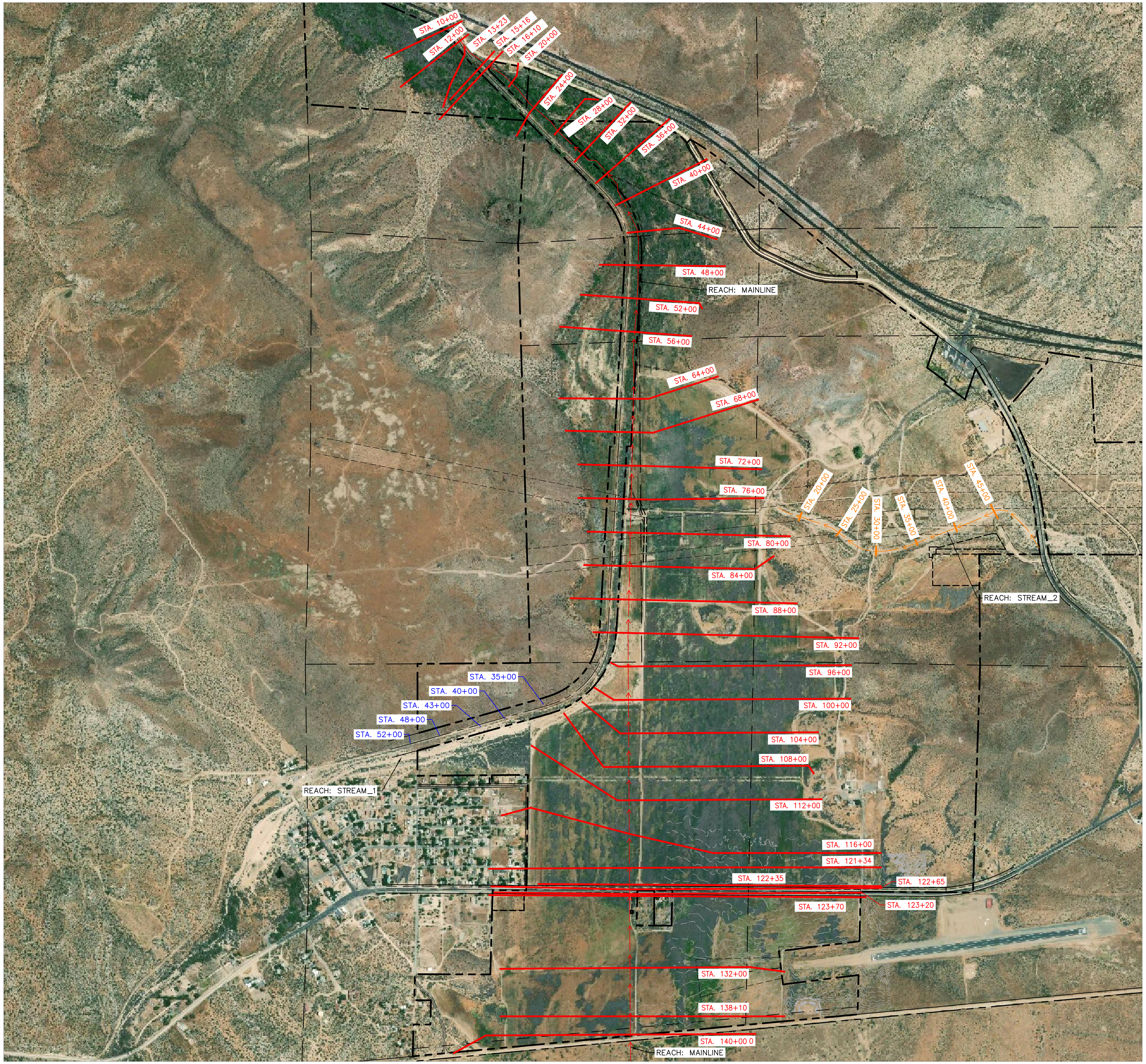
APPENDIX I

Drainage Study
JVR Energy Park
Part 5

Appendix C – Hydraulic Figures

PRE-CONSTRUCTION
CONDITION



LEGEND:

PROPERTY LINE

PROPOSED CHAINLINK FENCE

HEC-RAS SECTIONS

MAINLINE

STREAM_1

STREAM_2

NORTH

GRAPHIC SCALE IN FEET

0 300 600 1200

FIGURE 9

HYDRAULIC WORKMAP
PRE-DEVELOPMENT
100-YEAR; 24-HOUR STORM
JVR Energy Park
SAN DIEGO COUNTY, CALIFORNIA

Kimley»Horn

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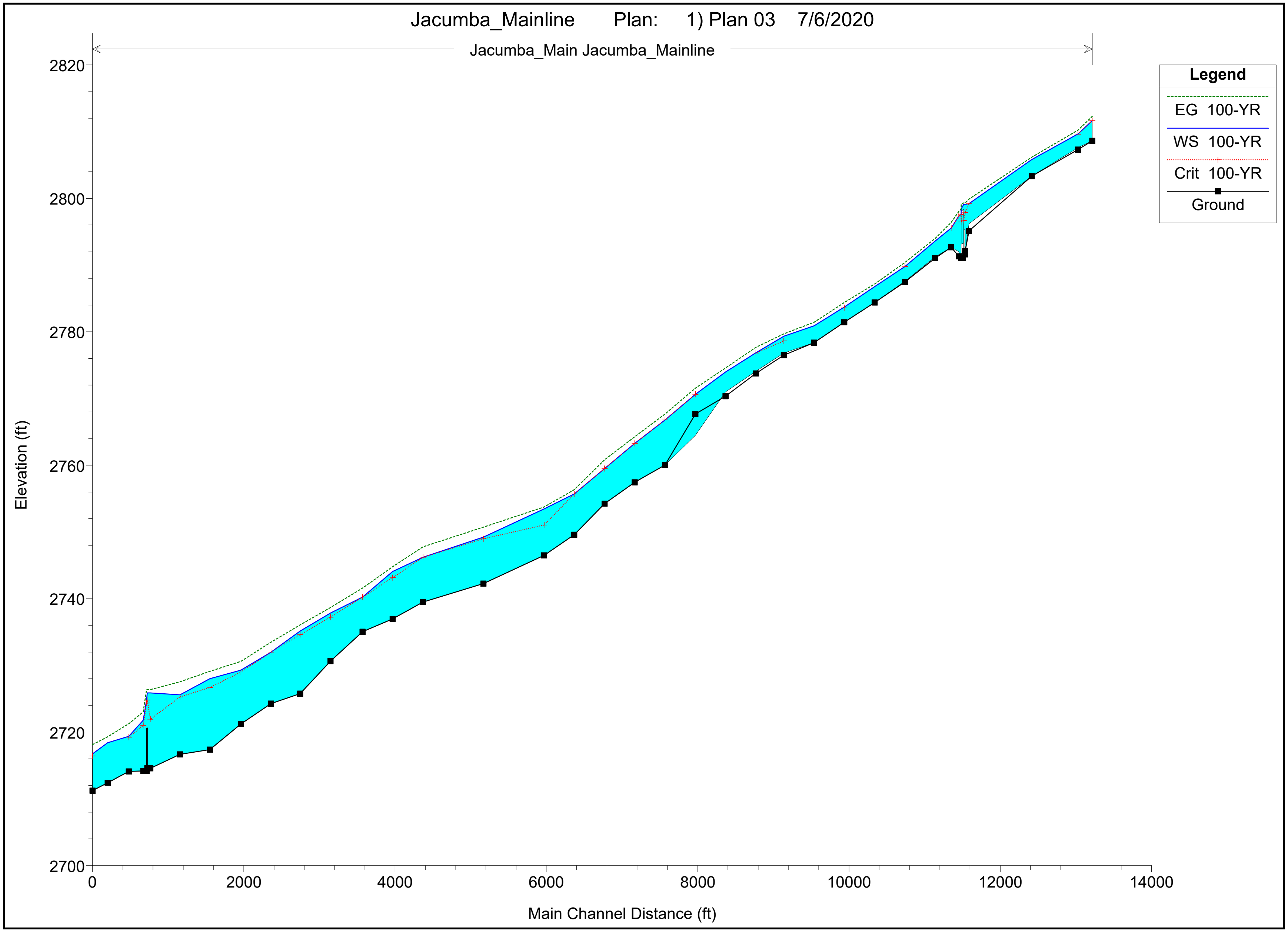
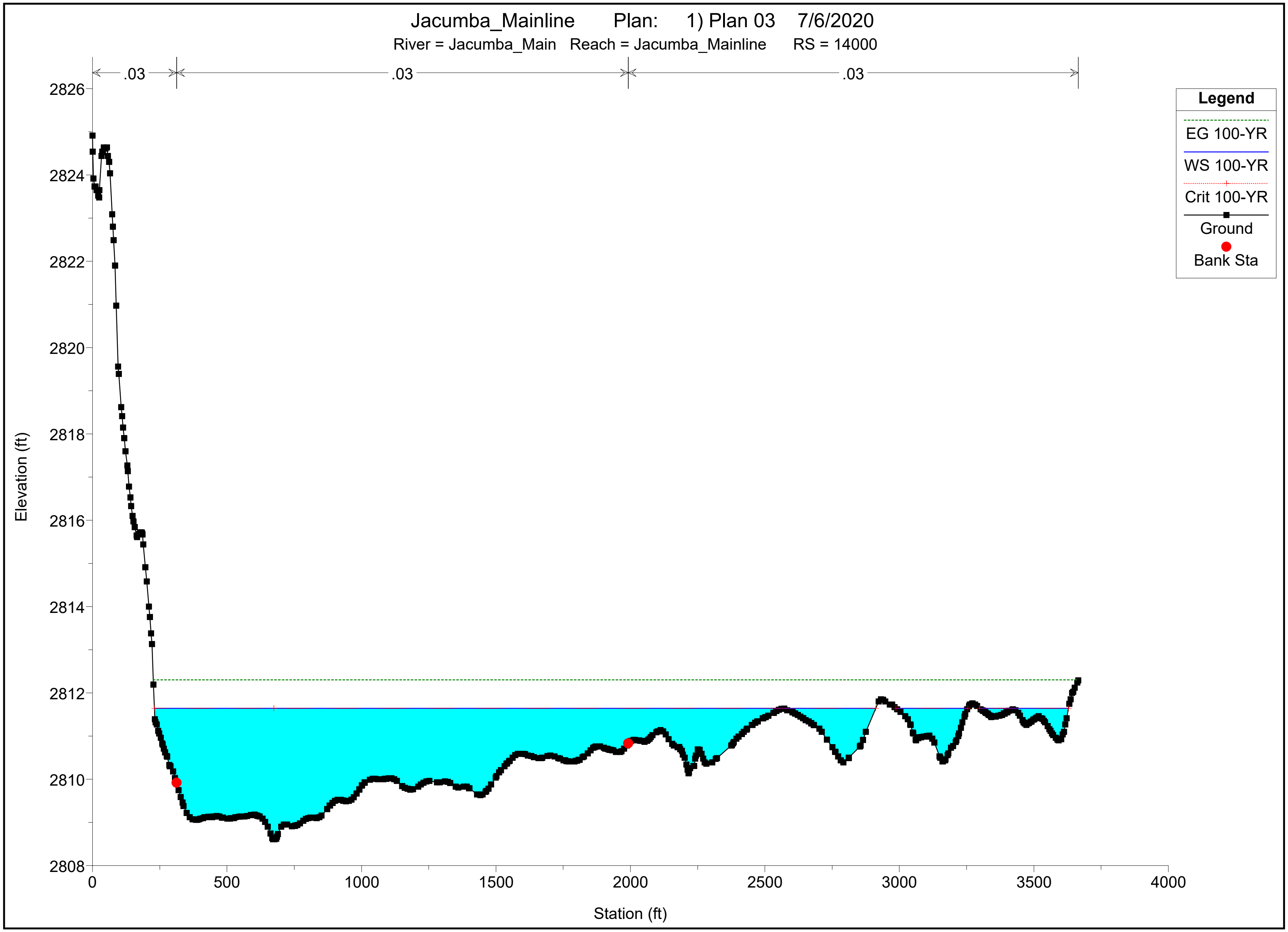
HEC-RAS Plan: Plan 03 River: Jacumba_Main Reach: Jacumba_Mainline Profile: 100-YR

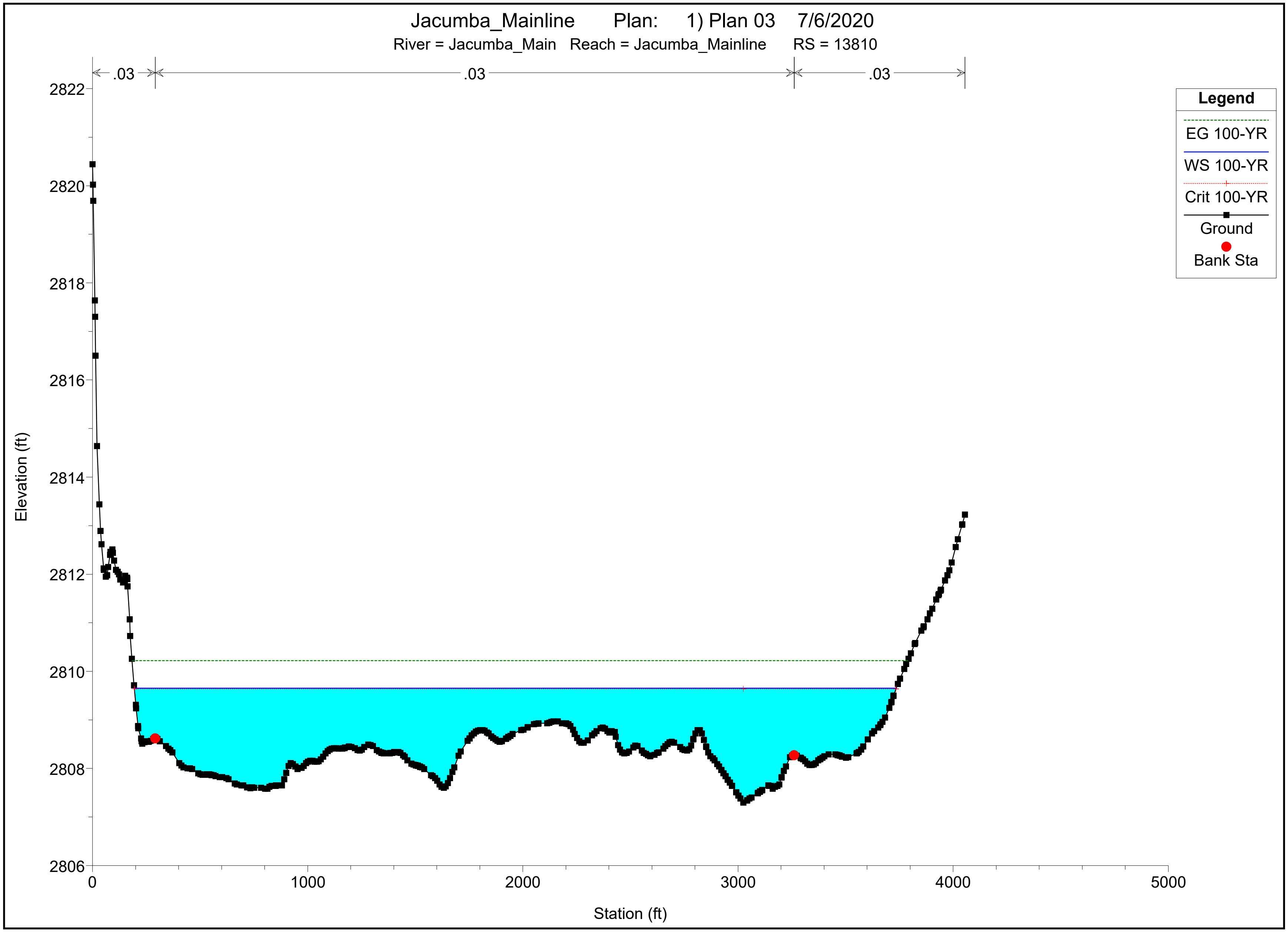
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Jacumba_Mainline	14000	100-YR	24661.00	2808.61	2811.64	2811.64	2812.30	0.008351	6.85	4083.96	3280.25	0.89
Jacumba_Mainline	13810	100-YR	24661.00	2807.58	2809.66	2809.64	2810.22	0.011950	6.11	4103.88	3518.81	0.98
Jacumba_Mainline	13200	100-YR	24661.00	2803.32	2805.83		2806.18	0.004103	4.85	5288.46	3253.49	0.62
Jacumba_Mainline	12370	100-YR	24661.00	2796.20	2799.20	2799.20	2799.89	0.012627	6.41	3717.67	2869.23	1.02
Jacumba_Mainline	12320	100-YR	24661.00	2792.11	2799.12	2797.88	2799.30	0.000354	3.78	7600.87	3978.97	0.39
Jacumba_Mainline	12300		Culvert									
Jacumba_Mainline	12265	100-YR	24661.00	2791.08	2797.56	2797.56	2798.39	0.002334	7.56	3497.38	2327.44	0.95
Jacumba_Mainline	12235	100-YR	24661.00	2792.00	2797.34	2797.34	2798.03	0.005204	8.94	4327.15	3188.75	0.79
Jacumba_Mainline	12134	100-YR	24661.00	2792.67	2795.53	2795.53	2796.38	0.011384	7.39	3337.53	2017.54	1.01
Jacumba_Mainline	11600	100-YR	24661.00	2791.21	2793.61		2793.96	0.006443	4.80	5164.32	4024.07	0.73
Jacumba_Mainline	11200	100-YR	24661.00	2787.58	2789.80	2789.80	2790.41	0.012871	6.26	3946.38	3379.87	1.02
Jacumba_Mainline	10800	100-YR	24661.00	2784.39	2786.76		2787.14	0.005151	4.93	5007.08	3082.75	0.68
Jacumba_Mainline	10400	100-YR	24661.00	2781.45	2783.70	2783.60	2784.39	0.009267	6.68	3718.10	2463.66	0.91
Jacumba_Mainline	10000	100-YR	24661.00	2778.37	2780.91		2781.43	0.005868	5.77	4308.27	2432.91	0.74
Jacumba_Mainline	9600	100-YR	25741.00	2776.83	2779.34	2778.64	2779.70	0.003217	4.87	5417.27	2677.75	0.57
Jacumba_Mainline	9200	100-YR	25741.00	2774.08	2776.83	2776.81	2777.66	0.010893	7.30	3558.12	2249.96	0.99
Jacumba_Mainline	8800	100-YR	25741.00	2770.98	2773.96		2774.57	0.005564	6.28	4168.27	1953.86	0.74
Jacumba_Mainline	8400	100-YR	25741.00	2764.48	2770.64	2770.64	2771.54	0.010572	7.59	3395.50	1877.63	0.99
Jacumba_Mainline	8000	100-YR	25741.00	2760.05	2766.79	2766.79	2767.69	0.006307	6.44	3751.66	1895.55	0.78
Jacumba_Mainline	7600	100-YR	25741.00	2757.44	2763.28	2763.28	2764.26	0.007236	8.26	3430.29	1538.54	0.87
Jacumba_Mainline	7200	100-YR	26164.00	2754.24	2759.51	2759.51	2760.81	0.009443	10.06	2864.73	1389.79	1.01
Jacumba_Mainline	6800	100-YR	26164.00	2749.59	2755.70	2755.70	2756.34	0.003753	8.54	4200.09	1486.40	0.69
Jacumba_Mainline	6400	100-YR	26164.00	2746.50	2753.48	2751.05	2753.74	0.000892	4.88	6789.47	1800.37	0.35
Jacumba_Mainline	5600	100-YR	26164.00	2742.25	2749.23	2748.97	2750.72	0.005911	12.04	2738.16	1455.83	0.89
Jacumba_Mainline	5200	100-YR	26164.00	2739.49	2746.19	2746.19	2747.76	0.007555	13.21	2687.49	1299.49	1.00
Jacumba_Mainline	4800	100-YR	26164.00	2736.97	2744.07	2743.17	2744.78	0.002851	9.09	4009.09	1353.35	0.63
Jacumba_Mainline	4400	100-YR	26164.00	2735.05	2740.24	2740.24	2741.60	0.007631	11.33	2906.06	1002.94	0.97
Jacumba_Mainline	4000	100-YR	26164.00	2730.65	2737.85	2737.20	2738.66	0.004048	10.06	3695.83	1152.99	0.73
Jacumba_Mainline	3600	100-YR	26164.00	2725.76	2735.15	2734.64	2736.07	0.004497	11.07	3491.82	1048.68	0.76
Jacumba_Mainline	3200	100-YR	26164.00	2724.29	2731.99	2731.99	2733.47	0.006682	12.46	2821.07	863.33	0.94
Jacumba_Mainline	2800	100-YR	26164.00	2721.21	2729.30	2729.00	2730.61	0.004545	11.21	3024.42	1050.65	0.79
Jacumba_Mainline	2400	100-YR	26164.00	2717.38	2728.01	2726.70	2729.12	0.002763	10.36	3180.88	1179.47	0.64
Jacumba_Mainline	2000	100-YR	26164.00	2716.66	2725.58	2725.26	2727.55	0.005224	12.14	2404.33	1072.63	0.86
Jacumba_Mainline	1610	100-YR	26164.00	2714.59	2725.89	2721.93	2726.37	0.000682	5.98	4829.56	1197.76	0.33
Jacumba_Mainline	1563		Bridge									
Jacumba_Mainline	1516	100-YR	26164.00	2714.20	2721.79	2721.01	2723.03	0.003316	9.78	3073.42	892.39	0.68
Jacumba_Mainline	1323	100-YR	26164.00	2714.12	2719.37	2719.24	2721.24	0.007121	11.53	2399.01	680.50	0.95
Jacumba_Mainline	1200	100-YR	26164.00	2712.42	2718.40		2719.31	0.003414	7.73	3436.40	813.70	0.65
Jacumba_Mainline	1000	100-YR	26164.00	2711.24	2716.73	2716.43	2718.14	0.006001	10.32	2838.65	807.90	0.87



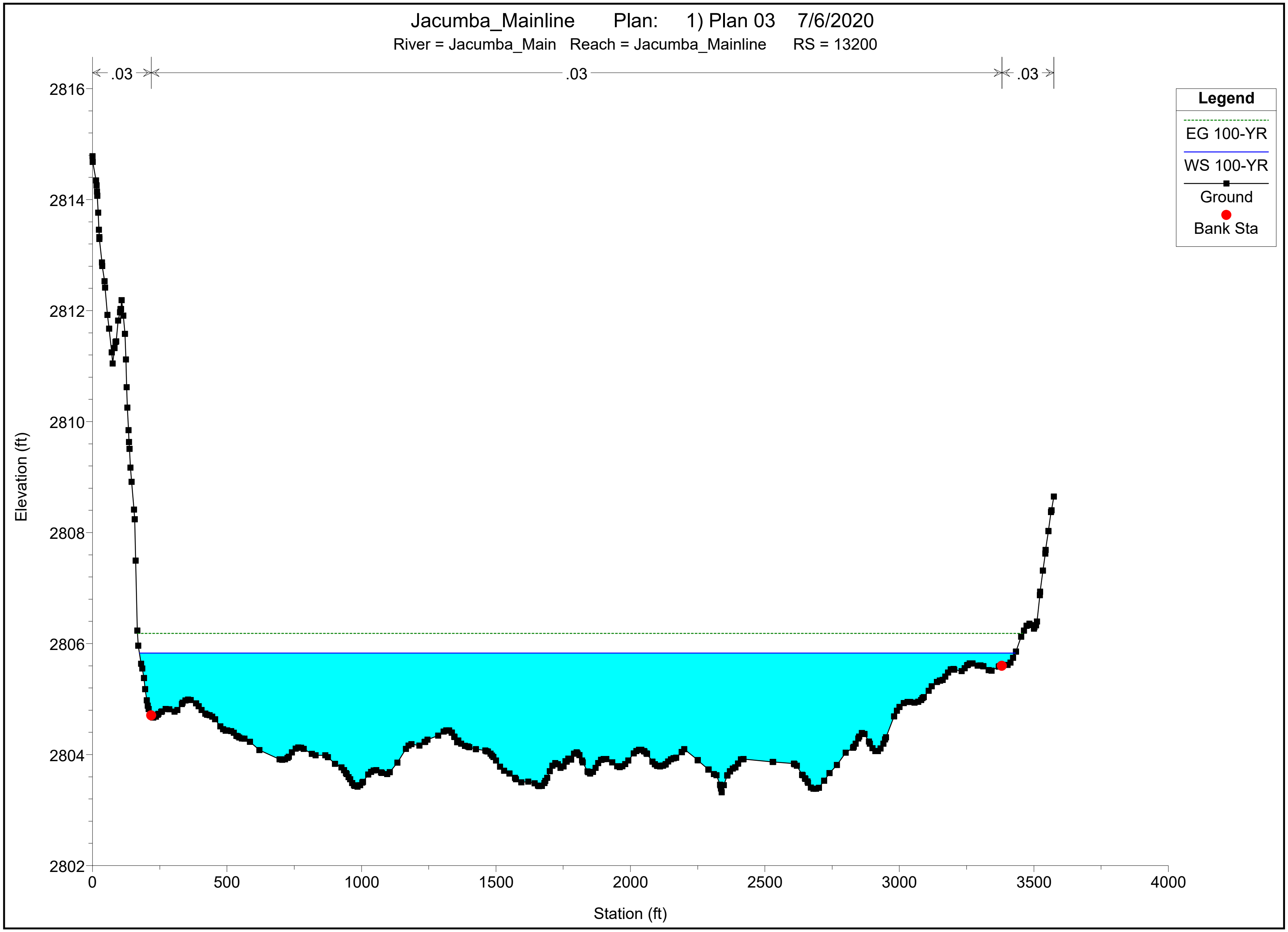
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
Jacumba_Main Jacumba_Mainline
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Elevation (ft)
2700
2720
2740
2760
2780
2800
2820
Main Channel Distance (ft)
0
2000
4000
6000
8000
10000
12000
14000

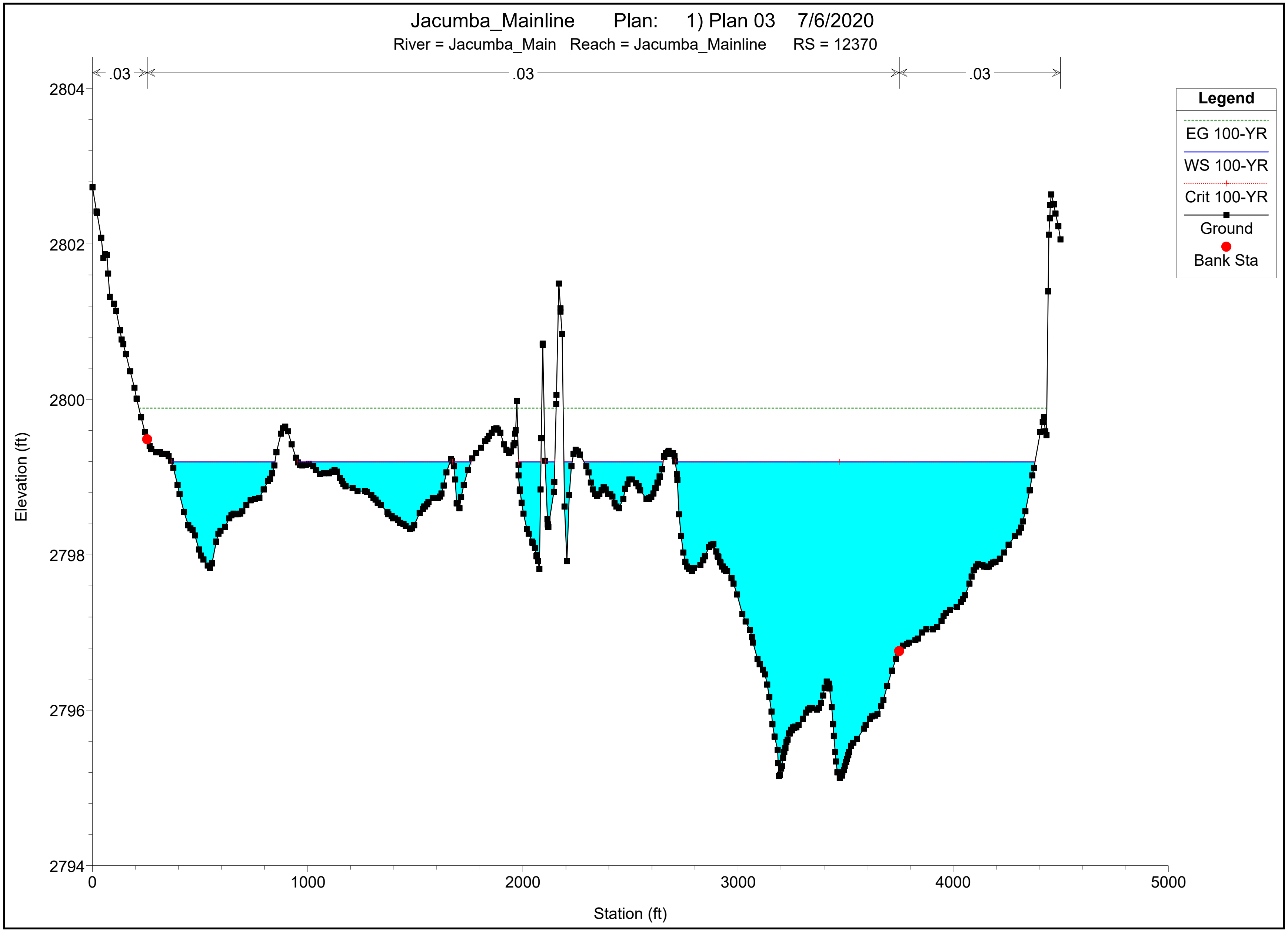


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 14000
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2808
2810
2812
2814
2816
2818
2820
2822
2824
2826
Station (ft)
0
500
1000
1500
2000
2500
3000
3500
4000

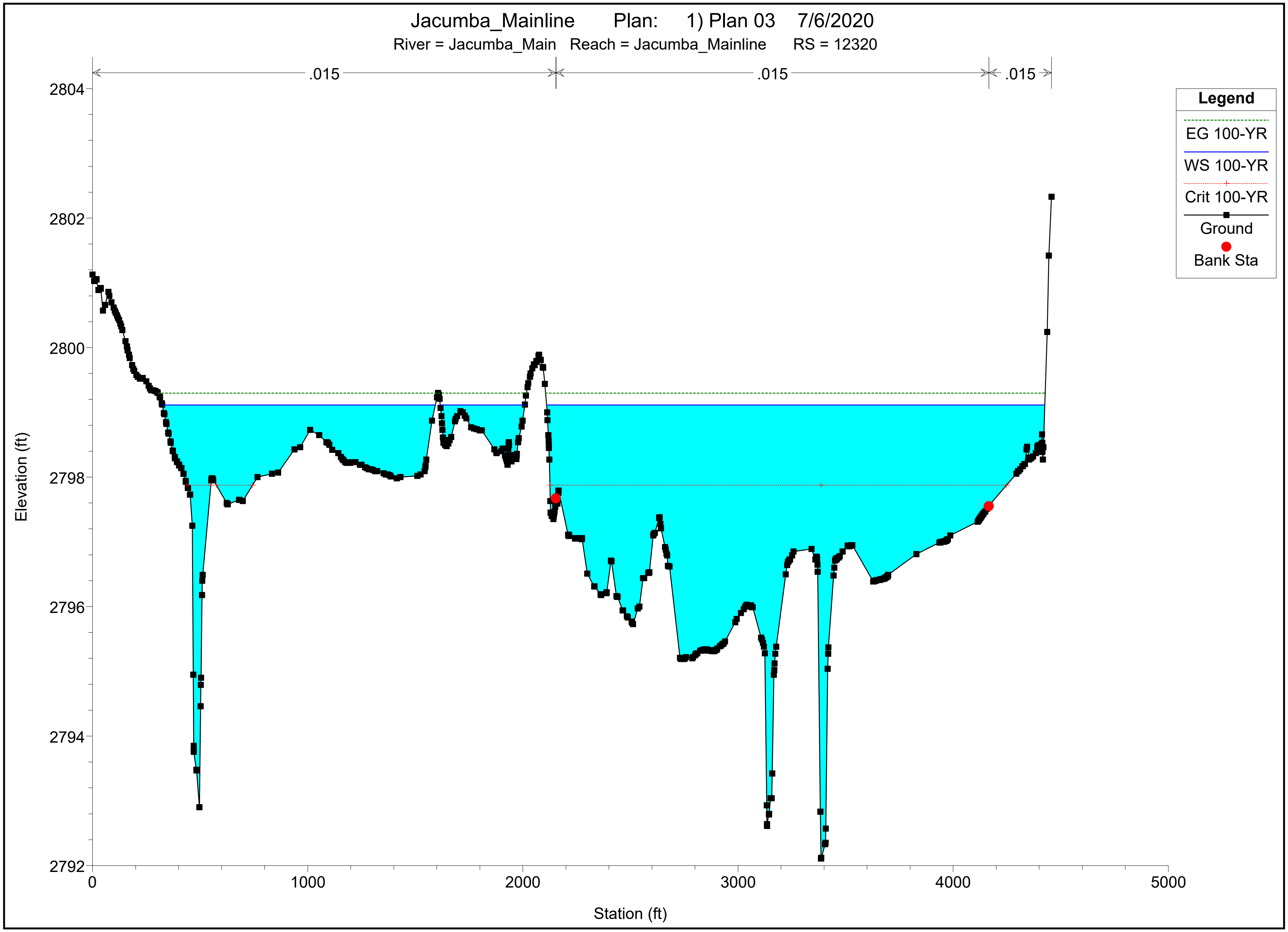


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 13810
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2822
2820
2818
2816
2814
2812
2810
2808
2806
0
1000
2000
3000
4000
5000
Station (ft)

