to poor drainage conditions (Lund, 1990). A generalized geologic structure map is shown in Figure 11.

Subsurface Conditions at the Site

Subsurface conditions along the levee alignment were assessed during the June 2009 field investigation and through interpretation of laboratory results performed on selected samples. In general, subsurface conditions across the site consist of alluvial deposits comprised of varying percentages of clay, silt, and fine-to-medium sand from the ground surface to the maximum extent penetrated (100 feet below ground surface). These alluvial soils can be divided into roughly two general categories: 1) levee fill, and 2) recent Jordan River alluvium and Lake Bonneville sediments.

Levee Fill

In some sections, the levee is constructed of compacted fill. Some of these sections were placed in the early 1980s; however, for some of the section the origin of the fill is not known. The fill varies across the project site, but it is most often a brown sandy silt material. Organics, gravels, and clays were also observed within the fill. In places the levee is topped with asphalt pavement and well-graded gravel sub-base. The thickness of the fill encountered varied from zero to 7.5 feet. SPT N-values in this material ranged from 6 to 27 blows per foot. The descriptions of the fill are considered to be applicable only to the area immediately surrounding the boring, because the nature and extent of the fill is highly variable.

Recent Alluvium and Lake Bonneville Deposits

Recent alluvium deposited by the Jordan River overlies Lake Bonneville sediments in the vicinity of the project site. Because of the meandering nature of the ancestral river and the incision, erosion, and re-deposition of Lake Bonneville sediments by the Jordan River, it was somewhat difficult to identify a distinct boundary between these two formations. For this reason, they are discussed together in this section.

The recent alluvium and Lake Bonneville soils underlying the existing levee typically consist of varying proportions of silt, silty clay, clay, organics, and fine to medium sand. Organics, roots, and other vegetative matter were encountered to the maximum extents penetrated (100 feet below ground surface). Some fine gravel was also encountered. These soils were found to be highly variable between borings. The relative density or consistency of the recent alluvium varies from very soft/very loose to stiff/very dense, with SPT N-values ranging from less than zero (Weight of Rod or Weight of Hammer) to 73 blows per foot. The average N-value is approximately 6 blows per foot. These descriptions are considered to be applicable only to the area immediately surrounding the boring, because the nature and extent of these materials is highly variable.

Groundwater Conditions

Groundwater levels were not directly measured at the site. Mud rotary drilling techniques prevent measurement of static groundwater levels in an open borehole, and relatively low permeability fine-grained sediments do not permit accurate measurements of groundwater levels in the relatively short amount of time required to complete a single hollow-stem auger boring. However, changes in water content with depth may give an indication of where the static groundwater table exists in situ. Because of the levee's proximity to the Jordan River, it is reasonable to assume that the groundwater surface elevation is similar to the river surface elevation.

References

Lund, W. R. ed. *Engineering Geology of the Salt Lake City Metropolitan Area, Utah.* Bulletin 126. Utah Geological and Mineral Survey. 1990.

ASTM 2001. *Annual Book of ASTM Standards 2001.* American Society of Testing and Materials. Section Four - Construction. Volume 04.08 - Soil and Rock (I): D420-D5779. Revisions are issued annually.

APPENDIX C

Existing Conditions of the Levee

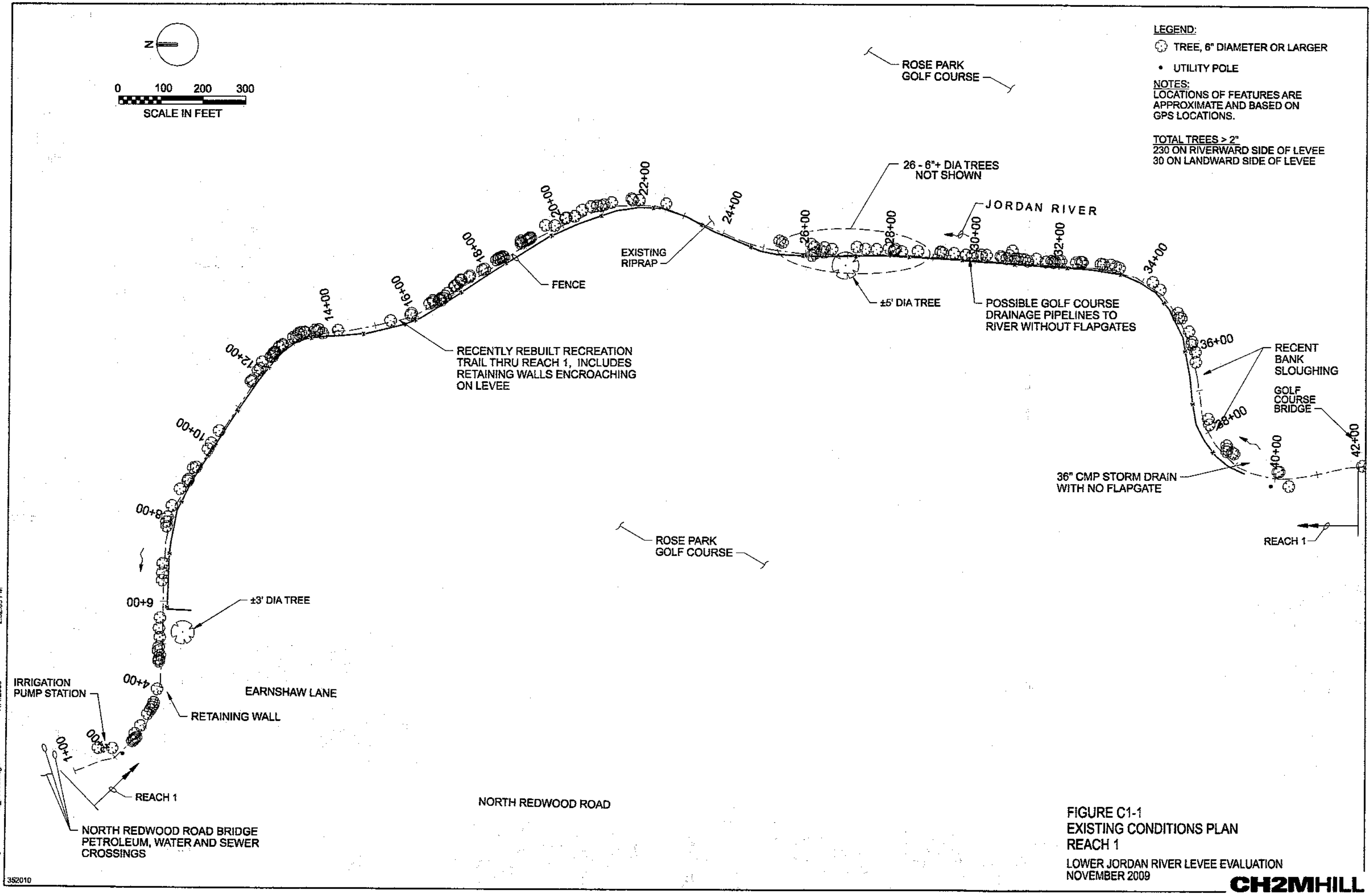

FIGURE C1-1
EXISTING CONDITIONS PLAN
REACH 1

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL

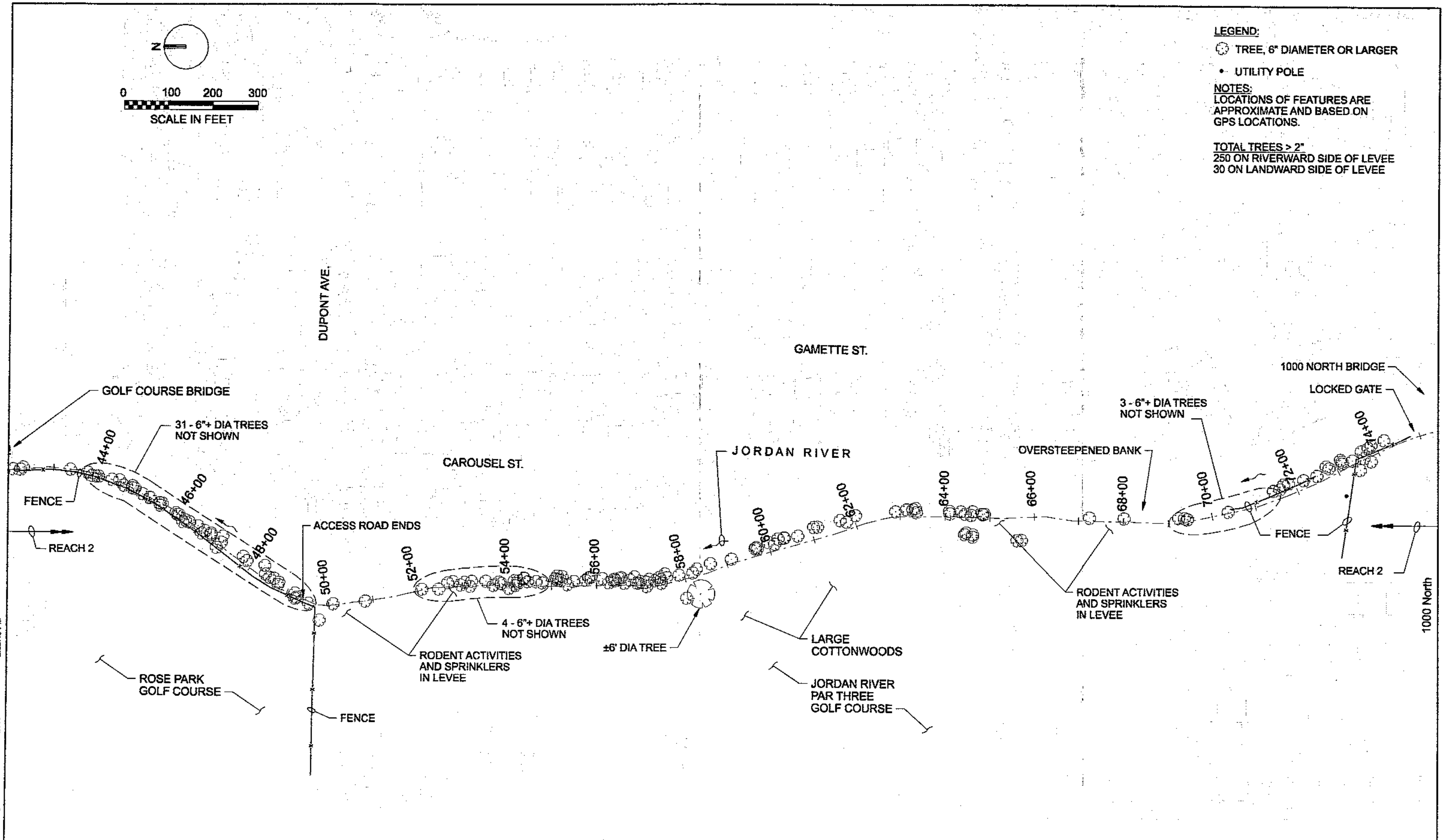

FIGURE C1-2
EXISTING CONDITIONS PLAN
REACH 2

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL

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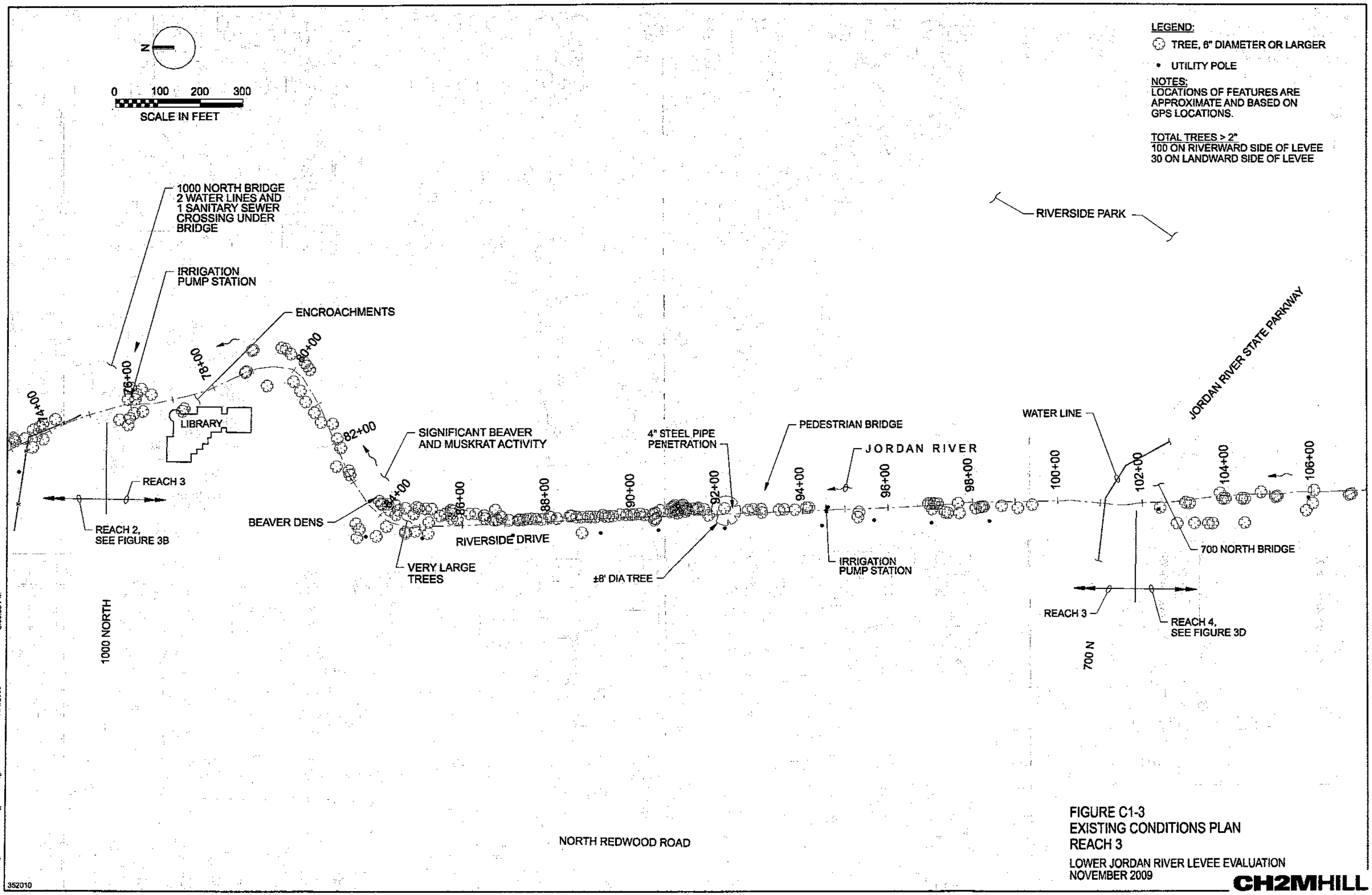

FIGURE C1-3
EXISTING CONDITIONS PLAN
REACH 3

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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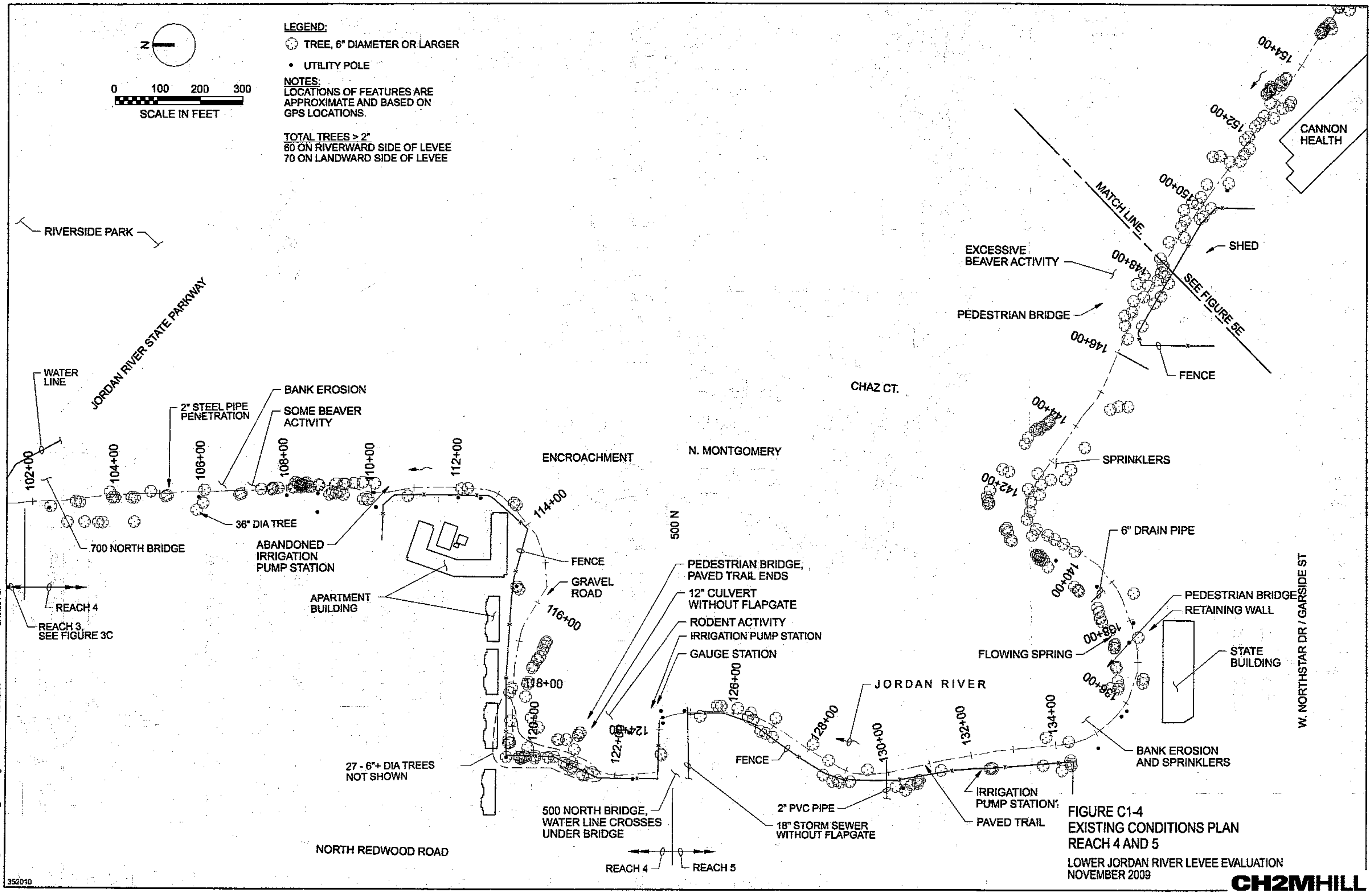

FIGURE C1-4
EXISTING CONDITIONS PLAN
REACH 4 AND 5

LOWER JORDAN RIVER LEVEE EVALUATION
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CH2MHILL

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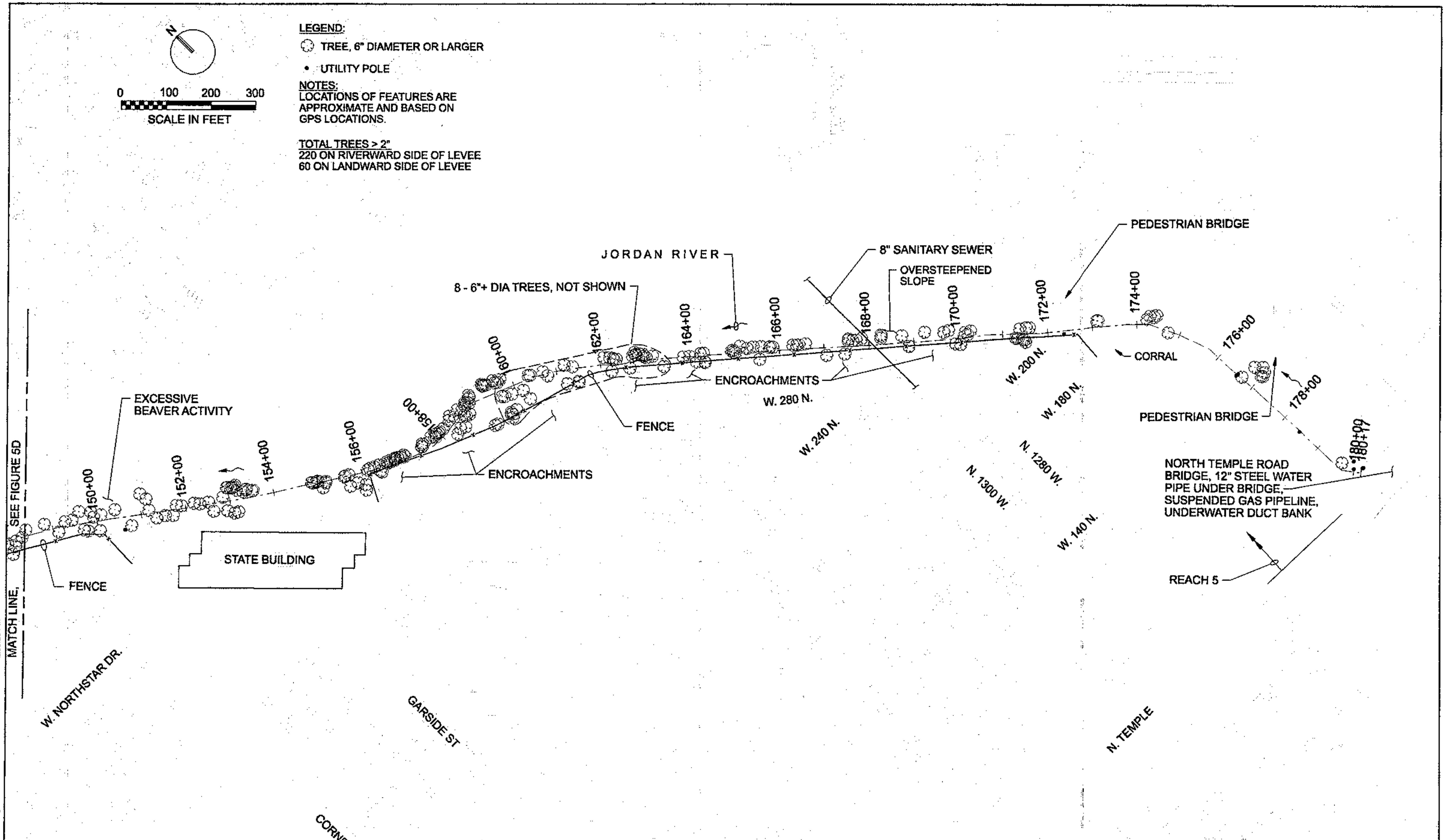