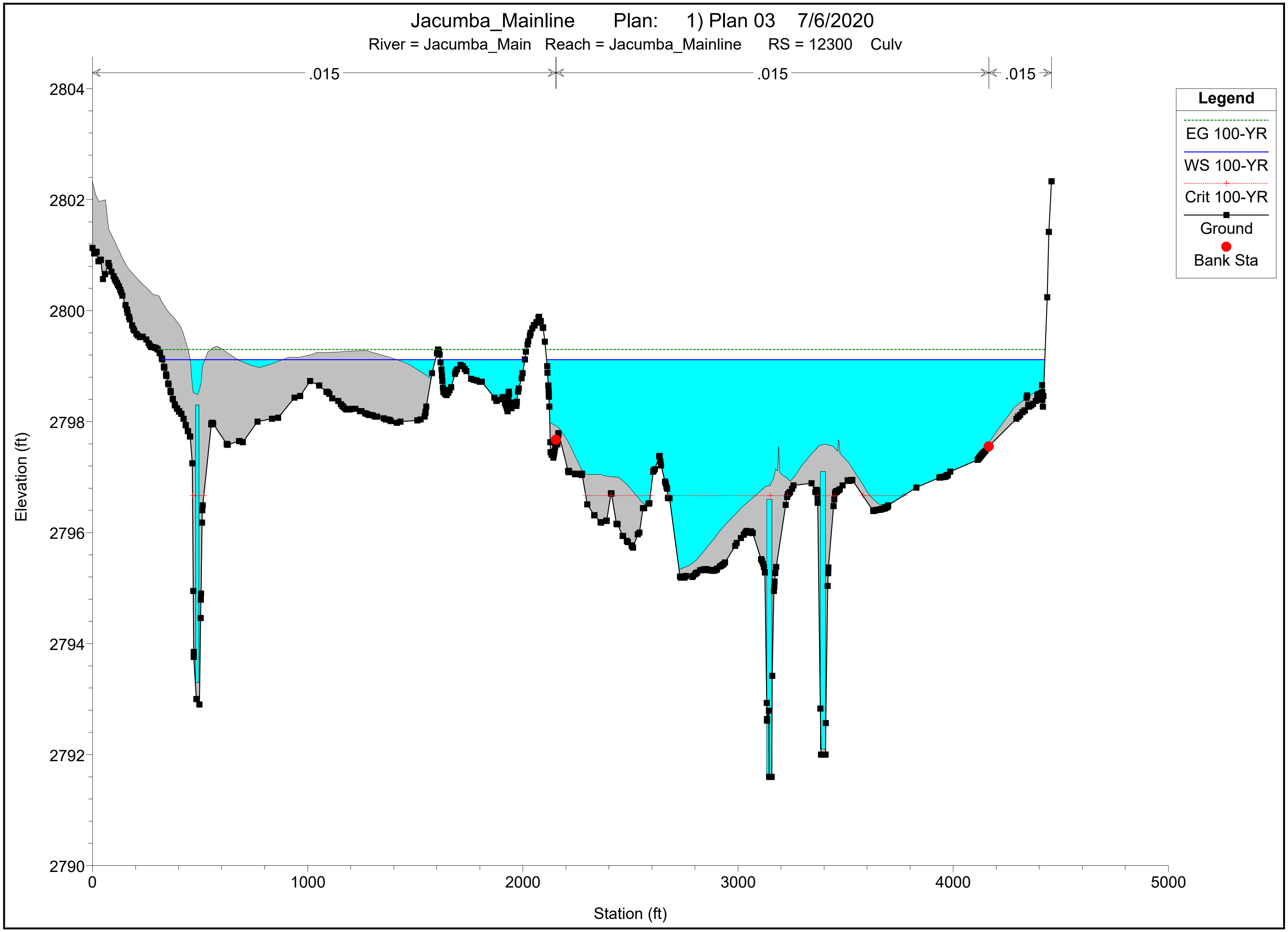

Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 13200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2816
2814
2812
2810
2808
2806
2804
2802
0
500
1000
1500
2000
2500
3000
3500
4000
Station (ft)

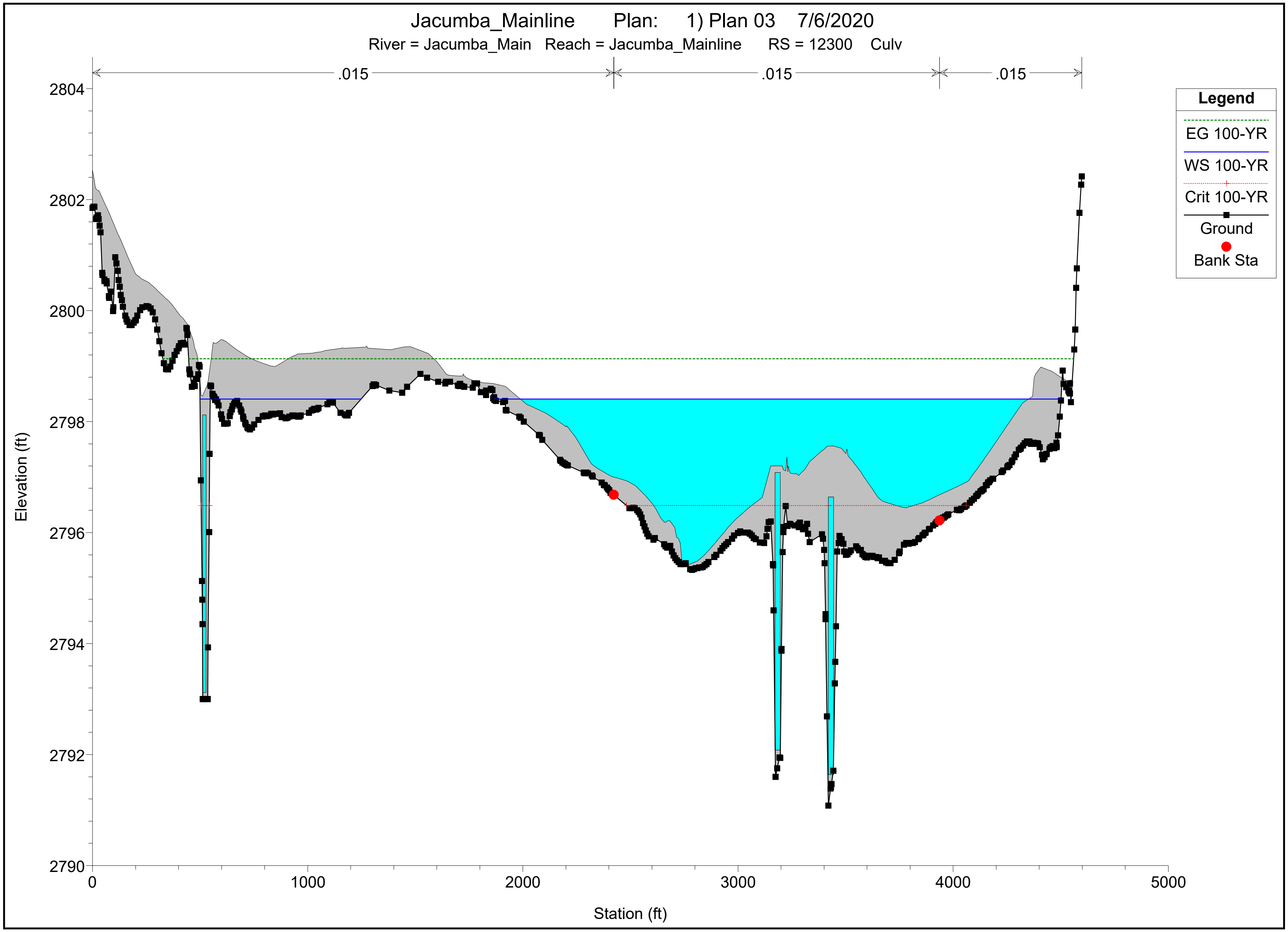


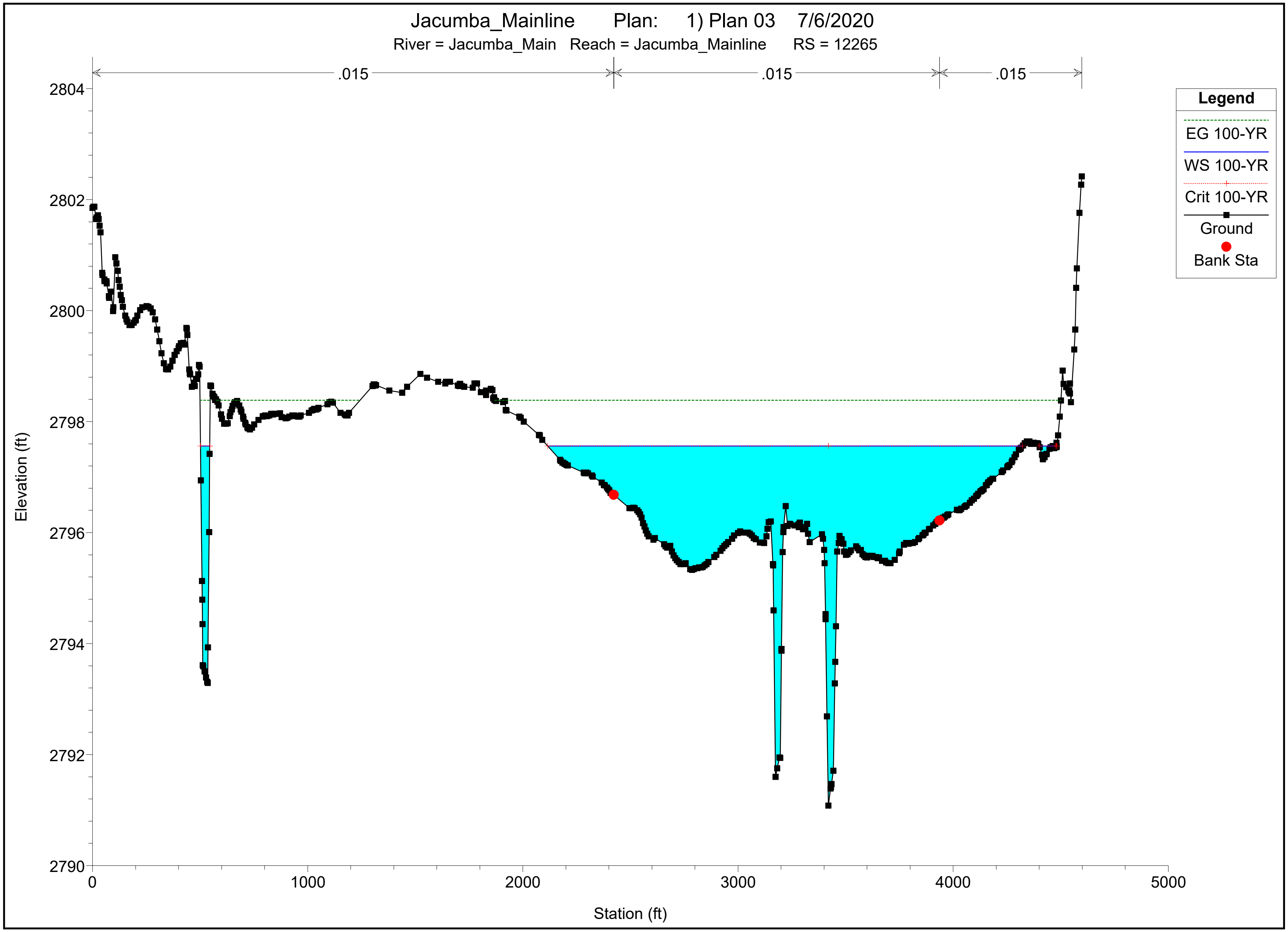
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12370
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2804
2802
2800
2798
2796
2794
0
1000
2000
3000
4000
5000
Station (ft)

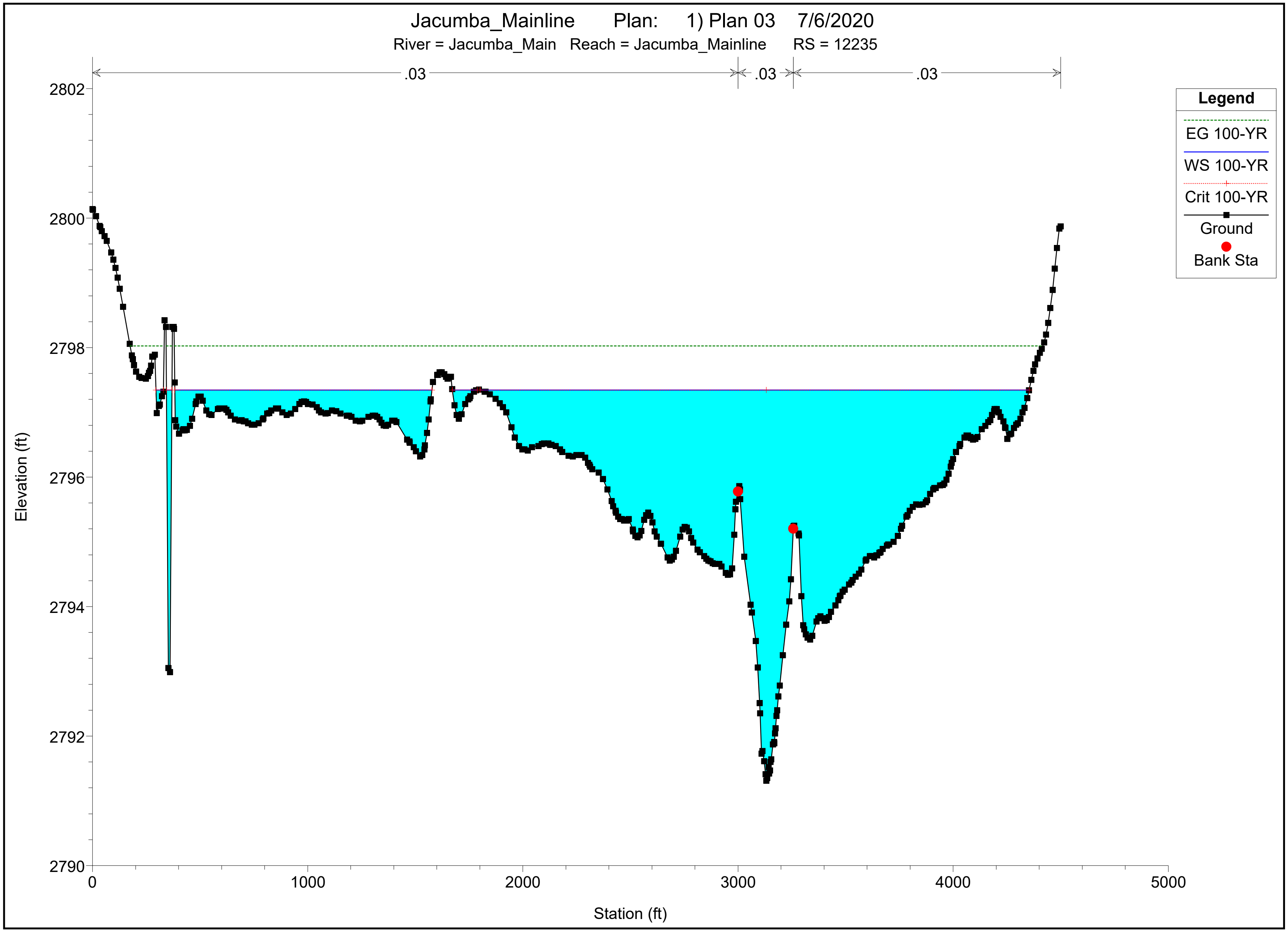


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12320
.015
.015
.015
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2804
2802
2800
2798
2796
2794
2792
0
1000
2000
3000
4000
5000
Station (ft)

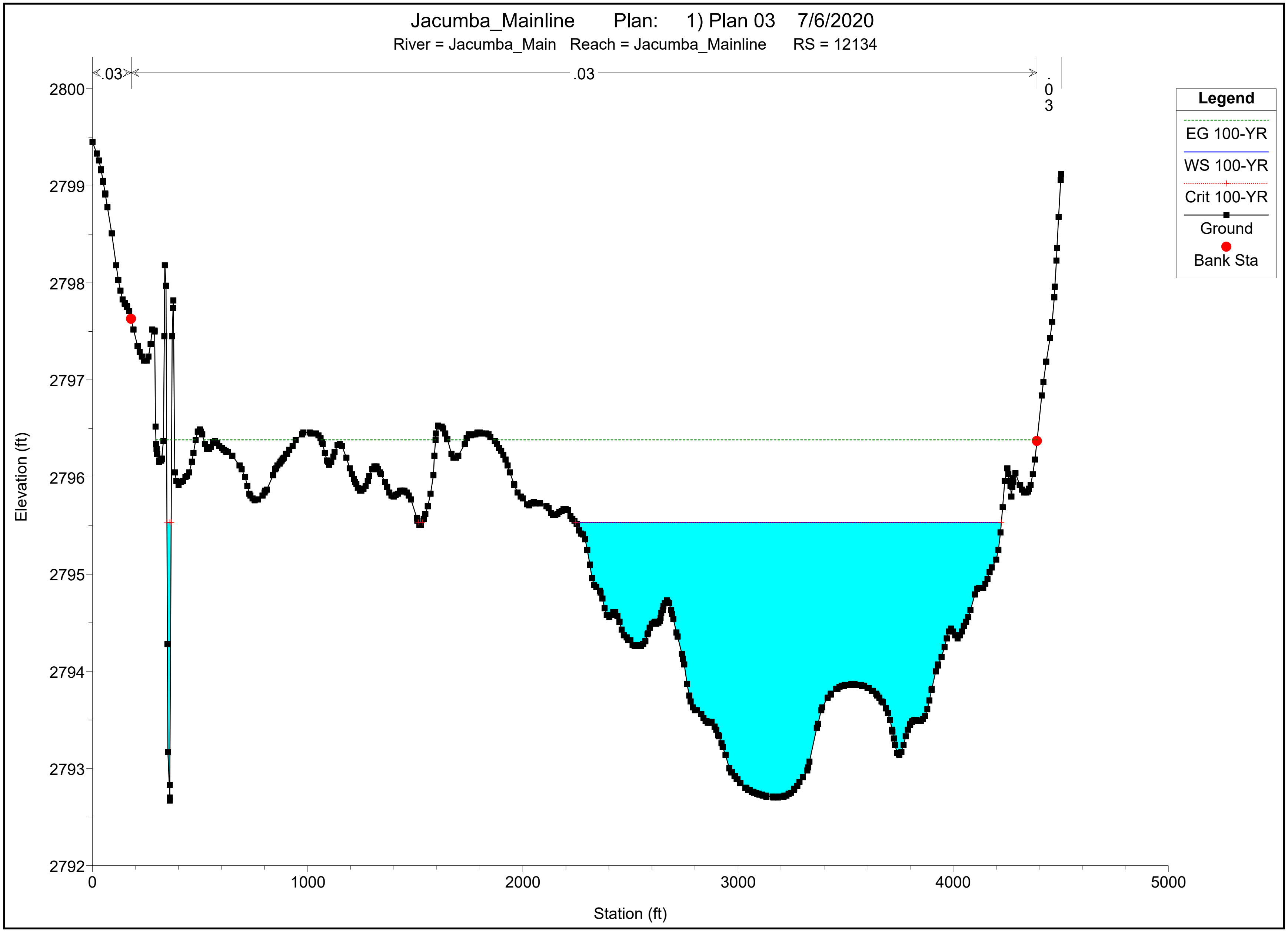

Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12300 Culv
.015
.015
.015
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2804
2802
2800
2798
2796
2794
2792
2790
0
1000
2000
3000
4000
5000
Station (ft)


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12300 Culv
.015
.015
.015
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2804
2802
2800
2798
2796
2794
2792
2790
0
1000
2000
3000
4000
5000

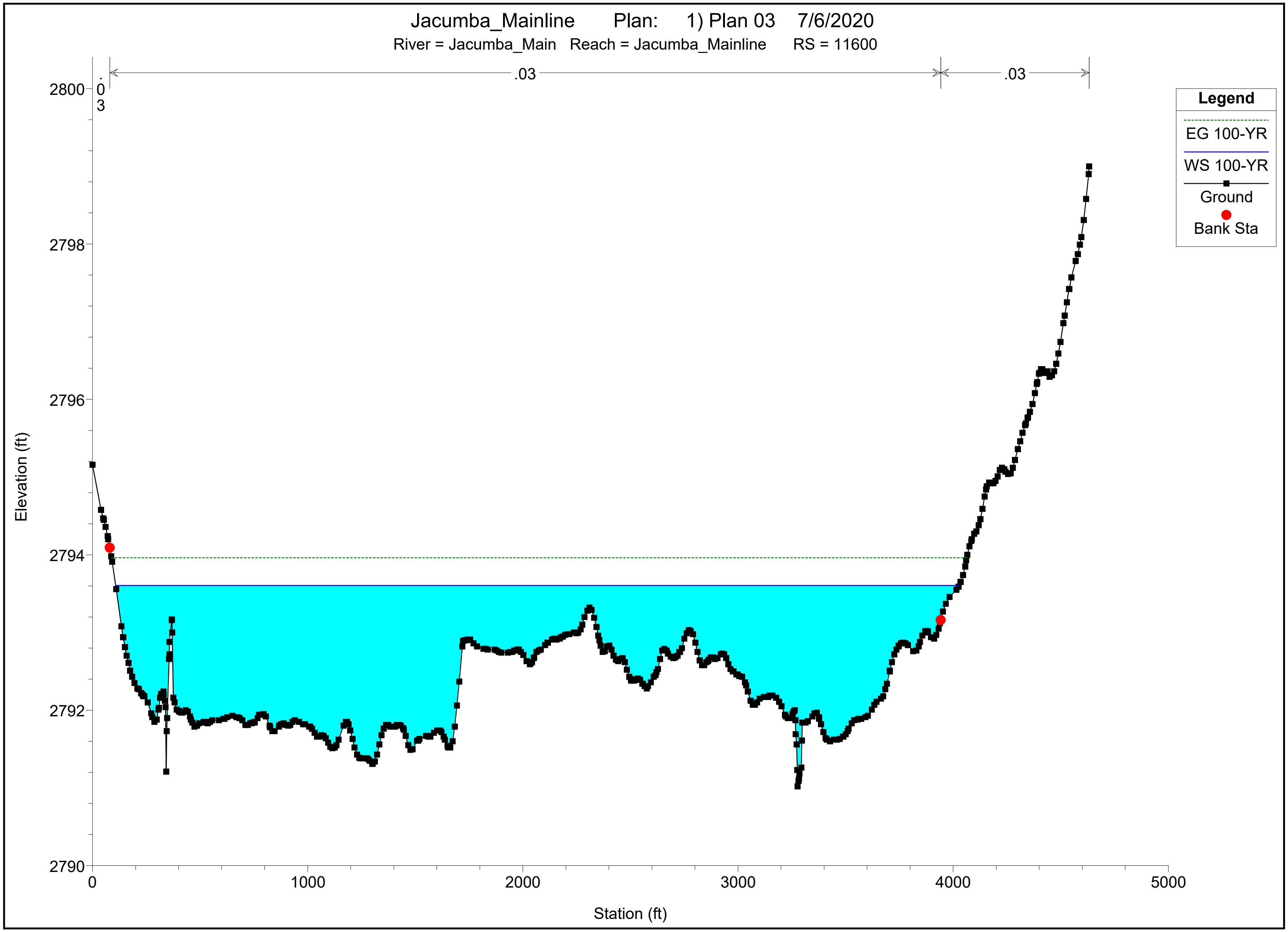

Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12265
.015
.015
.015
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2804
2802
2800
2798
2796
2794
2792
2790
0
1000
2000
3000
4000
5000
Station (ft)

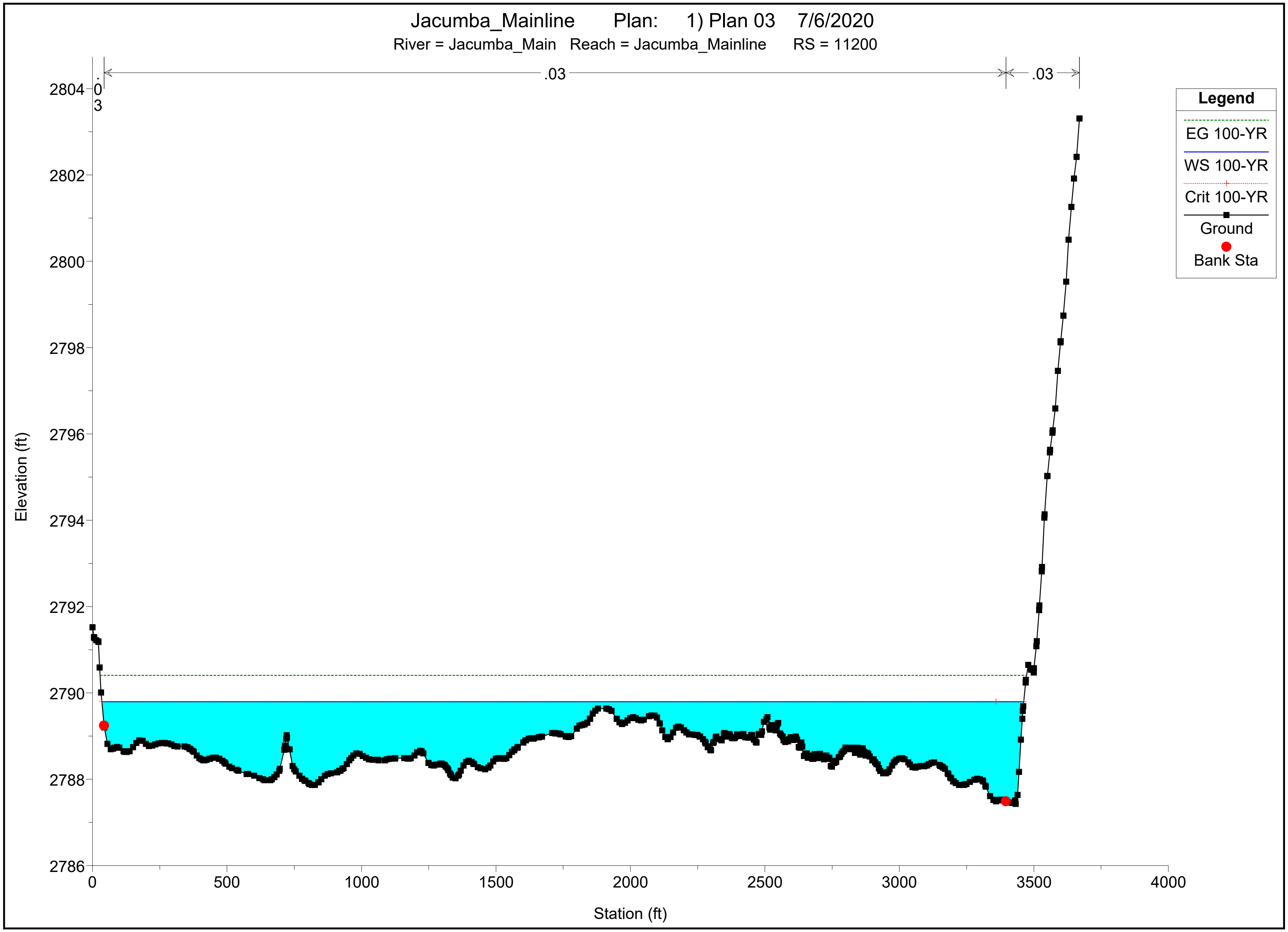


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12235
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2802
2800
2798
2796
2794
2792
2790
0
1000
2000
3000
4000
5000
Station (ft)

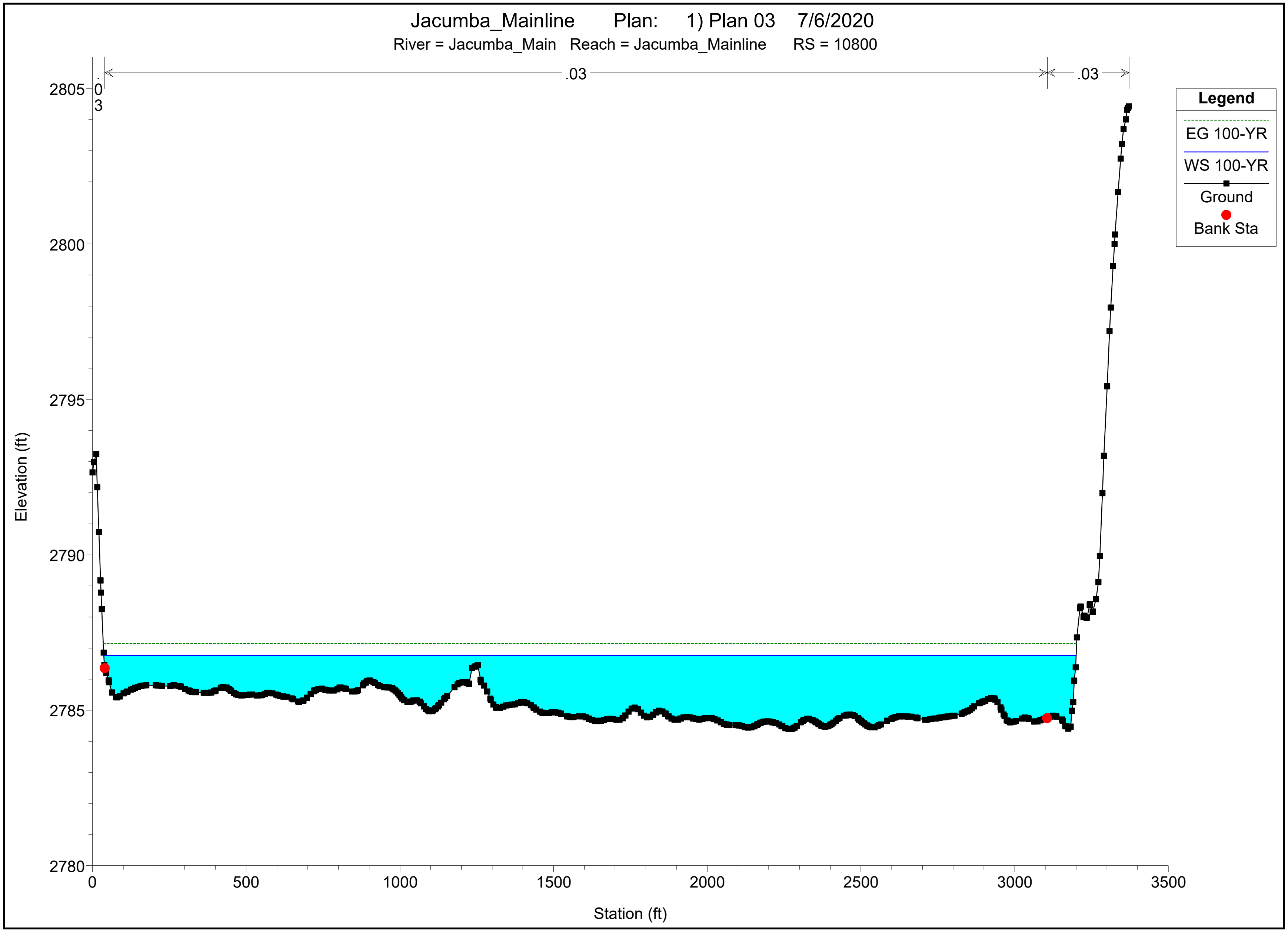


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12134
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2800
2799
2798
2797
2796
2795
2794
2793
2792
0
1000
2000
3000
4000
5000
Station (ft)

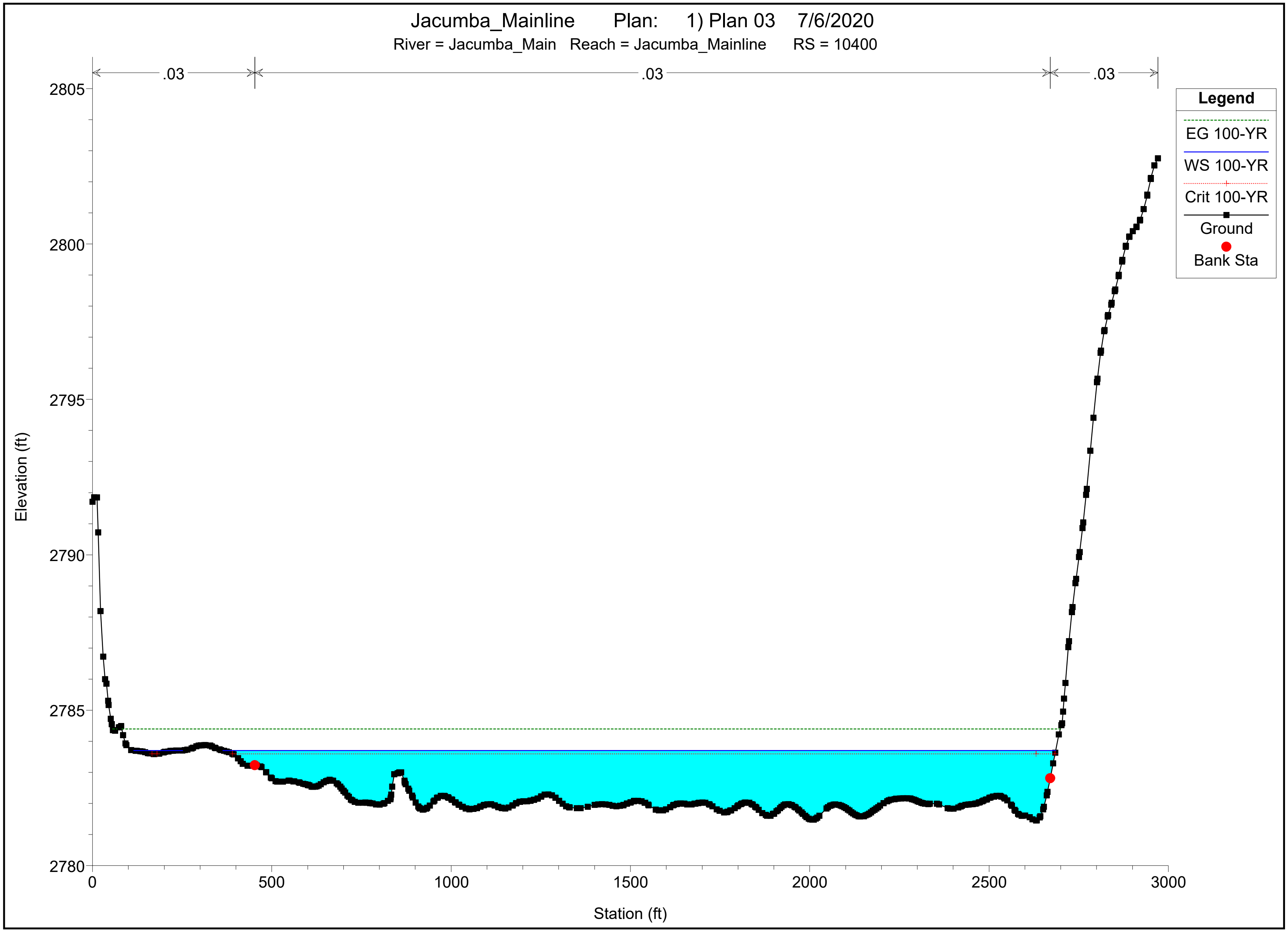

Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 11600
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2800
2798
2796
2794
2792
2790
0
1000
2000
3000
4000
5000
Station (ft)