FIGURE C1-5
EXISTING CONDITIONS PLAN
REACH 5

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL

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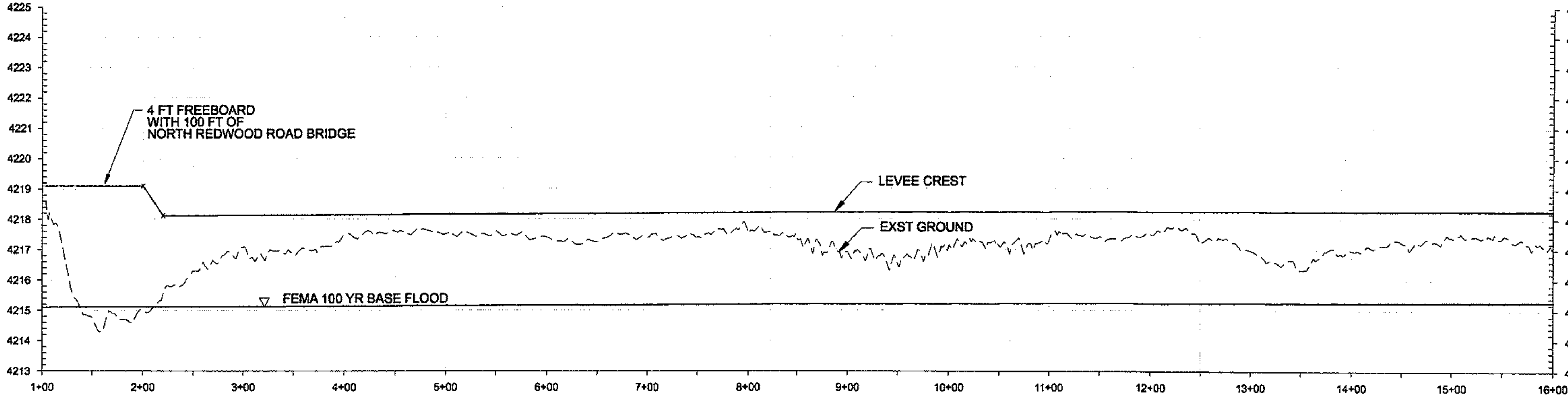
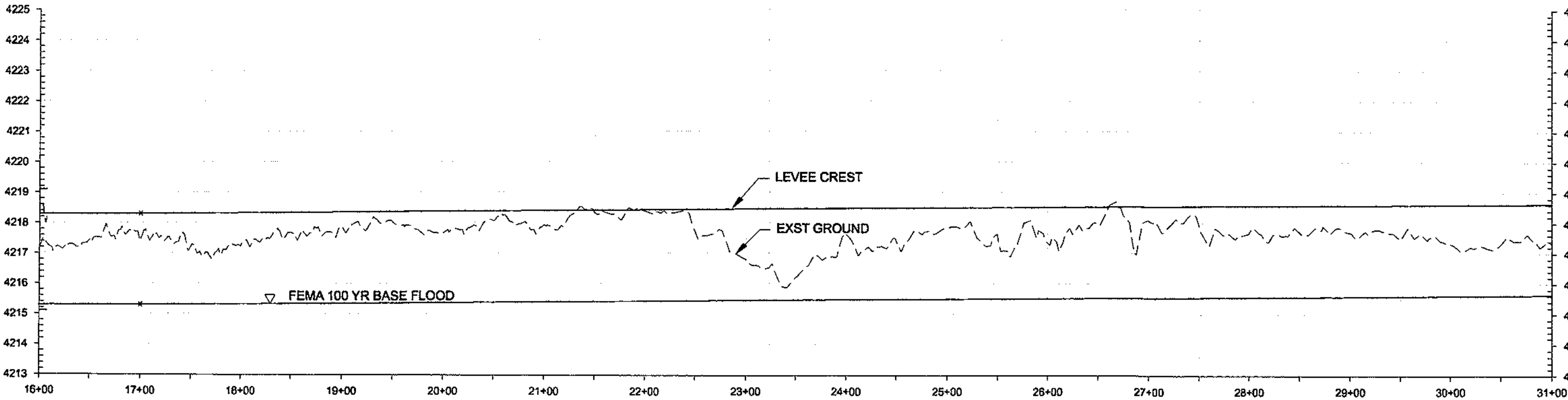


Profile



Profile

FIGURE C2-1
EXISTING LEVEE PROFILE
STA 1+00 TO 31+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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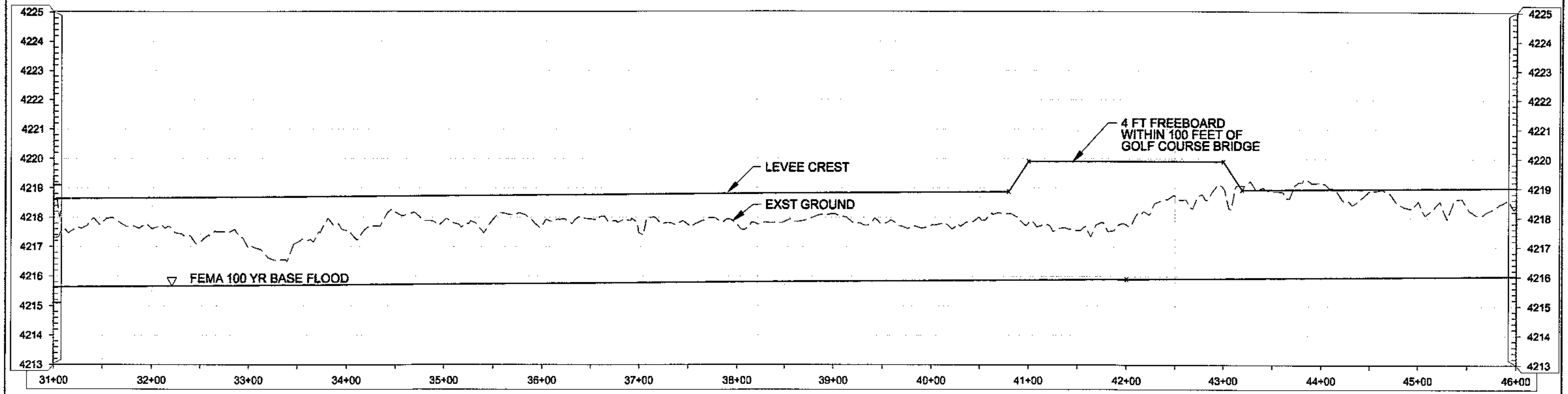

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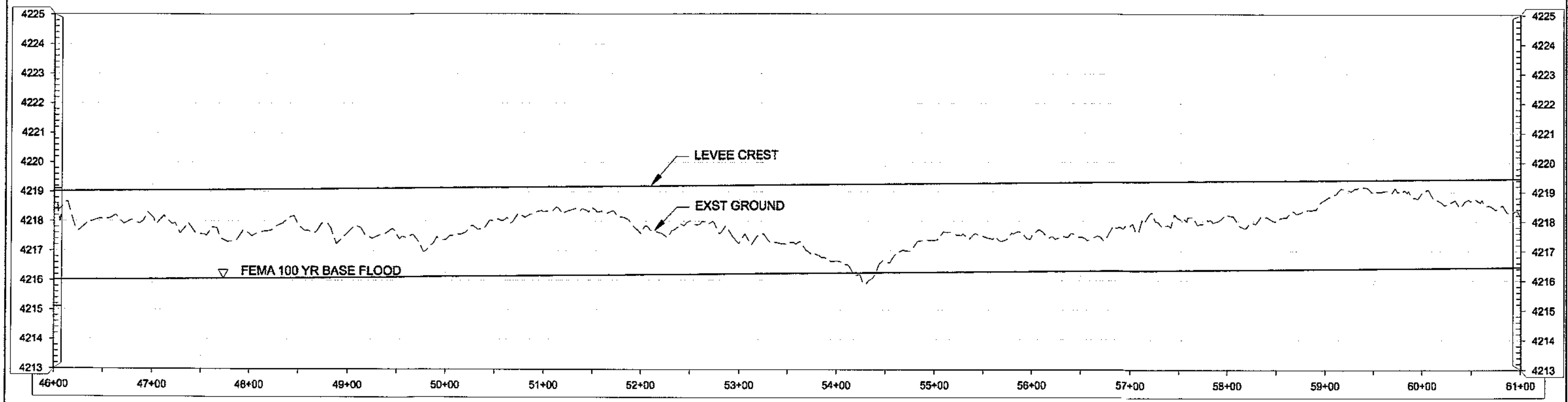

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FIGURE C2-2
EXISTING LEVEE PROFILE
STA 31+00 TO 61+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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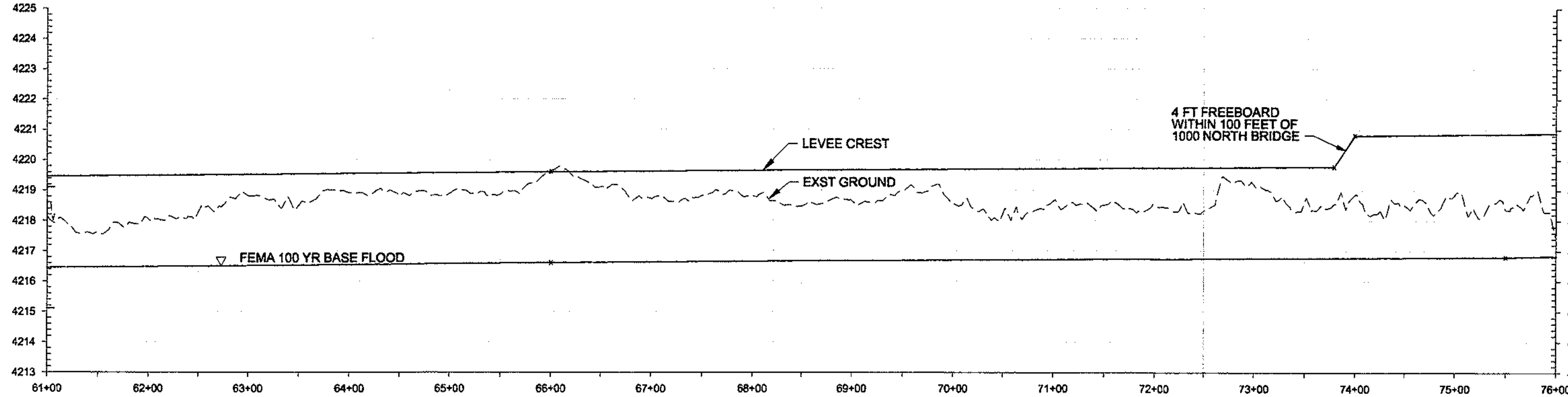

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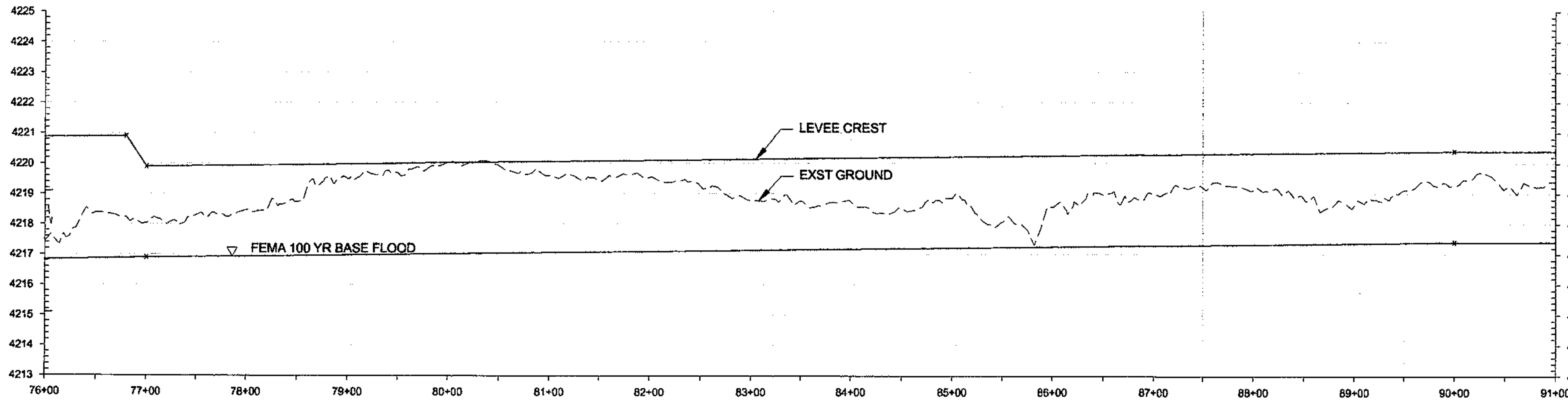

Profile

FIGURE C2-3
EXISTING LEVEE PROFILE
STA 61+00 TO 91+00

LOWER JORDAN RIVER LEVEE EVALUATION
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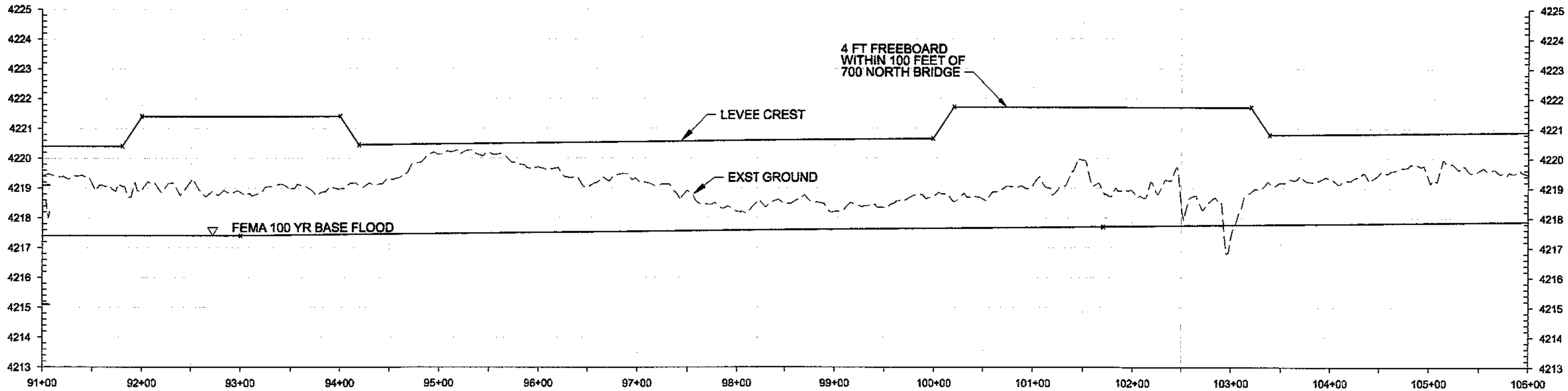

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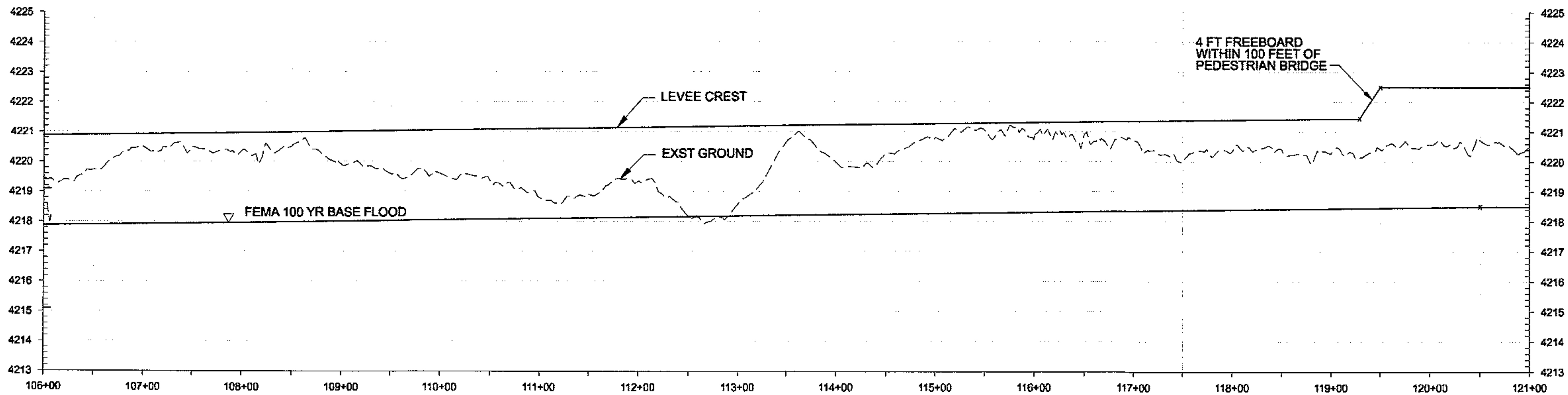

Profile

FIGURE C2-4
EXISTING LEVEE PROFILE
STA 91+00 TO 121+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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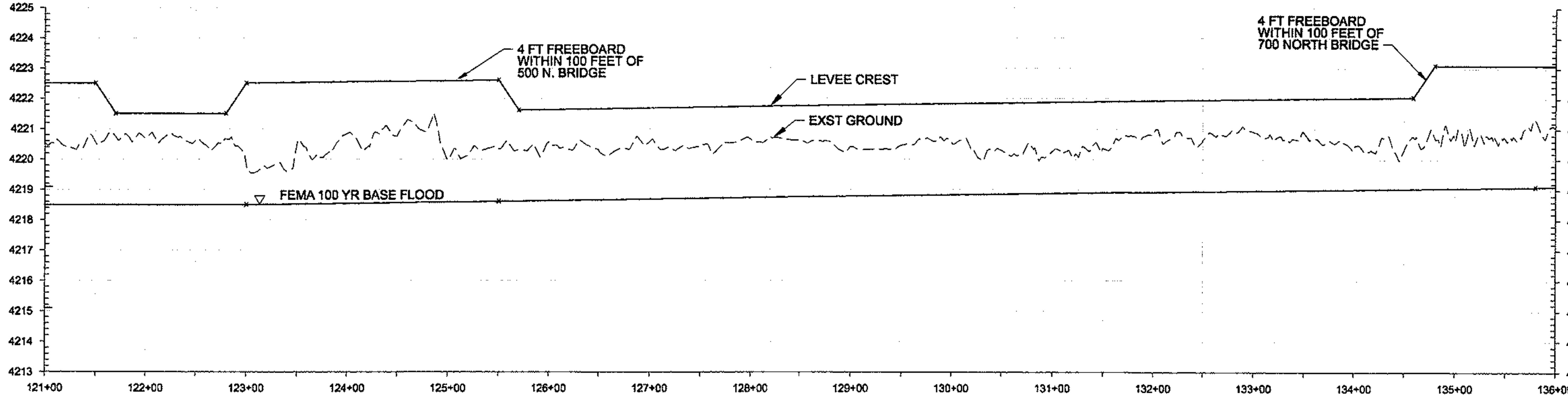