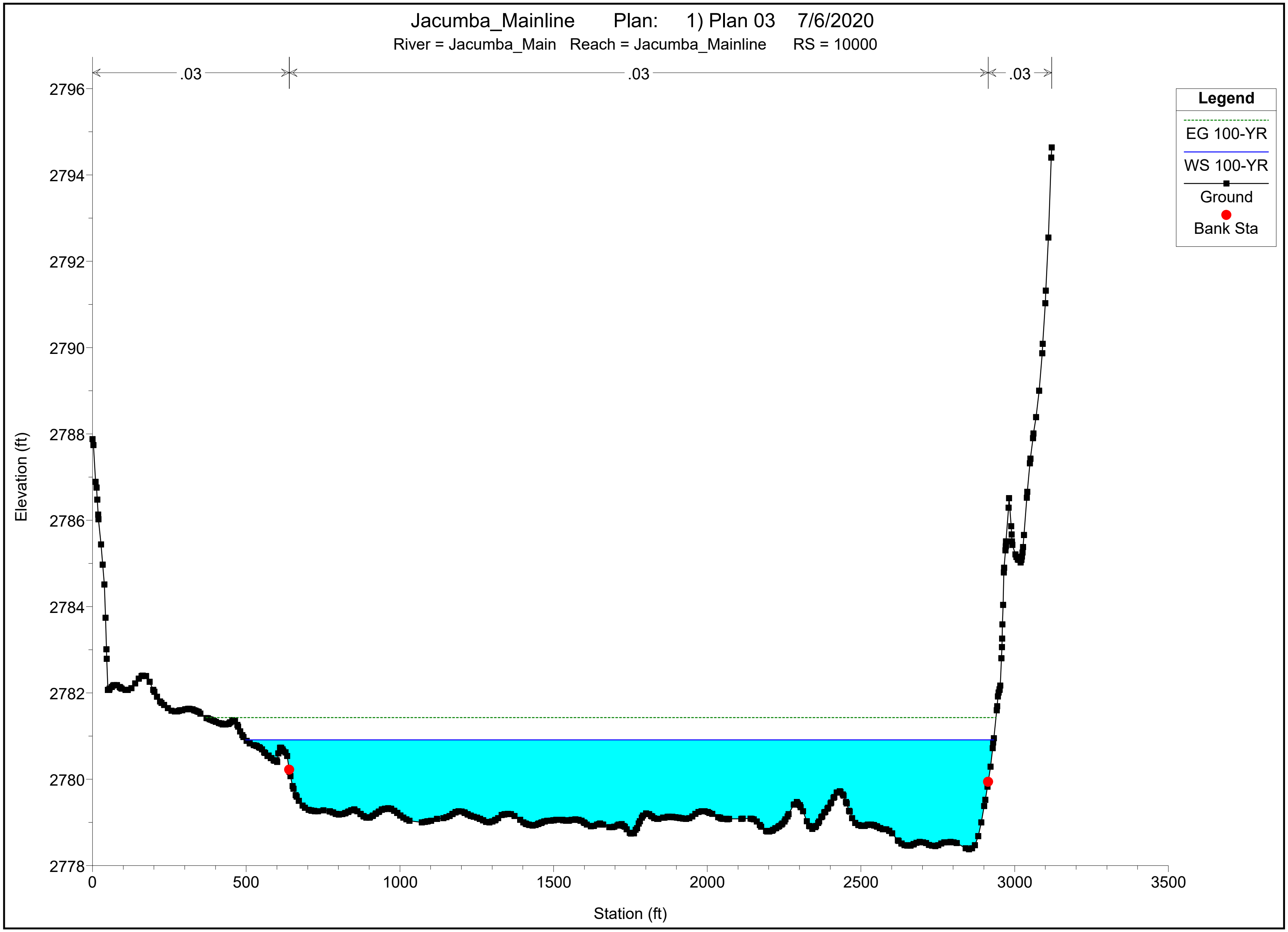
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 11200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2786
2788
2790
2792
2794
2796
2798
2800
2802
2804
0
500
1000
1500
2000
2500
3000
3500
4000
Station (ft)



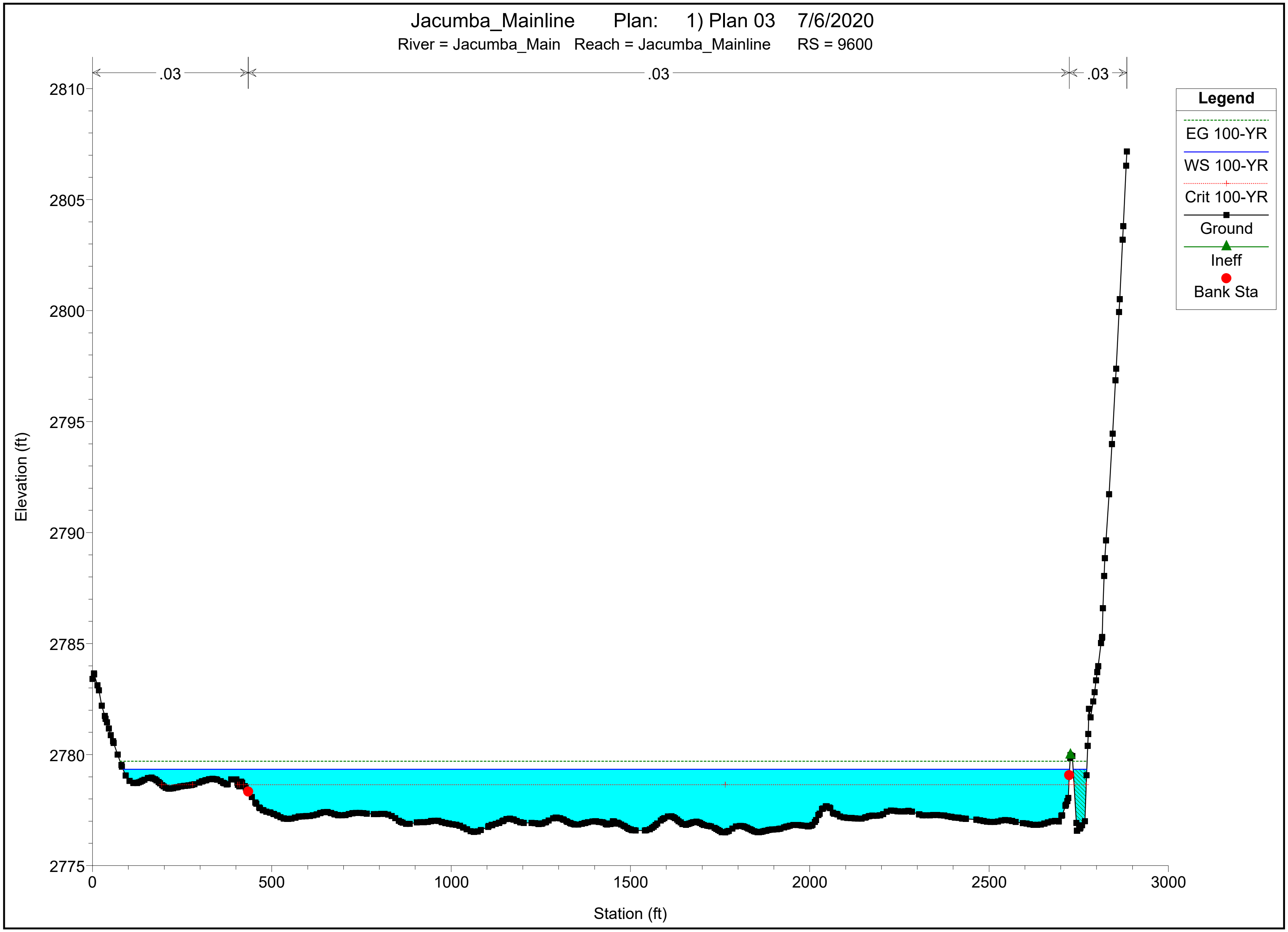
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 10800
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2805
2800
2795
2790
2785
2780
0
500
1000
1500
2000
2500
3000
3500
Station (ft)



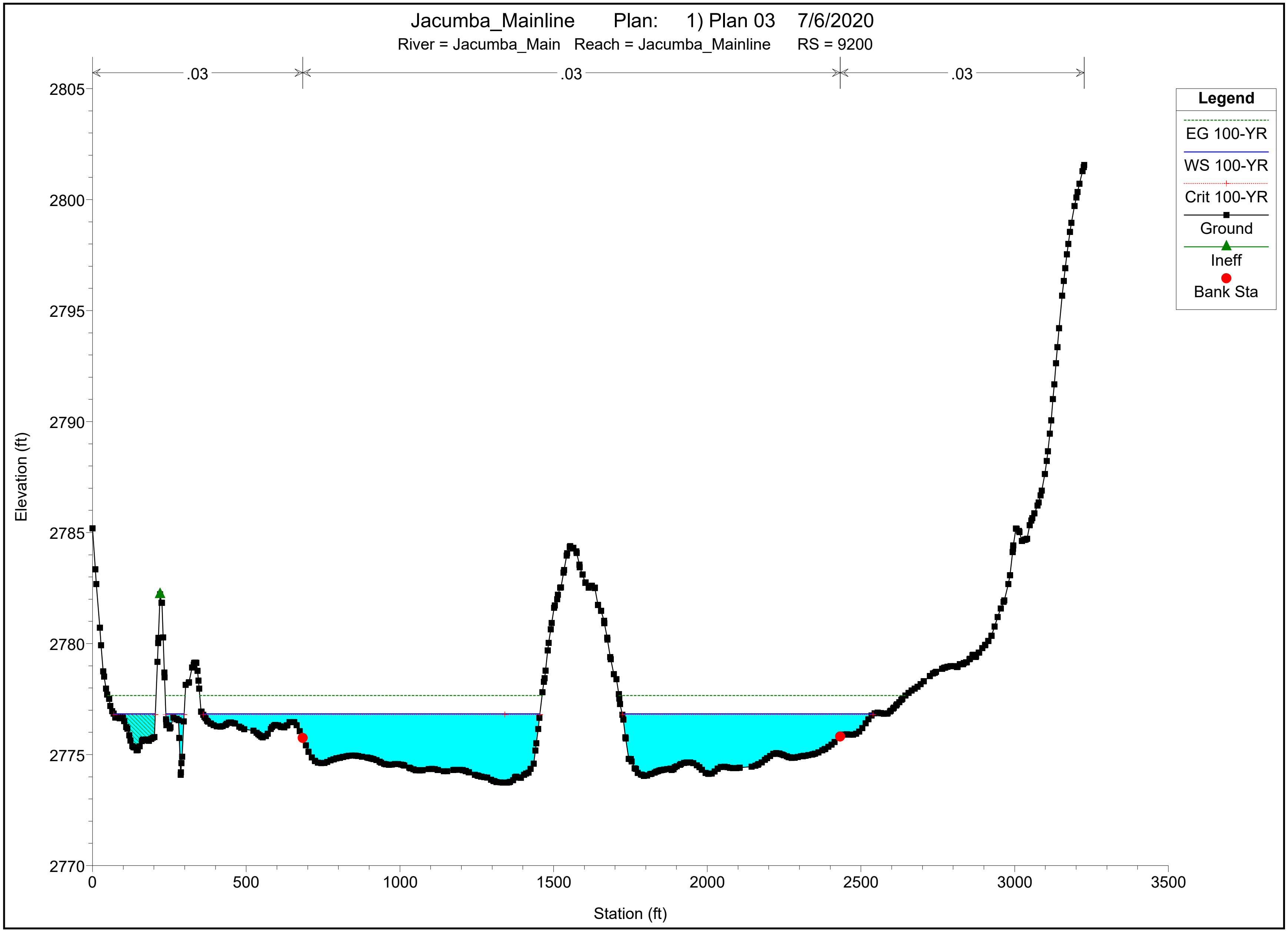
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 10400
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2805
2800
2795
2790
2785
2780
0
500
1000
1500
2000
2500
3000
Station (ft)

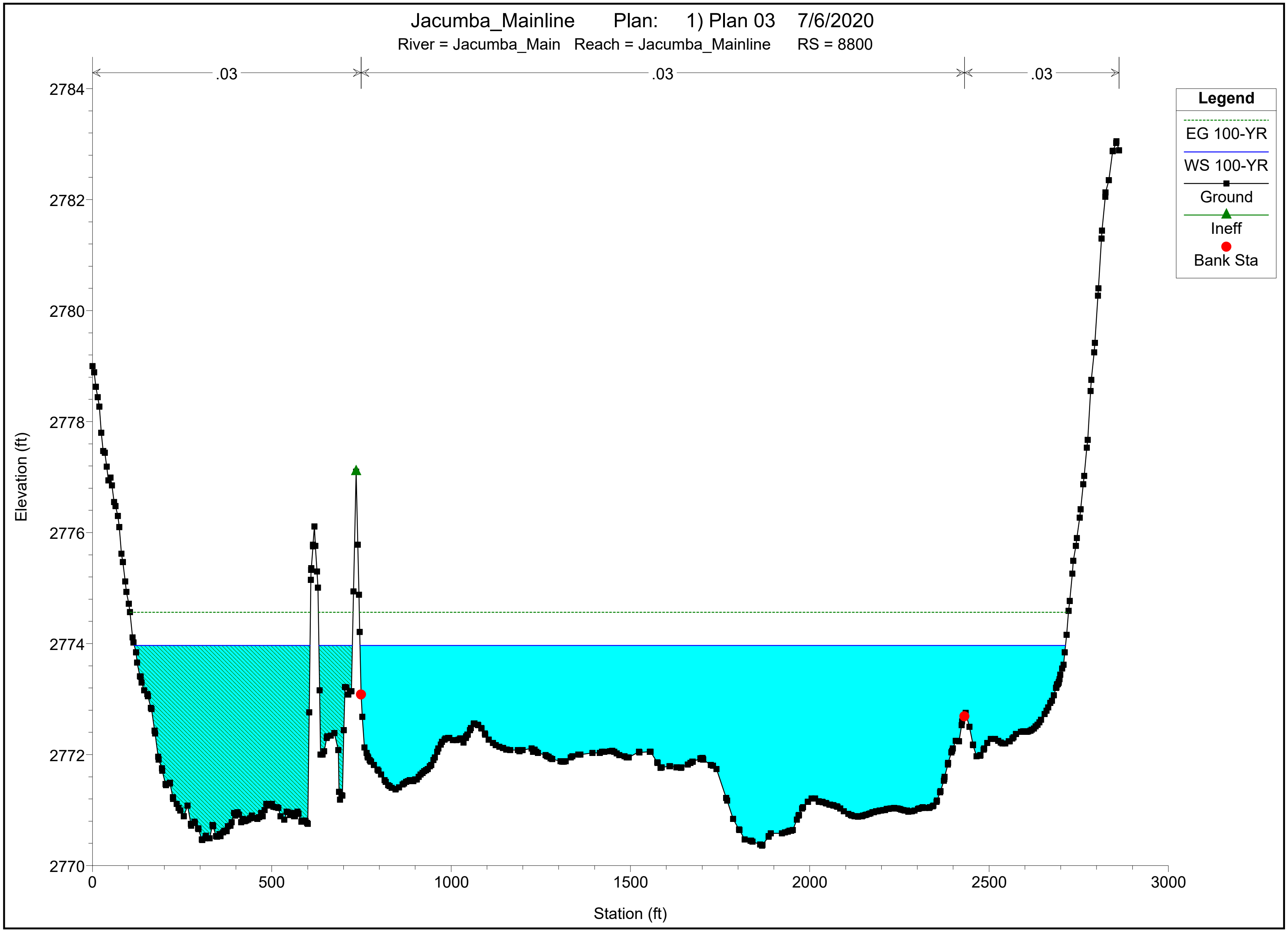


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 10000
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2796
2794
2792
2790
2788
2786
2784
2782
2780
2778
0
500
1000
1500
2000
2500
3000
3500
Station (ft)

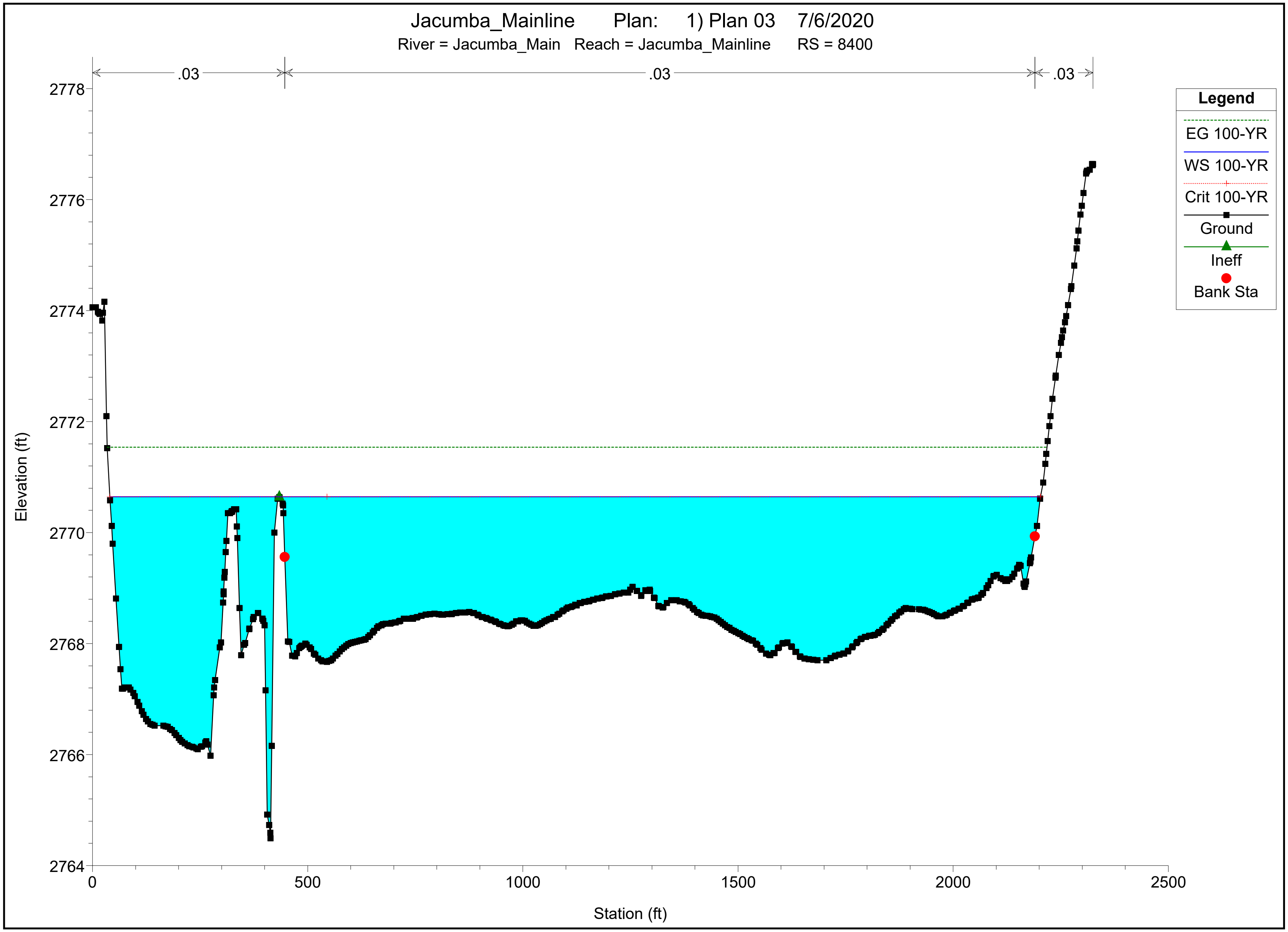


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 9600
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2775
2780
2785
2790
2795
2800
2805
2810
Station (ft)
0
500
1000
1500
2000
2500
3000

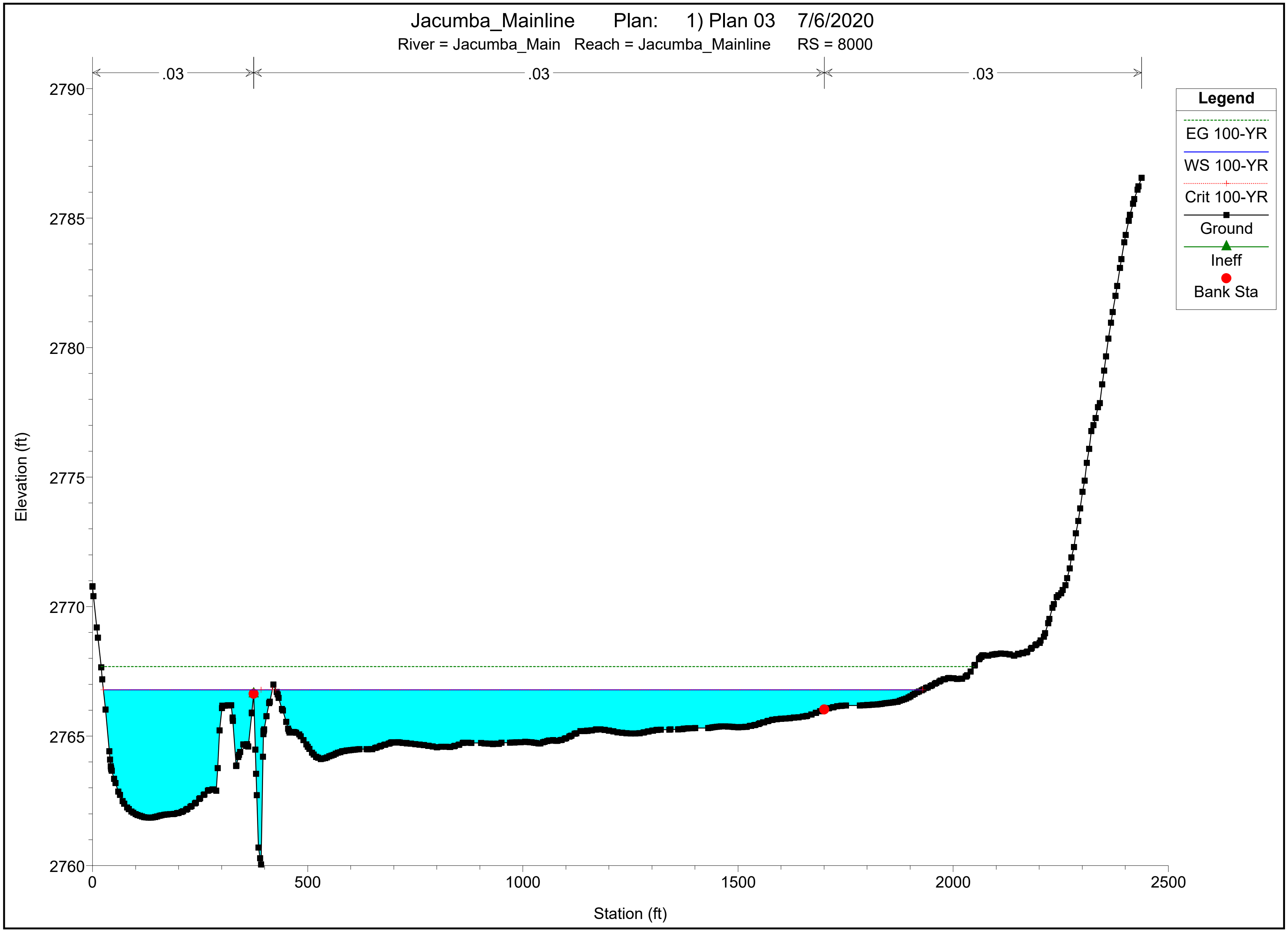

Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 9200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2805
2800
2795
2790
2785
2780
2775
2770
0
500
1000
1500
2000
2500
3000
3500
Station (ft)



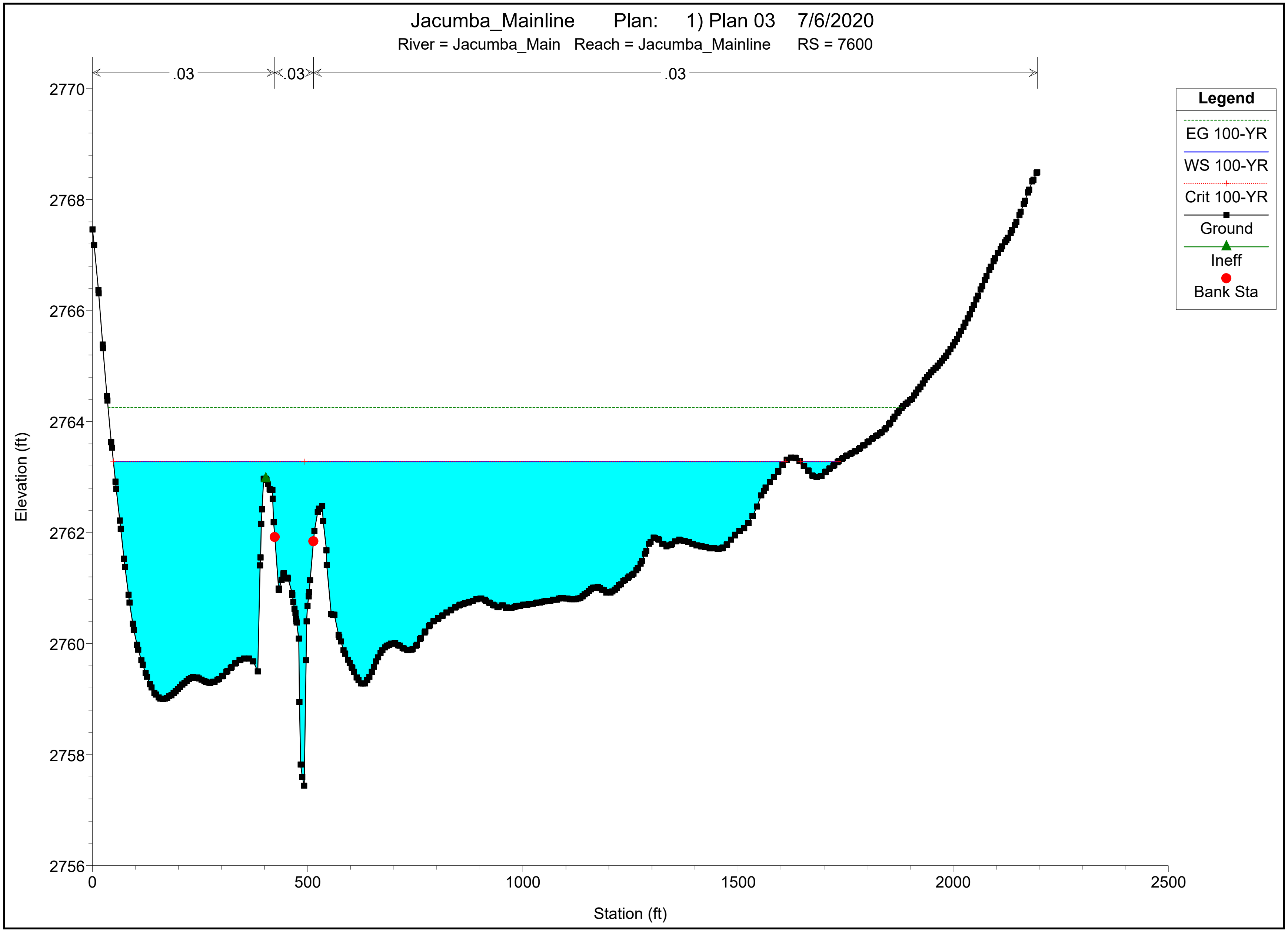
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 8800
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2784
2782
2780
2778
2776
2774
2772
2770
0
500
1000
1500
2000
2500
3000
Station (ft)



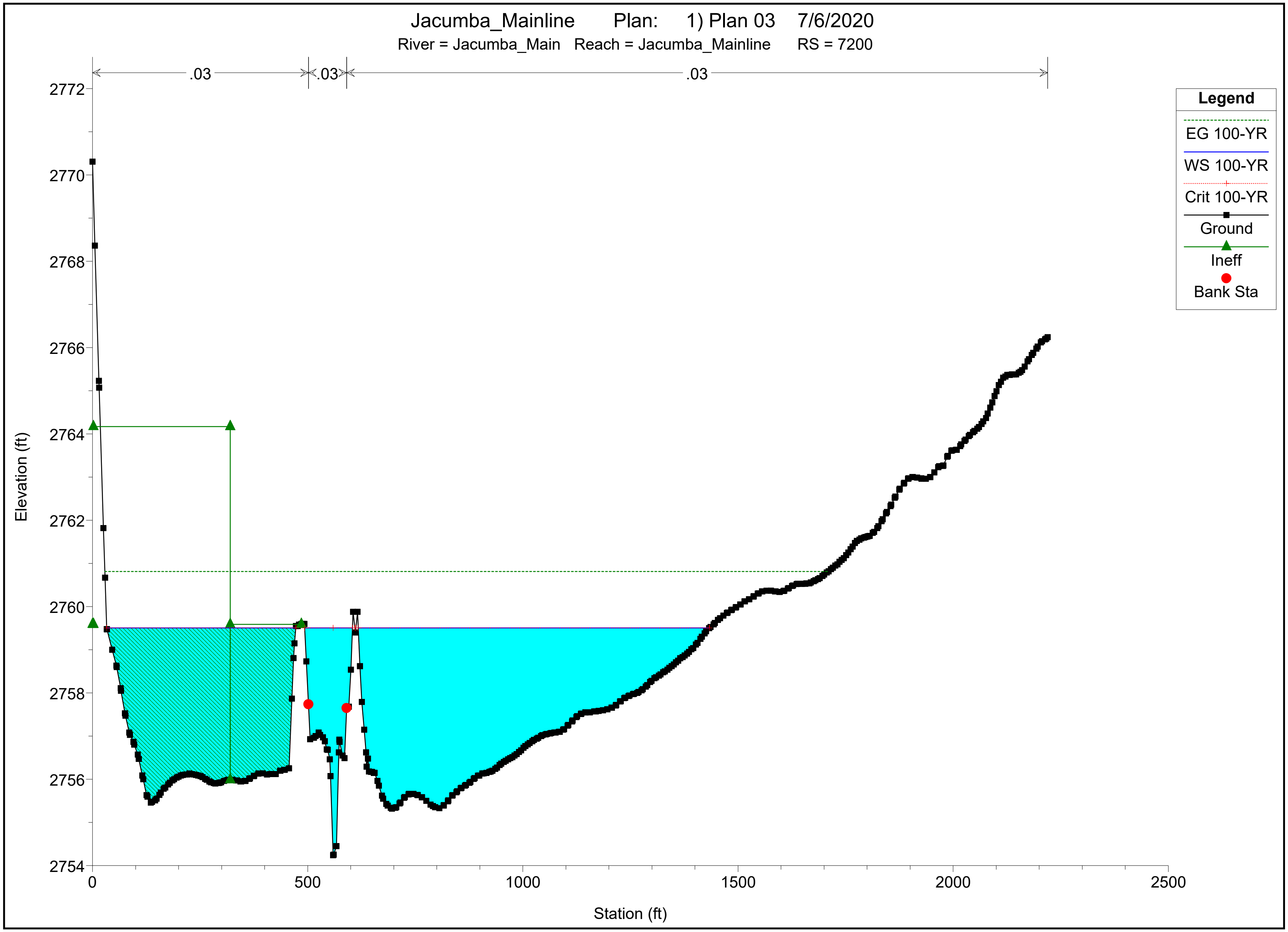
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 8400
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2778
2776
2774
2772
2770
2768
2766
2764
0
500
1000
1500
2000
2500
Station (ft)



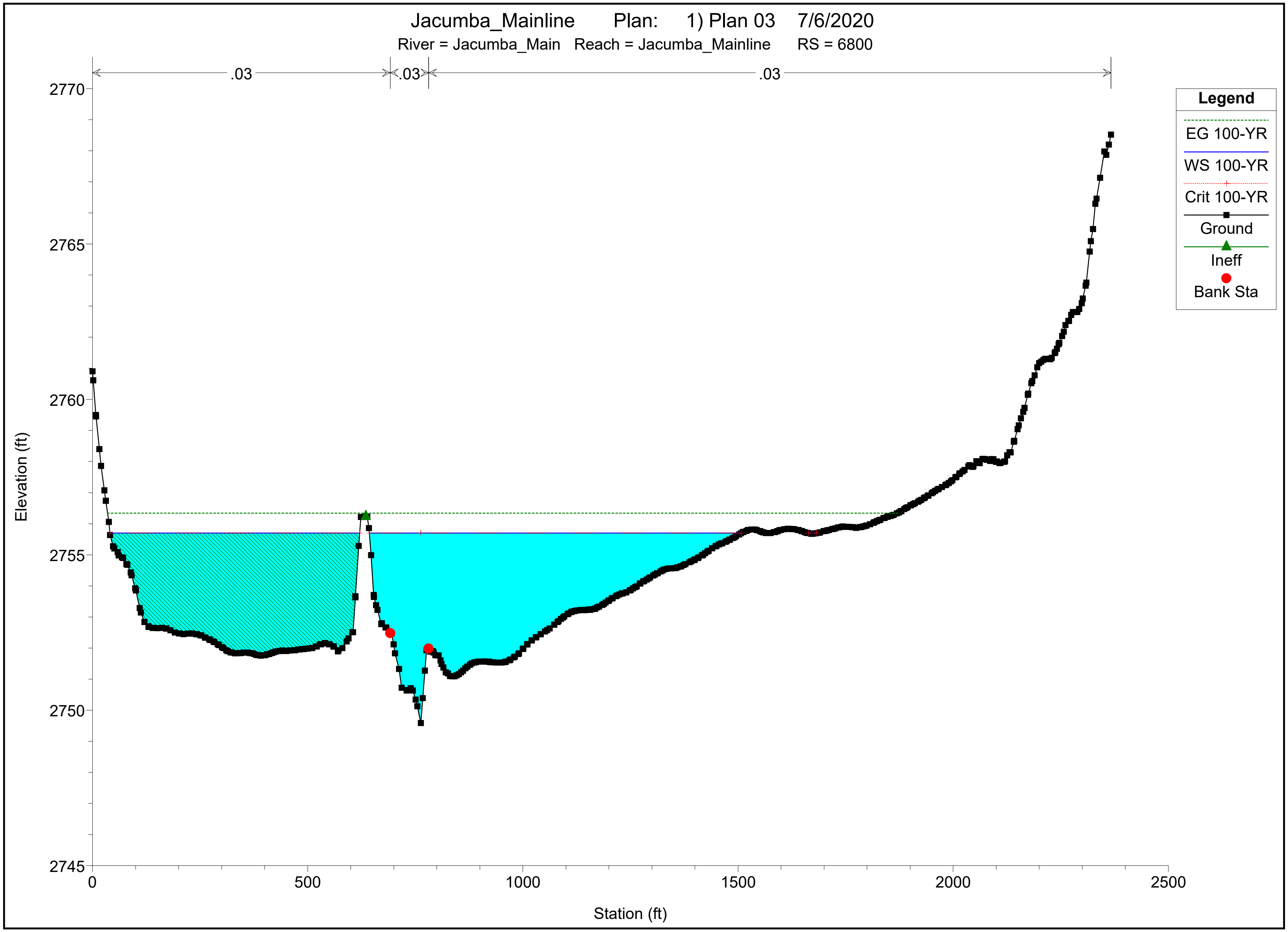
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 8000
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2790
2785
2780
2775
2770
2765
2760
0
500
1000
1500
2000
2500
Station (ft)



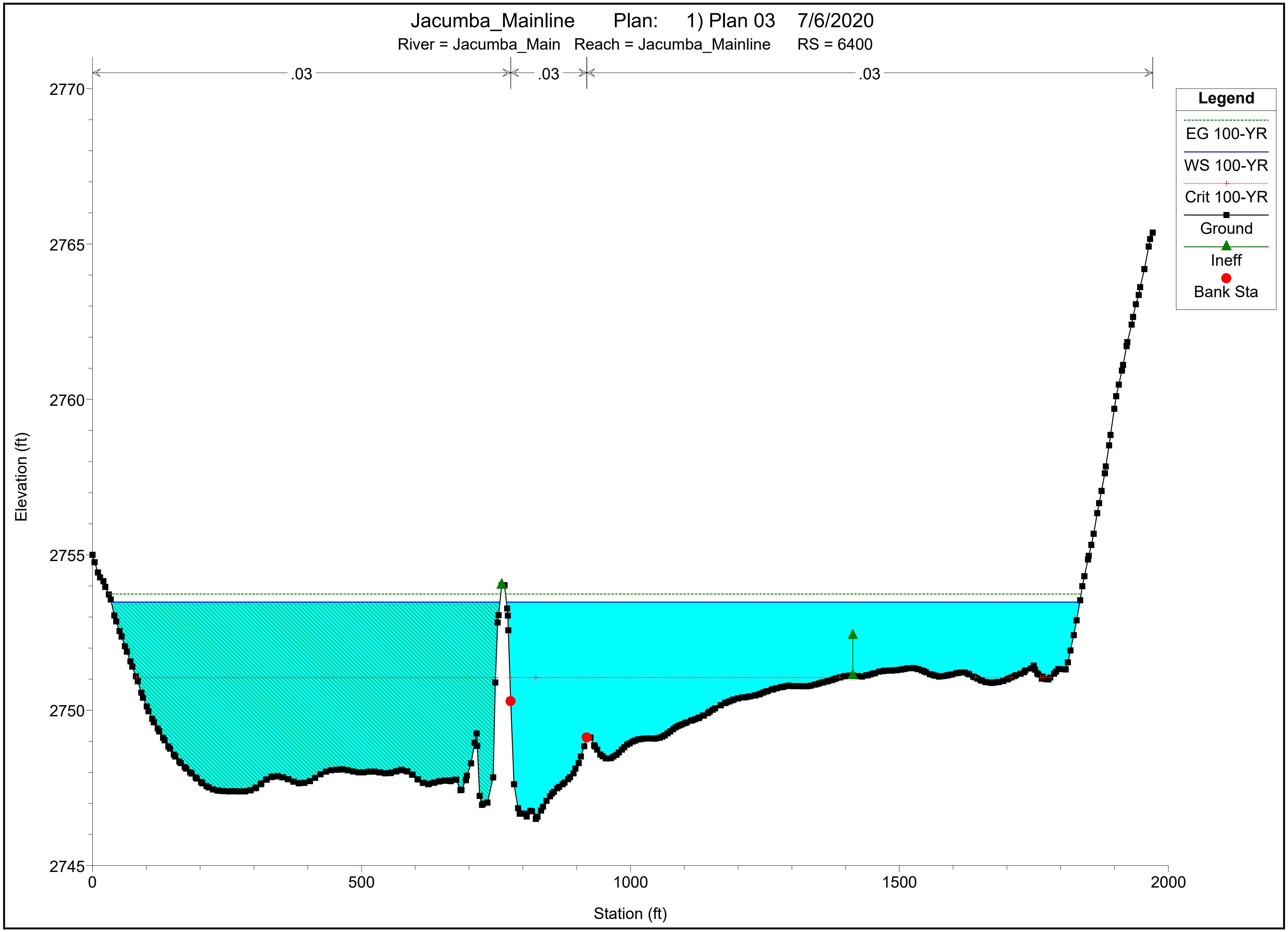
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 7600
.03
.03
.03
2770
2768
2766
2764
2762
2760
2758
2756
Elevation (ft)
0
500
1000
1500
2000
2500
Station (ft)
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta



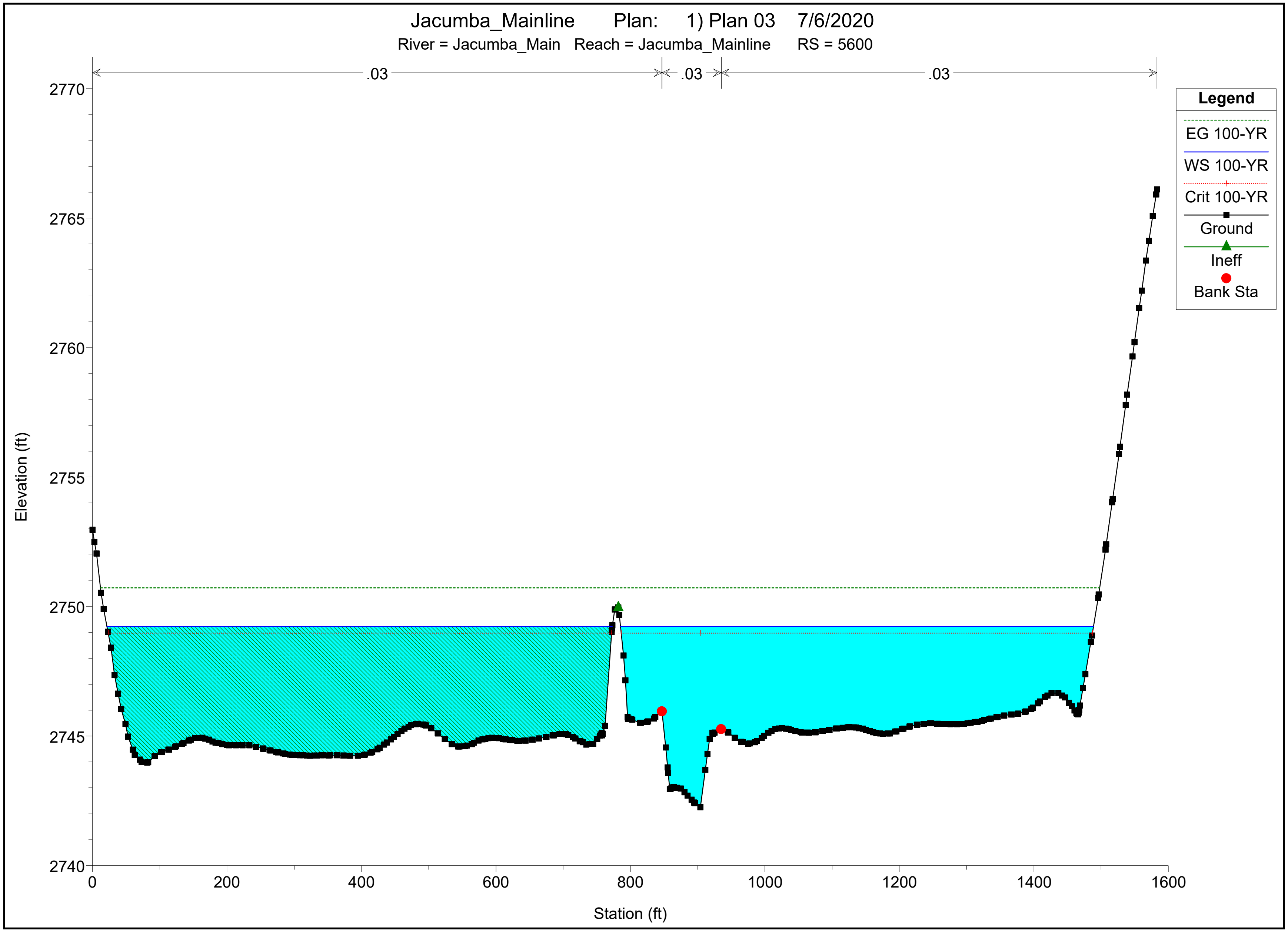
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 7200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2772
2770
2768
2766
2764
2762
2760
2758
2756
2754
0
500
1000
1500
2000
2500
Station (ft)



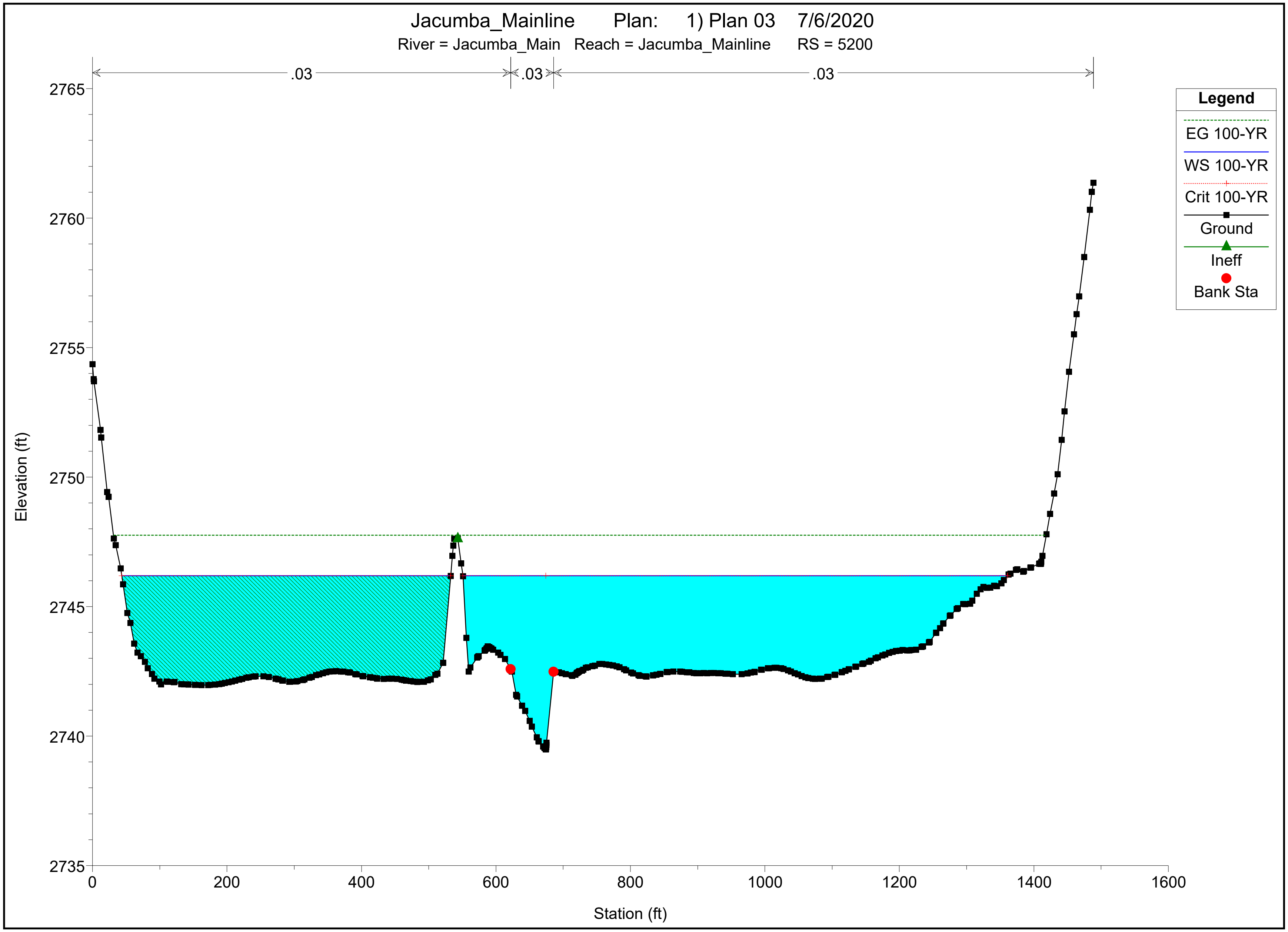
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 6800
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2770
2765
2760
2755
2750
2745
0
500
1000
1500
2000
2500
Station (ft)



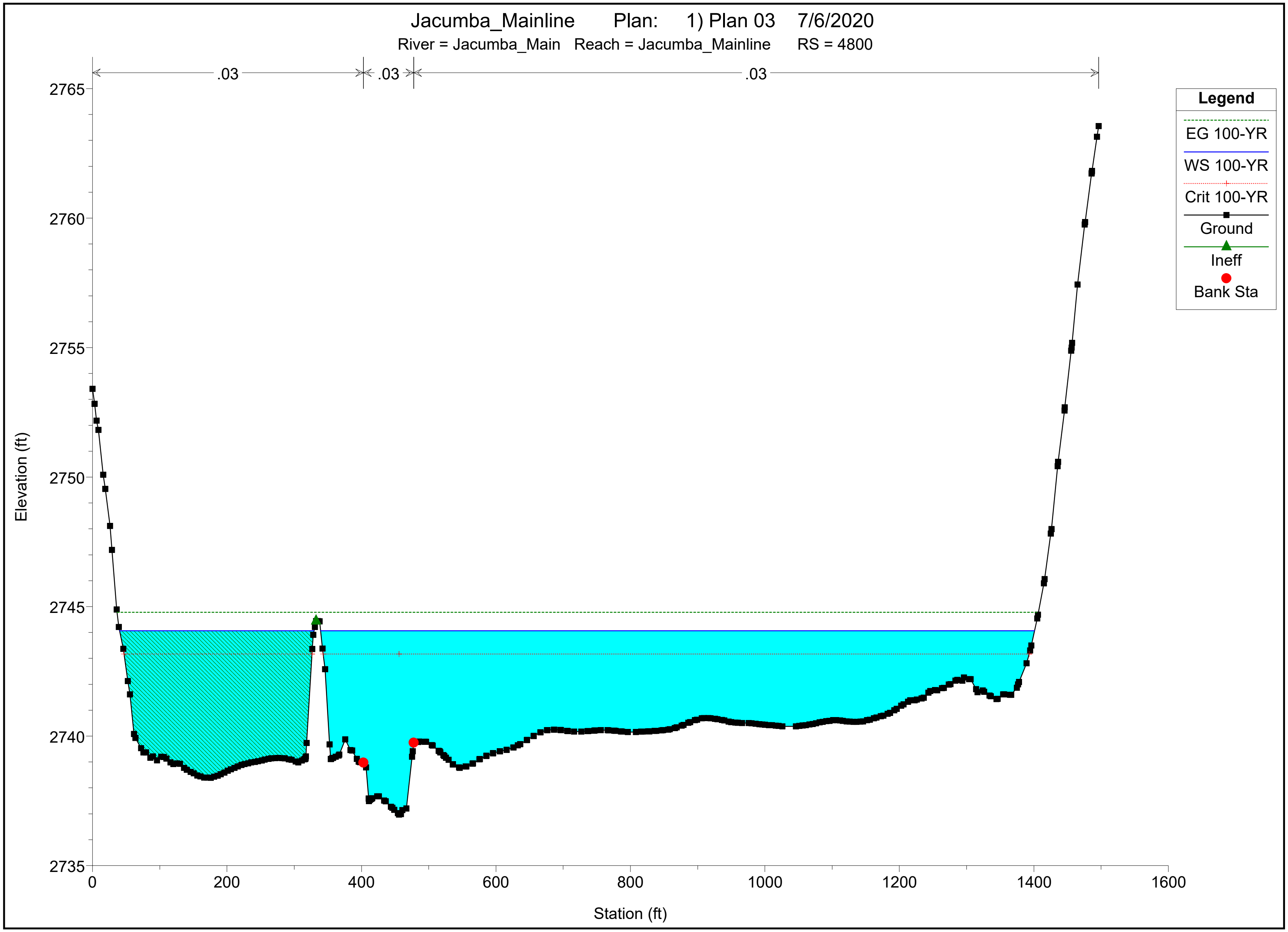
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 6400
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2770
2765
2760
2755
2750
2745
0
500
1000
1500
2000
Station (ft)



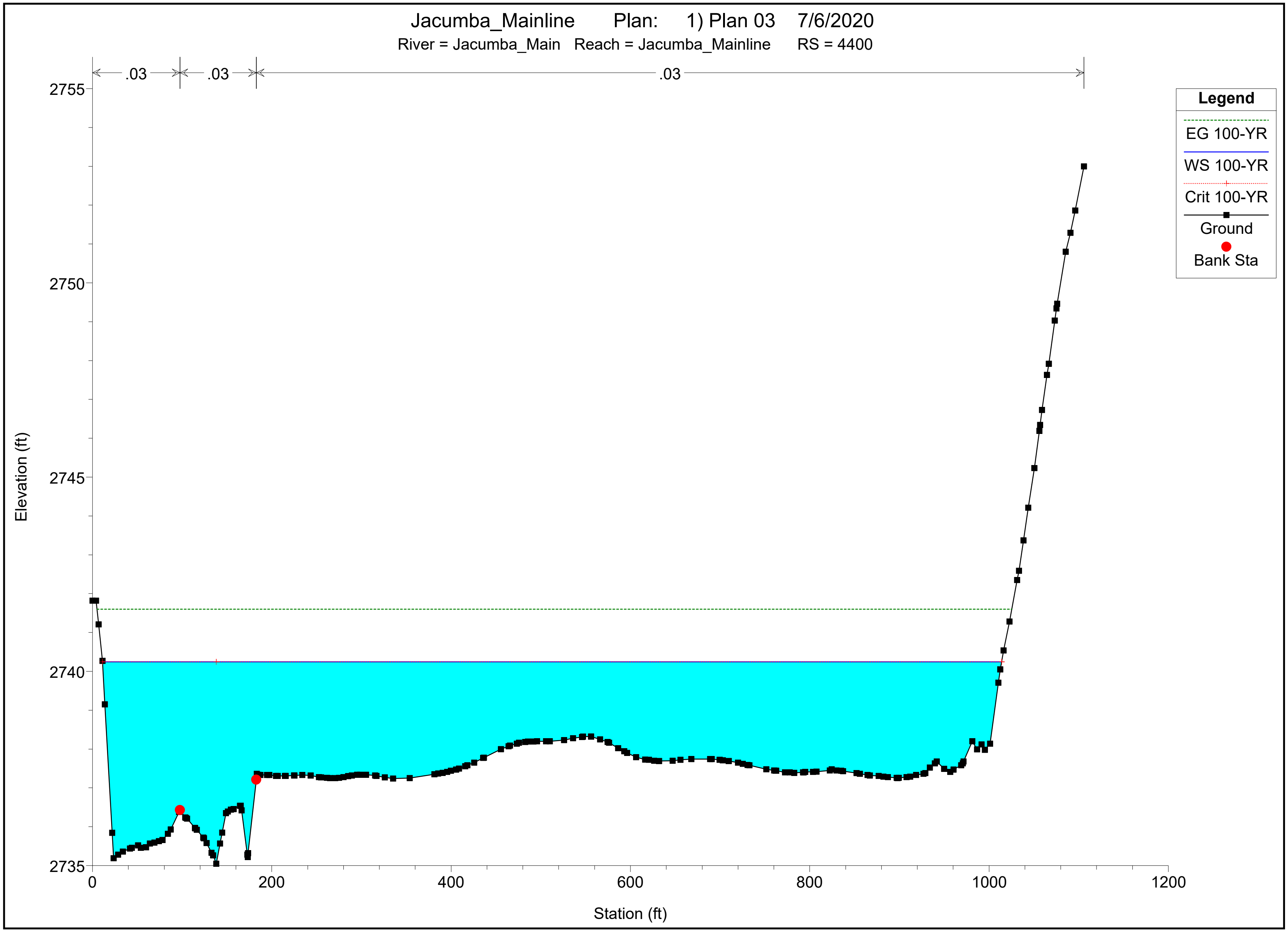
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 5600
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2770
2765
2760
2755
2750
2745
2740
0
200
400
600
800
1000
1200
1400
1600
Station (ft)



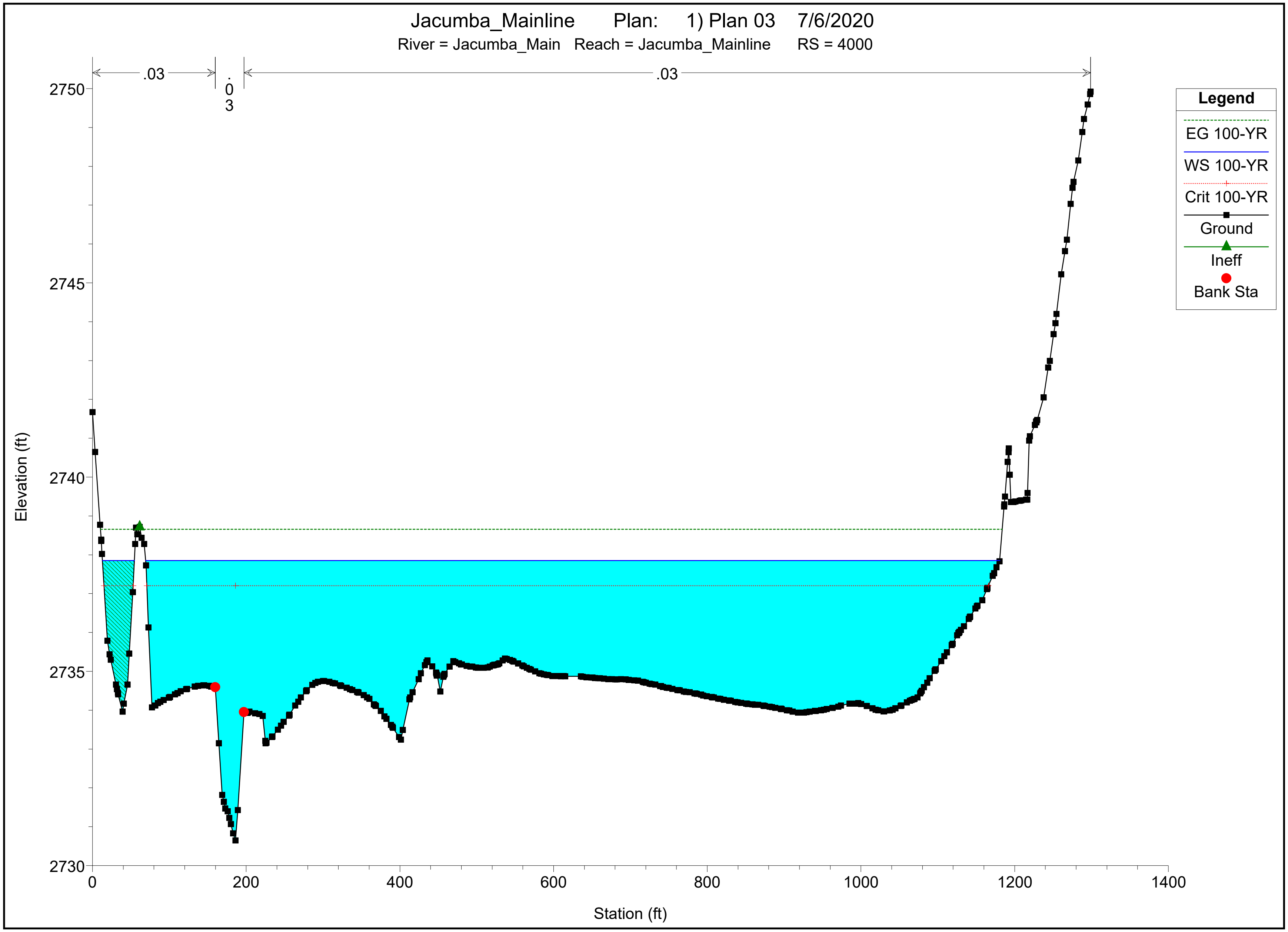
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 5200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2765
2760
2755
2750
2745
2740
2735
0
200
400
600
800
1000
1200
1400
1600
Station (ft)

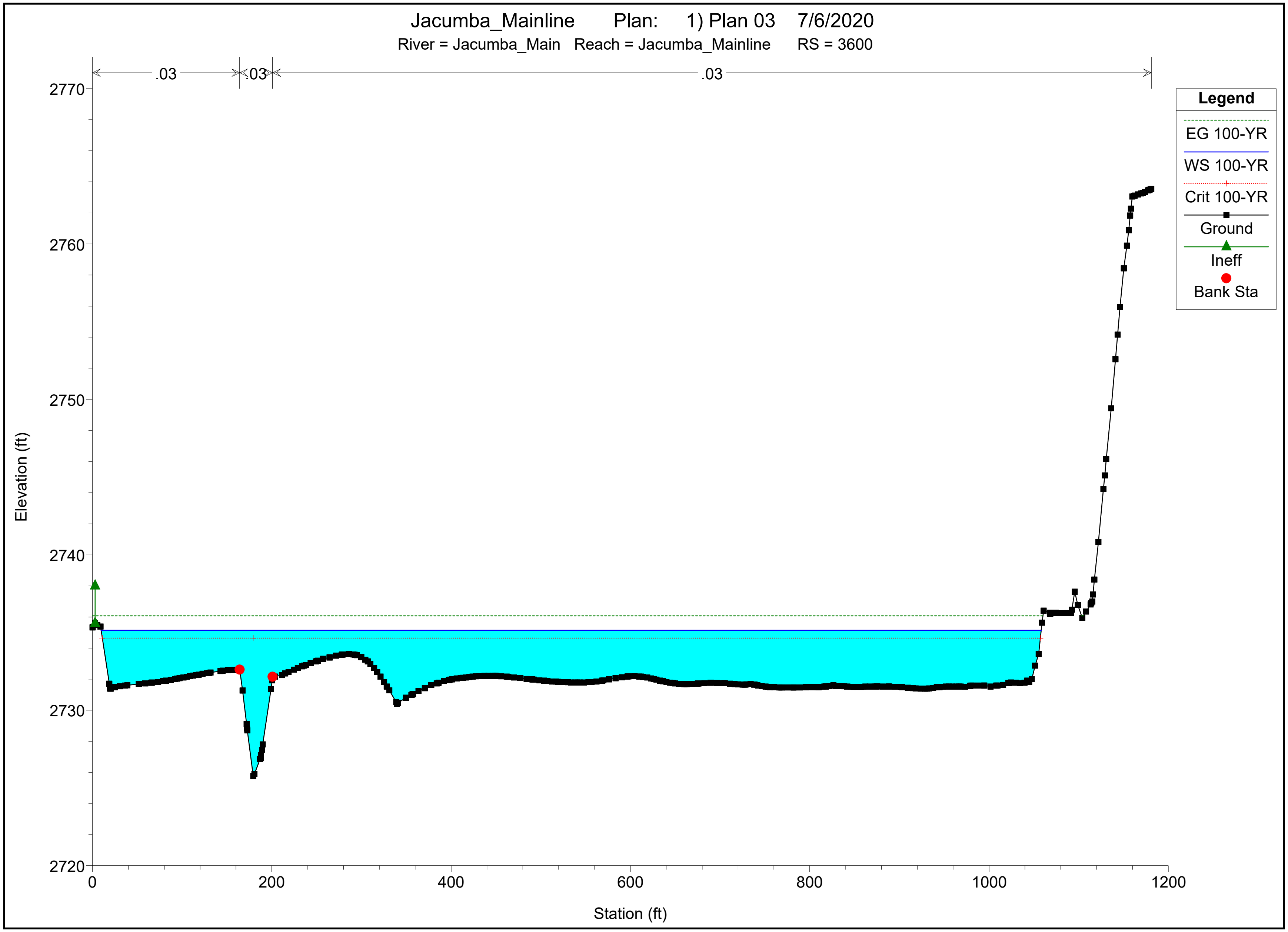


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 4800
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2765
2760
2755
2750
2745
2740
2735
0
200
400
600
800
1000
1200
1400
1600
Station (ft)

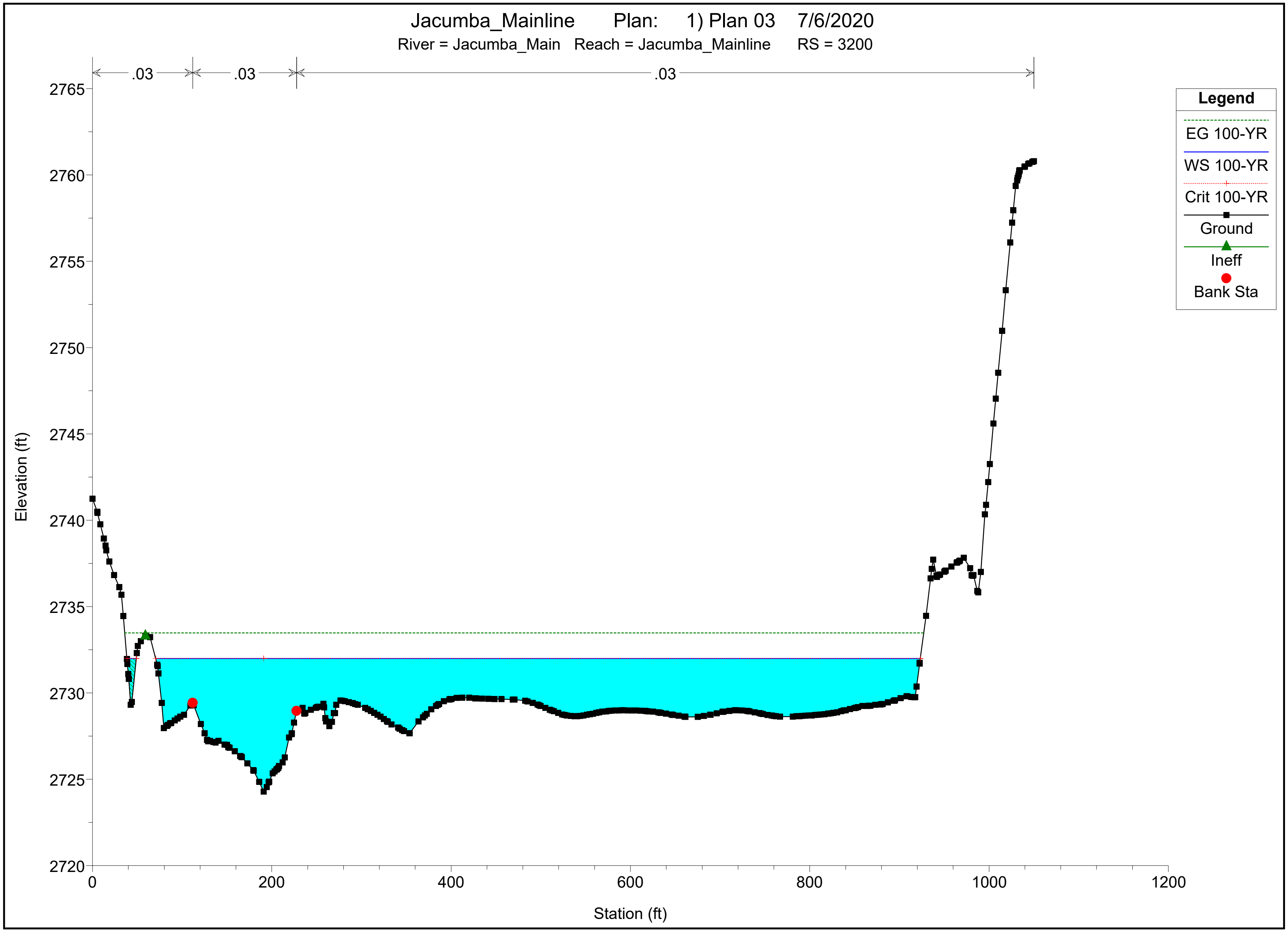


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 4400
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2755
2750
2745
2740
2735
0
200
400
600
800
1000
1200
Station (ft)