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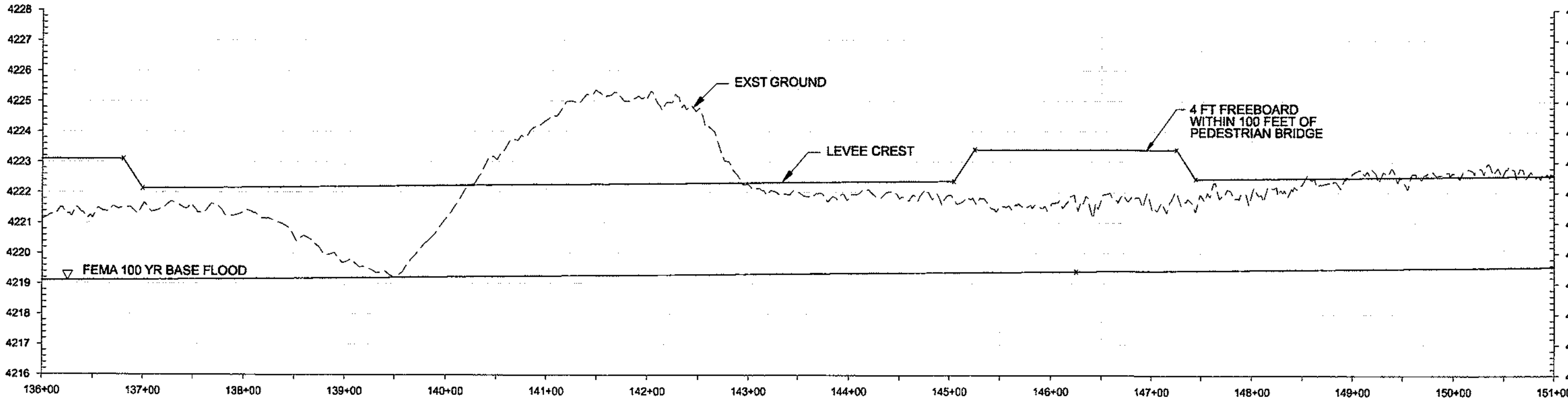

Profile

FIGURE C2-5
EXISTING LEVEE PROFILE
STA 121+00 TO 151+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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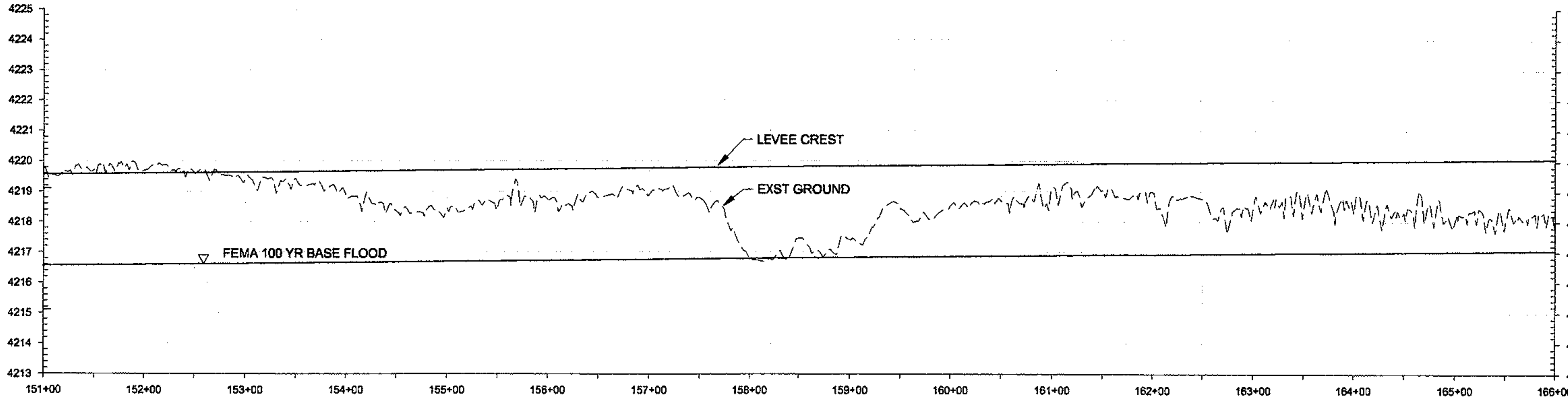

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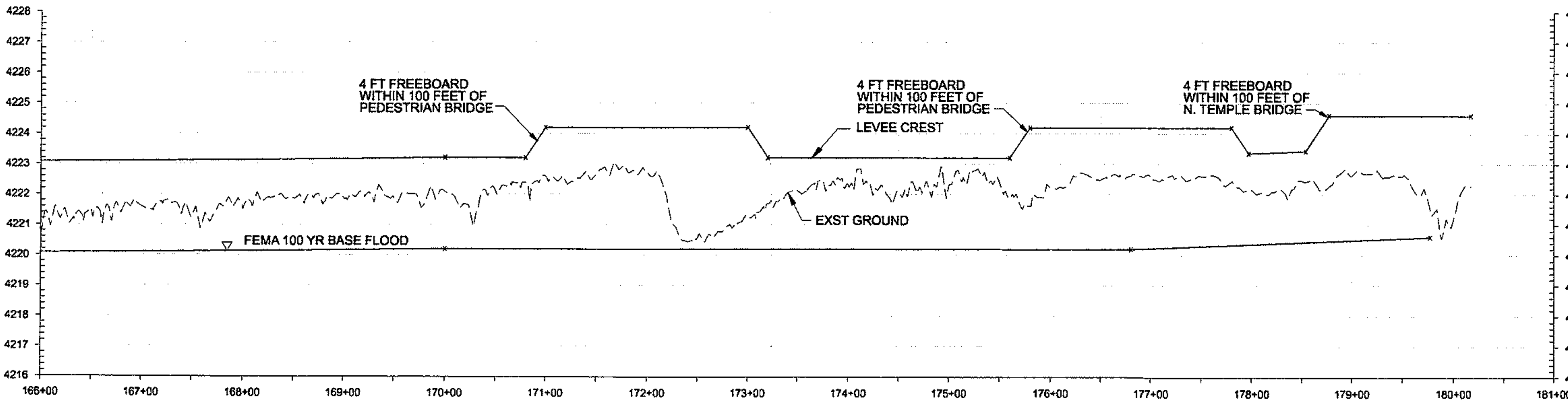

Profile

FIGURE C2-6
EXISTING LEVEE PROFILE
STA 151+00 TO 181+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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APPENDIX D

Riverbank Slopes

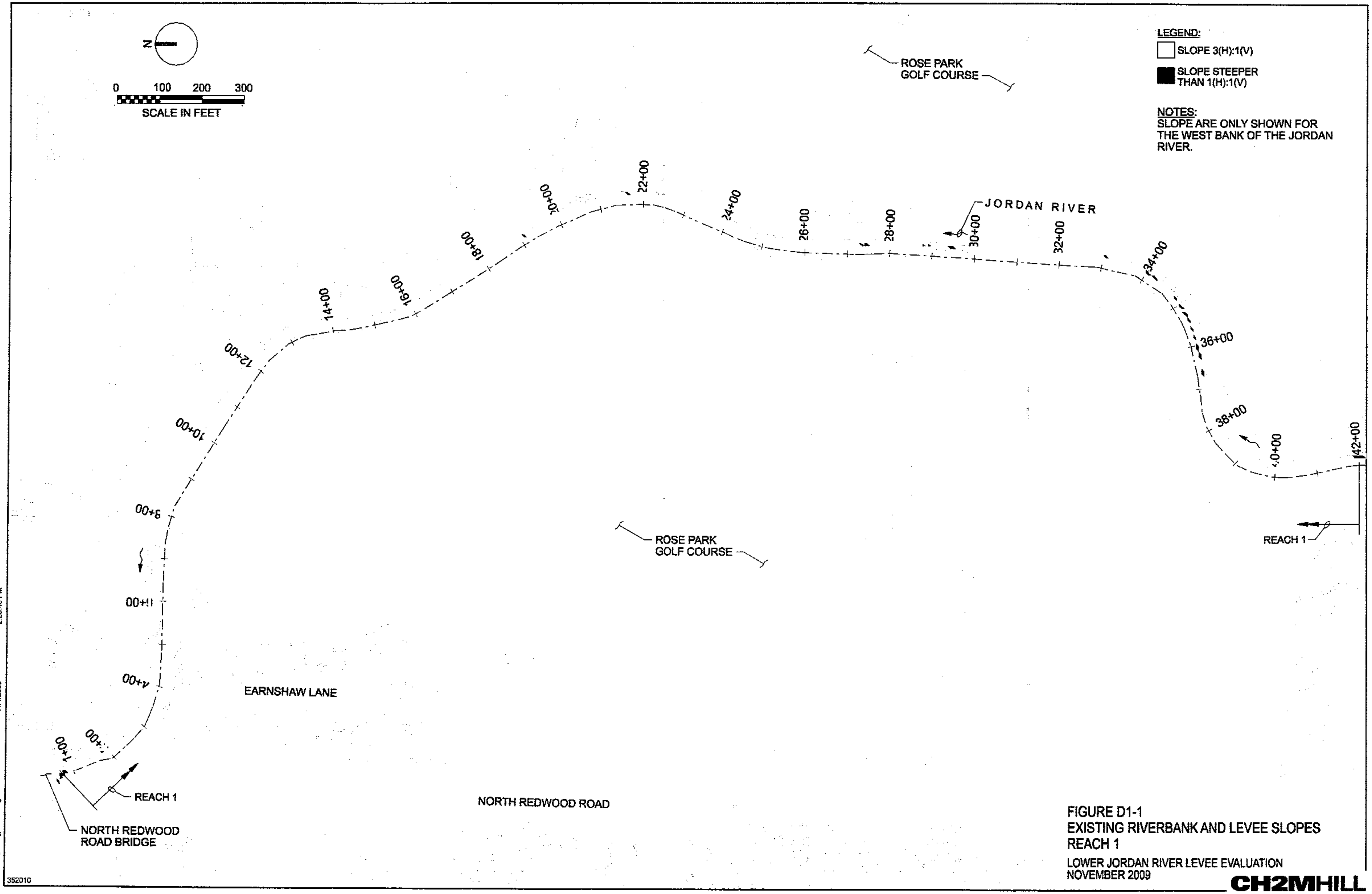

FIGURE D1-1
EXISTING RIVERBANK AND LEVEE SLOPES
REACH 1

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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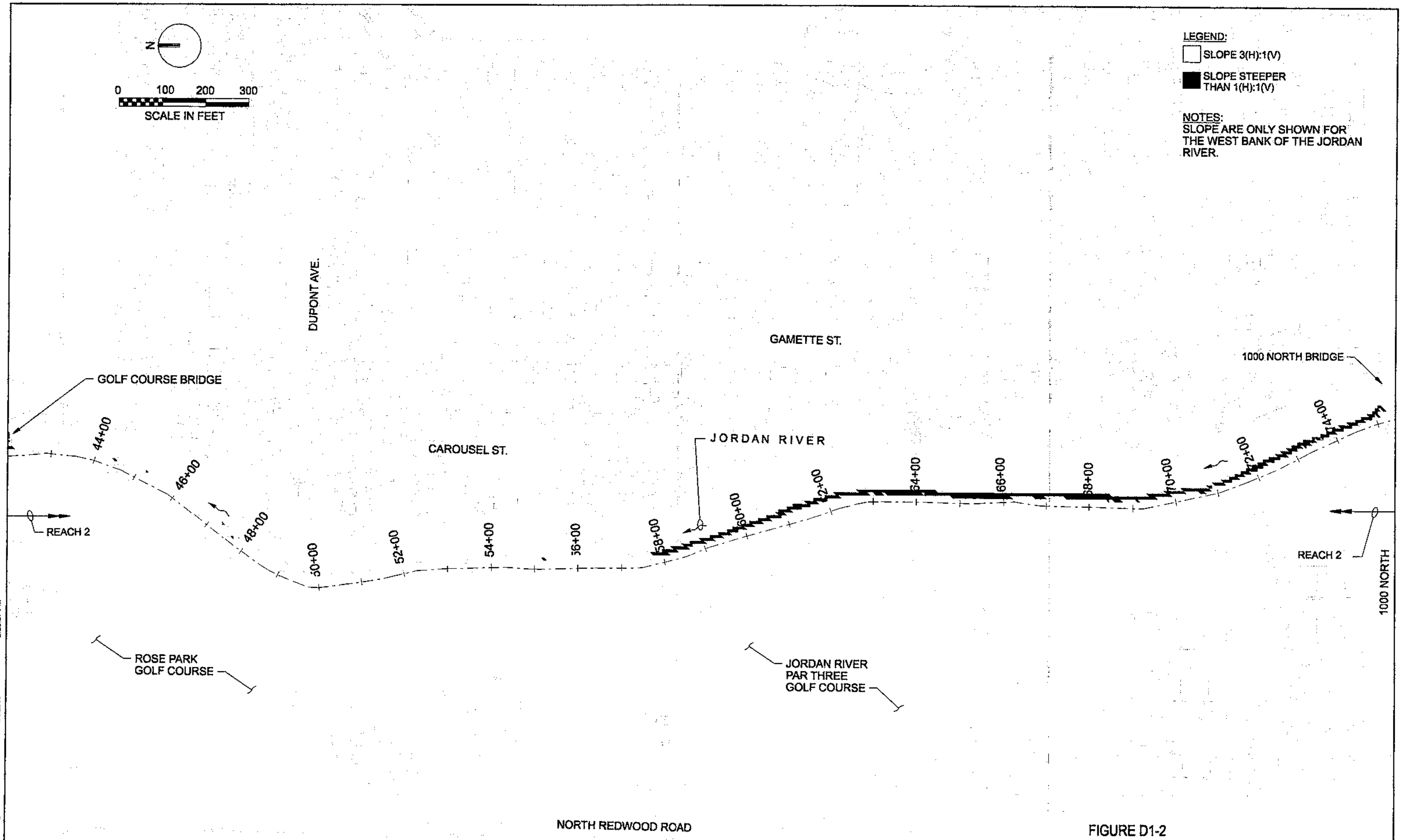

FIGURE D1-2
EXISTING RIVERBANK AND LEVEE SLOPES
REACH 2

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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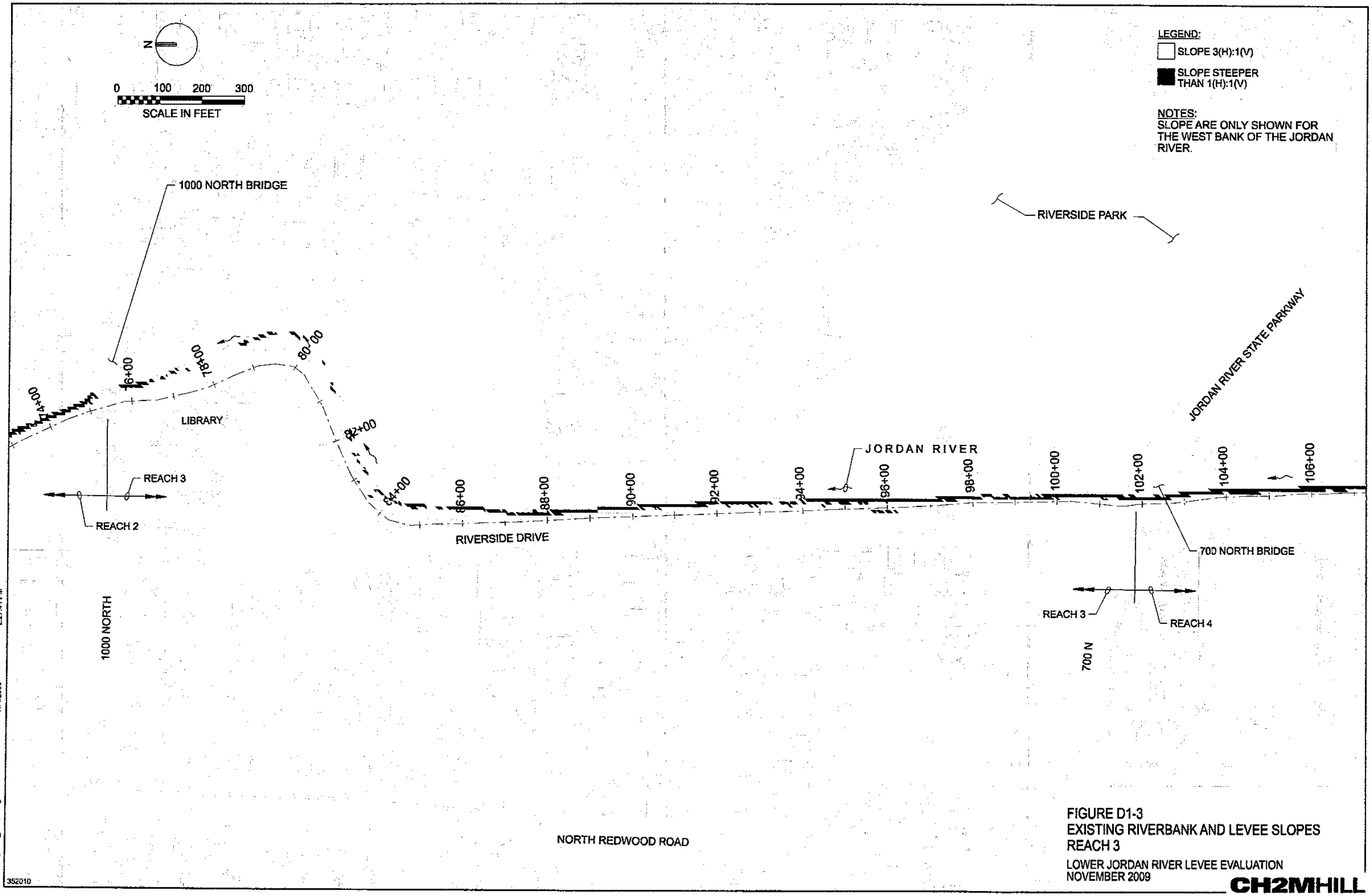

FIGURE D1-3
EXISTING RIVERBANK AND LEVEE SLOPES
REACH 3

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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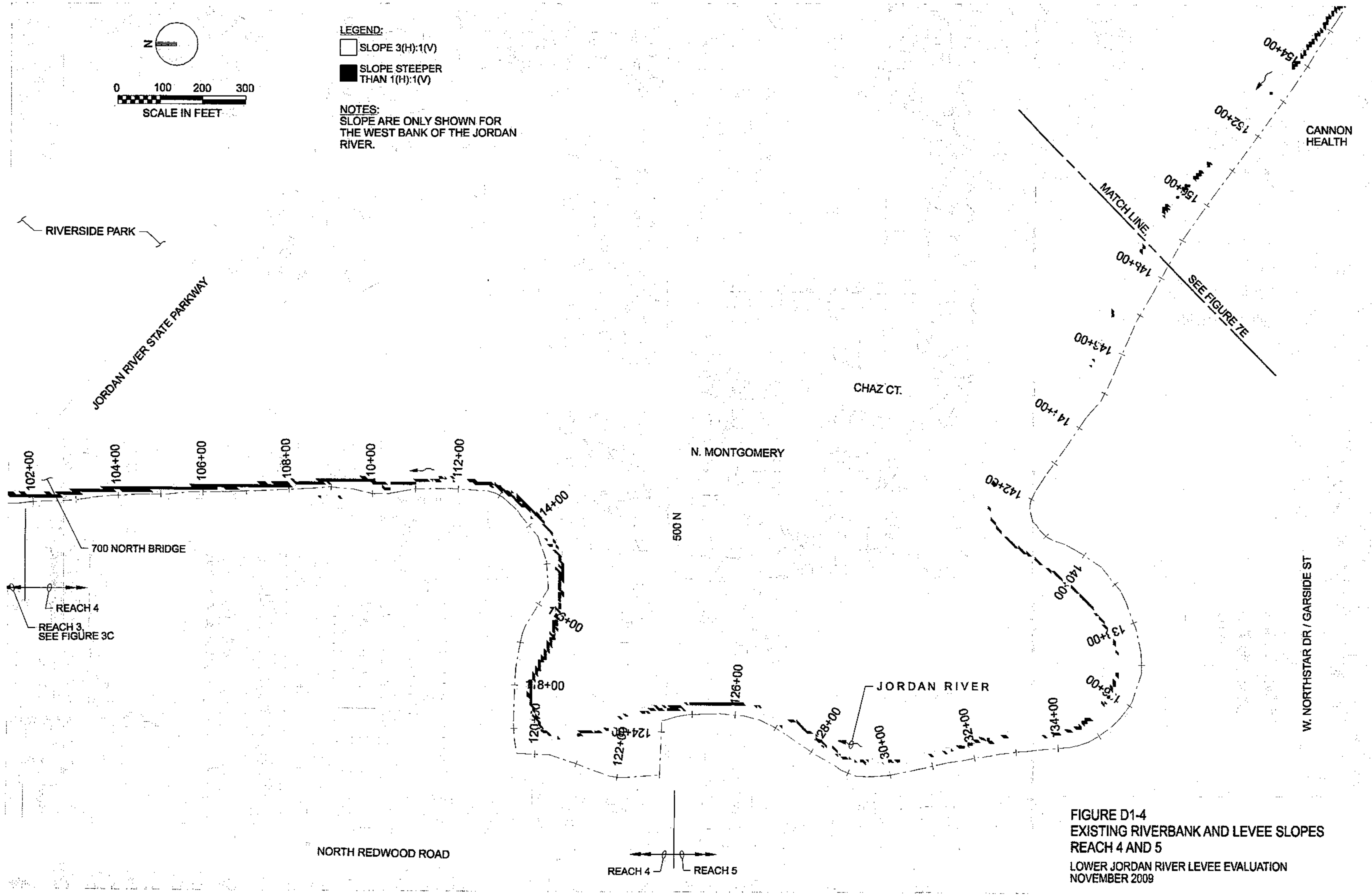