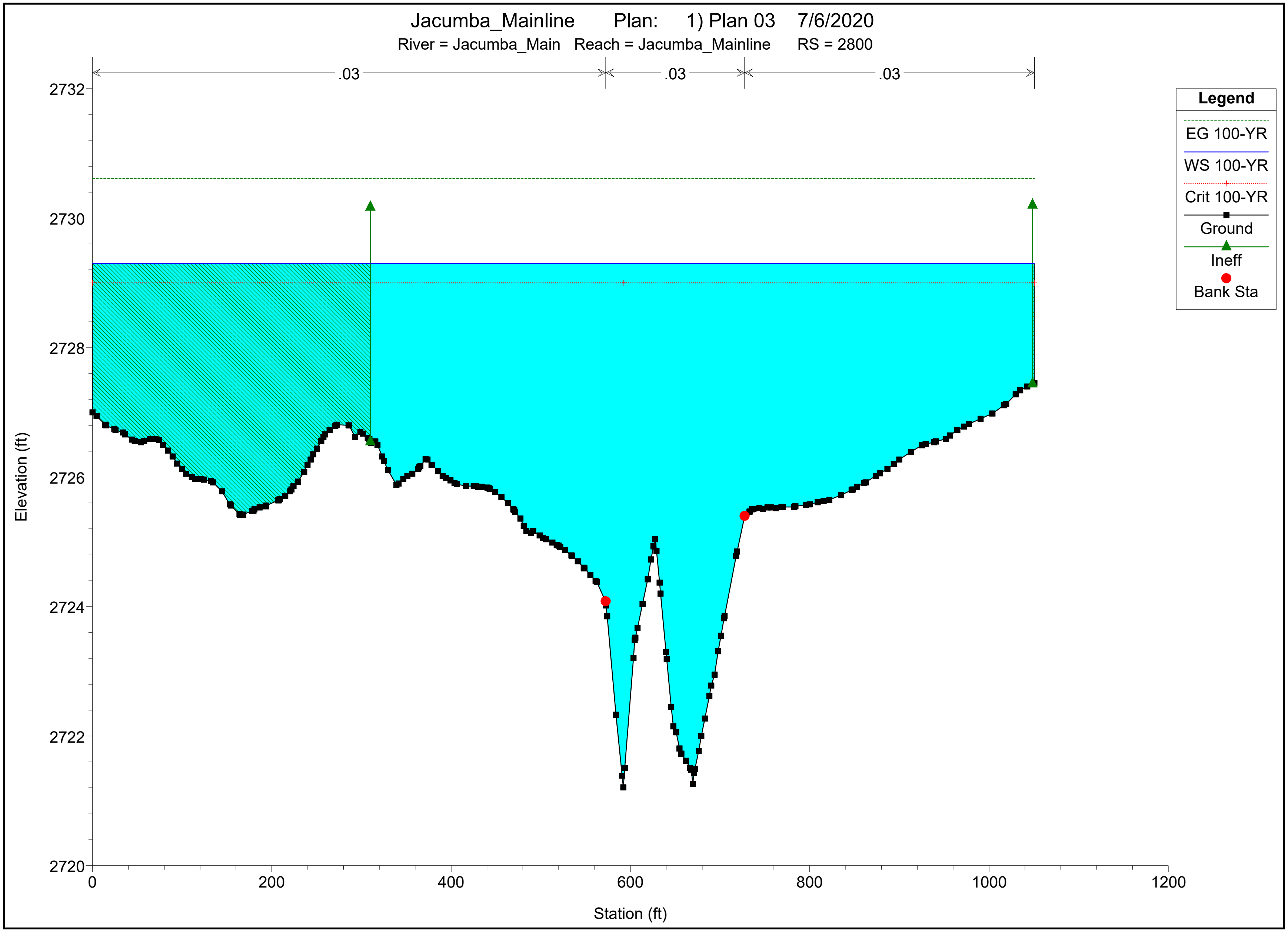

Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 4000
.03
.
0
3
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2750
2745
2740
2735
2730
0
200
400
600
800
1000
1200
1400
Station (ft)

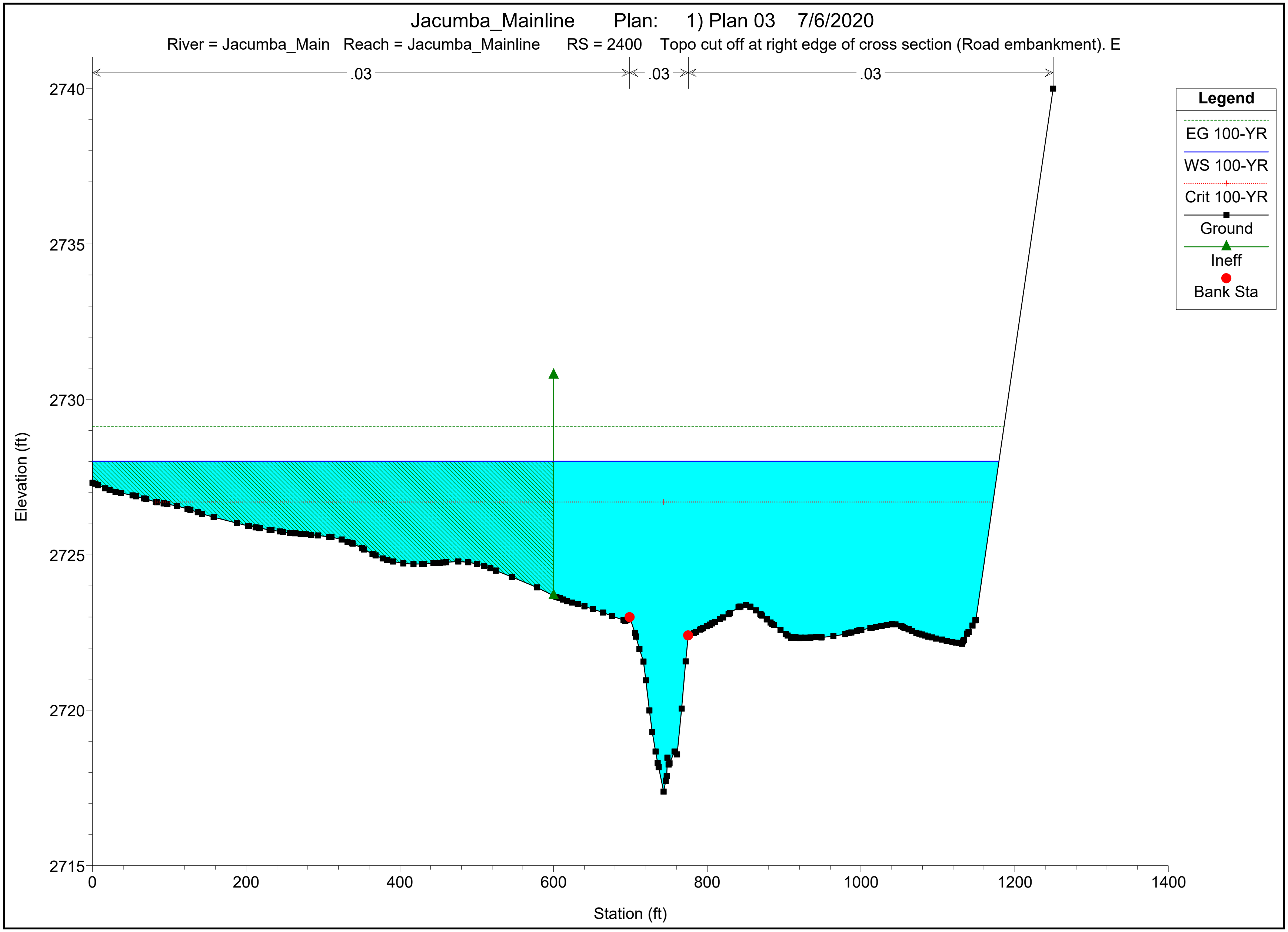


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 3600
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2770
2760
2750
2740
2730
2720
0
200
400
600
800
1000
1200
Station (ft)

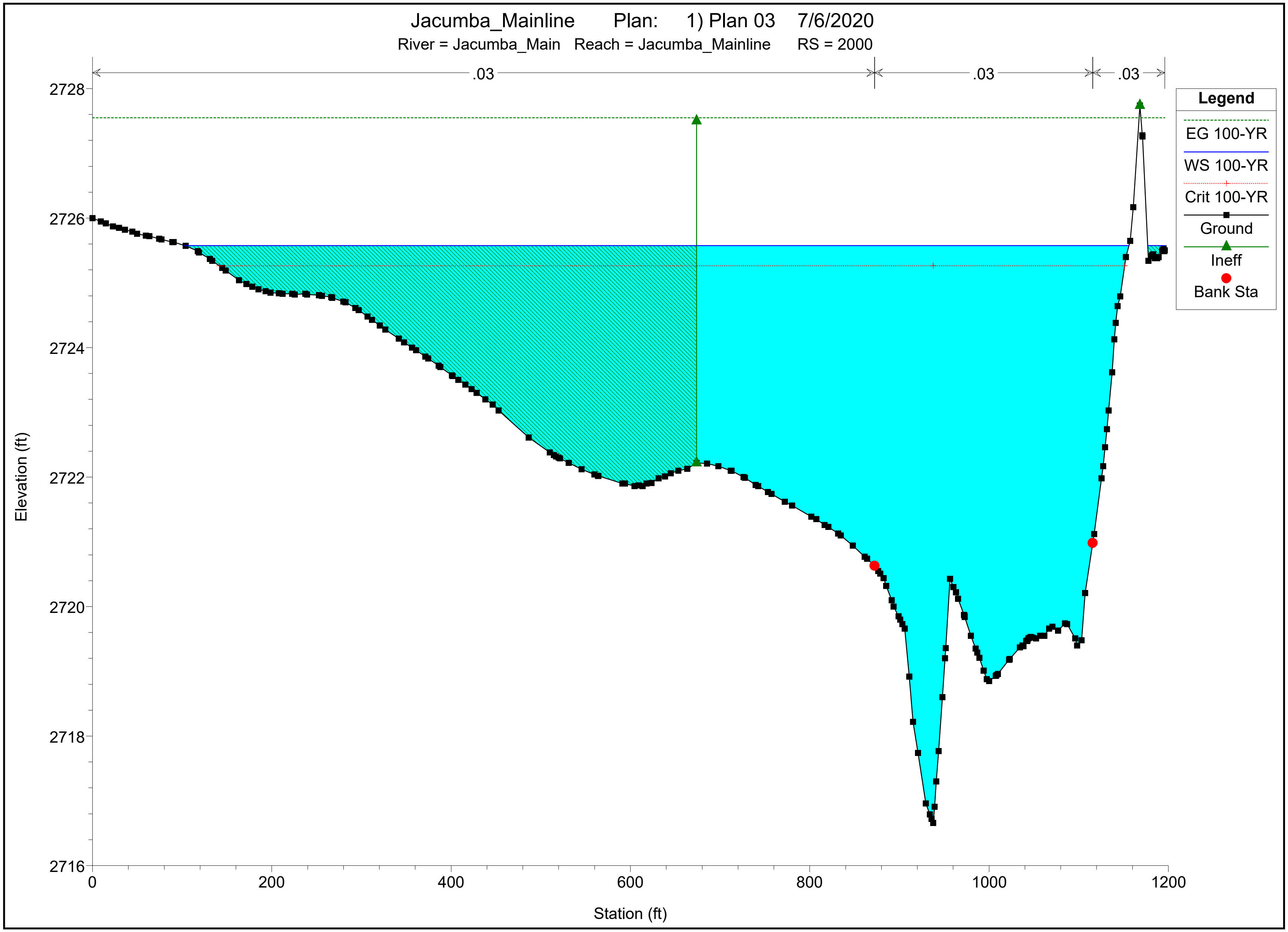


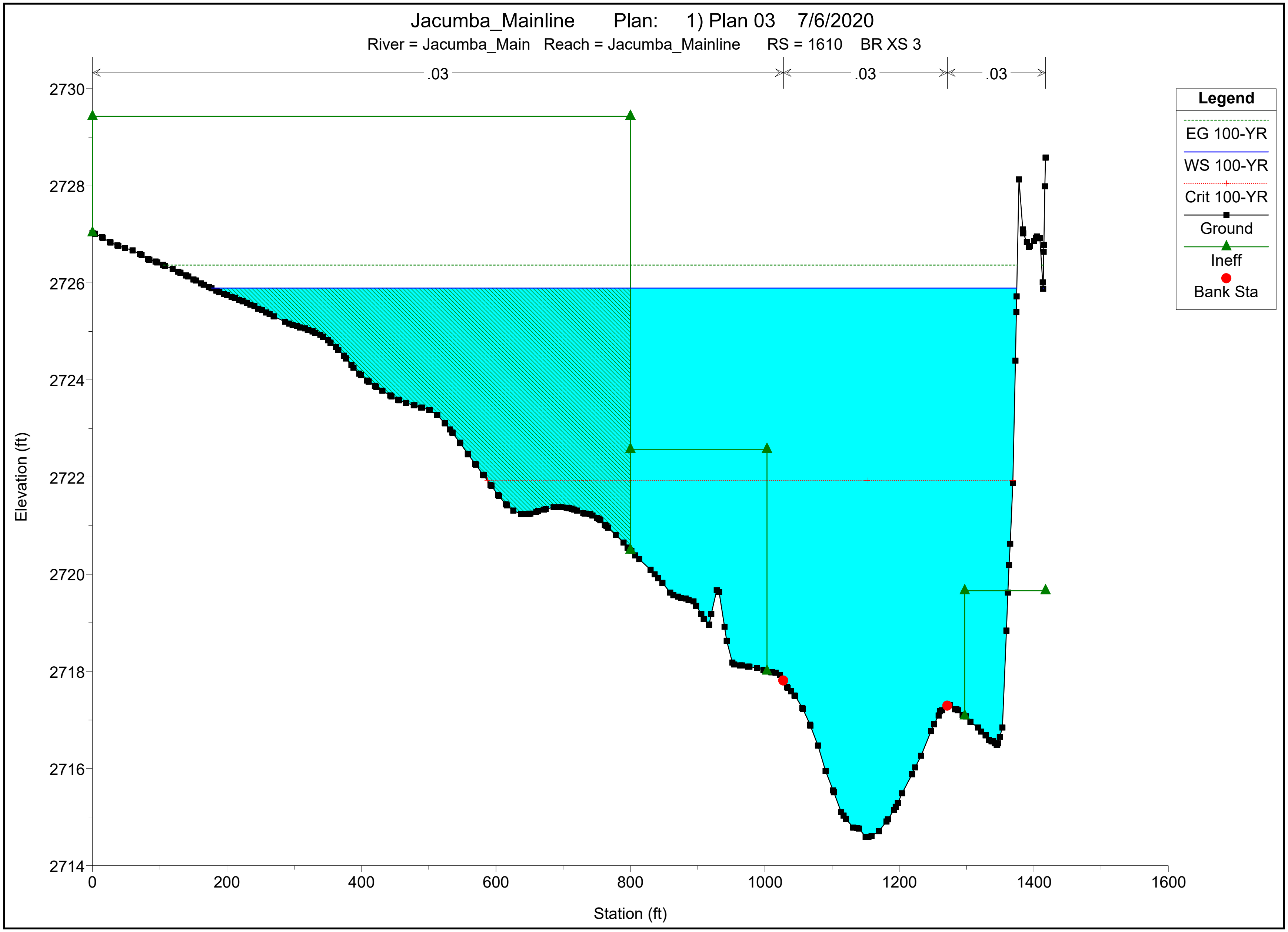
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 3200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2765
2760
2755
2750
2745
2740
2735
2730
2725
2720
0
200
400
600
800
1000
1200

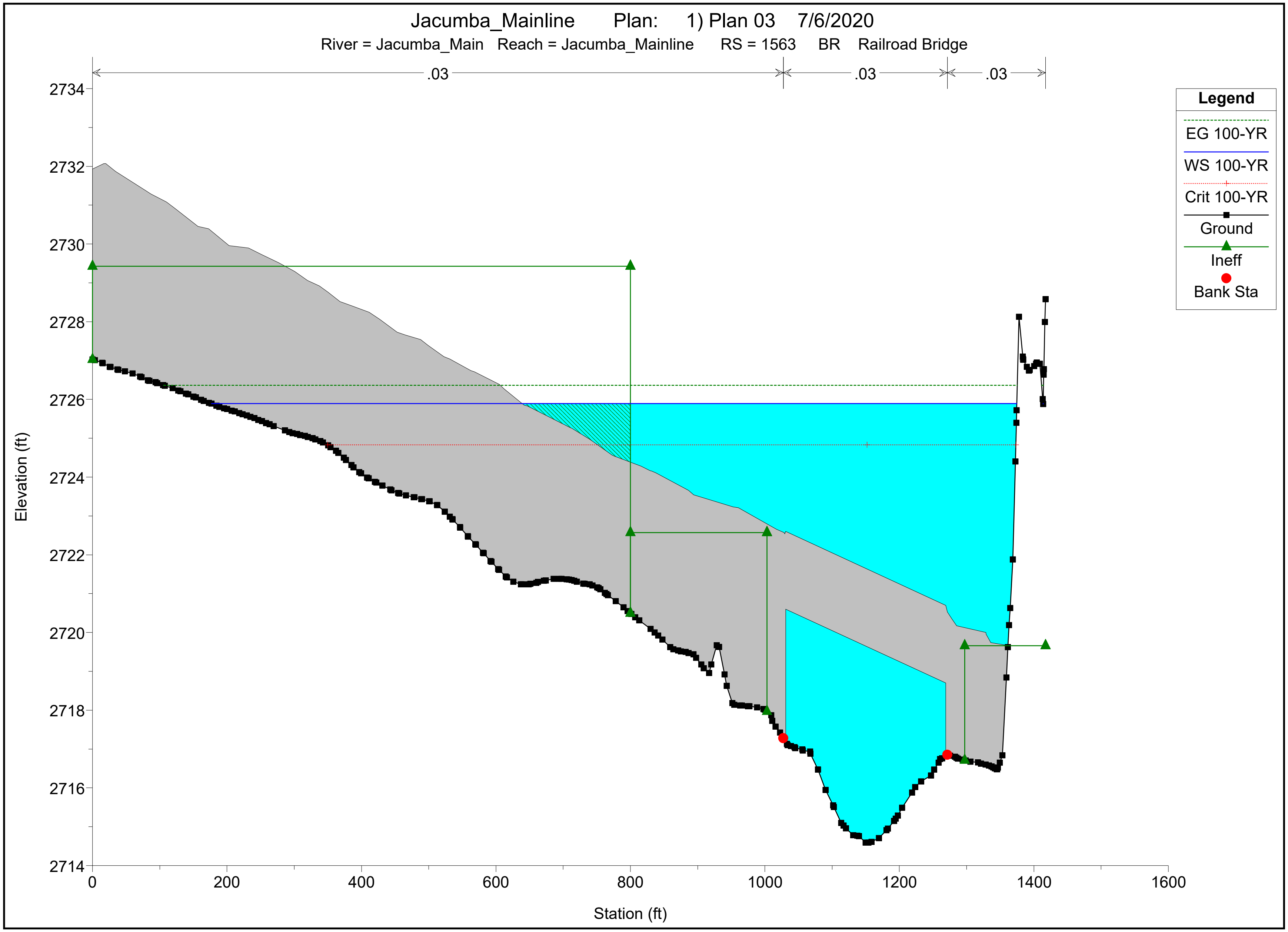

Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 2800
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2732
2730
2728
2726
2724
2722
2720
0
200
400
600
800
1000
1200
Station (ft)



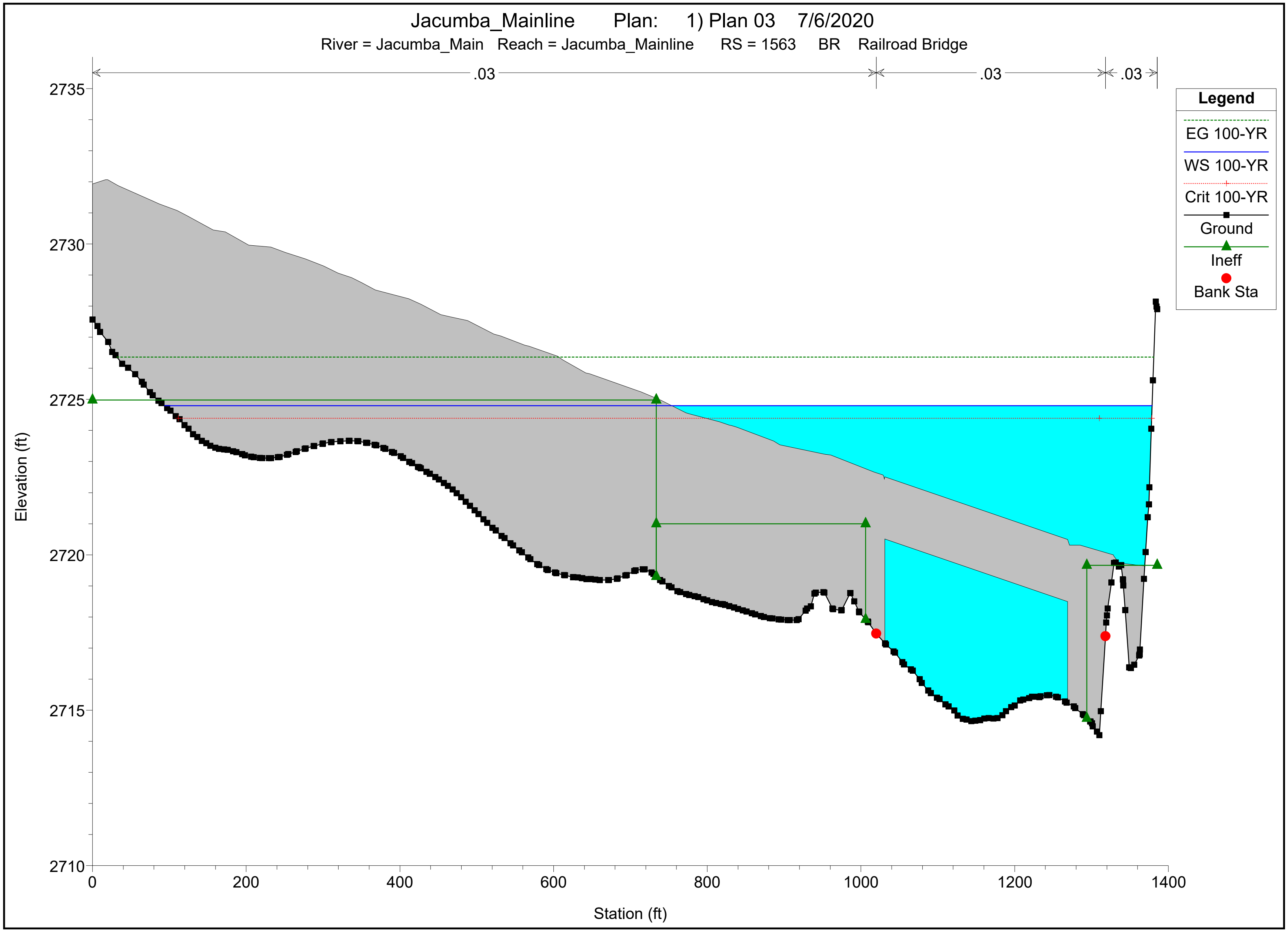
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 2400 Topo cut off at right edge of cross section (Road embankment). E
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2740
2735
2730
2725
2720
2715
0
200
400
600
800
1000
1200
1400
Station (ft)


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 2000
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2728
2726
2724
2722
2720
2718
2716
0
200
400
600
800
1000
1200
Station (ft)

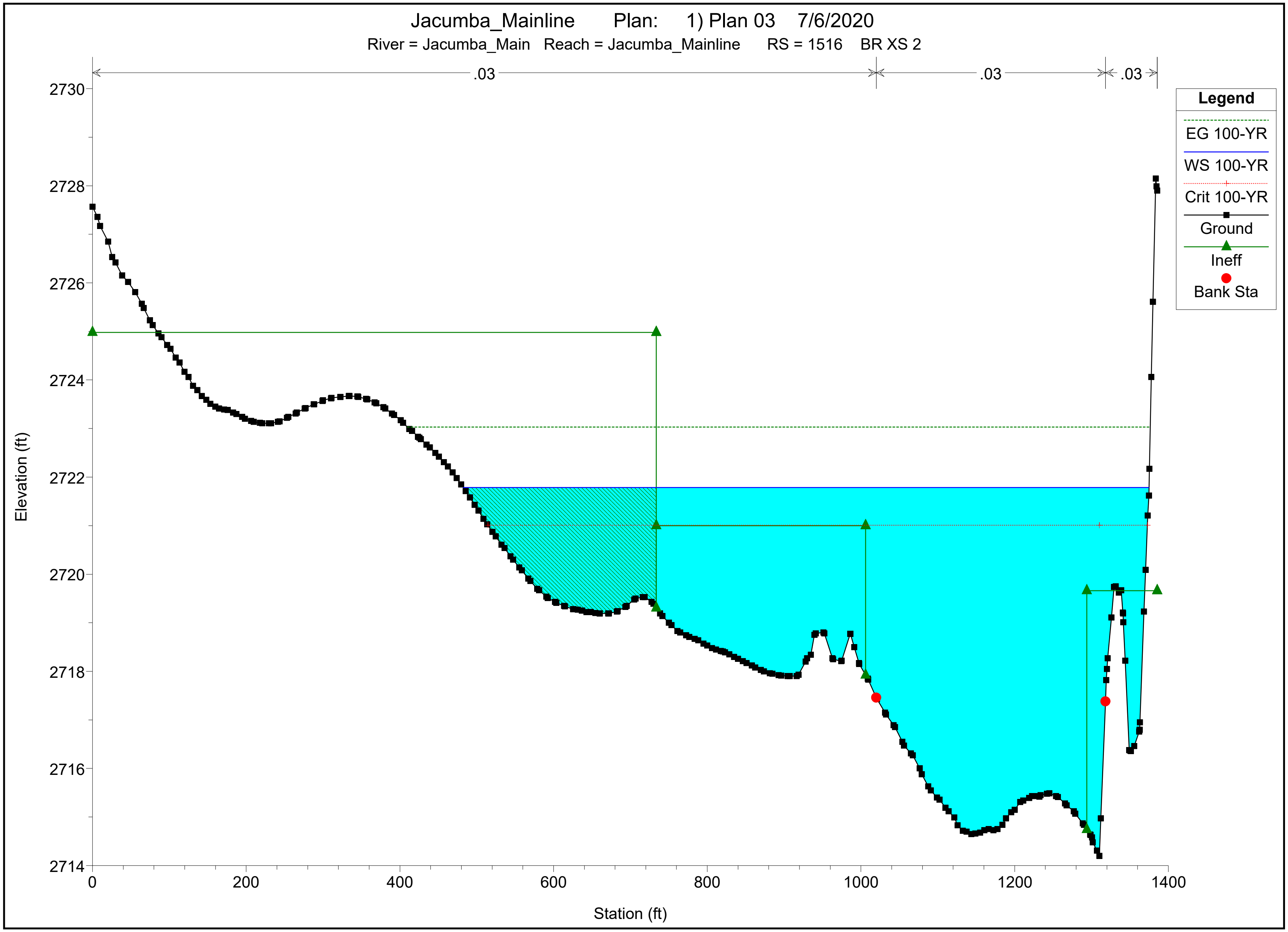

Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1610 BR XS 3
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2730
2728
2726
2724
2722
2720
2718
2716
2714
0
200
400
600
800
1000
1200
1400
1600
Station (ft)



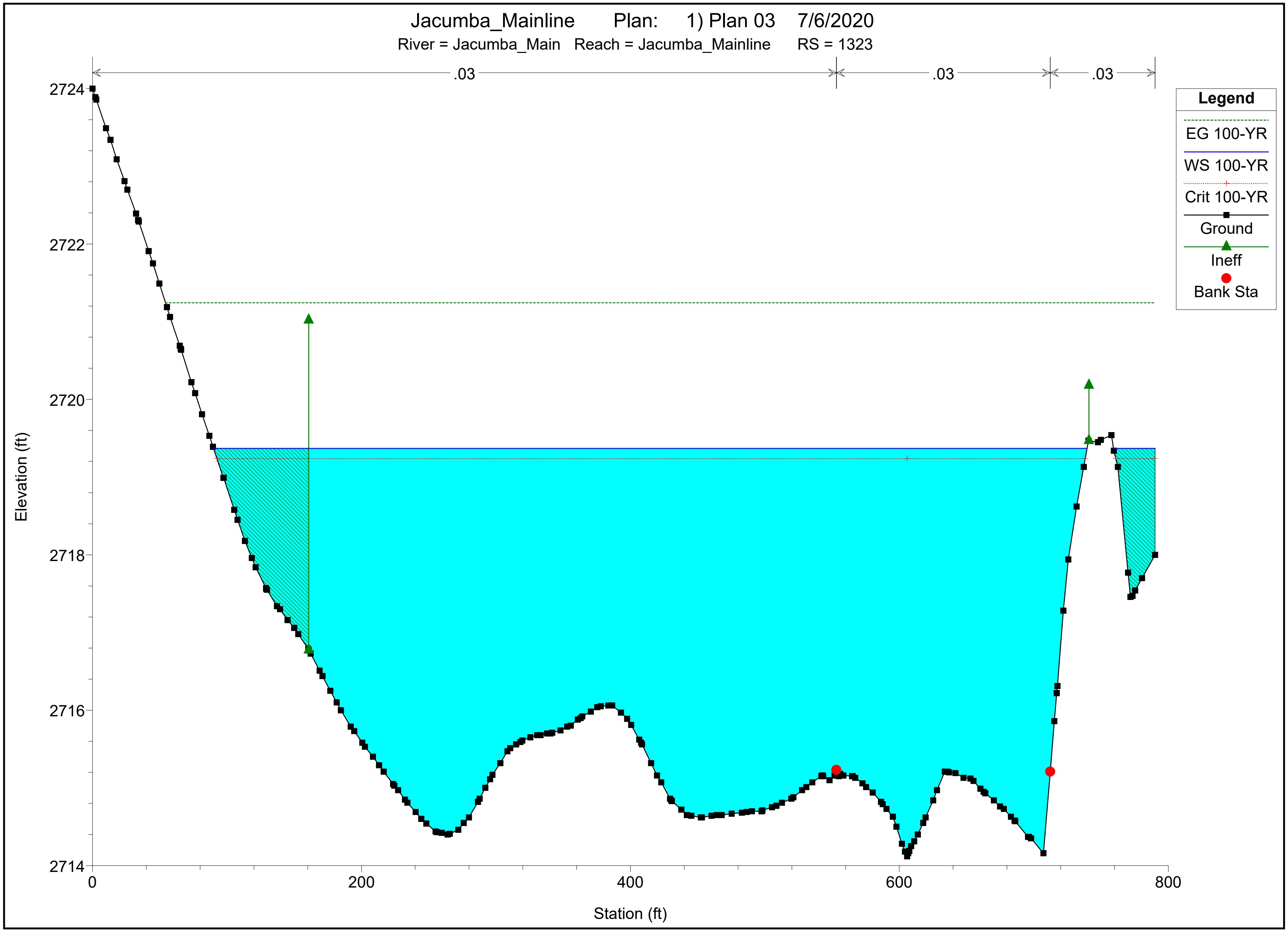
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1563 BR Railroad Bridge
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2734
2732
2730
2728
2726
2724
2722
2720
2718
2716
2714
0
200
400
600
800
1000
1200
1400
1600
Station (ft)