FIGURE D1-4
EXISTING RIVERBANK AND LEVEE SLOPES
REACH 4 AND 5
LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

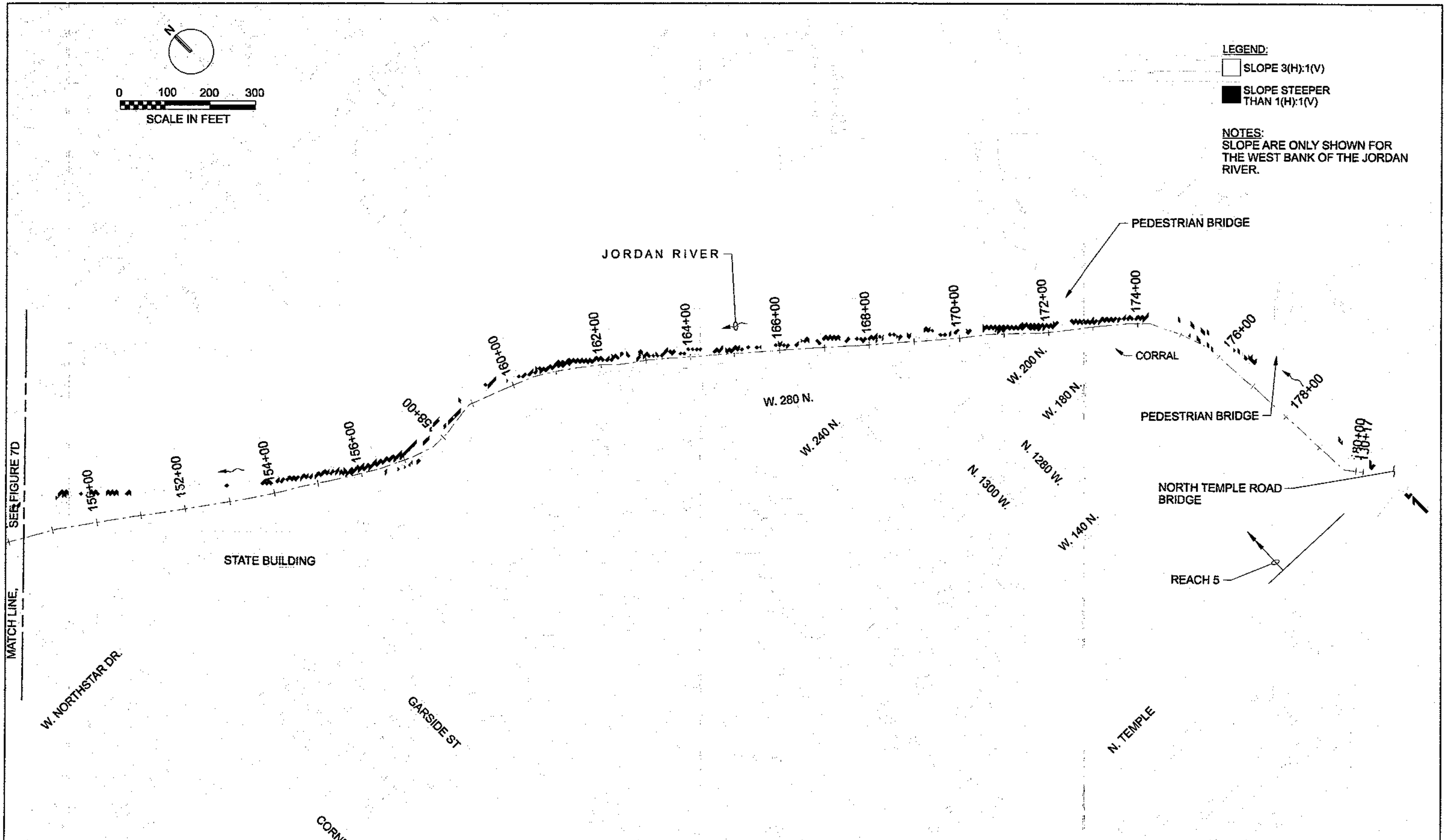

FIGURE D1-5
EXISTING RIVERBANK AND LEVEE SLOPES
REACH 5

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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APPENDIX E

Levee Alignment Alternative No. 1
Keep Existing Alignment

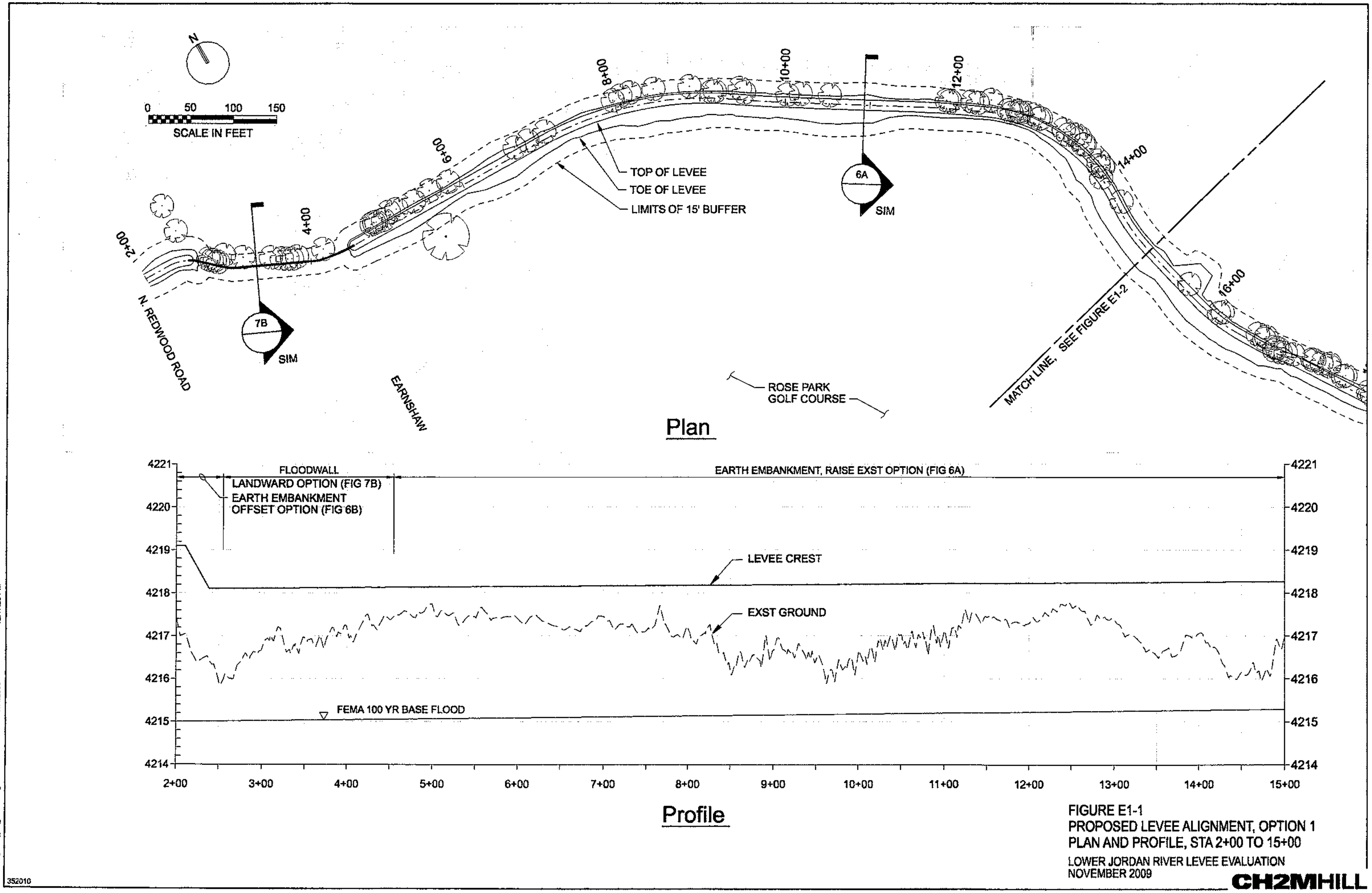

FIGURE E1-1
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 2+00 TO 15+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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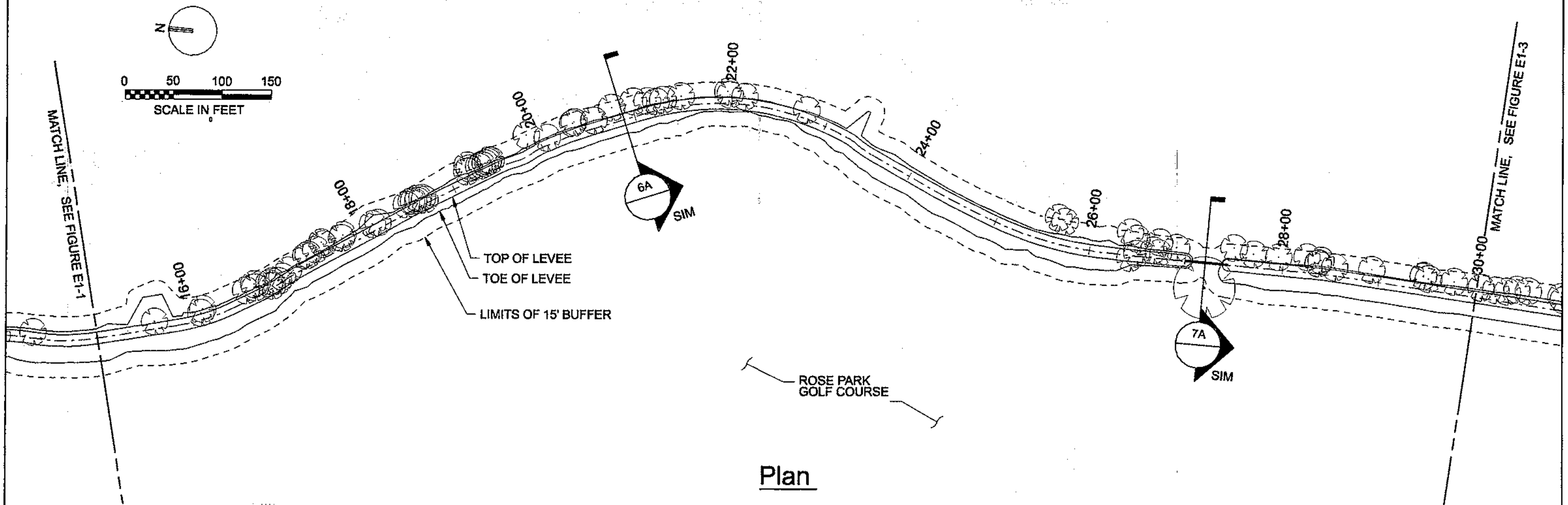

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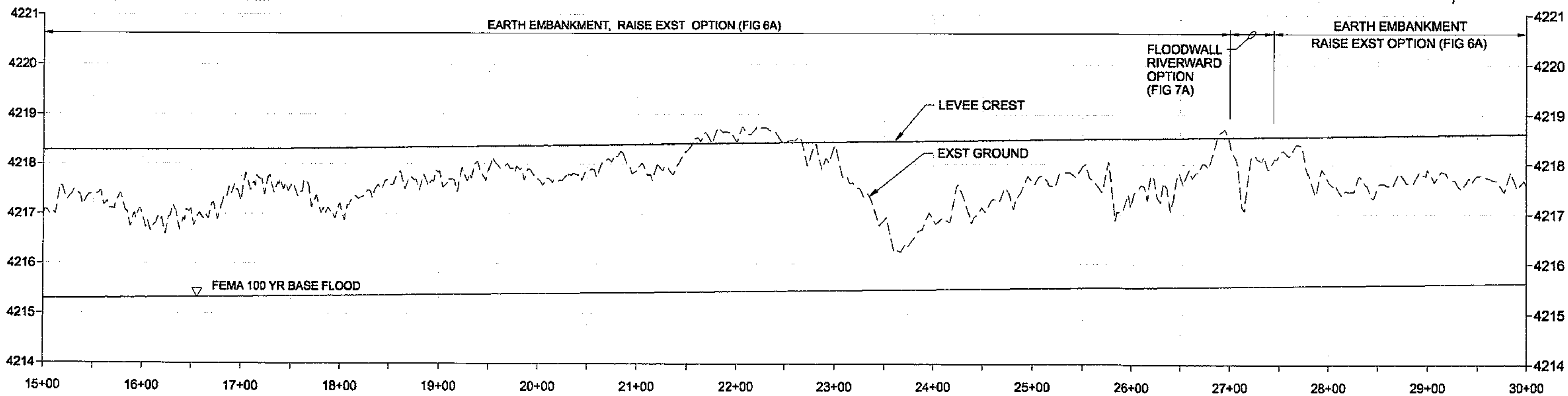

Profile

FIGURE E1-2
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 15+00 TO 30+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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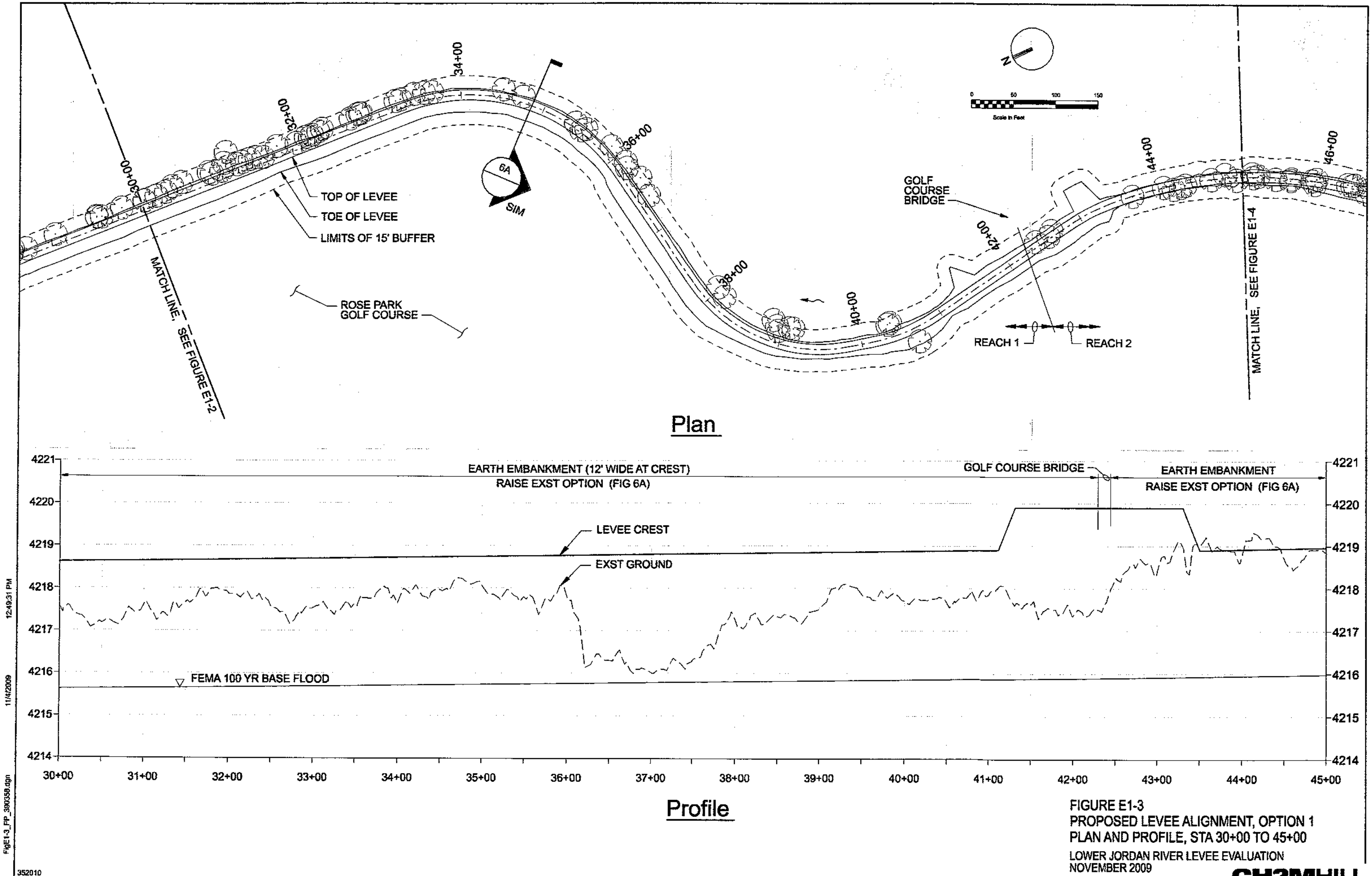
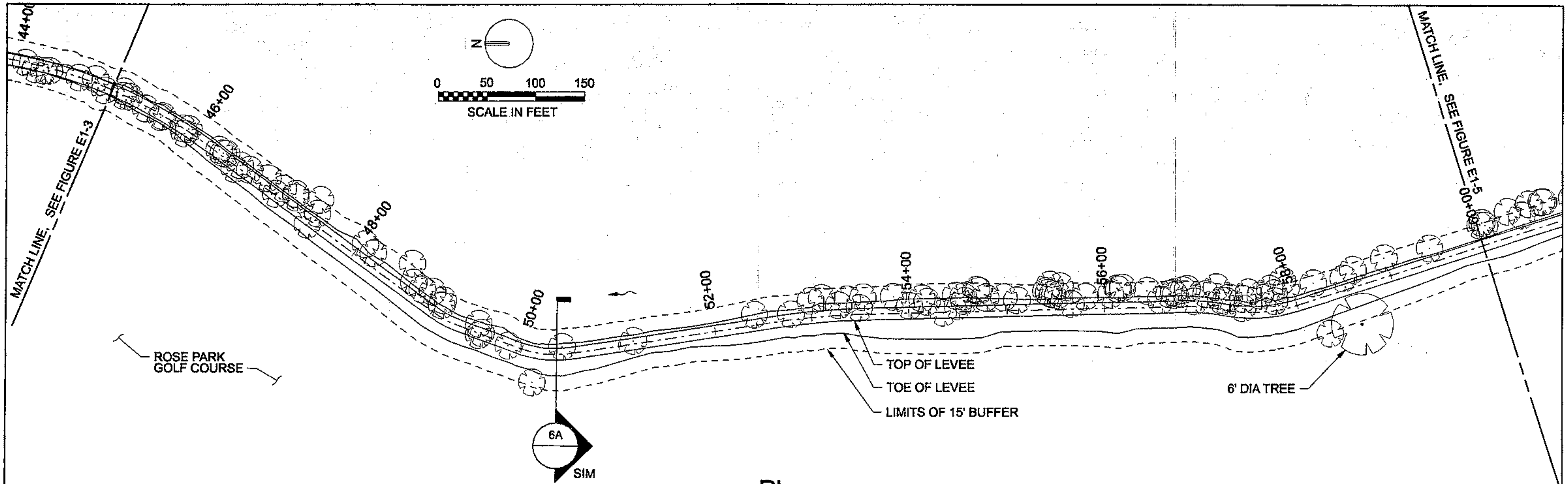


FIGURE E1-3
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 30+00 TO 45+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL



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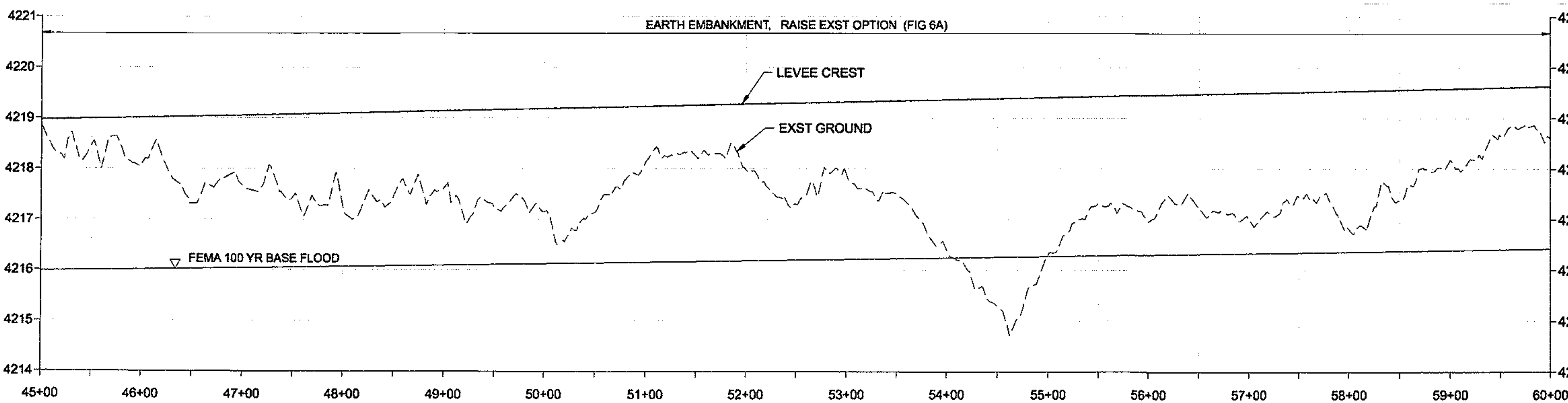

Profile

FIGURE E1-4
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 45+00 TO 60+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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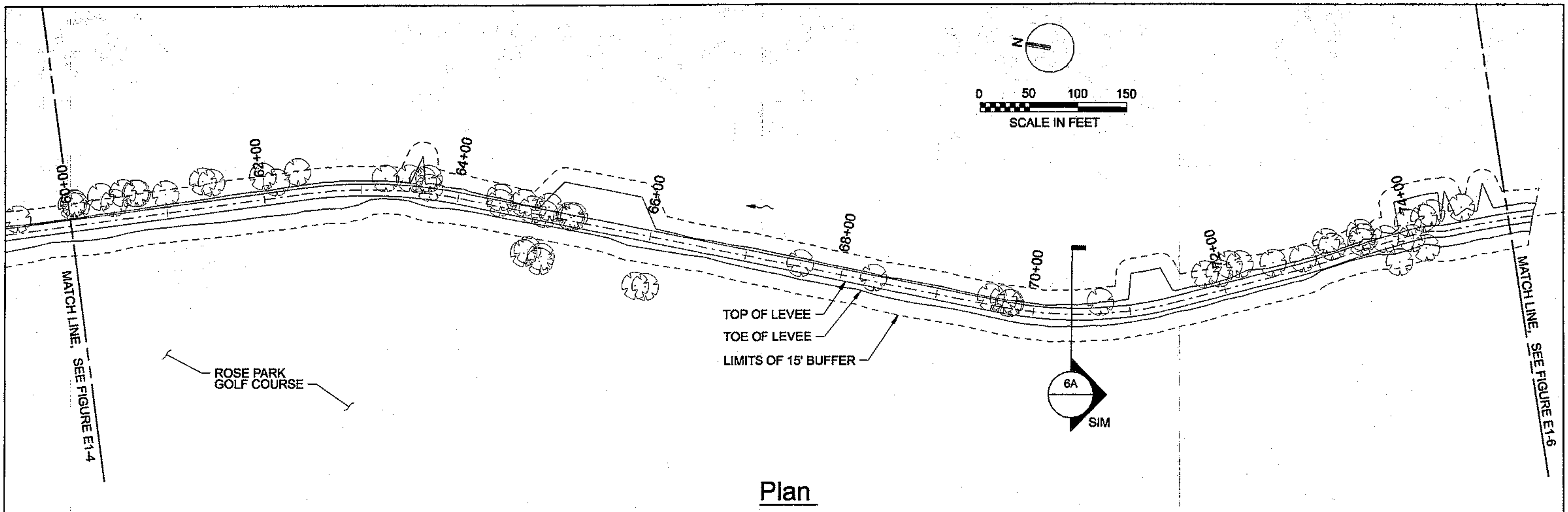

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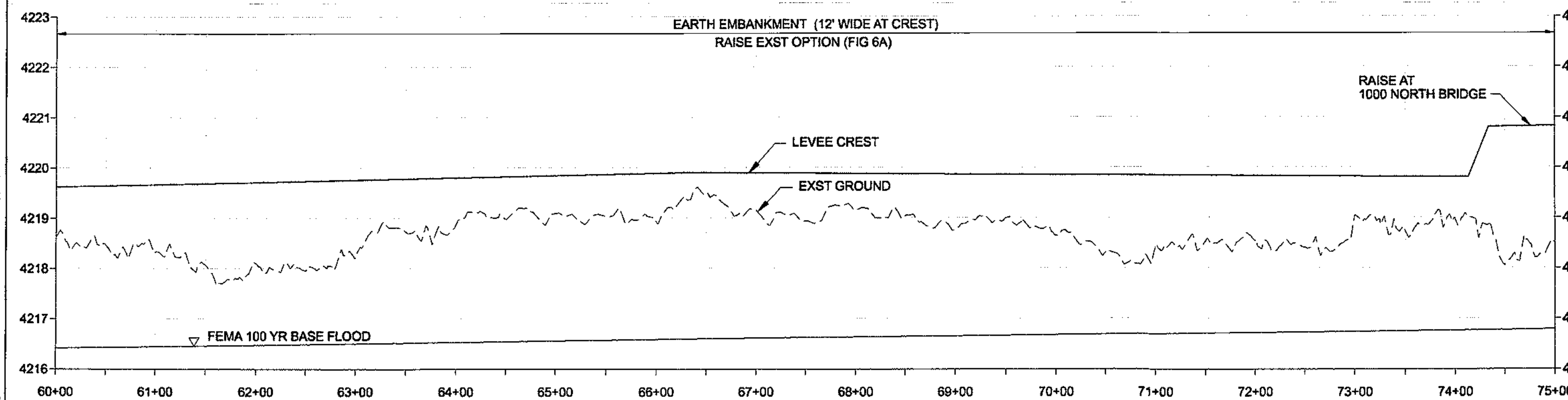

Profile

FIGURE E1-5
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 60+00 TO 75+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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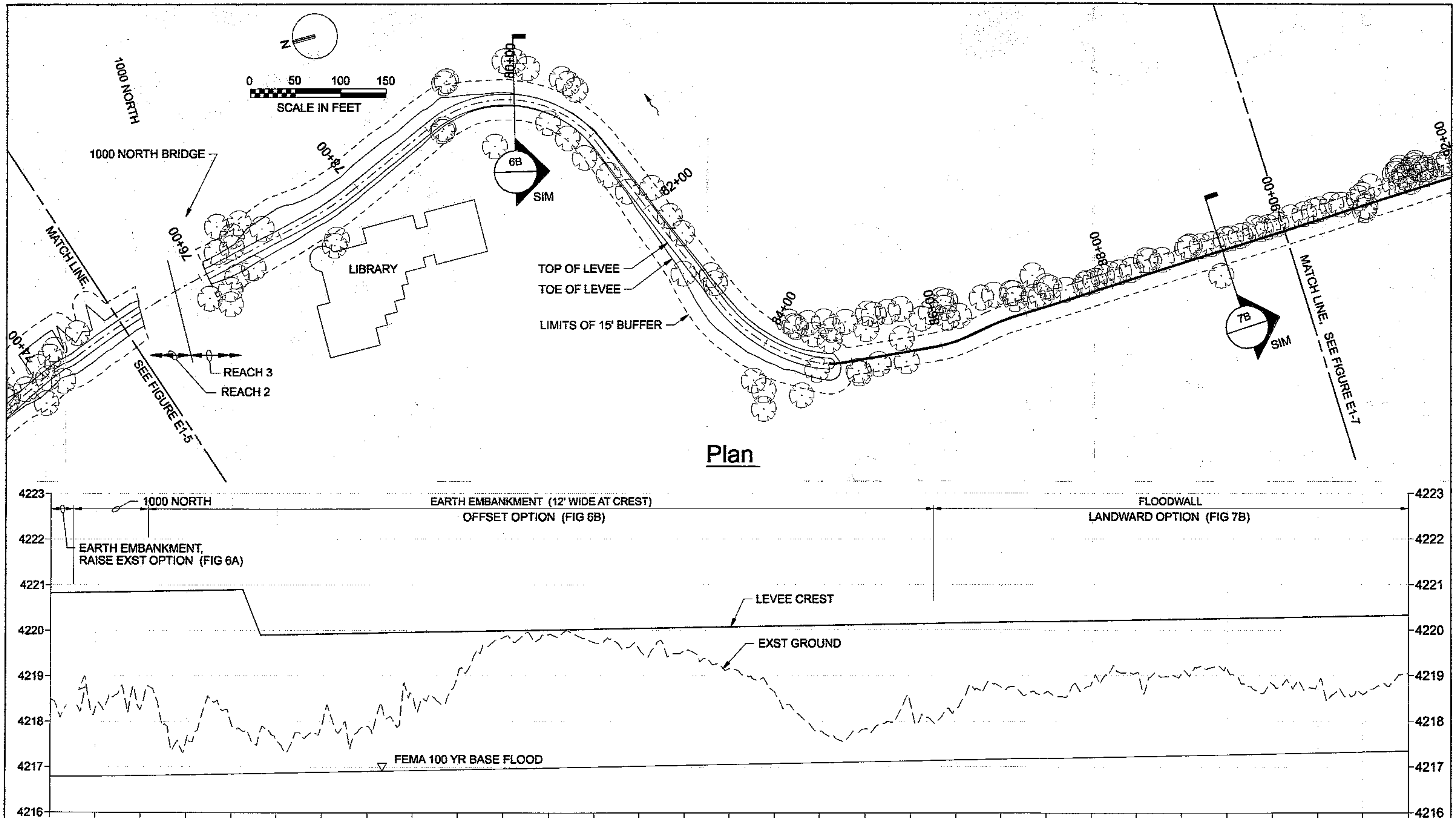

FIGURE E1-6
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 75+00 TO 90+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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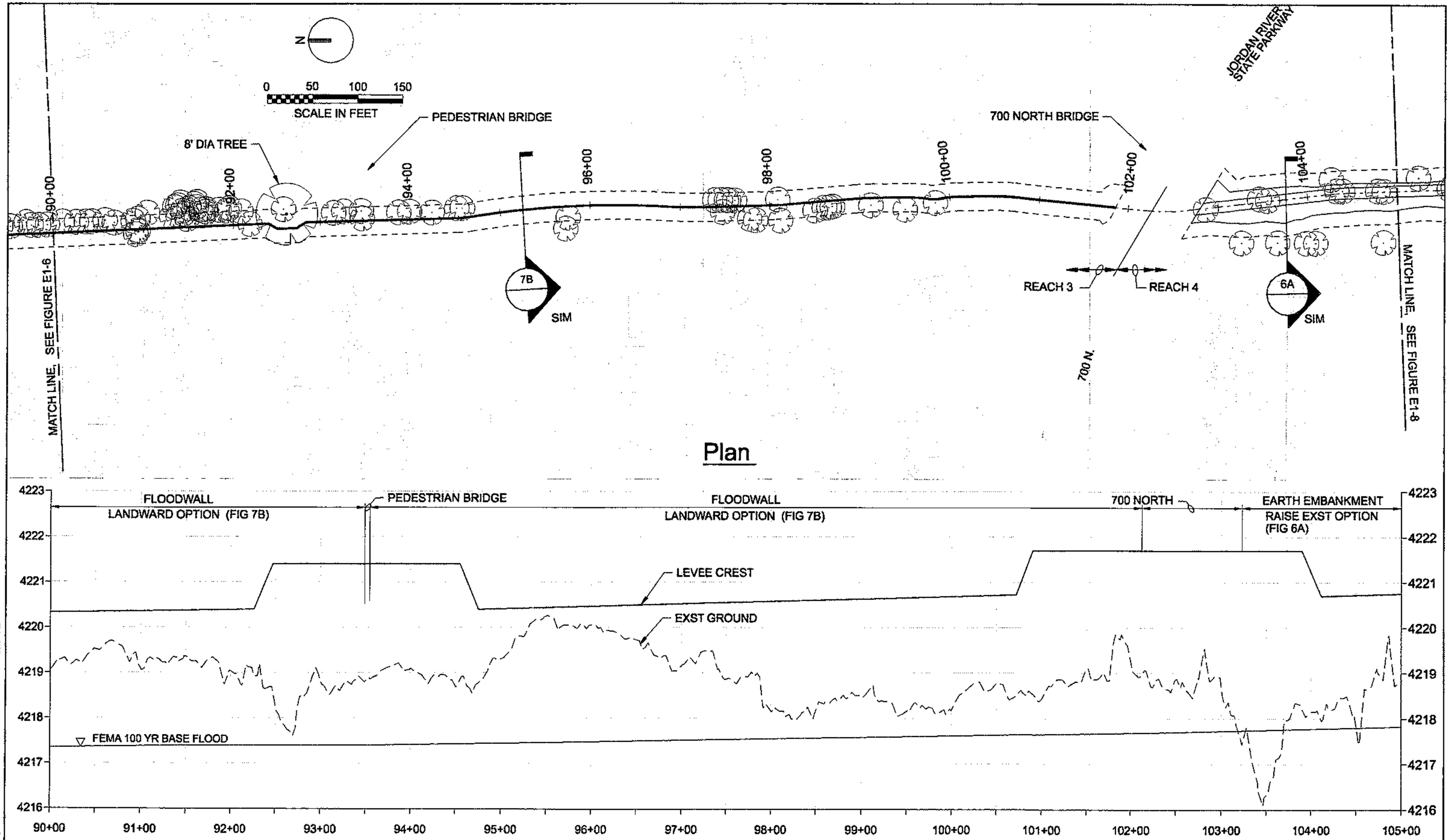

FIGURE E1-7
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 90+00 TO 105+00

LOWER JORDAN RIVER LEVEE EVALUATION
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352010 FigE1-7_FP_380358.dgn 11/4/2009 1:00:01 PM

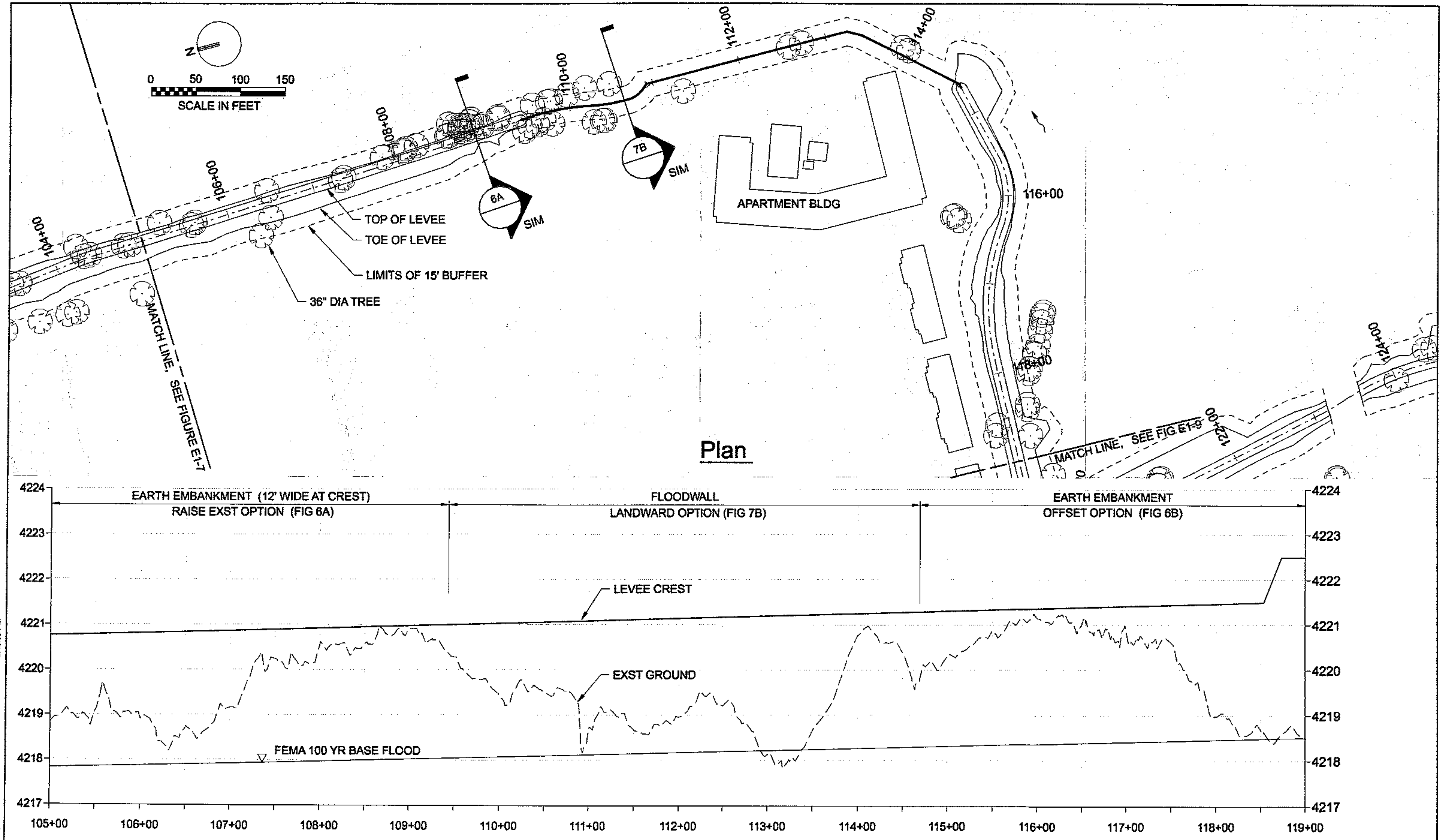

FIGURE E1-8
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 105+00 TO 119+00

LOWER JORDAN RIVER LEVEE EVALUATION
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FigE1-8_PP_390358.dgn 11/4/2009 2:46:09 PM
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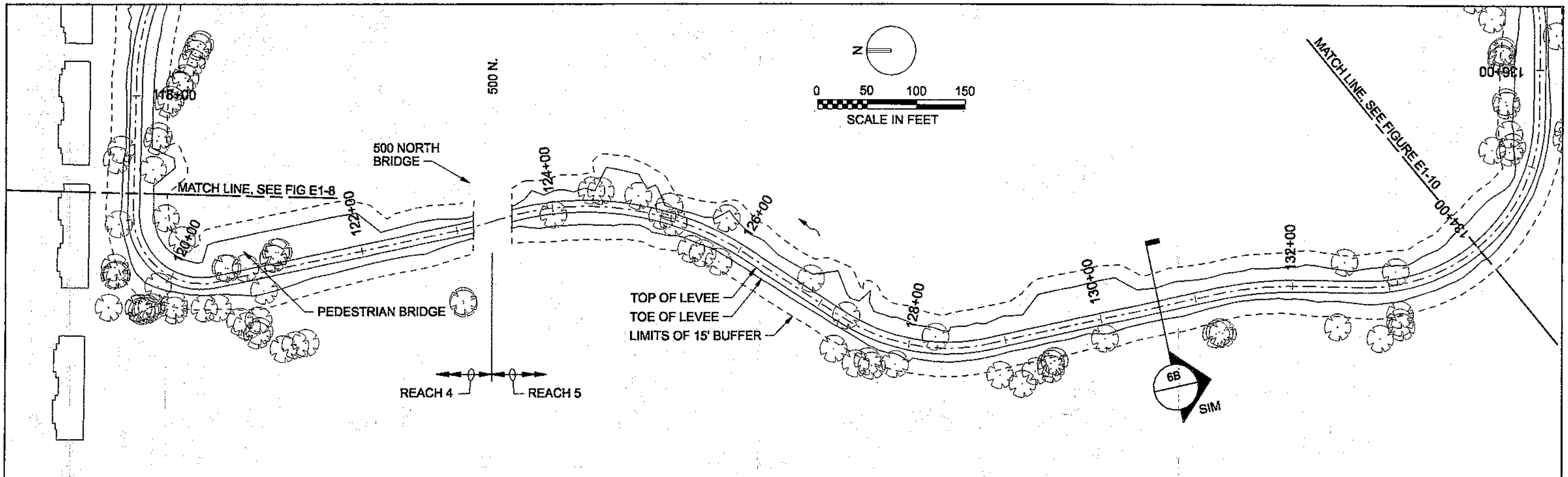

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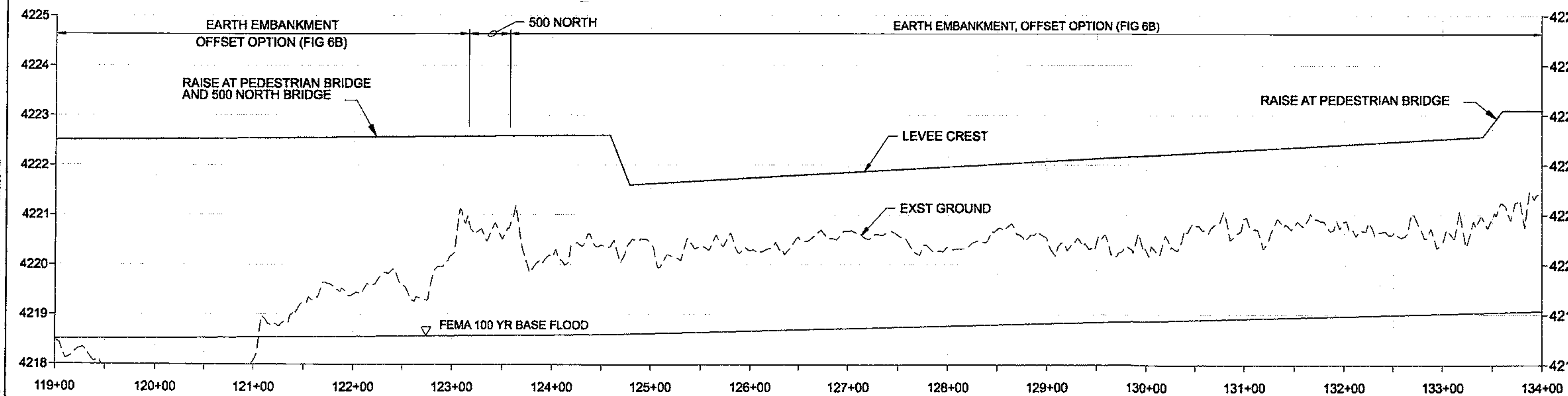