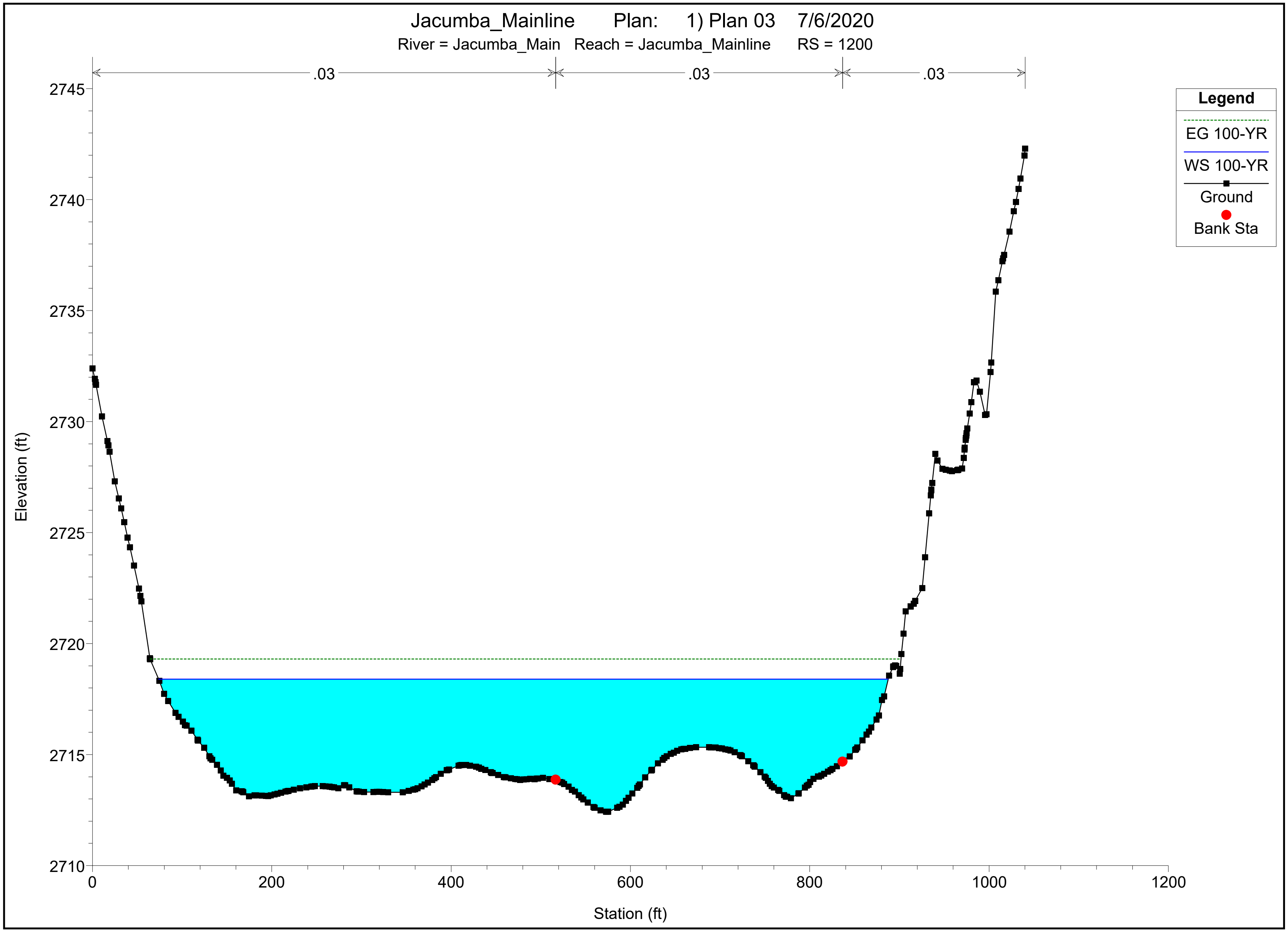


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1563 BR Railroad Bridge
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2735
2730
2725
2720
2715
2710
0
200
400
600
800
1000
1200
1400
Station (ft)

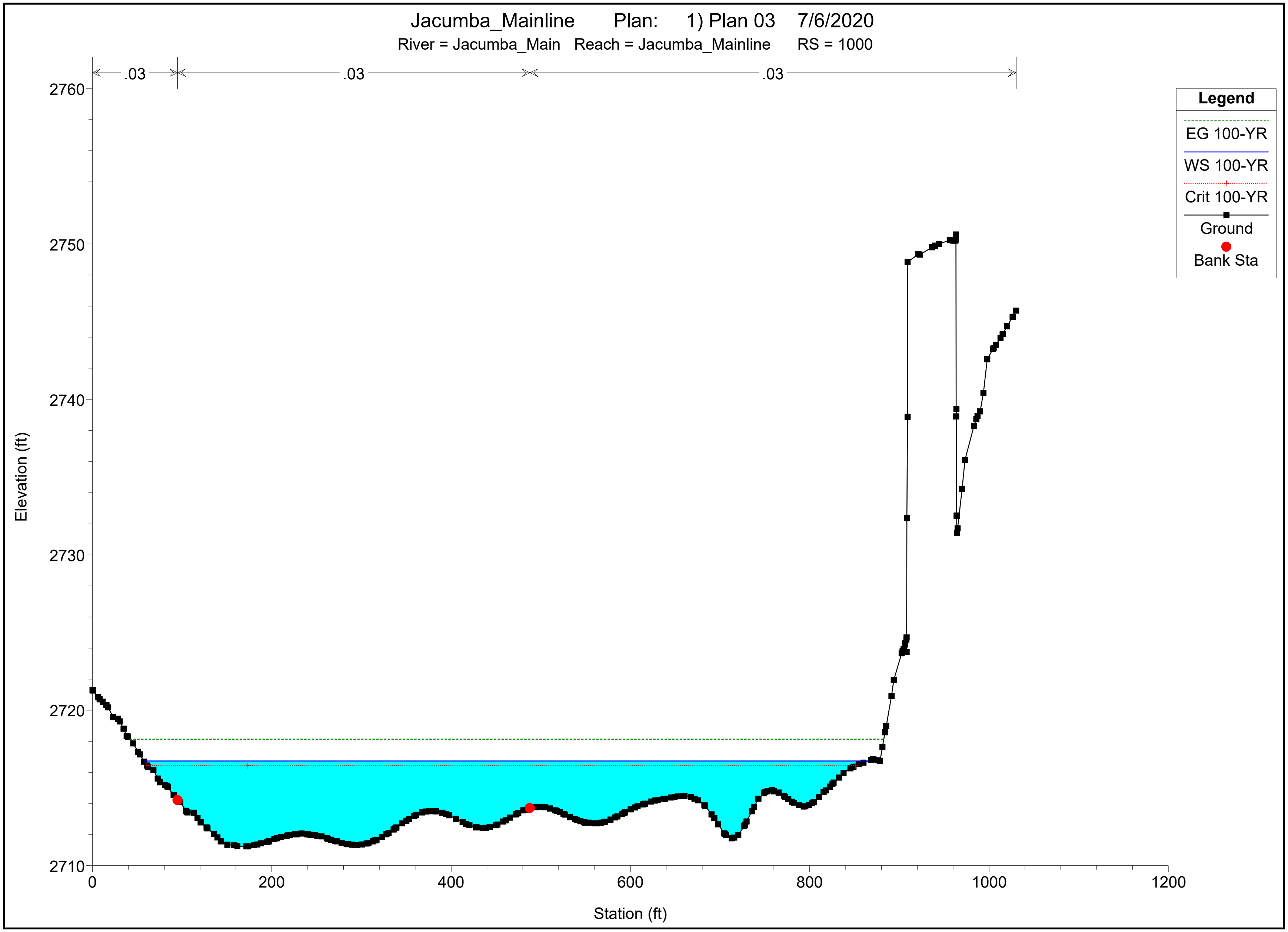


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1516 BR XS 2
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2730
2728
2726
2724
2722
2720
2718
2716
2714
0
200
400
600
800
1000
1200
1400


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1323
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2724
2722
2720
2718
2716
2714
0
200
400
600
800
Station (ft)



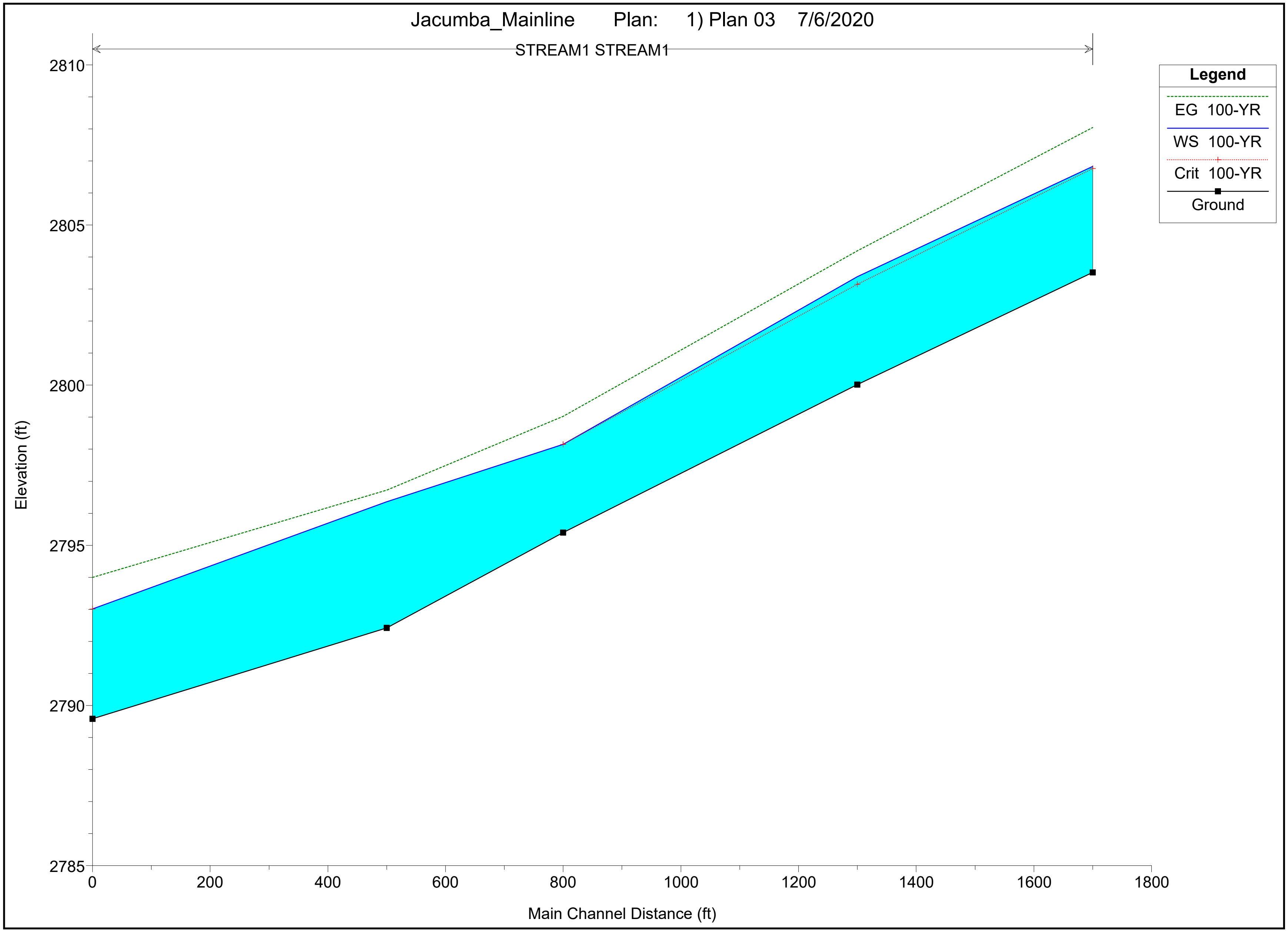
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2745
2740
2735
2730
2725
2720
2715
2710
0
200
400
600
800
1000
1200
Station (ft)

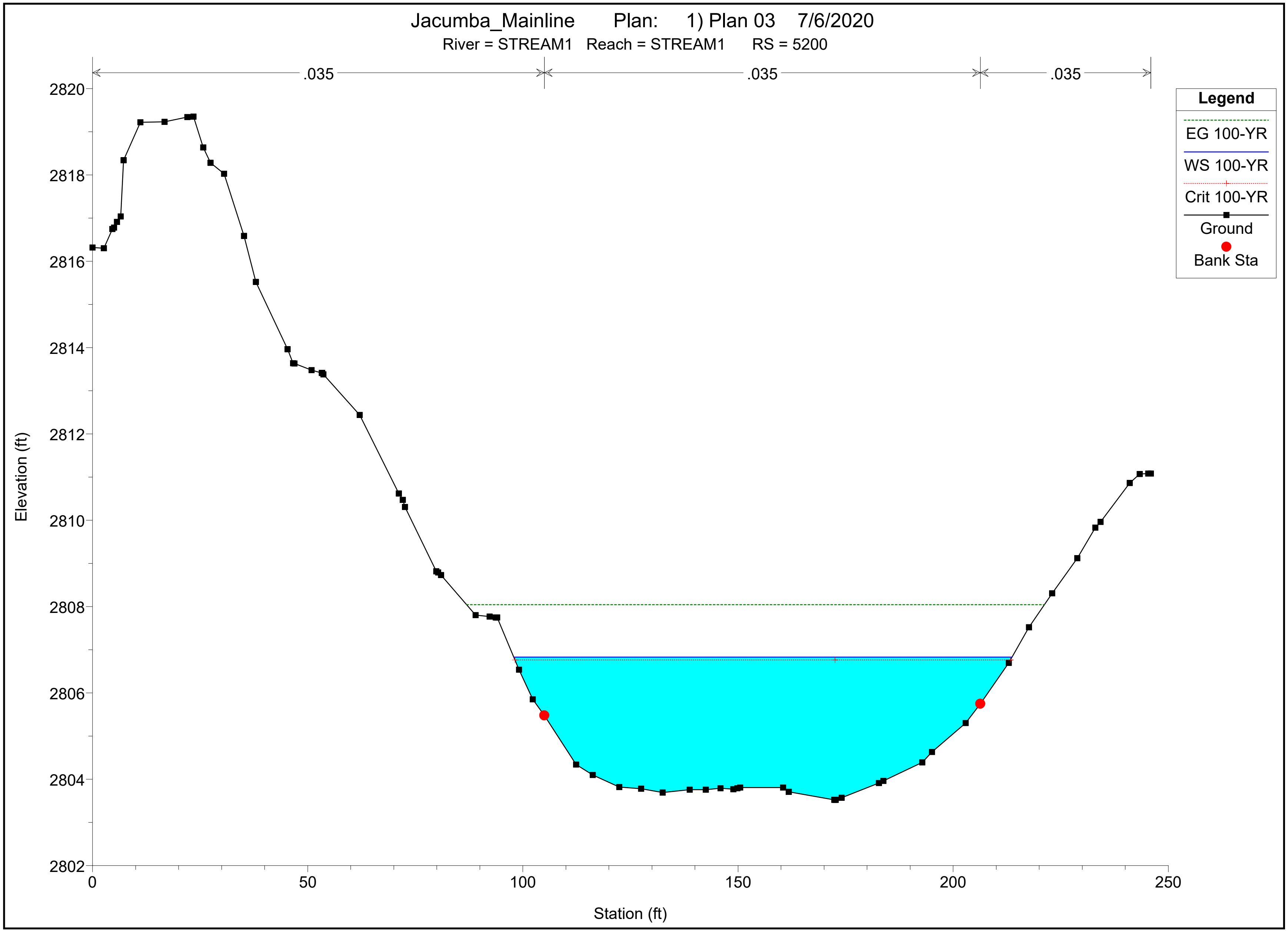


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1000
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2760
2750
2740
2730
2720
2710
0
200
400
600
800
1000
1200
Station (ft)

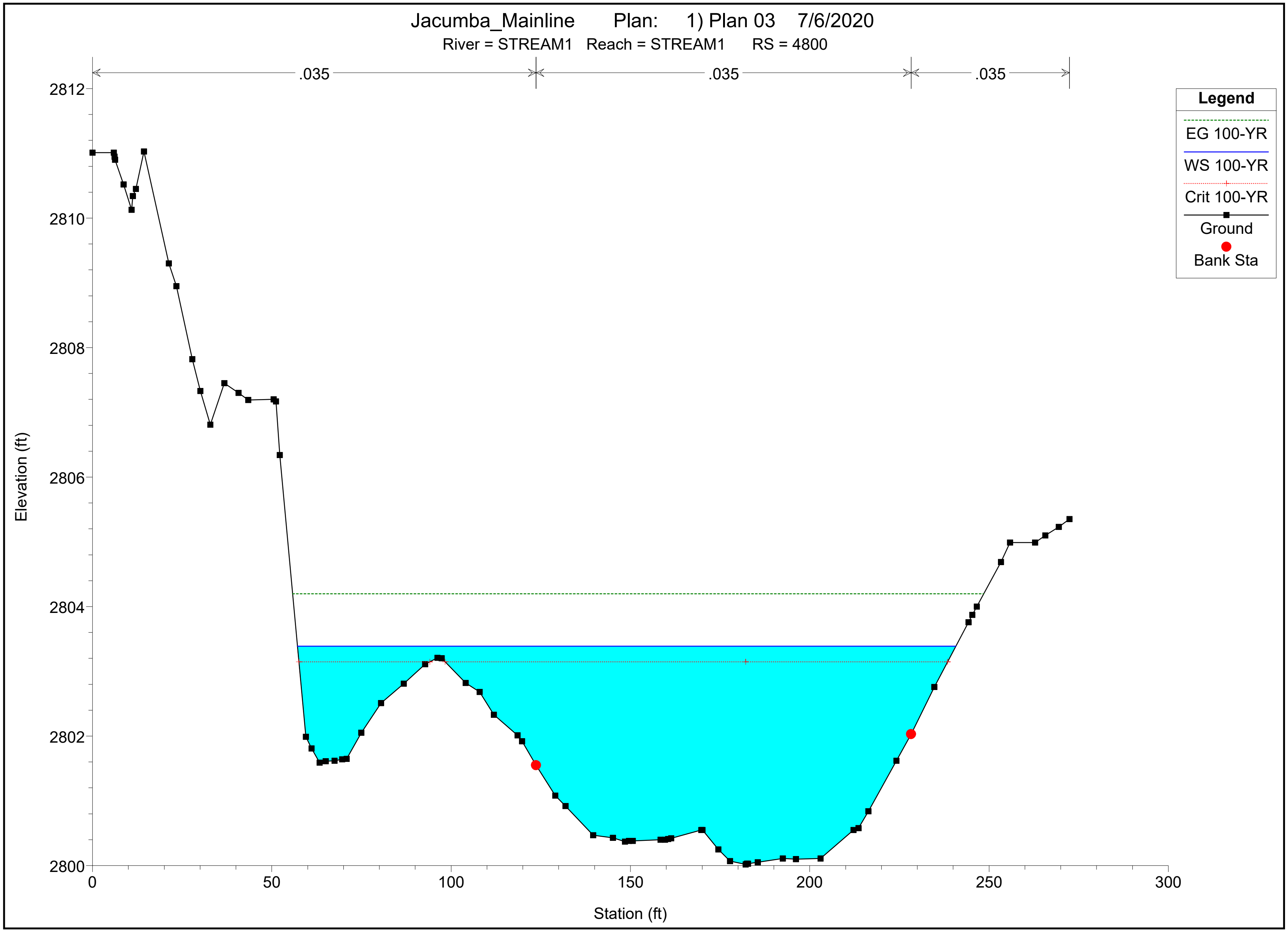
HEC-RAS Plan: Plan 03 River: STREAM1 Reach: STREAM1 Profile: 100-YR

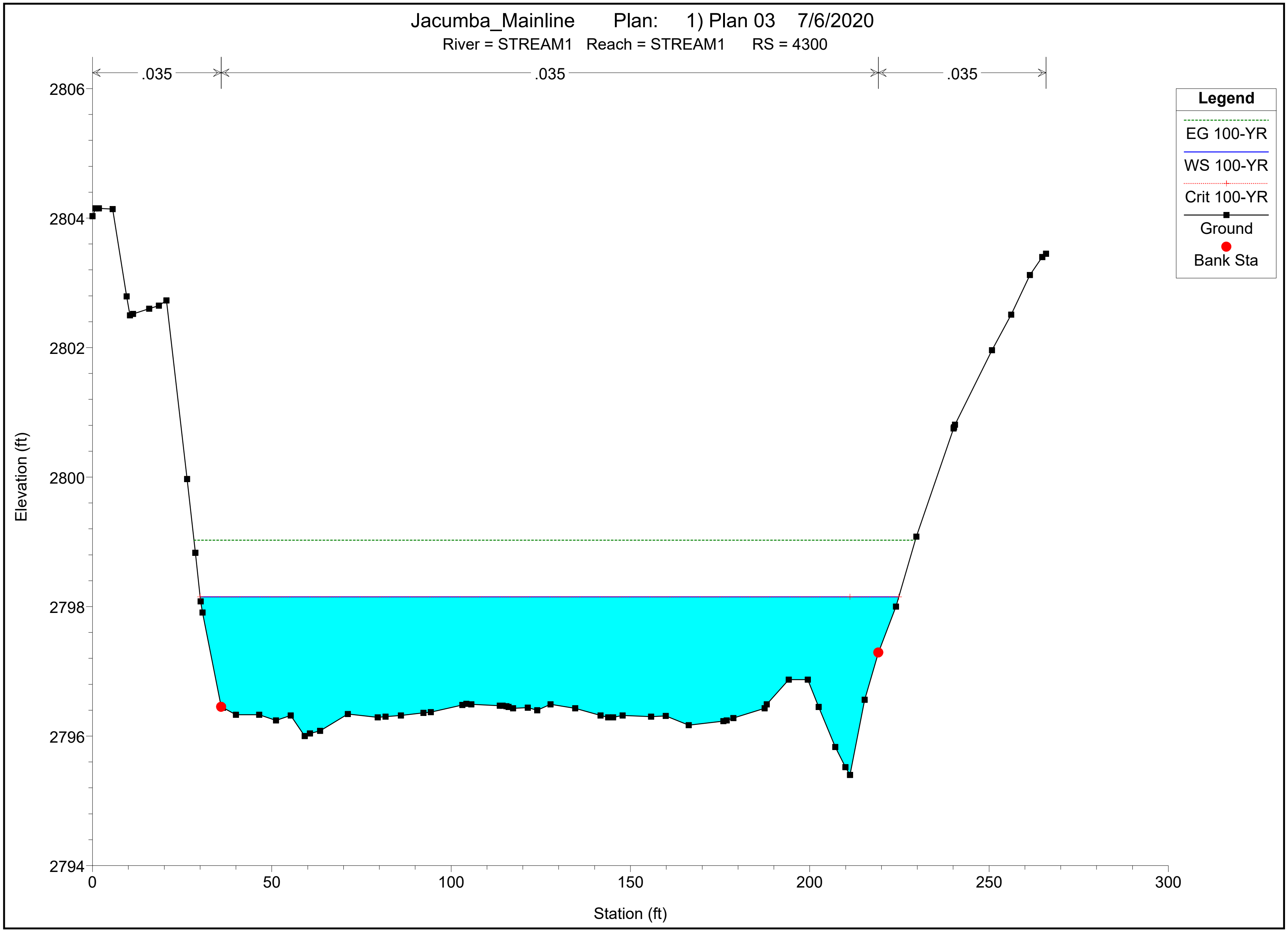
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
STREAM1	5200	100-YR	2522.00	2803.52	2806.83	2806.76	2808.05	0.011367	8.90	289.20	115.74	0.94
STREAM1	4800	100-YR	2522.00	2800.02	2803.39	2803.15	2804.20	0.007777	7.53	373.62	183.60	0.79
STREAM1	4300	100-YR	2522.00	2795.40	2798.15	2798.15	2799.03	0.014392	7.54	338.22	194.85	0.99
STREAM1	4000	100-YR	2522.00	2792.42	2796.36		2796.72	0.002883	5.26	551.44	210.95	0.49
STREAM1	3500	100-YR	2522.00	2789.58	2793.01	2793.01	2794.00	0.012950	8.08	322.62	164.04	0.97


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
STREAM1 STREAM1
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Elevation (ft)
2810
2805
2800
2795
2790
2785
0
200
400
600
800
1000
1200
1400
1600
1800
Main Channel Distance (ft)

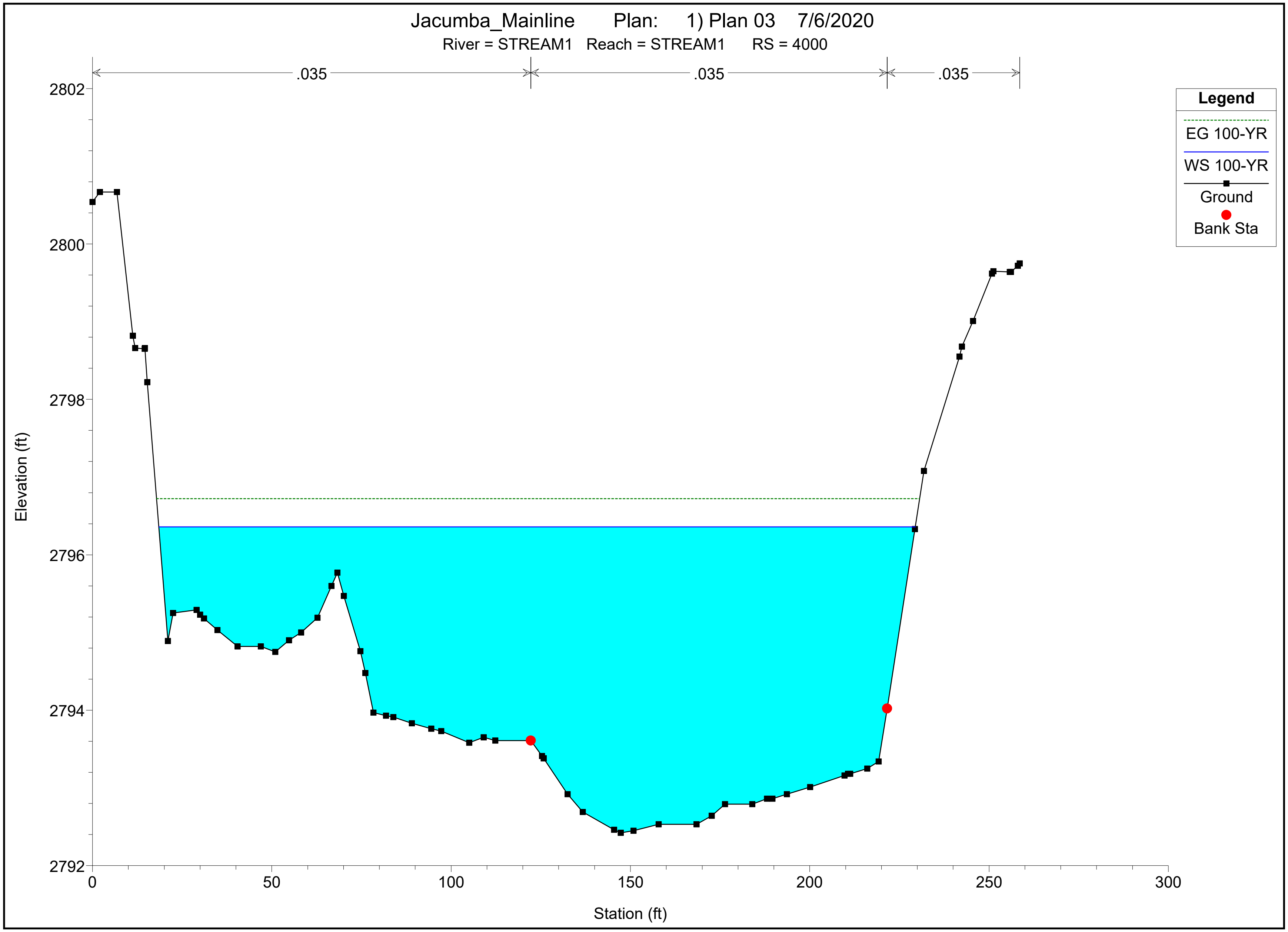


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM1 Reach = STREAM1 RS = 5200
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2820
2818
2816
2814
2812
2810
2808
2806
2804
2802
0
50
100
150
200
250
Station (ft)

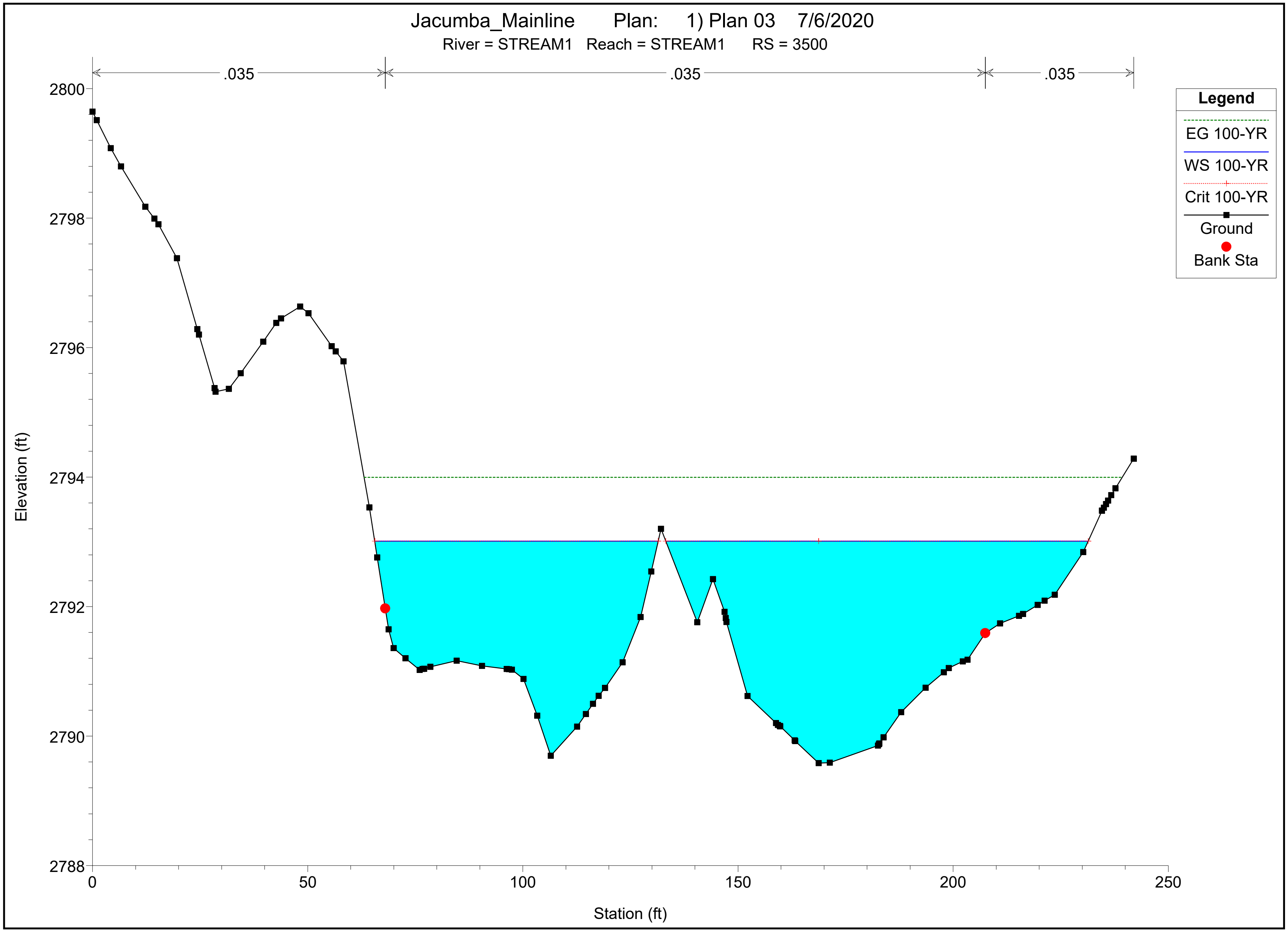

Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM1 Reach = STREAM1 RS = 4800
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2812
2810
2808
2806
2804
2802
2800
0
50
100
150
200
250
300
Station (ft)



Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM1 Reach = STREAM1 RS = 4300
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2806
2804
2802
2800
2798
2796
2794
0
50
100
150
200
250
300
Station (ft)

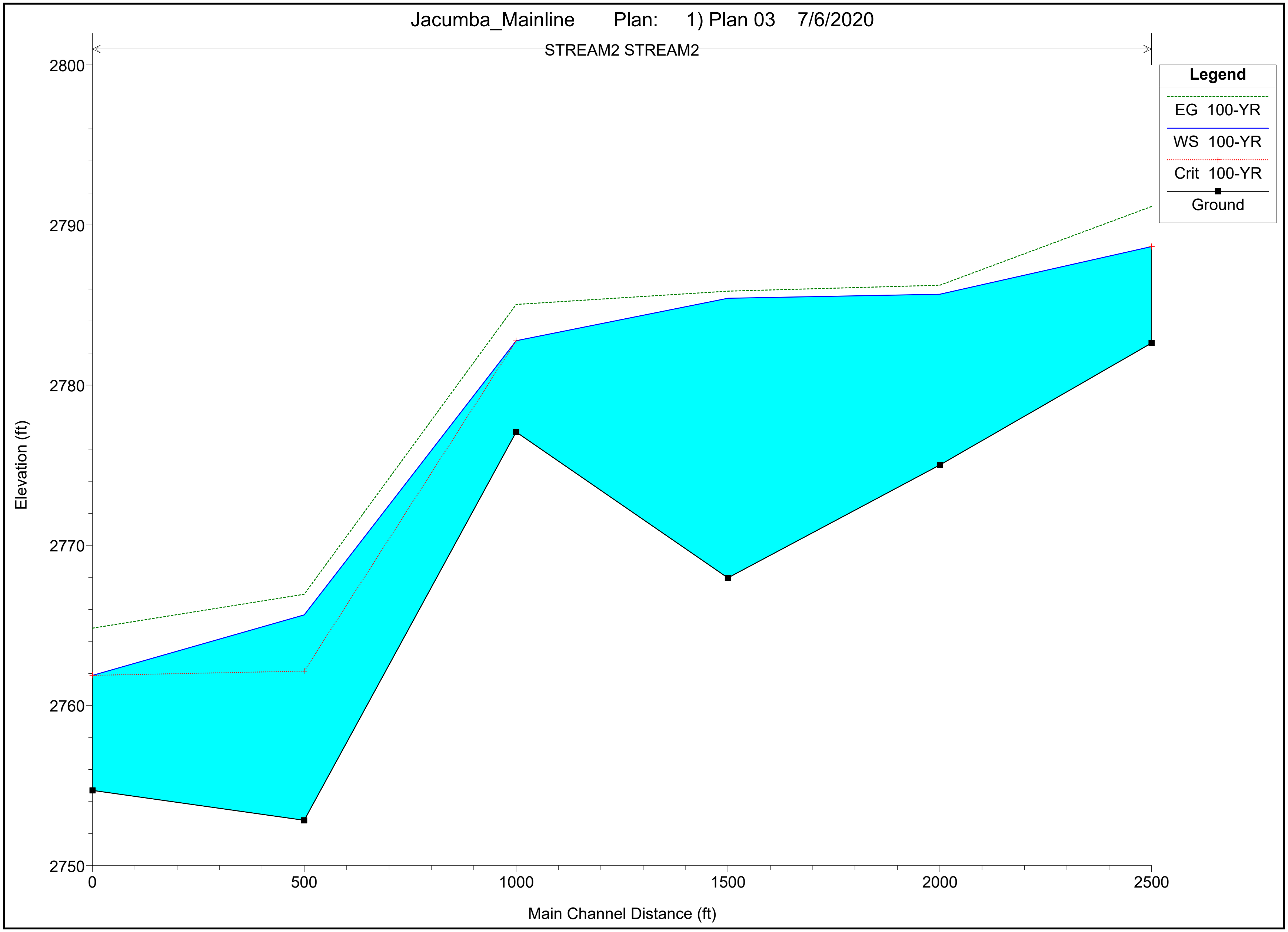


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM1 Reach = STREAM1 RS = 4000
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2802
2800
2798
2796
2794
2792
0
50
100
150
200
250
300
Station (ft)

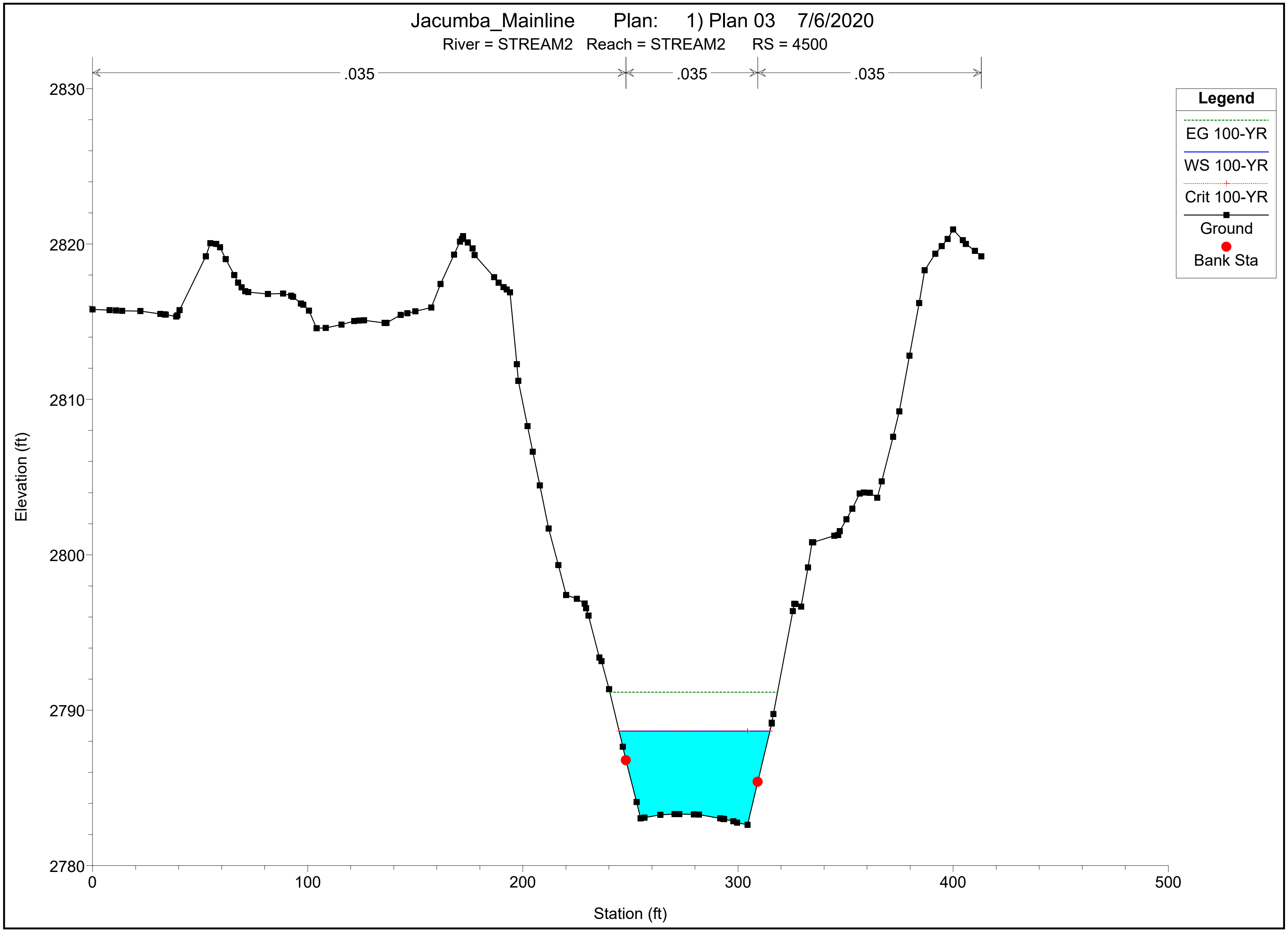

Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM1 Reach = STREAM1 RS = 3500
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
2800
2798
2796
2794
2792
2790
2788
Elevation (ft)
0
50
100
150
200
250
Station (ft)

HEC-RAS Plan: Plan 03 River: STREAM2 Reach: STREAM2 Profile: 100-YR

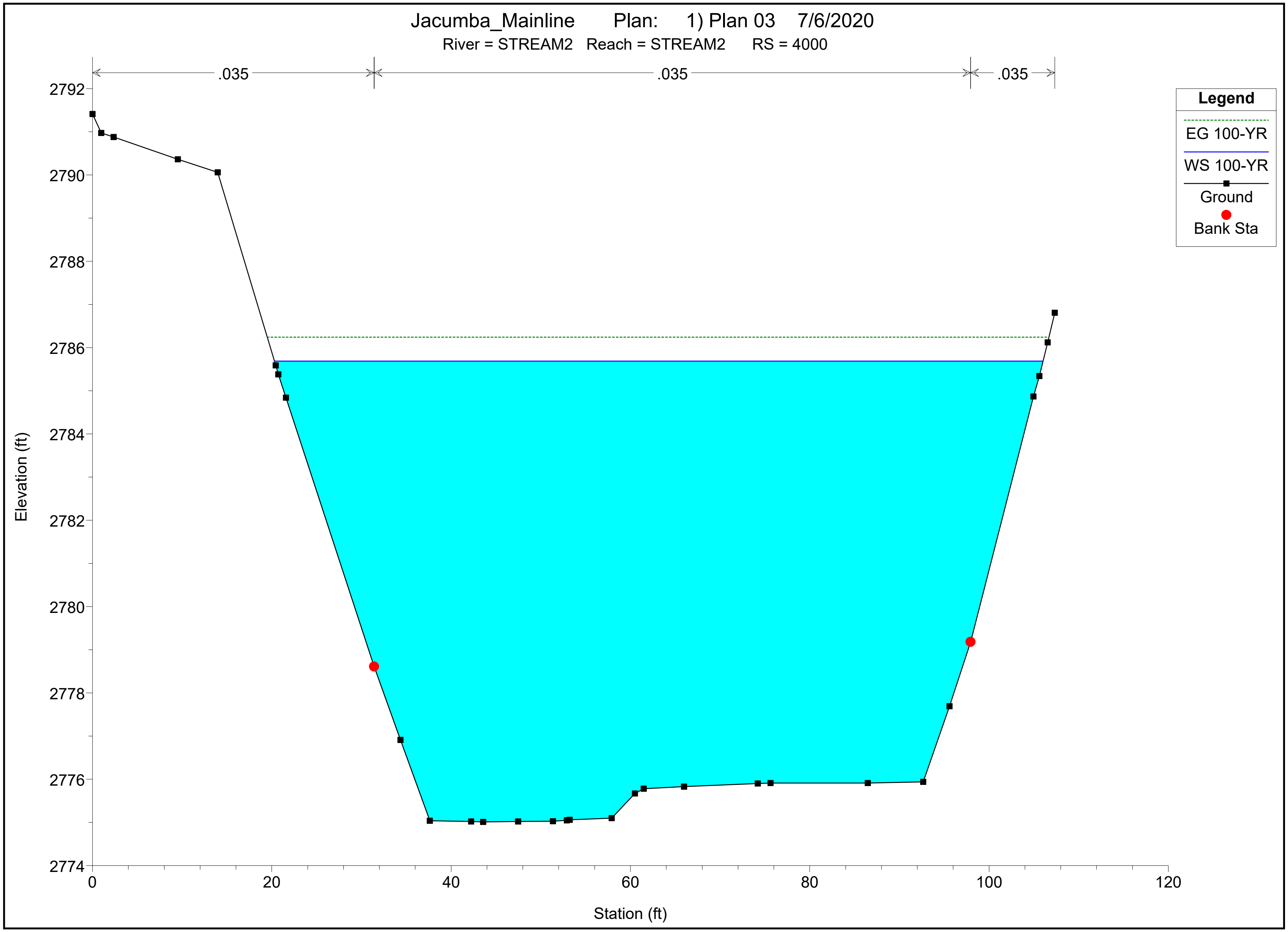
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
STREAM2	4500	100-YR	4181.00	2782.63	2788.66	2788.66	2791.16	0.010247	12.77	334.89	70.13	0.98
STREAM2	4000	100-YR	4181.00	2775.01	2785.68		2786.24	0.001016	6.10	721.55	85.73	0.34
STREAM2	3500	100-YR	4181.00	2767.97	2785.43		2785.87	0.000481	5.55	844.20	76.86	0.25
STREAM2	3000	100-YR	4181.00	2777.08	2782.77	2782.77	2785.04	0.010161	12.23	353.55	79.69	0.98
STREAM2	2500	100-YR	4181.00	2752.83	2765.65	2762.15	2766.94	0.002169	9.49	490.36	58.02	0.50
STREAM2	2000	100-YR	4181.00	2754.70	2761.88	2761.88	2764.82	0.008980	14.00	314.74	55.86	0.95



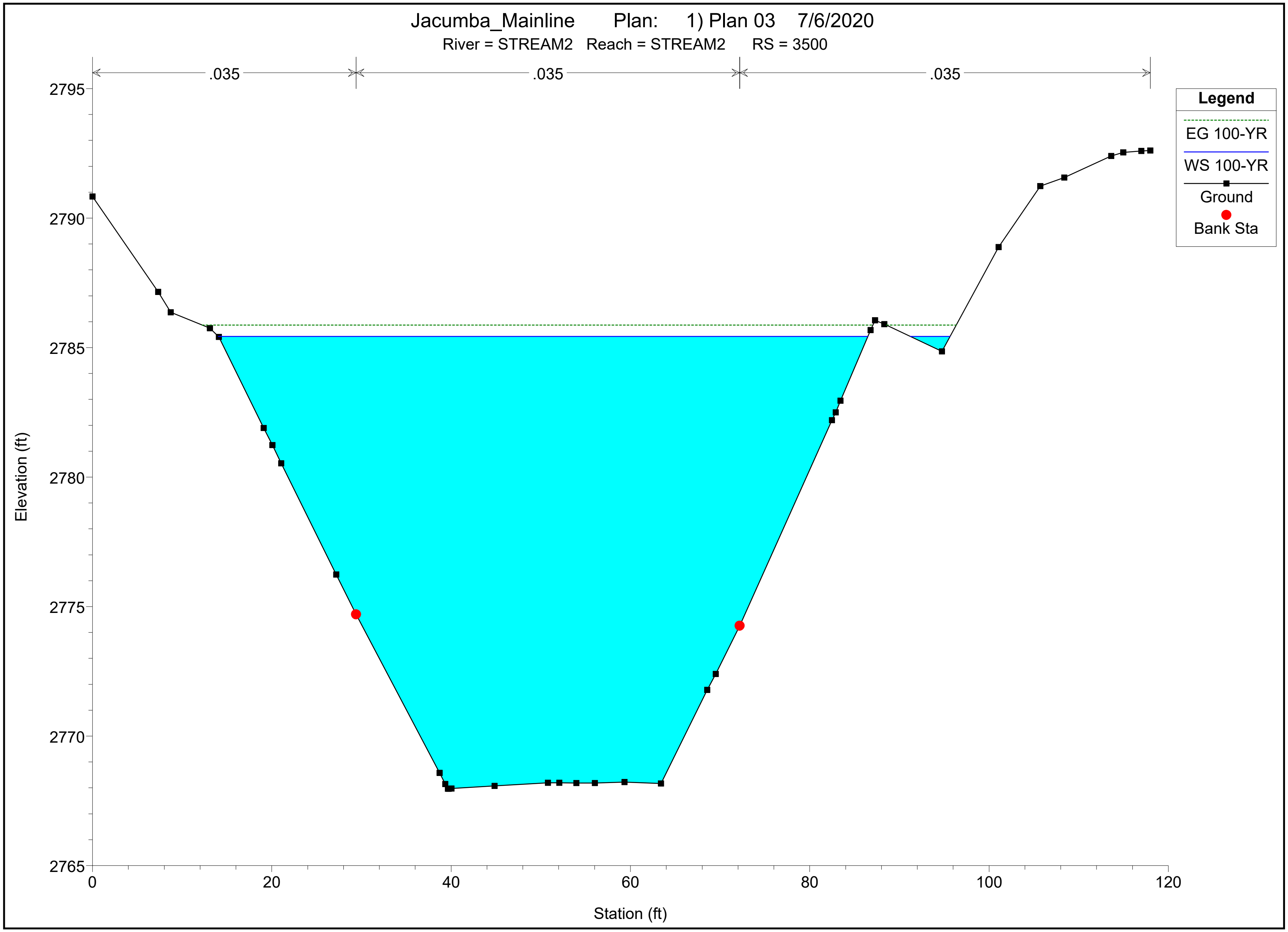
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
STREAM2 STREAM2
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Elevation (ft)
2800
2790
2780
2770
2760
2750
0
500
1000
1500
2000
2500
Main Channel Distance (ft)

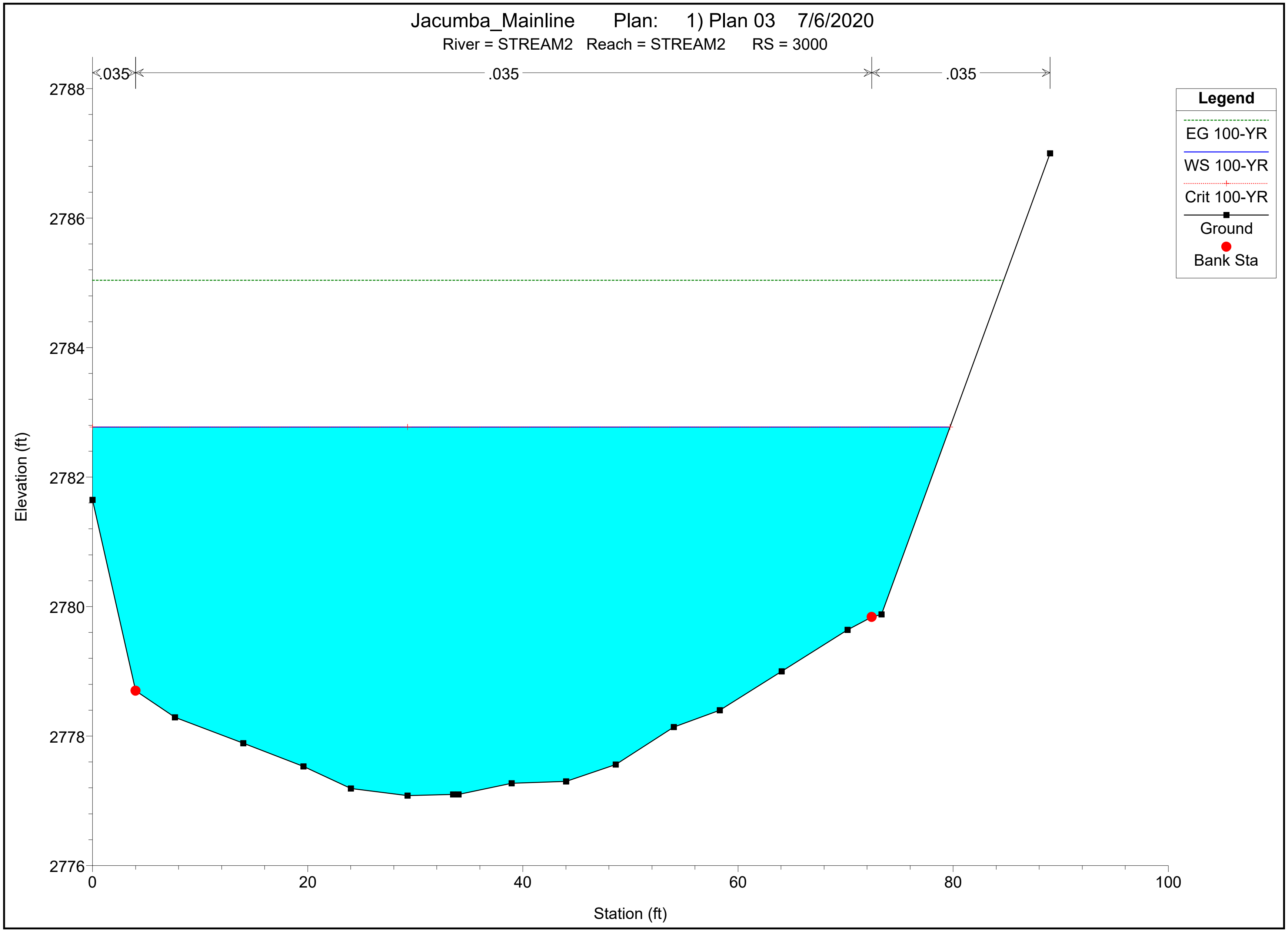


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM2 Reach = STREAM2 RS = 4500
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
2830
2820
2810
2800
2790
2780
Elevation (ft)
0
100
200
300
400
500
Station (ft)

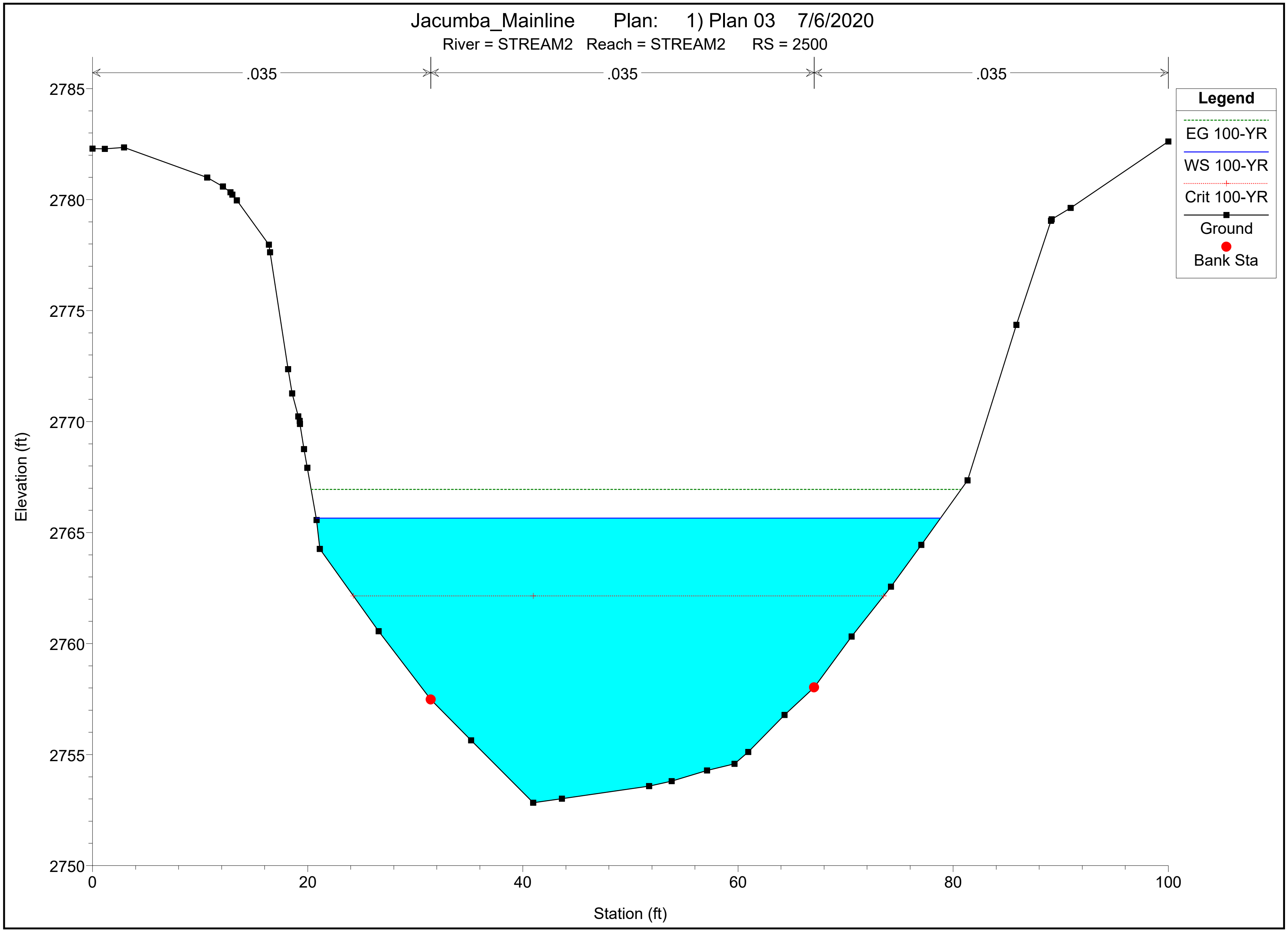


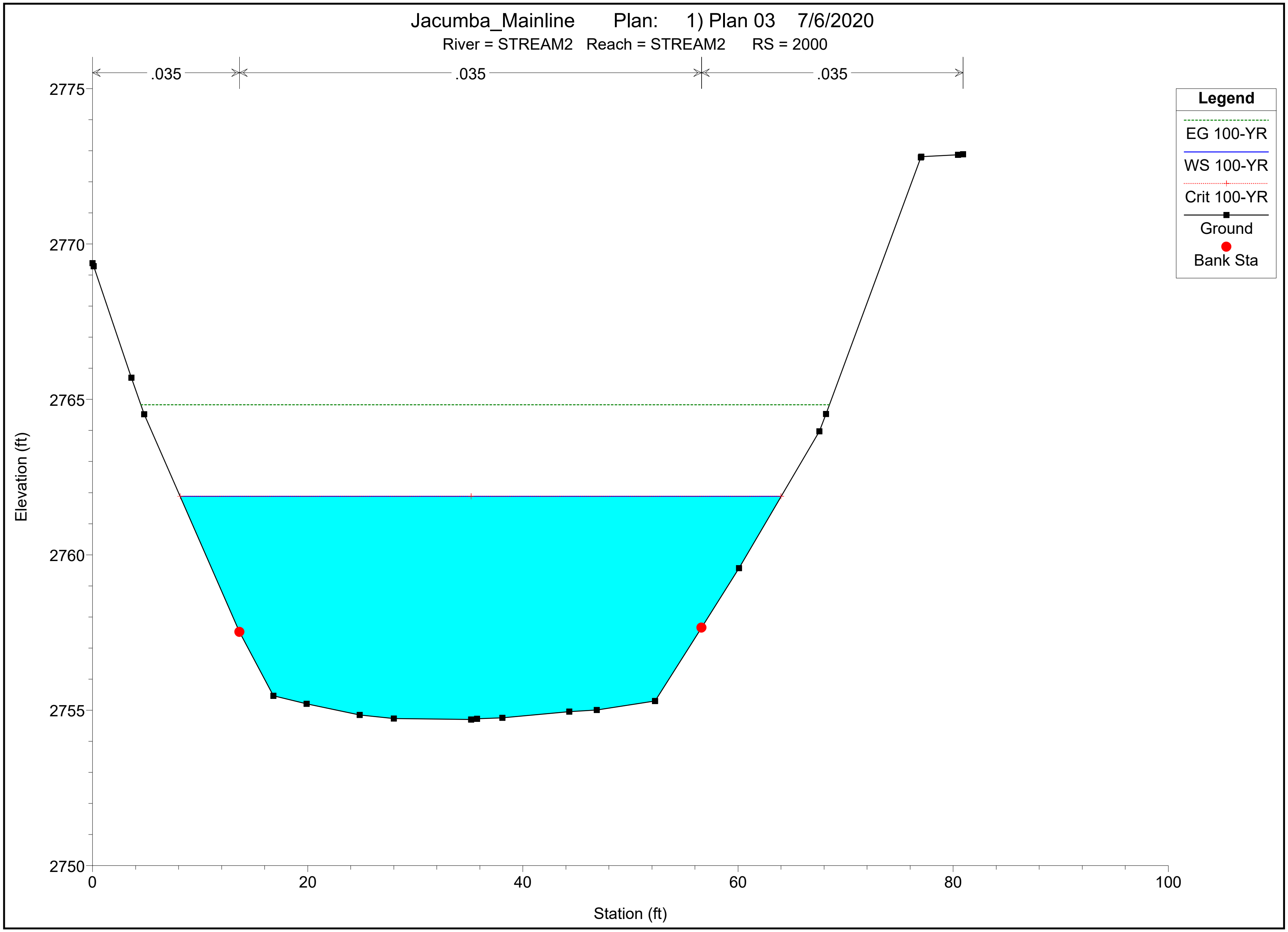
Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM2 Reach = STREAM2 RS = 4000
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2792
2790
2788
2786
2784
2782
2780
2778
2776
2774
0
20
40
60
80
100
120


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM2 Reach = STREAM2 RS = 3500
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2795
2790
2785
2780
2775
2770
2765
0
20
40
60
80
100
120
Station (ft)

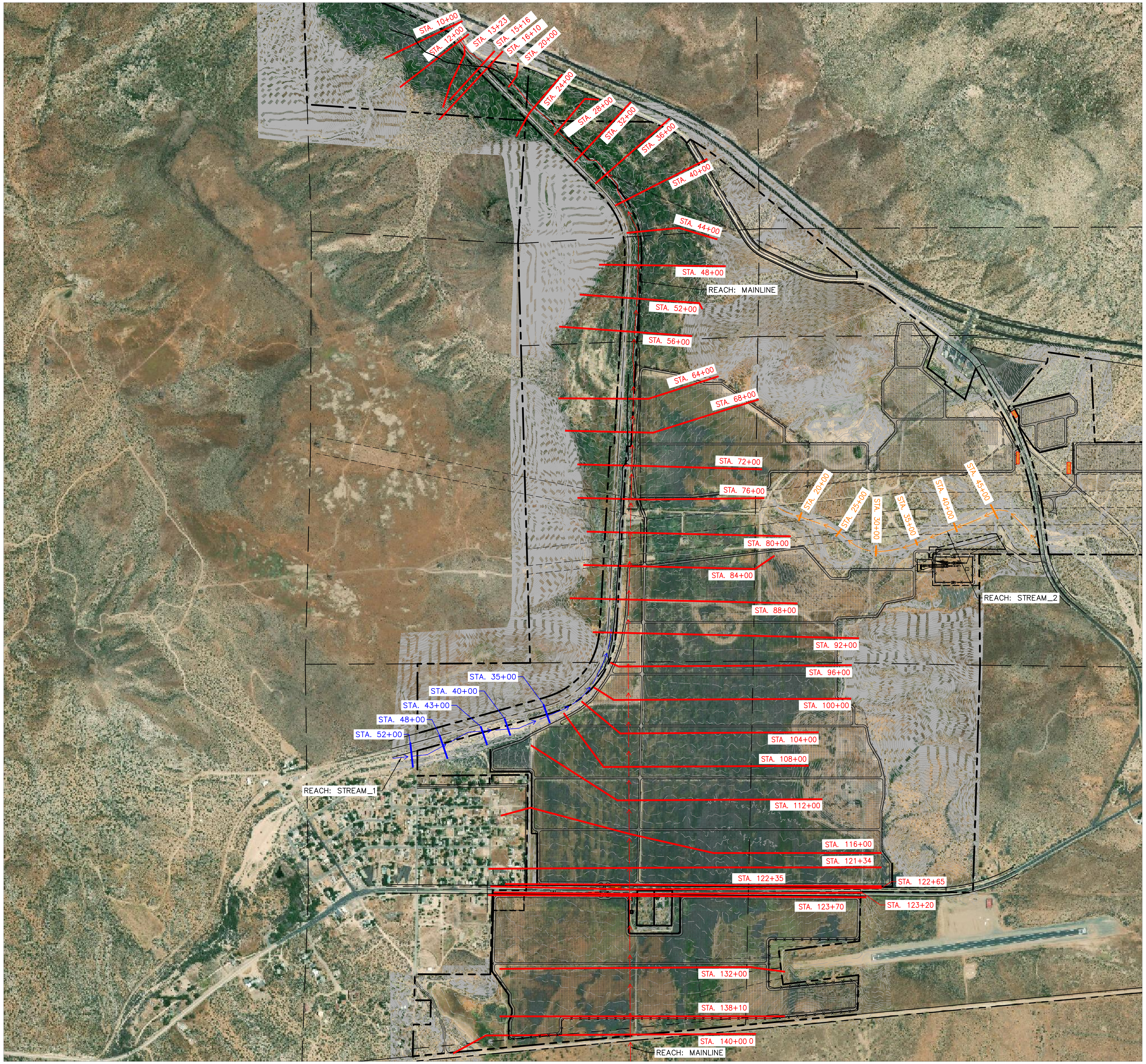


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM2 Reach = STREAM2 RS = 3000
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2788
2786
2784
2782
2780
2778
2776
0
20
40
60
80
100
Station (ft)


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM2 Reach = STREAM2 RS = 2500
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2785
2780
2775
2770
2765
2760
2755
2750
0
20
40
60
80
100
Station (ft)


Jacumba_Mainline Plan: 1) Plan 03 7/6/2020
River = STREAM2 Reach = STREAM2 RS = 2000
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2775
2770
2765
2760
2755
2750
0
20
40
60
80
100
Station (ft)

POST-CONSTRUCTION CONDITION



LEGEND:

PROPERTY LINE

PROPOSED CHAINLINK FENCE

HEC-RAS SECTIONS

MAINLINE

STREAM_1

STREAM_2

NORTH

GRAPHIC SCALE IN FEET
0 300 600 1200

FIGURE 10

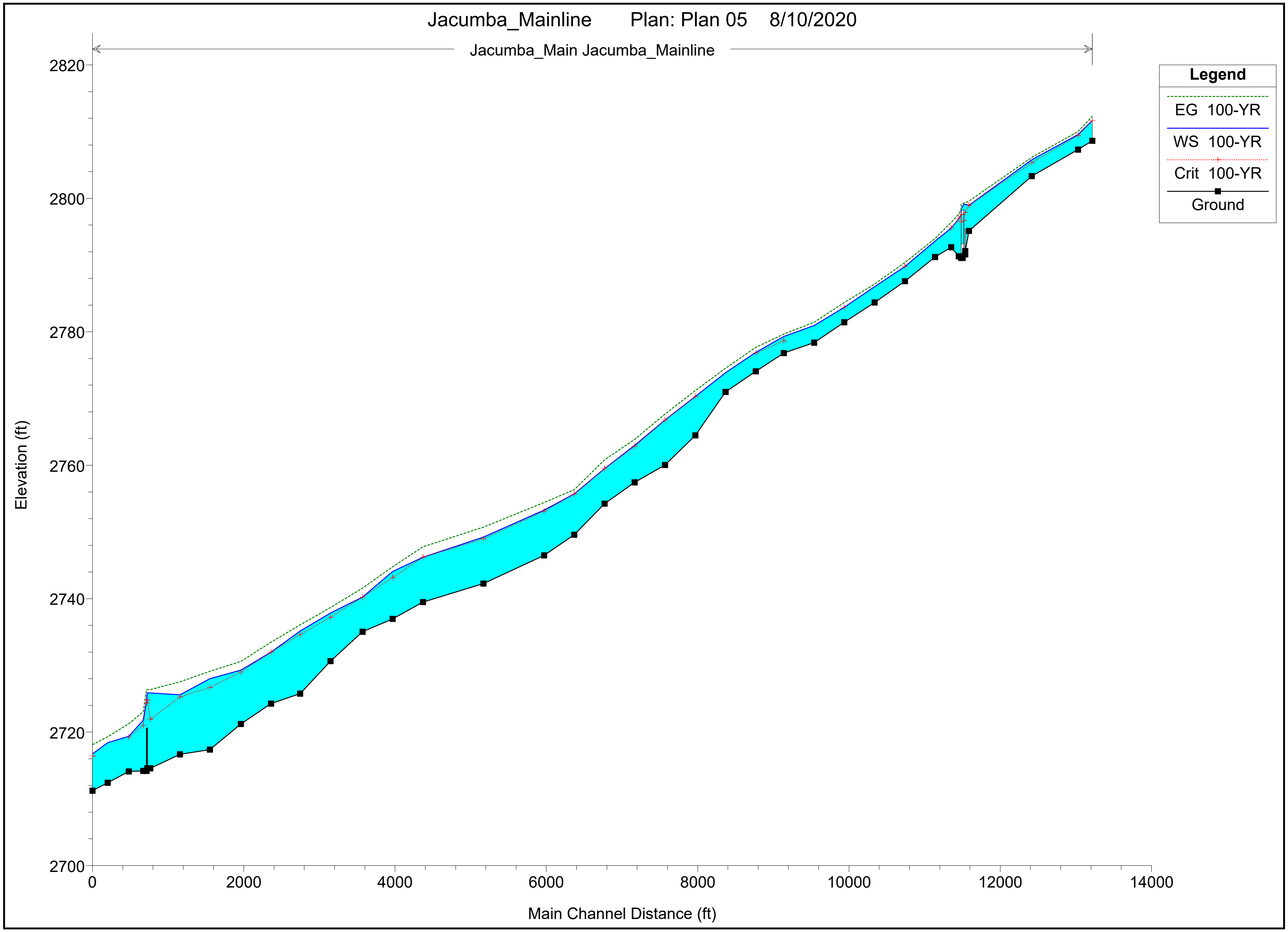
HYDRAULIC WORKMAP
POST-DEVELOPMENT
100-YEAR; 24-HOUR STORM
JVR Energy Park
SAN DIEGO COUNTY, CALIFORNIA