Profile

FIGURE E1-9
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 119+00 TO 134+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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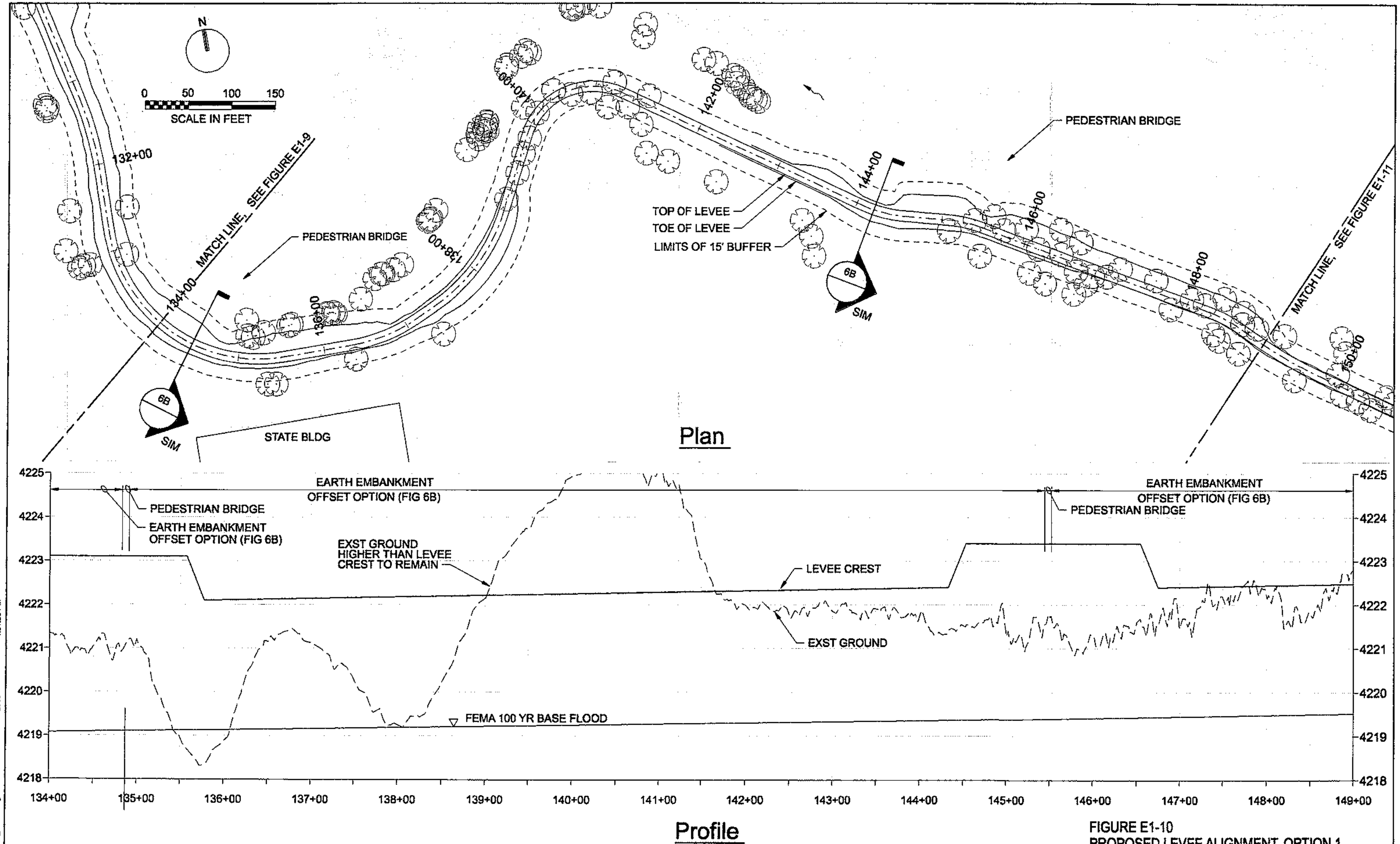

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FigE1-10_PP_390358.dgn
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FIGURE E1-10
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 134+00 TO 149+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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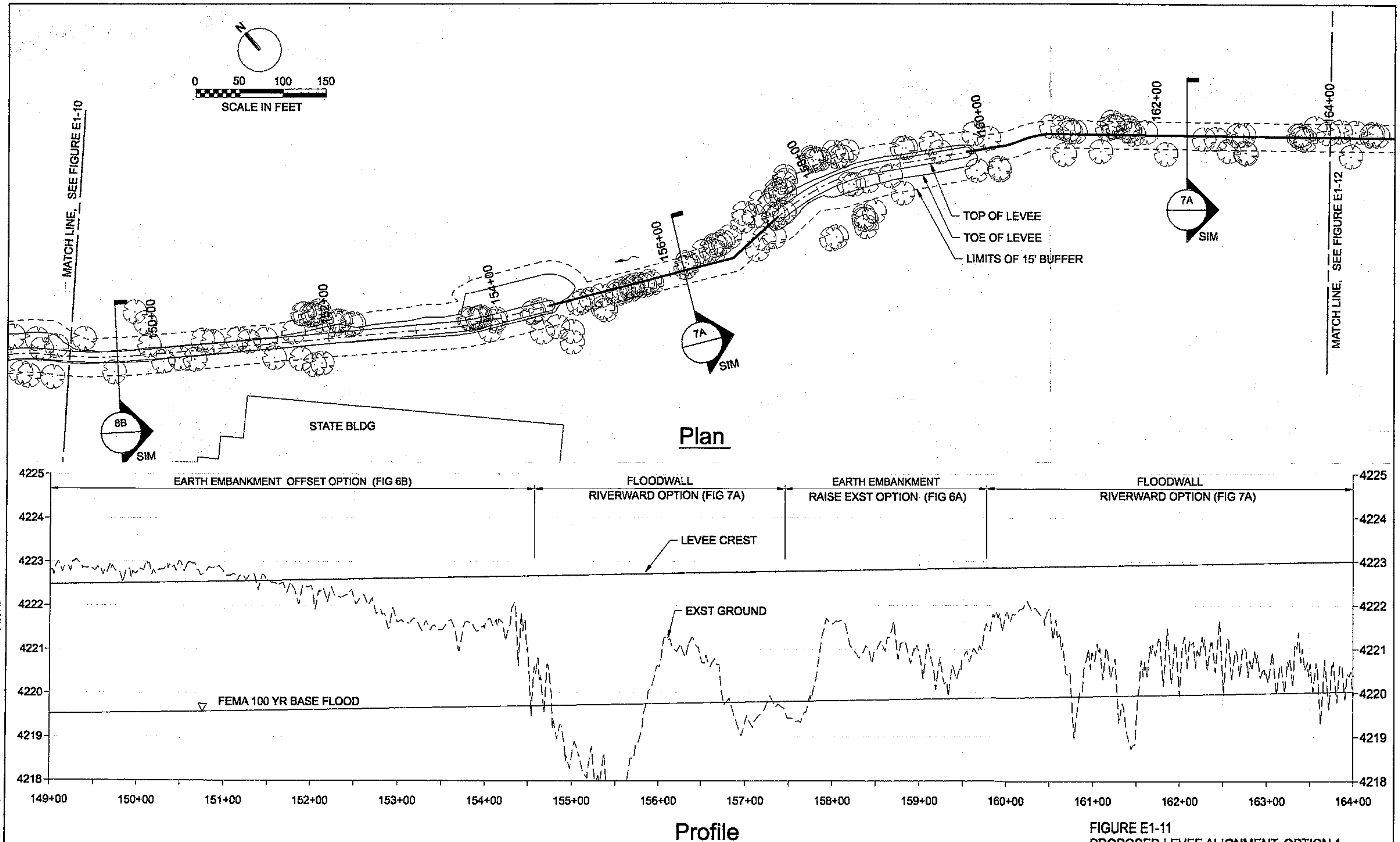
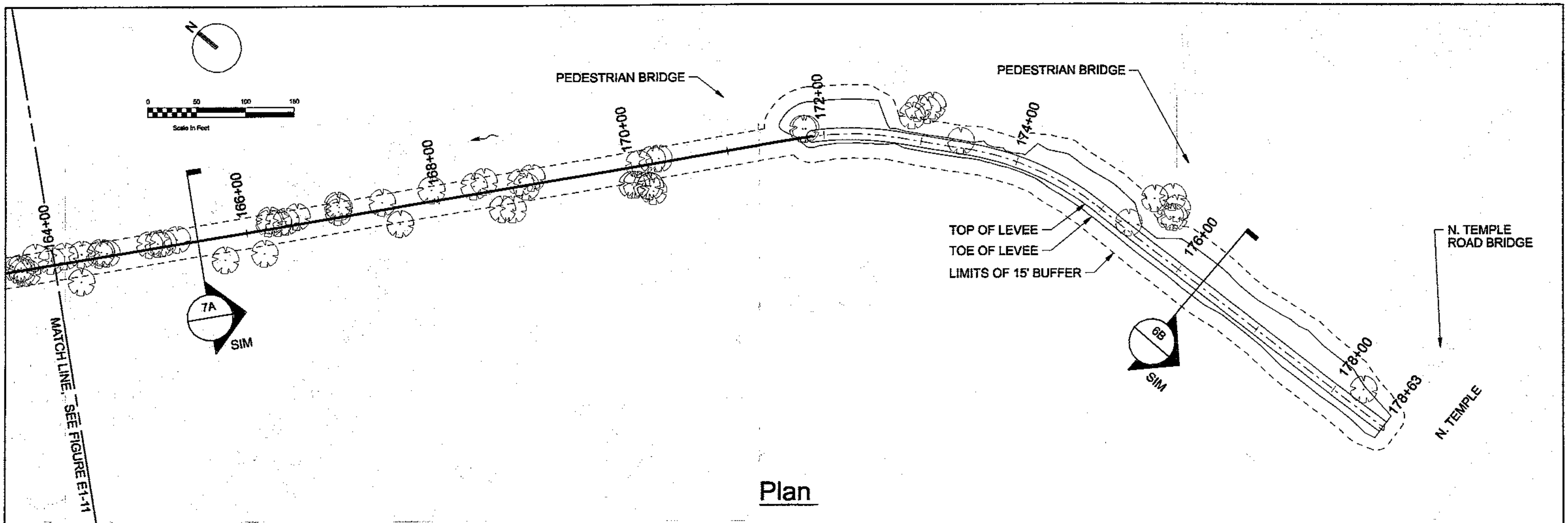


FIGURE E1-11
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 149+00 TO 164+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL



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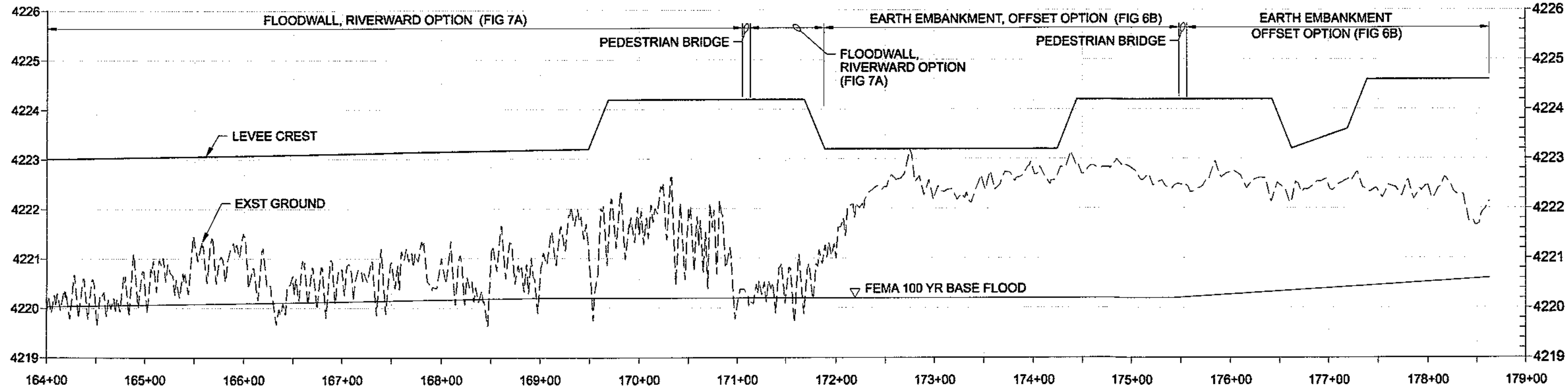

Profile

FIGURE E1-12
PROPOSED LEVEE ALIGNMENT, OPTION 1
PLAN AND PROFILE, STA 164+00 TO END

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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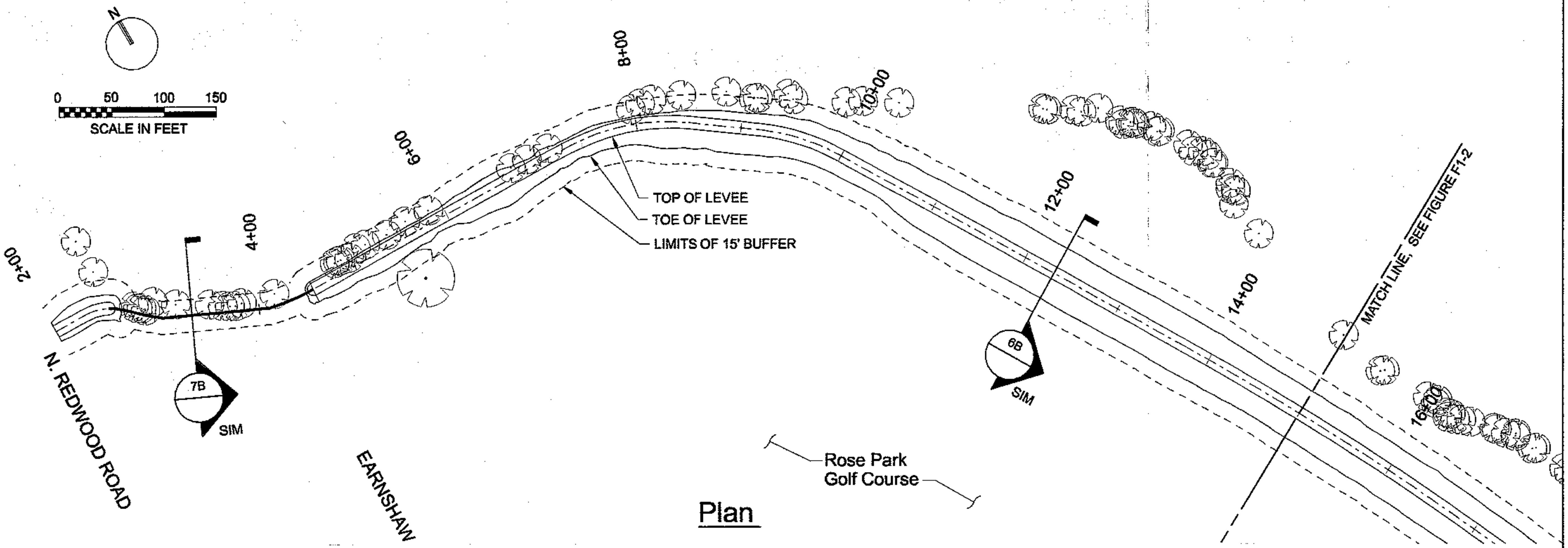
APPENDIX F

Levee Alignment Alternative No. 2
Offset Alignment



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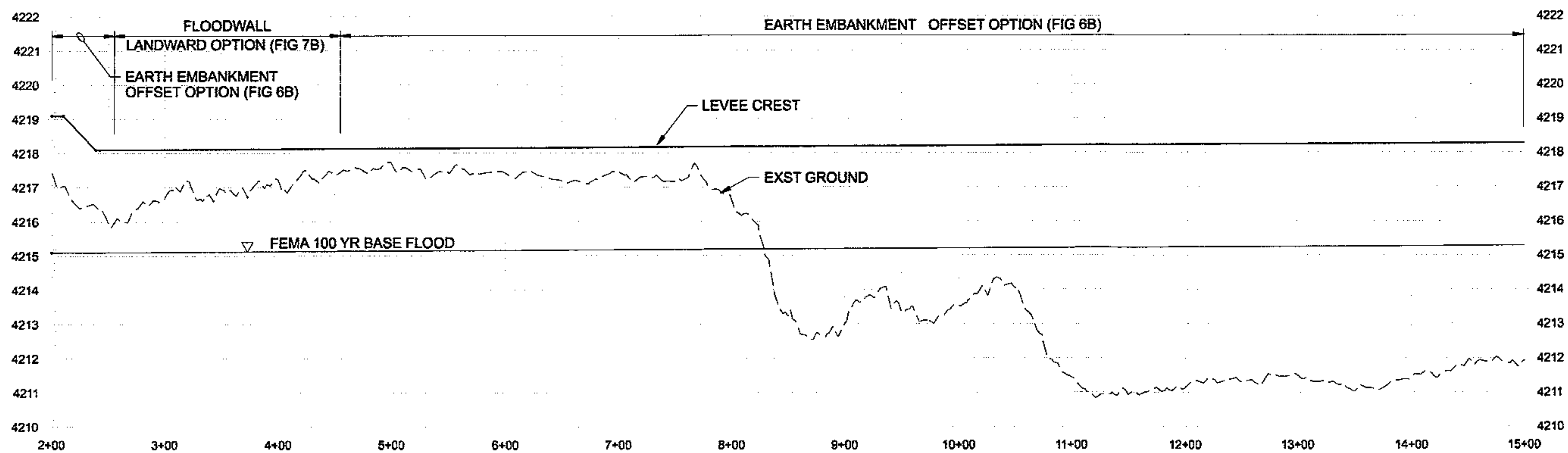

Profile

FIGURE F1-1
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 2+00 TO 15+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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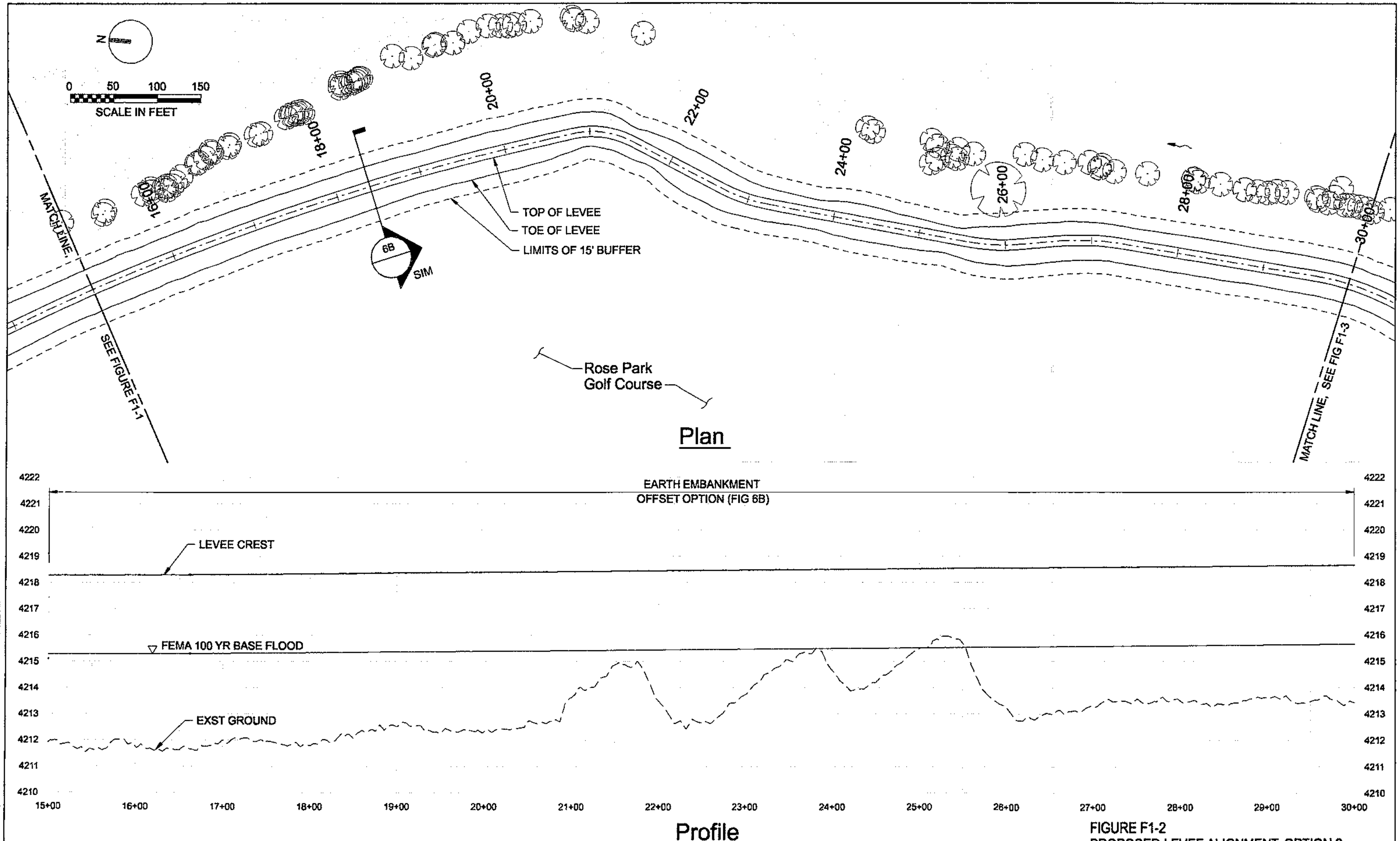

FIGURE F1-2
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 15+00 TO 30+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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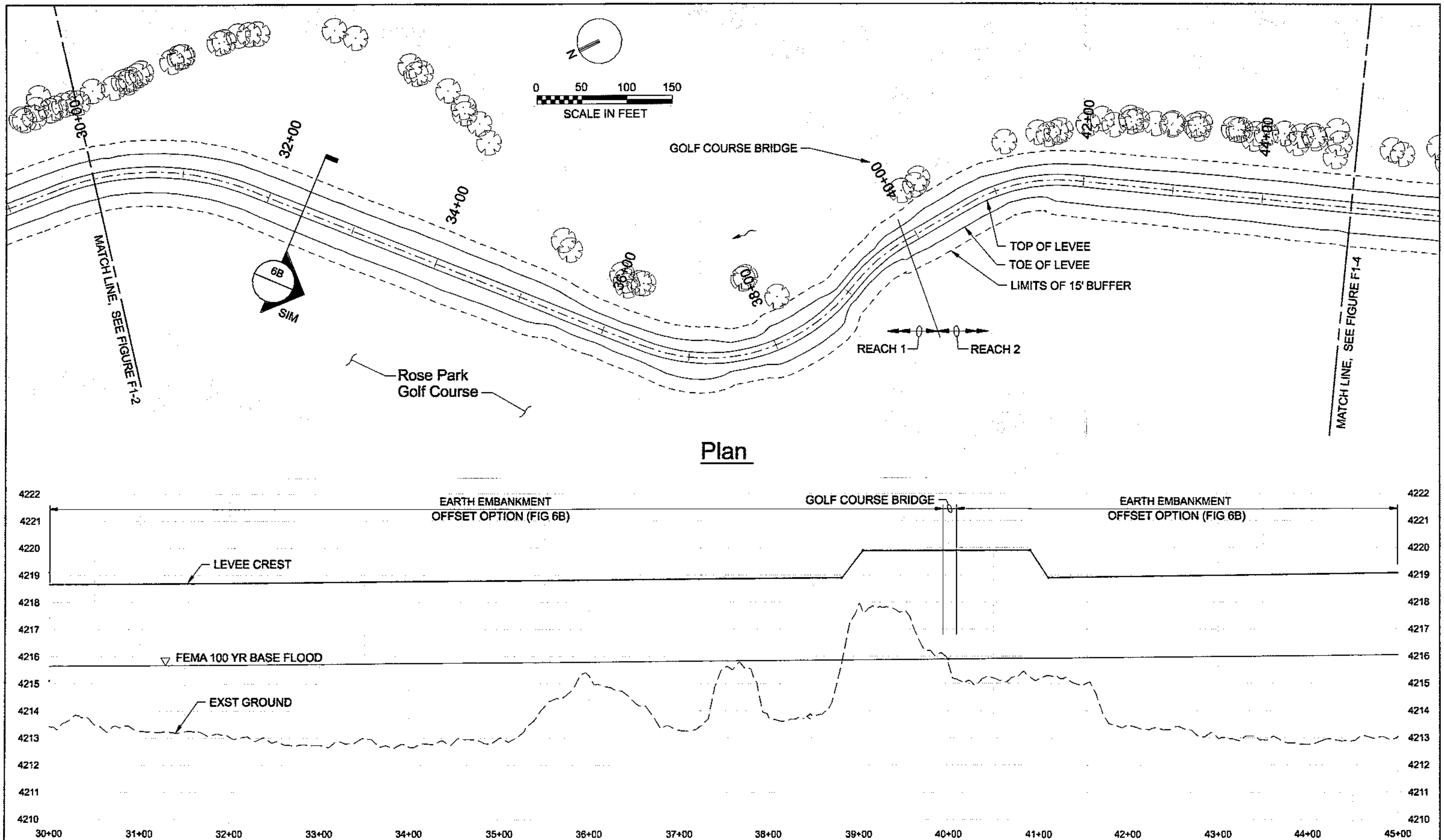

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FIGURE F1-3
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 30+00 TO 45+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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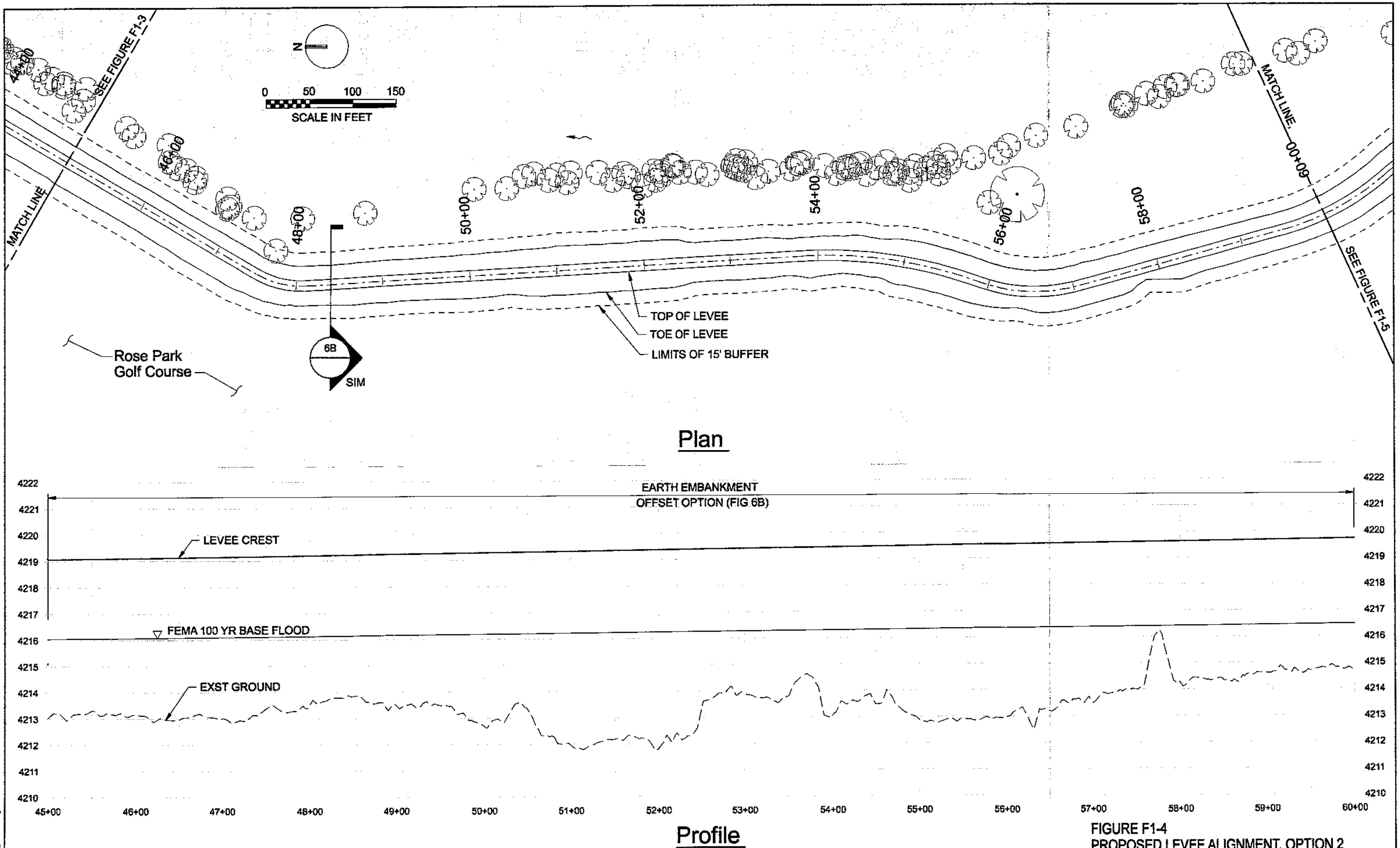

FIGURE F1-4
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 45+00 TO 60+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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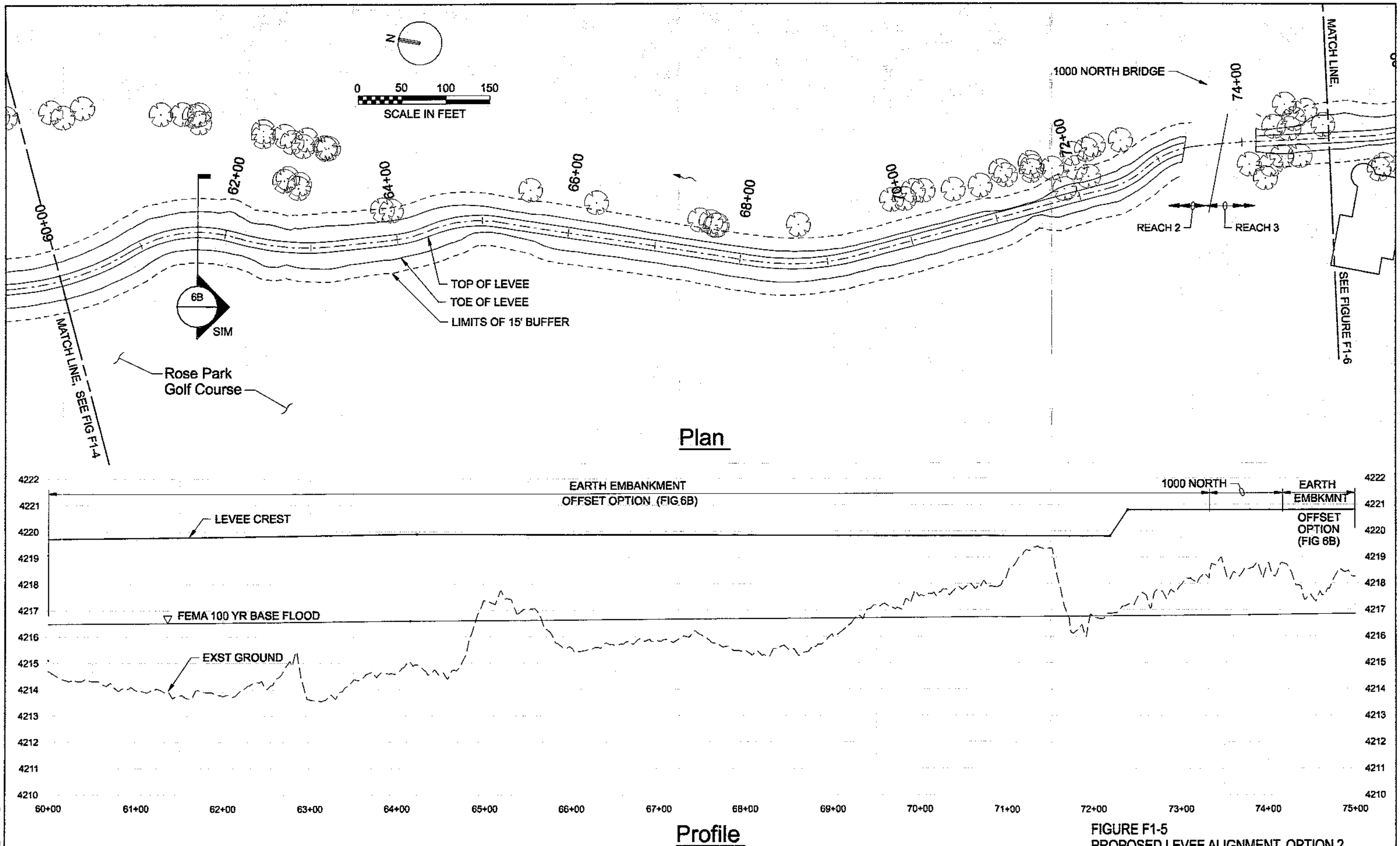

FIGURE F1-5
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 60+00 TO 75+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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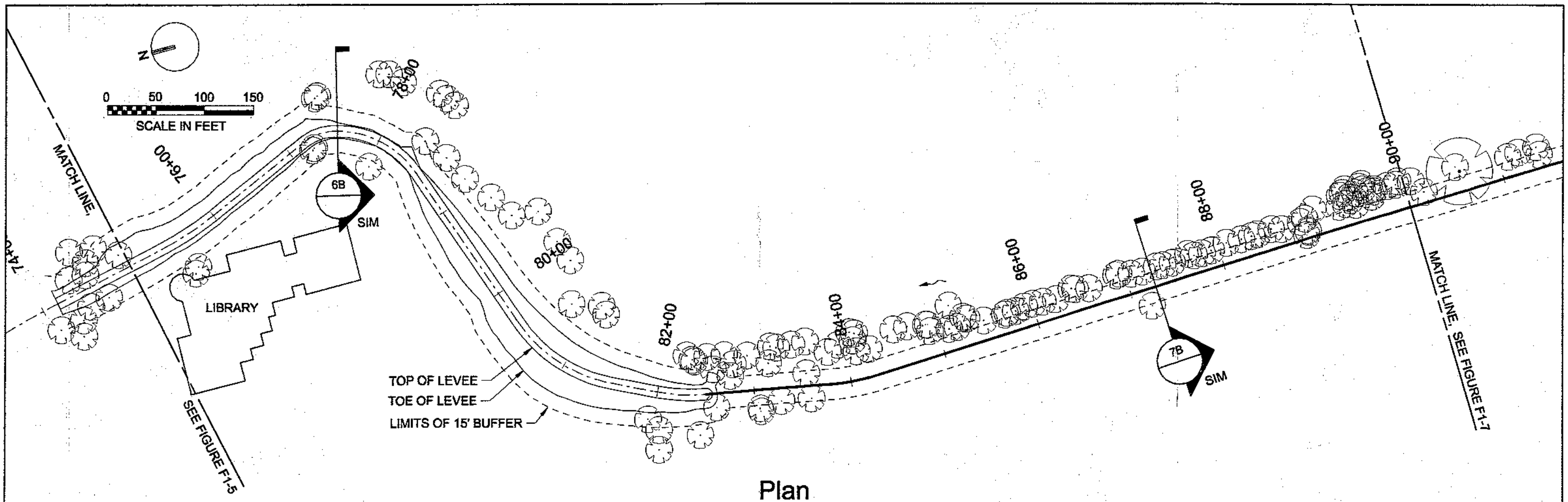

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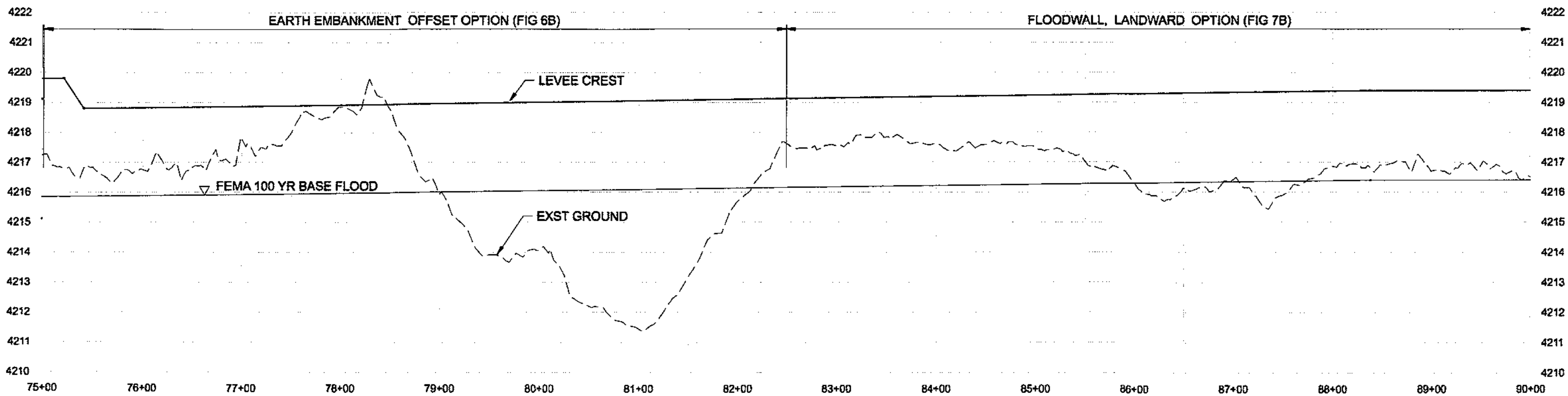

Profile

FIGURE F1-6
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 75+00 TO 90+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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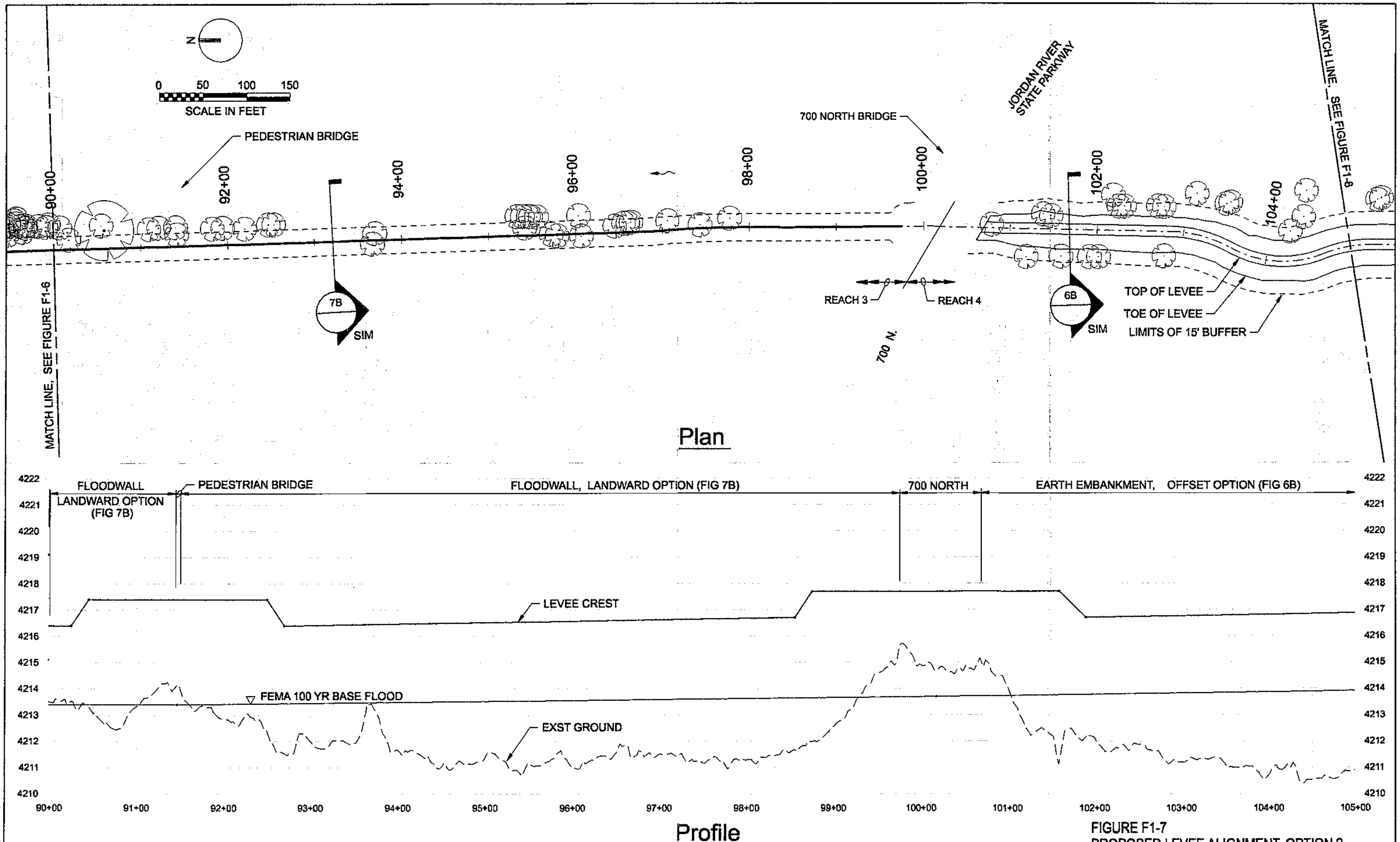

FIGURE F1-7
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 90+00 TO 105+00

LOWER JORDAN RIVER LEVEE EVALUATION
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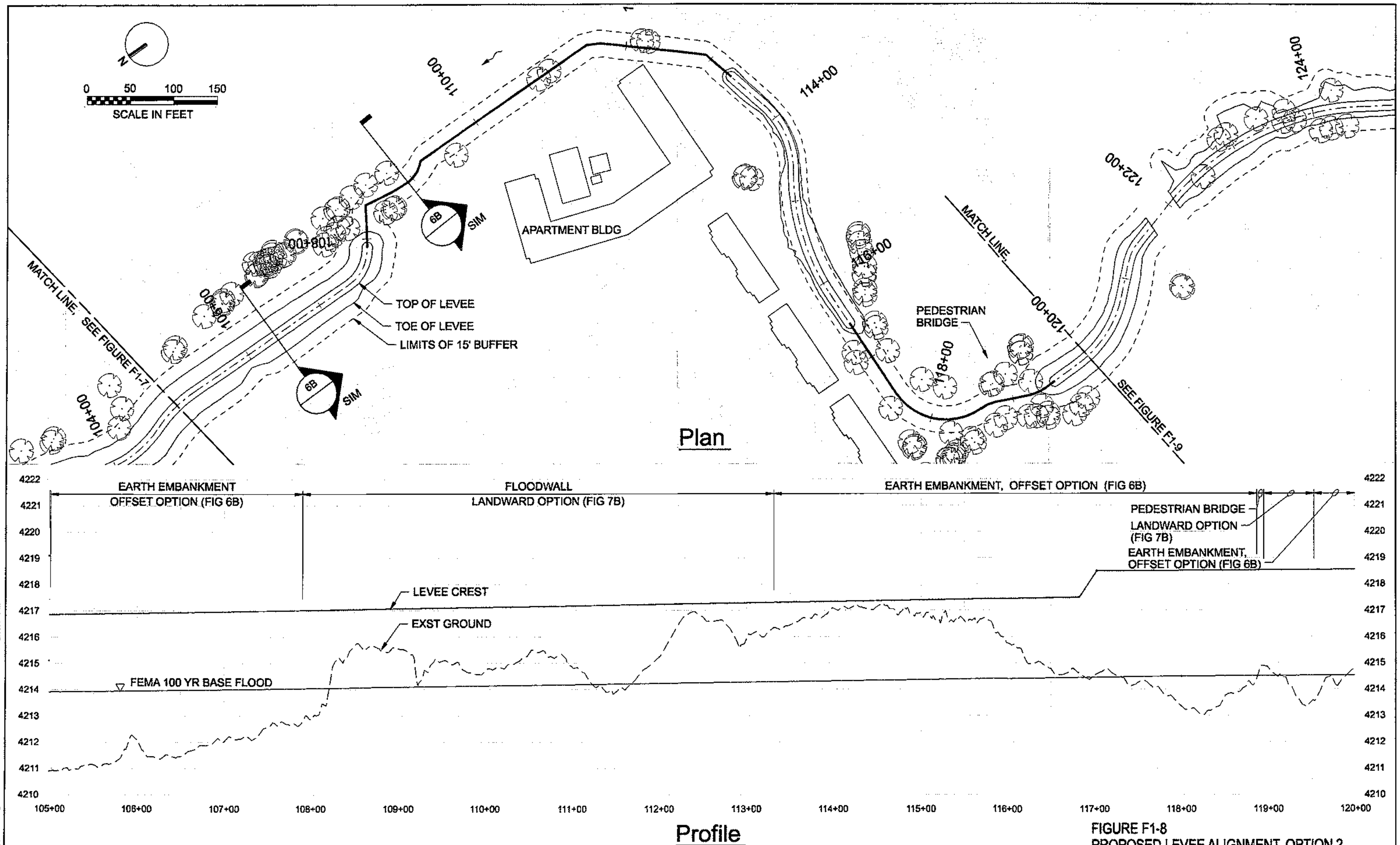

FIGURE F1-8
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 105+00 TO 120+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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FigF1-8_PP_380358.dgn 11/4/2009 2:03:47 PM

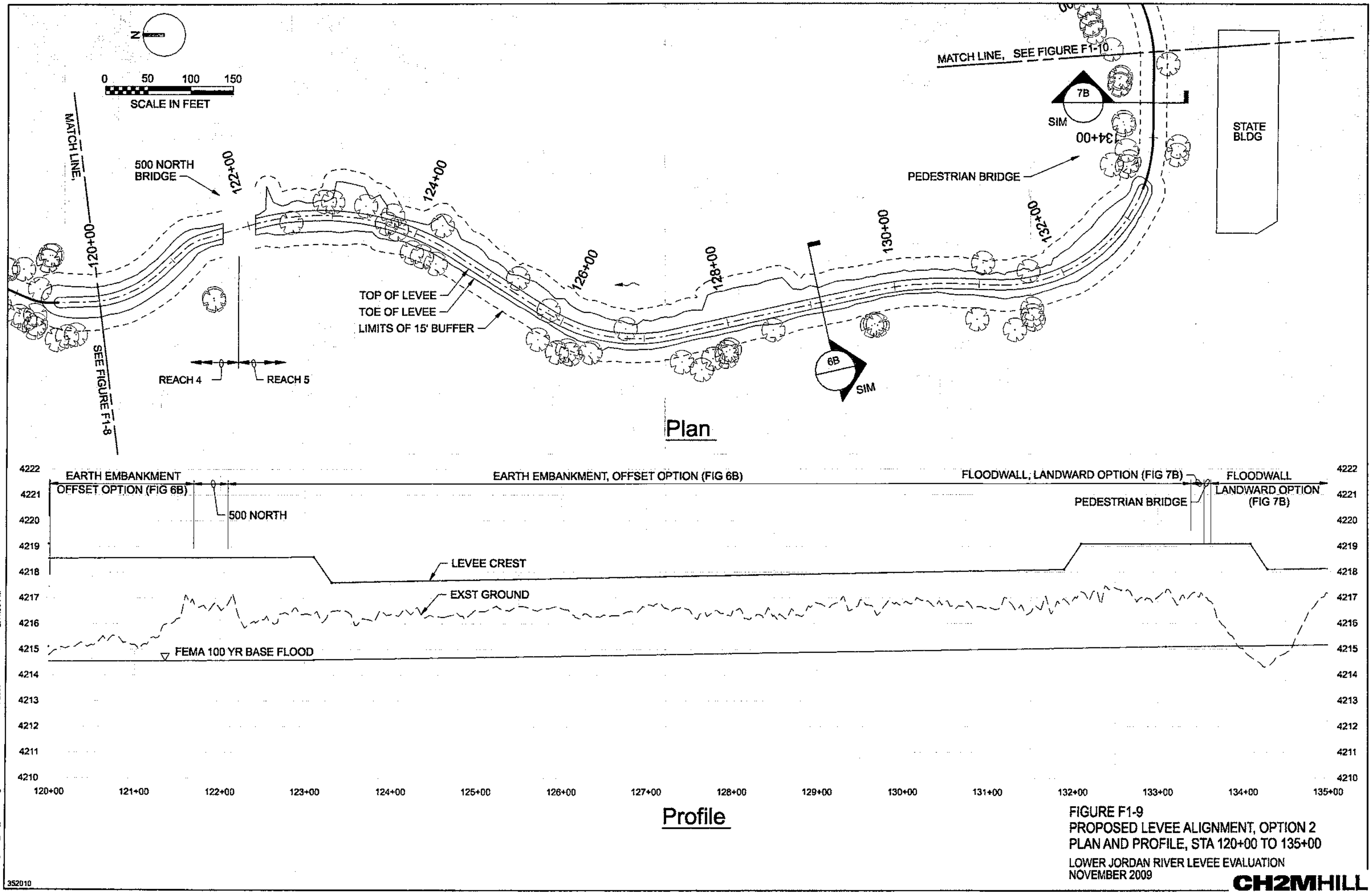

FIGURE F1-9
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 120+00 TO 135+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL

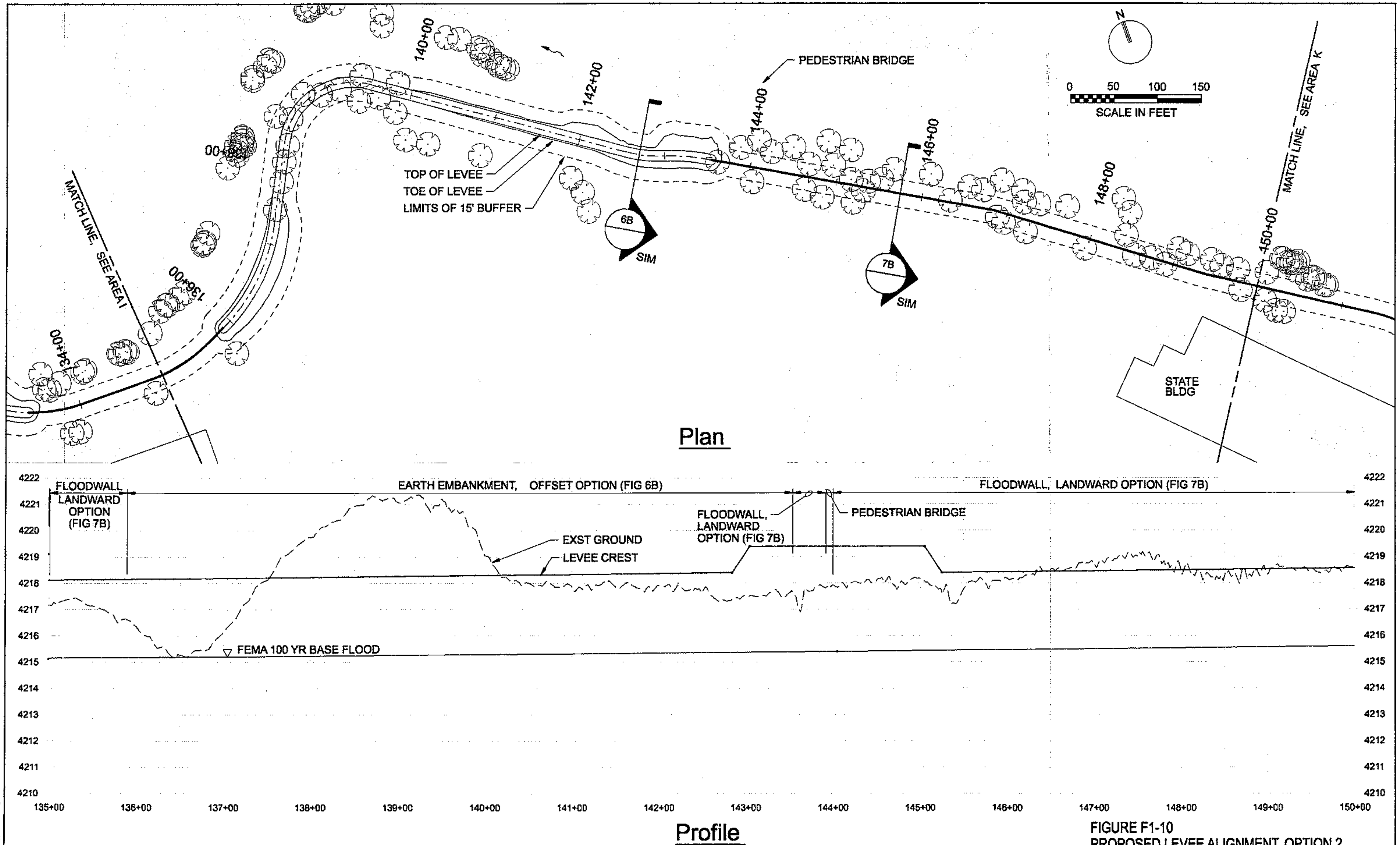

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FIGURE F1-10
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 135+00 TO 150+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL

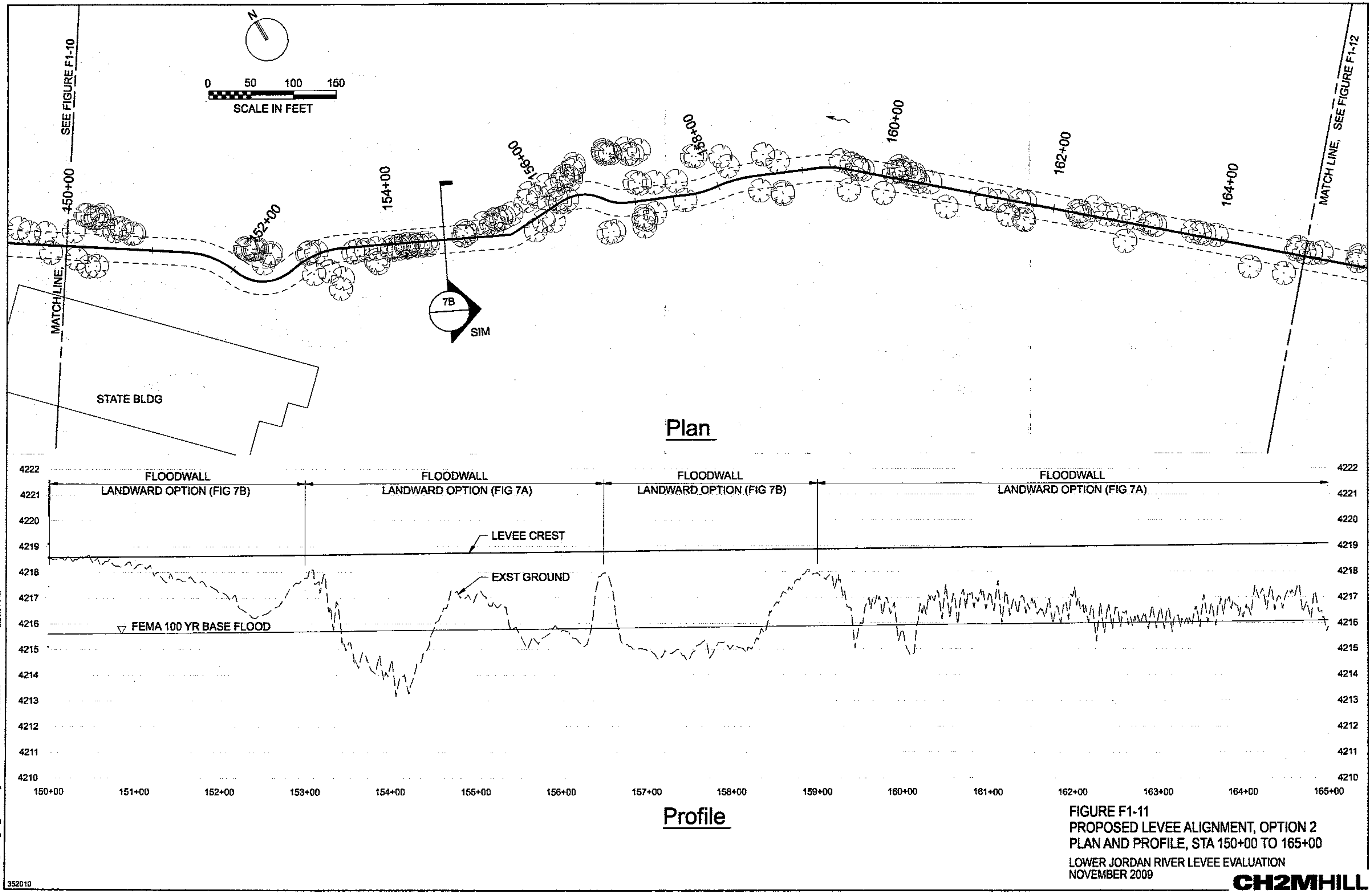
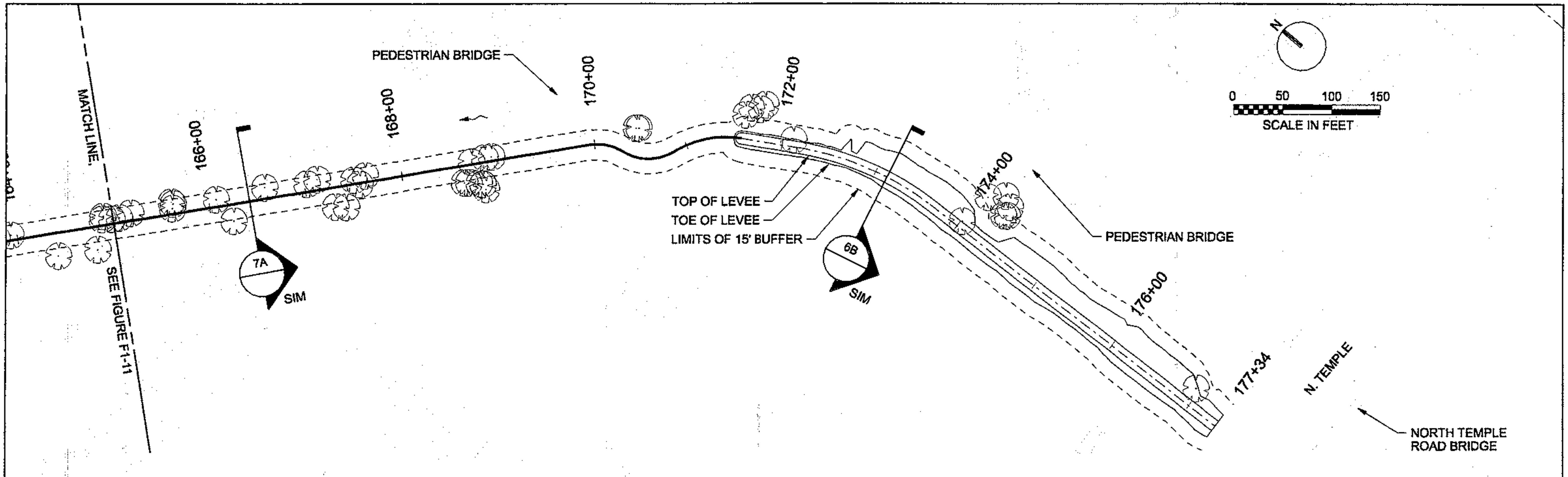


FIGURE F1-11
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 150+00 TO 165+00

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

CH2MHILL



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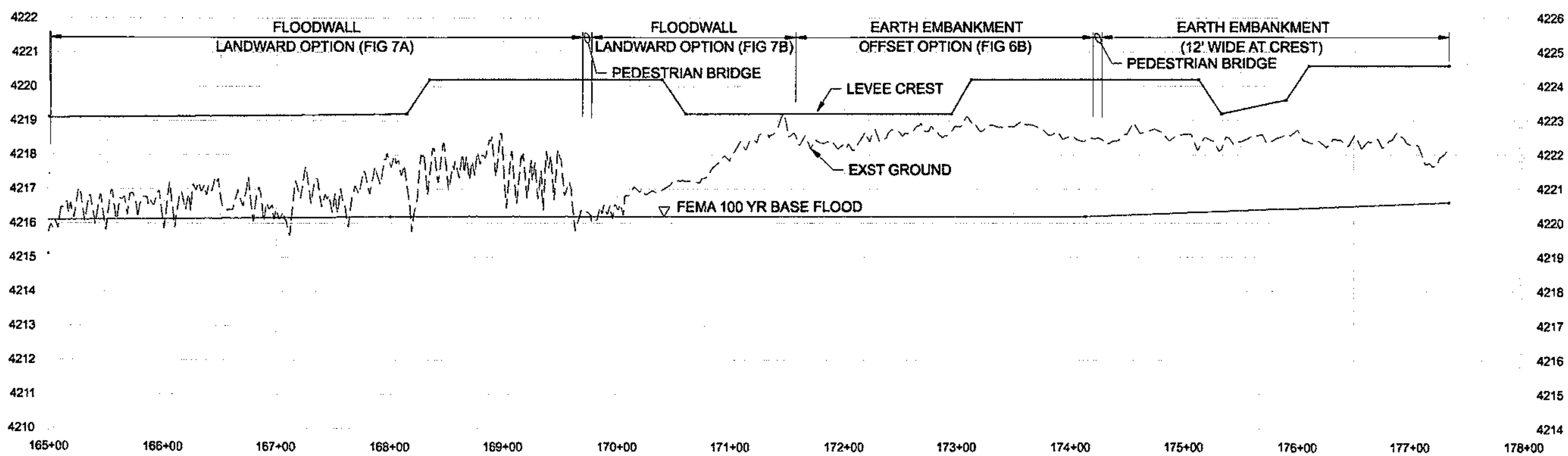

Profile

FIGURE F1-12
PROPOSED LEVEE ALIGNMENT, OPTION 2
PLAN AND PROFILE, STA 165+00 TO END

LOWER JORDAN RIVER LEVEE EVALUATION
NOVEMBER 2009

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APPENDIX J
SURVEY DATA
(INCLUDED DIGITALLY)

APPENDIX K
HECRAS MODEL
(INCLUDED DIGITALLY)

APPENDIX L
PHOTOS
(INCLUDED DIGITALLY)

BOWEN COLLINS
& ASSOCIATES