Kimley»Horn

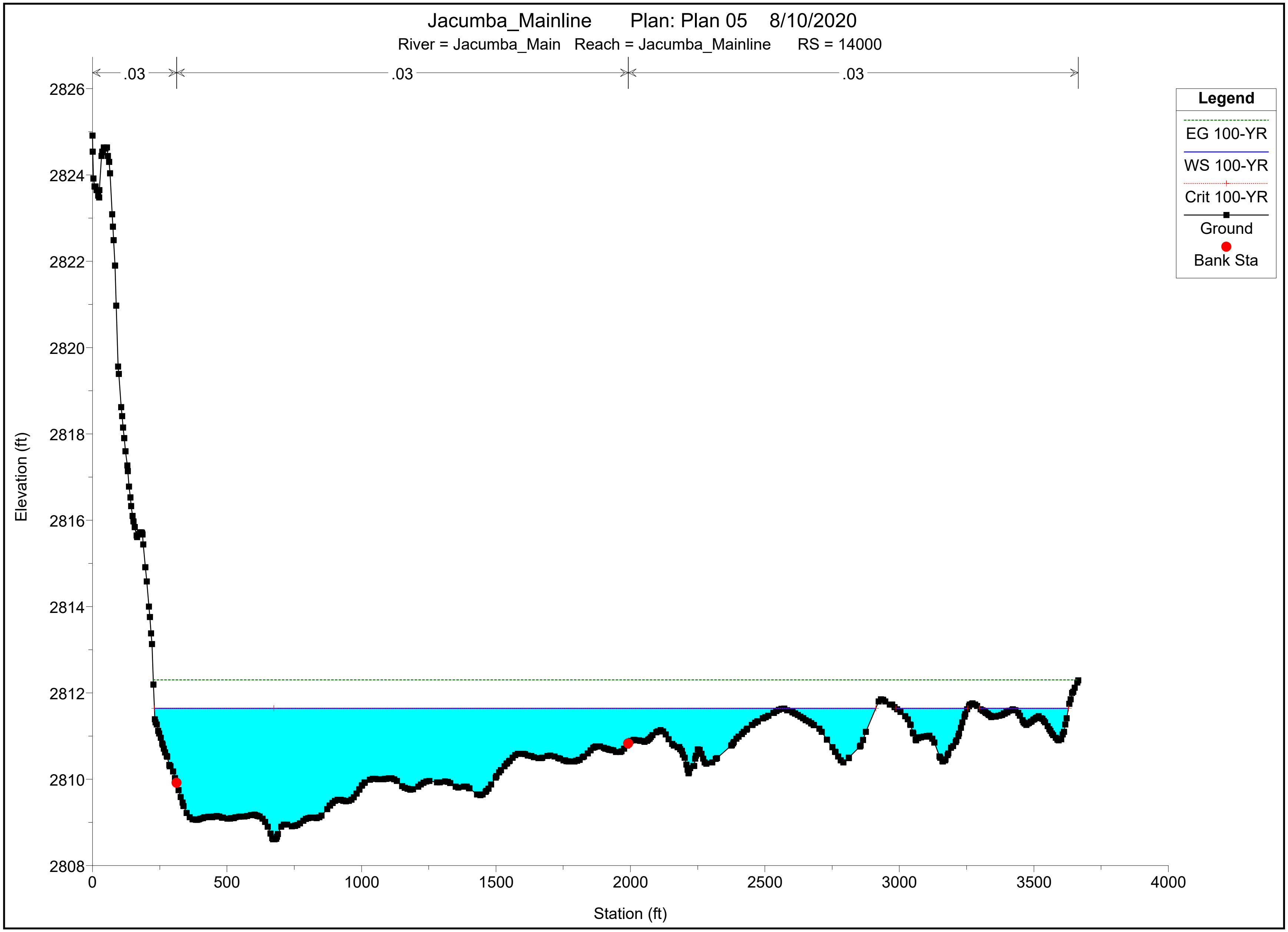
© 2020 KIMLEY-HORN AND ASSOCIATES, INC.
765 THE CITY DRIVE, SUITE 200, ORANGE, CA 92868
PHONE: 714-939-1030 FAX: 714-938-9488

HEC-RAS Plan:

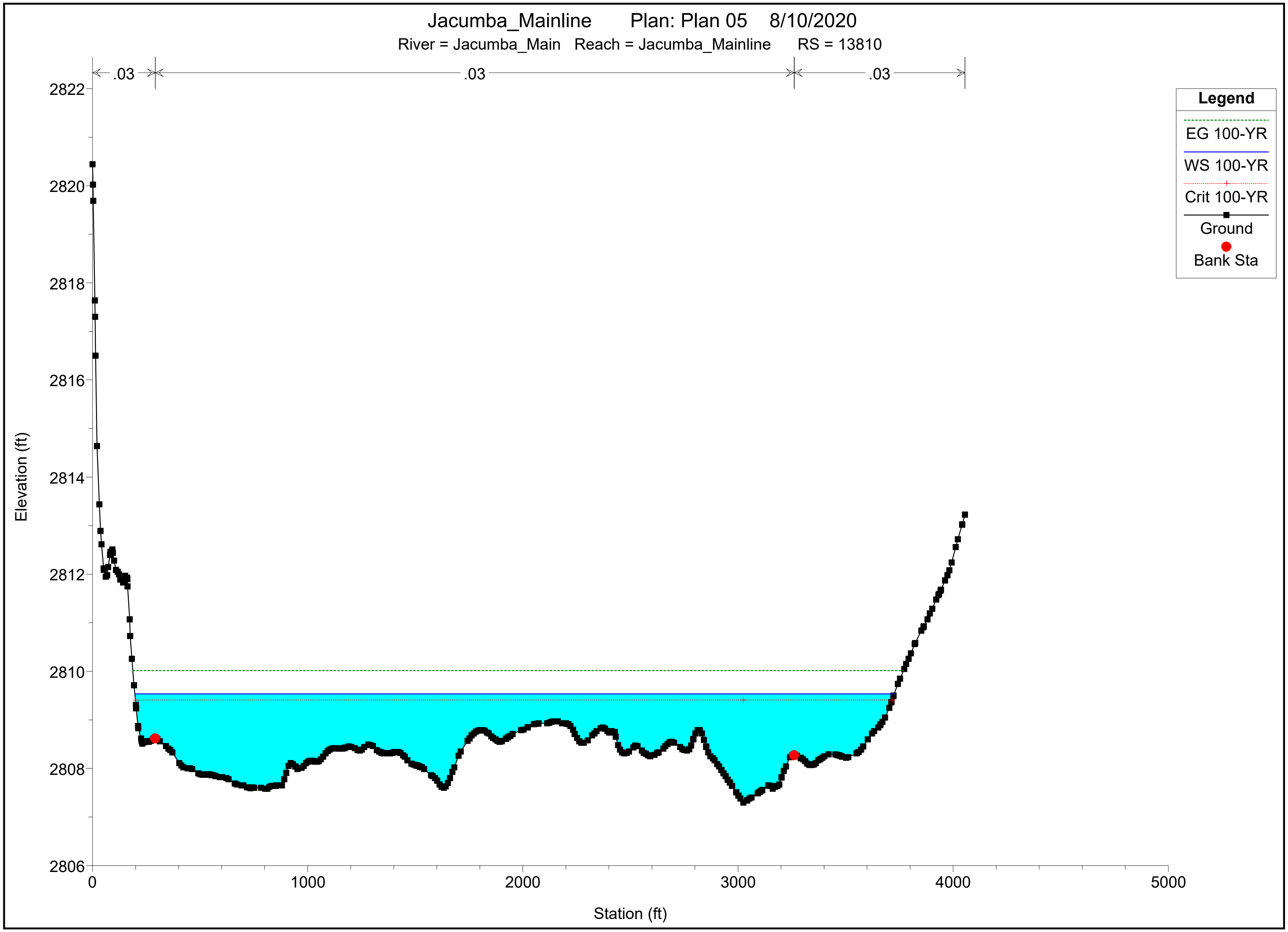
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Jacumba_Mainline	14000	100-YR	24661.00	2808.61	2811.64	2811.64	2812.30	0.008347	6.85	4084.76	3280.39	0.88
Jacumba_Mainline	13810	100-YR	24661.00	2807.30	2809.54	2809.41	2810.02	0.009155	5.64	4445.91	3529.17	0.87
Jacumba_Mainline	13200	100-YR	24661.00	2803.32	2805.77	2805.36	2806.15	0.004585	5.02	5100.41	3246.56	0.65
Jacumba_Mainline	12370	100-YR	24661.00	2795.13	2798.96	2798.96	2799.60	0.012355	6.30	3843.45	3061.15	1.00
Jacumba_Mainline	12320	100-YR	24661.00	2792.11	2799.12	2797.88	2799.30	0.000354	3.78	7600.87	3978.97	0.39
Jacumba_Mainline	12300		Culvert									
Jacumba_Mainline	12265	100-YR	24661.00	2791.08	2797.56	2797.56	2798.39	0.002334	7.56	3497.38	2327.44	0.95
Jacumba_Mainline	12235	100-YR	24661.00	2791.31	2796.92	2796.92	2797.65	0.006156	9.18	4096.09	2898.62	0.85
Jacumba_Mainline	12134	100-YR	24661.00	2792.67	2795.53	2795.53	2796.38	0.011384	7.39	3337.53	2017.54	1.01
Jacumba_Mainline	11600	100-YR	24661.00	2791.21	2793.61		2793.96	0.006443	4.80	5164.32	4024.07	0.73
Jacumba_Mainline	11200	100-YR	24661.00	2787.58	2789.80	2789.80	2790.41	0.012871	6.26	3946.38	3379.87	1.02
Jacumba_Mainline	10800	100-YR	24661.00	2784.39	2786.77		2787.14	0.005073	4.91	5030.41	3083.06	0.68
Jacumba_Mainline	10400	100-YR	24661.00	2781.45	2783.69	2783.60	2784.39	0.009553	6.74	3681.79	2424.67	0.93
Jacumba_Mainline	10000	100-YR	24661.00	2778.37	2780.93		2781.44	0.005685	5.71	4351.05	2434.86	0.73
Jacumba_Mainline	9600	100-YR	25741.00	2776.83	2779.29	2778.64	2779.67	0.003434	4.97	5305.81	2676.23	0.59
Jacumba_Mainline	9200	100-YR	25741.00	2774.08	2776.91	2776.81	2777.67	0.009387	6.98	3733.08	2297.14	0.93
Jacumba_Mainline	8800	100-YR	25741.00	2770.98	2773.86		2774.52	0.006595	6.61	3956.35	1947.51	0.80
Jacumba_Mainline	8400	100-YR	25741.00	2764.48	2770.30	2770.30	2771.21	0.010565	7.63	3375.58	1845.53	0.99
Jacumba_Mainline	8000	100-YR	25741.00	2760.05	2766.79	2766.79	2767.69	0.006307	6.44	3751.66	1895.55	0.78
Jacumba_Mainline	7600	100-YR	25741.00	2757.44	2763.00	2762.83	2763.87	0.006866	7.51	3528.25	1534.01	0.83
Jacumba_Mainline	7200	100-YR	26164.00	2754.24	2759.51	2759.51	2760.81	0.009443	10.06	2864.73	1389.79	1.01
Jacumba_Mainline	6800	100-YR	26164.00	2749.59	2755.70	2755.70	2756.34	0.003753	8.54	4200.09	1486.40	0.69
Jacumba_Mainline	6400	100-YR	26164.00	2746.50	2753.27	2753.11	2754.41	0.004878	11.17	3334.50	1783.35	0.82
Jacumba_Mainline	5600	100-YR	26164.00	2742.25	2749.23	2748.97	2750.72	0.005911	12.04	2738.16	1455.83	0.89
Jacumba_Mainline	5200	100-YR	26164.00	2739.49	2746.19	2746.19	2747.76	0.007555	13.21	2687.49	1299.49	1.00
Jacumba_Mainline	4800	100-YR	26164.00	2736.97	2744.07	2743.17	2744.78	0.002851	9.09	4009.09	1353.35	0.63
Jacumba_Mainline	4400	100-YR	26164.00	2735.05	2740.24	2740.24	2741.60	0.007631	11.33	2906.06	1002.94	0.97
Jacumba_Mainline	4000	100-YR	26164.00	2730.65	2737.85	2737.20	2738.66	0.004048	10.06	3695.83	1152.99	0.73
Jacumba_Mainline	3600	100-YR	26164.00	2725.76	2735.15	2734.64	2736.07	0.004497	11.07	3491.82	1048.68	0.76
Jacumba_Mainline	3200	100-YR	26164.00	2724.29	2731.99	2731.99	2733.47	0.006682	12.46	2821.07	863.33	0.94
Jacumba_Mainline	2800	100-YR	26164.00	2721.21	2729.30	2729.00	2730.61	0.004545	11.21	3024.42	1050.65	0.79
Jacumba_Mainline	2400	100-YR	26164.00	2717.38	2728.01	2726.70	2729.12	0.002763	10.36	3180.88	1179.47	0.64
Jacumba_Mainline	2000	100-YR	26164.00	2716.66	2725.58	2725.26	2727.55	0.005224	12.14	2404.33	1072.63	0.86
Jacumba_Mainline	1610	100-YR	26164.00	2714.59	2725.89	2721.93	2726.37	0.000682	5.98	4829.56	1197.76	0.33
Jacumba_Mainline	1563		Bridge									
Jacumba_Mainline	1516	100-YR	26164.00	2714.20	2721.79	2721.01	2723.03	0.003316	9.78	3073.42	892.39	0.68
Jacumba_Mainline	1323	100-YR	26164.00	2714.12	2719.37	2719.24	2721.24	0.007121	11.53	2399.01	680.50	0.95
Jacumba_Mainline	1200	100-YR	26164.00	2712.42	2718.40		2719.31	0.003414	7.73	3436.40	813.70	0.65
Jacumba_Mainline	1000	100-YR	26164.00	2711.24	2716.73	2716.43	2718.14	0.006001	10.32	2838.65	807.90	0.87

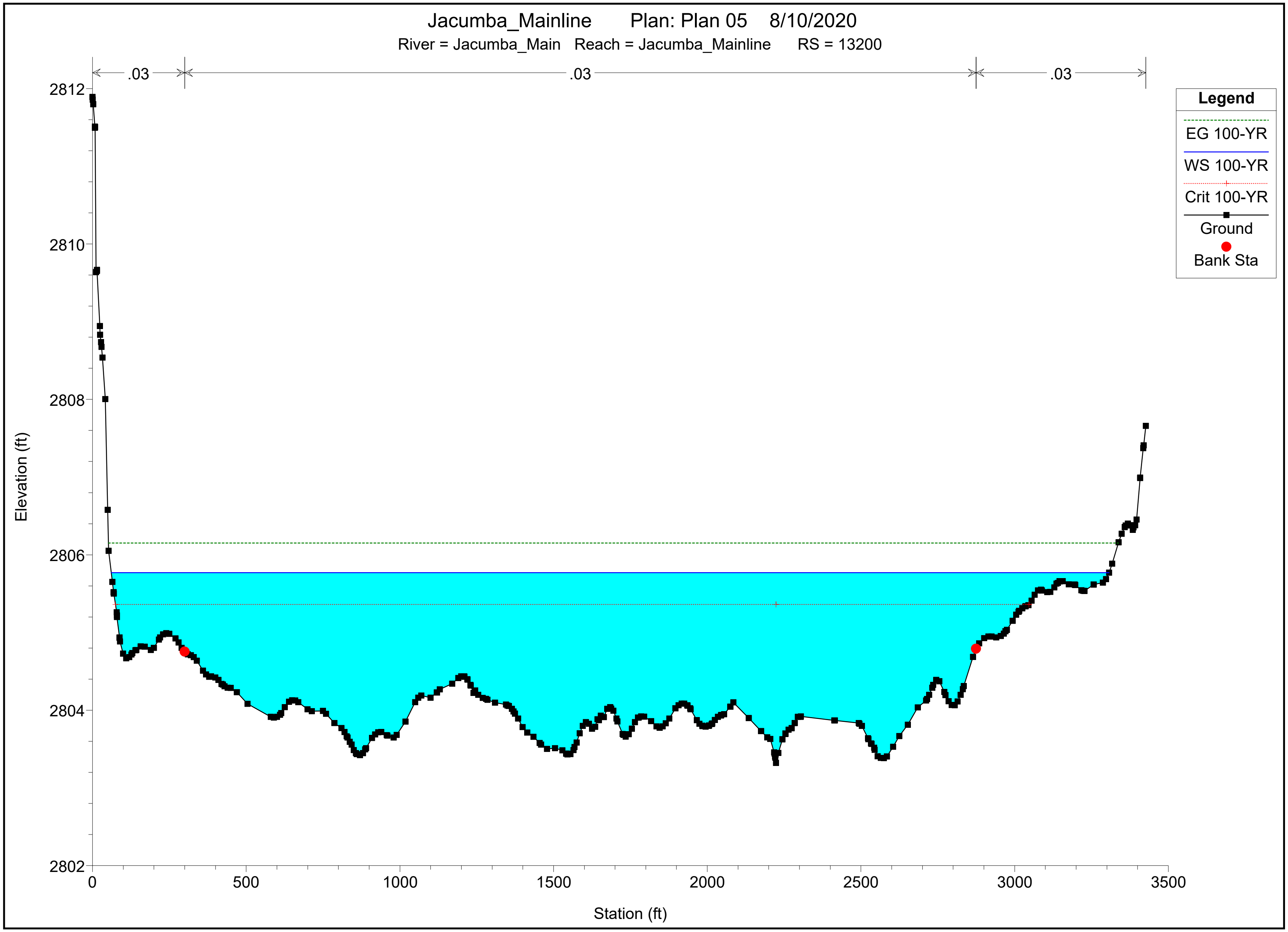


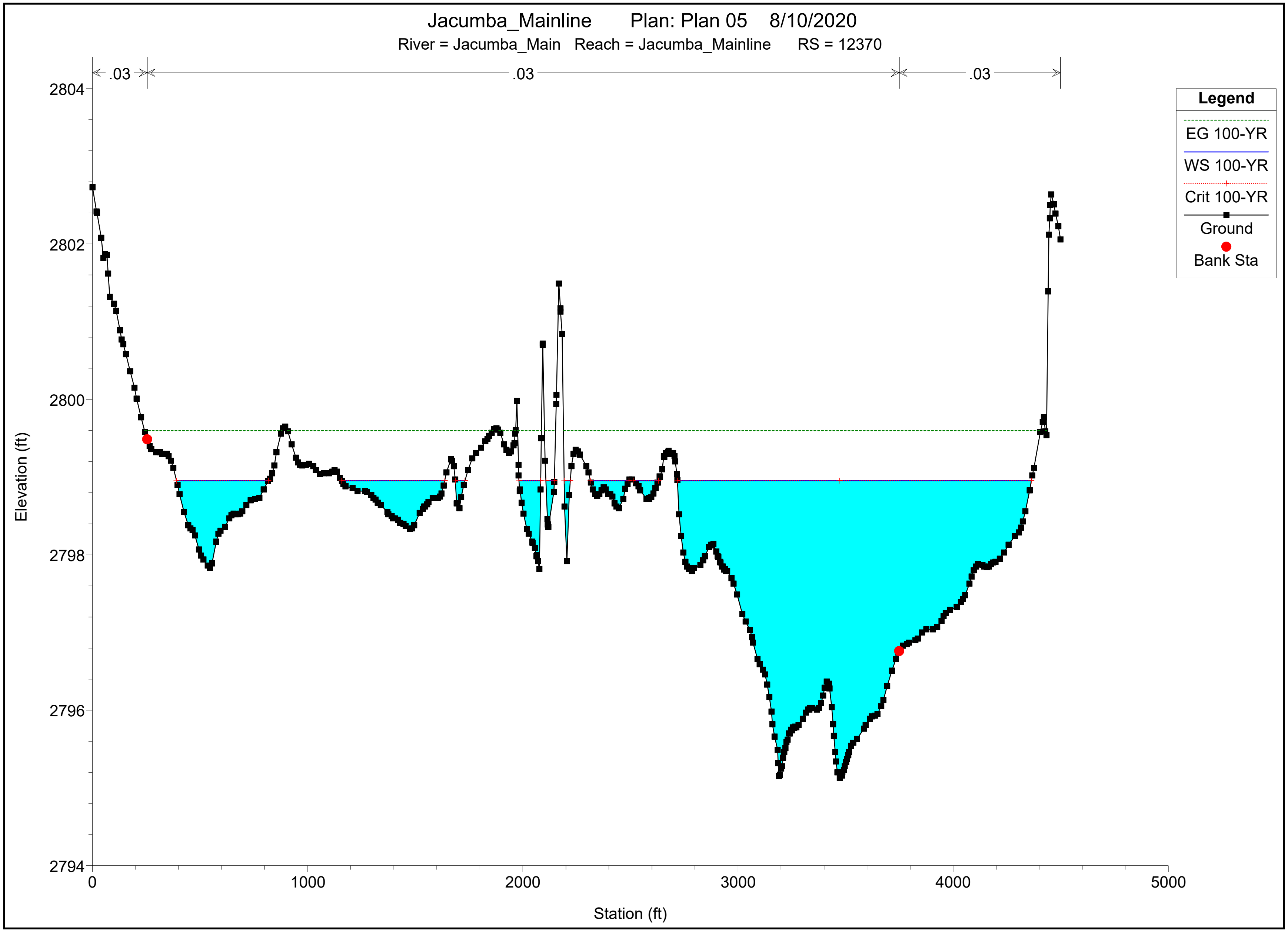
Jacumba_Mainline Plan: Plan 05 8/10/2020
Jacumba_Main Jacumba_Mainline
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Elevation (ft)
2700
2720
2740
2760
2780
2800
2820
Main Channel Distance (ft)
0
2000
4000
6000
8000
10000
12000
14000

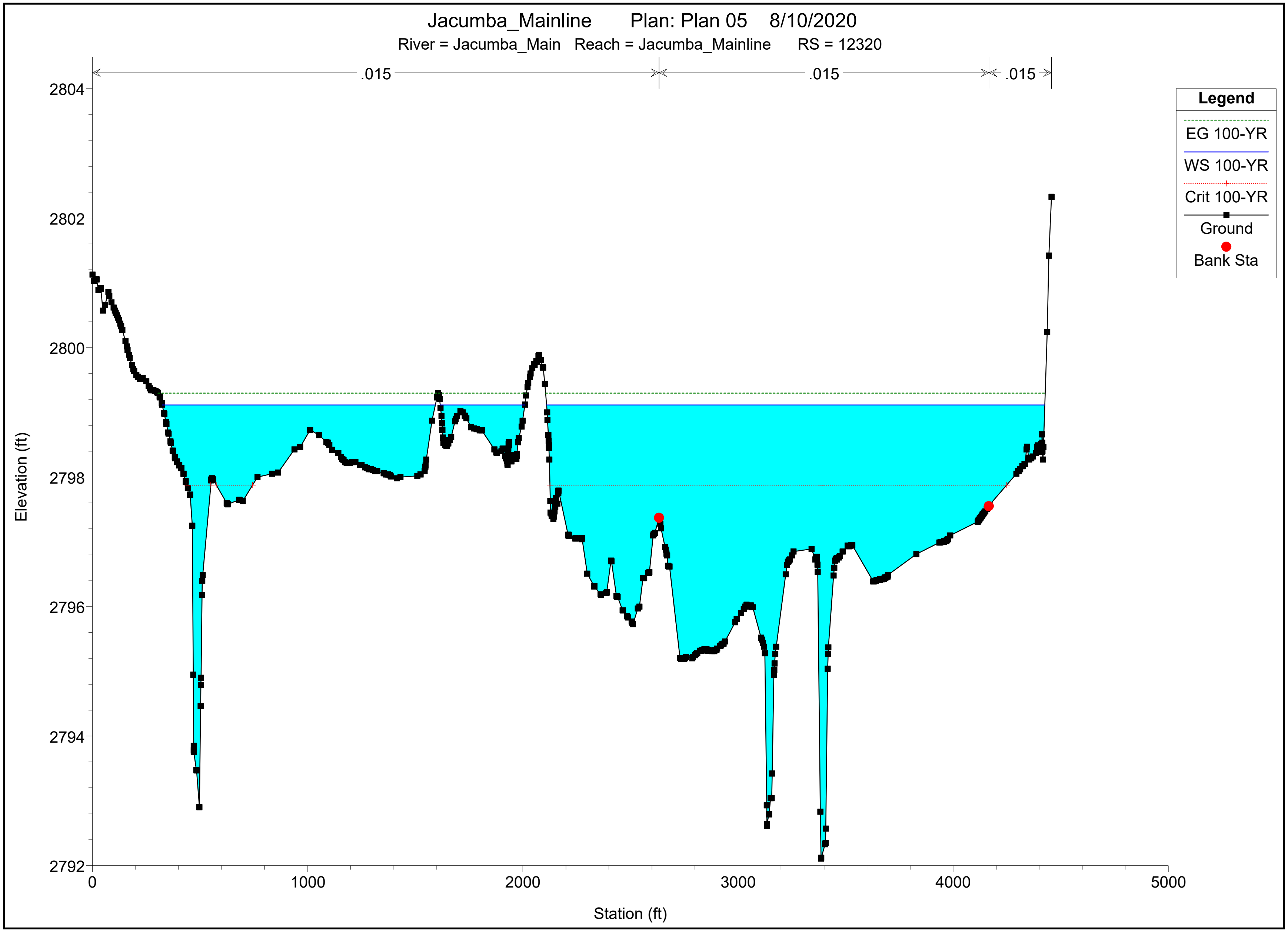


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 14000
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2826
2824
2822
2820
2818
2816
2814
2812
2810
2808
0
500
1000
1500
2000
2500
3000
3500
4000
Station (ft)

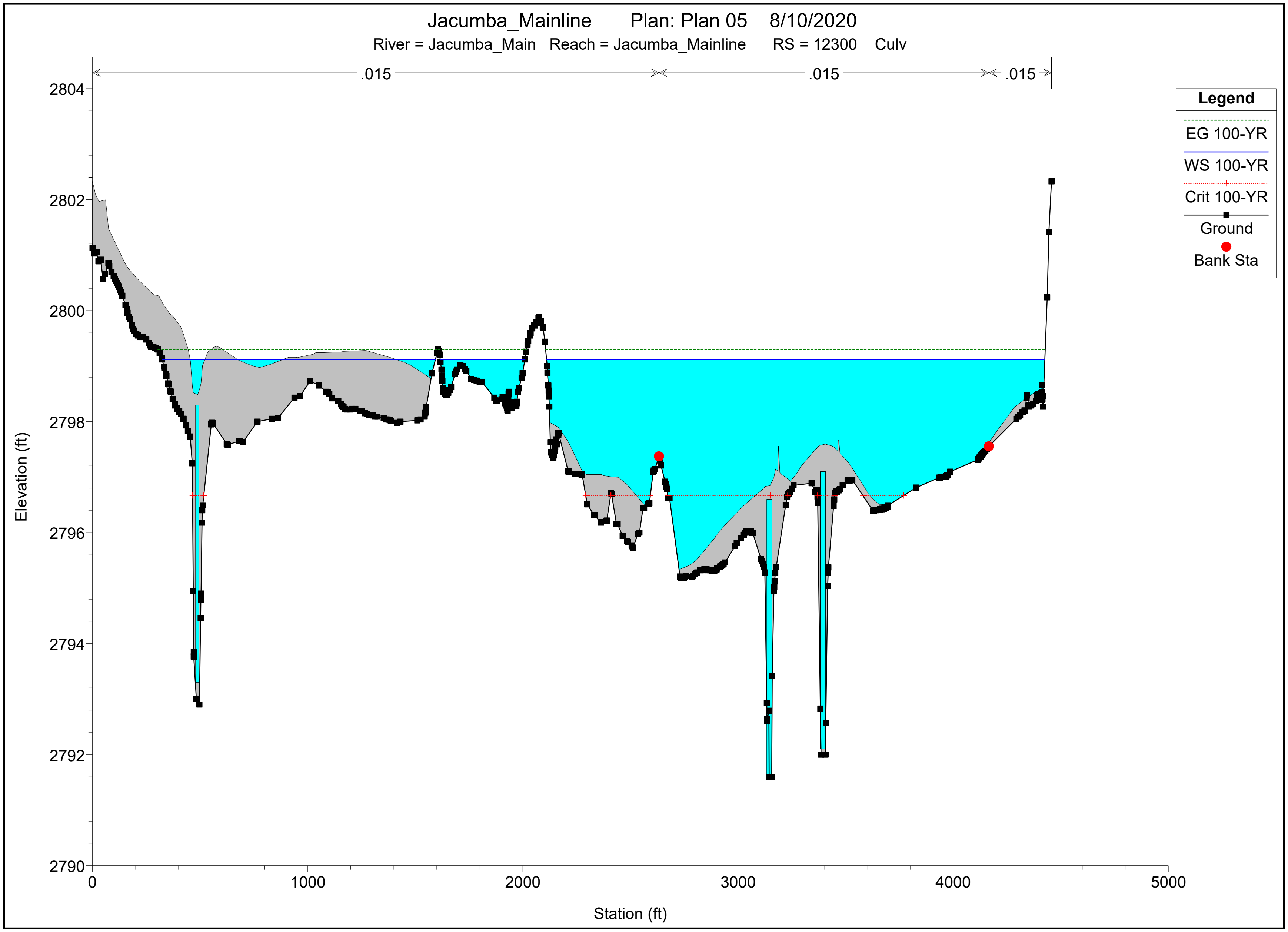

Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 13810
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2806
2808
2810
2812
2814
2816
2818
2820
2822
Station (ft)
0
1000
2000
3000
4000
5000


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 13200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2812
2810
2808
2806
2804
2802
0
500
1000
1500
2000
2500
3000
3500
Station (ft)

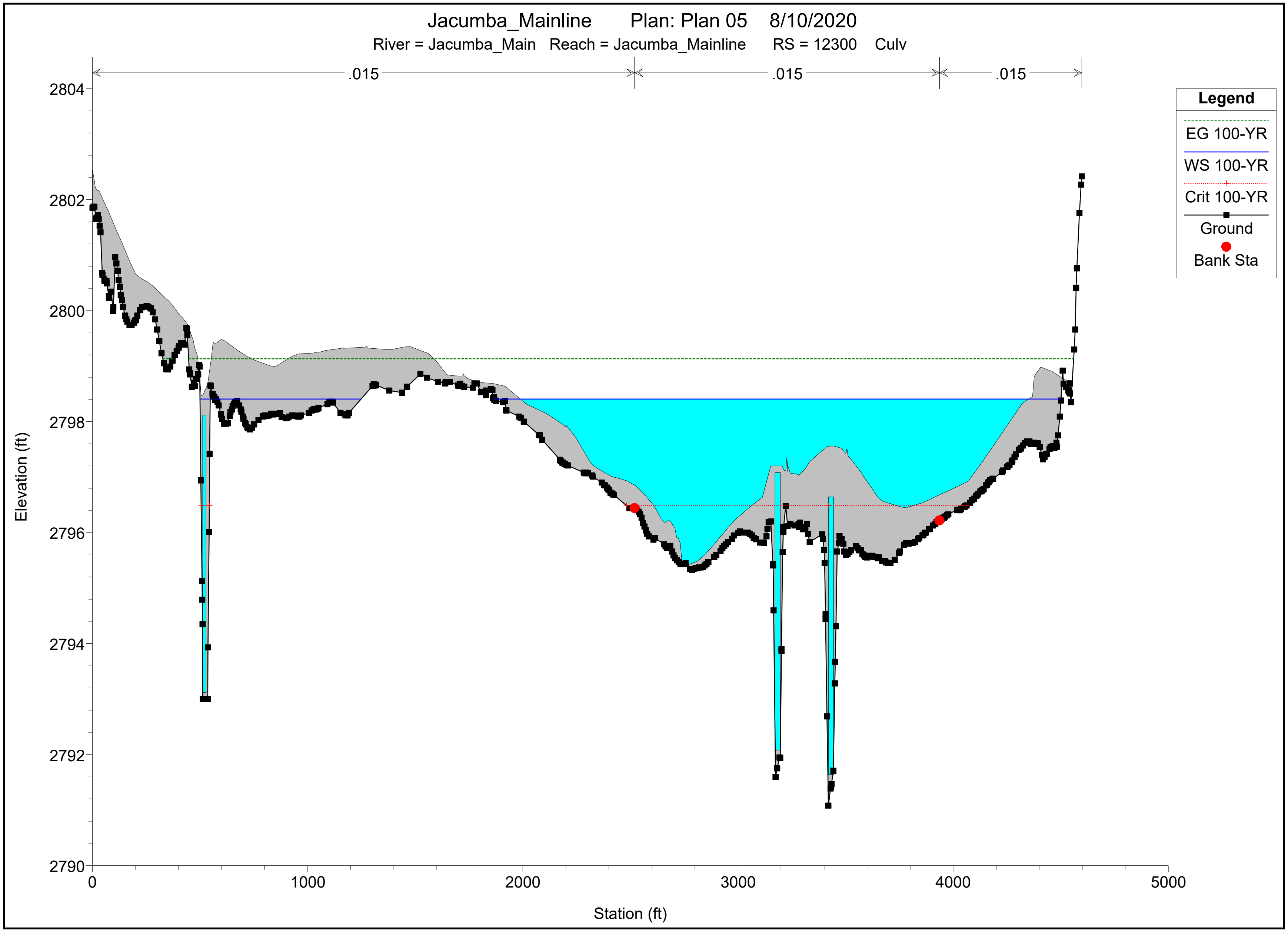

Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12370
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2804
2802
2800
2798
2796
2794
0
1000
2000
3000
4000
5000
Station (ft)



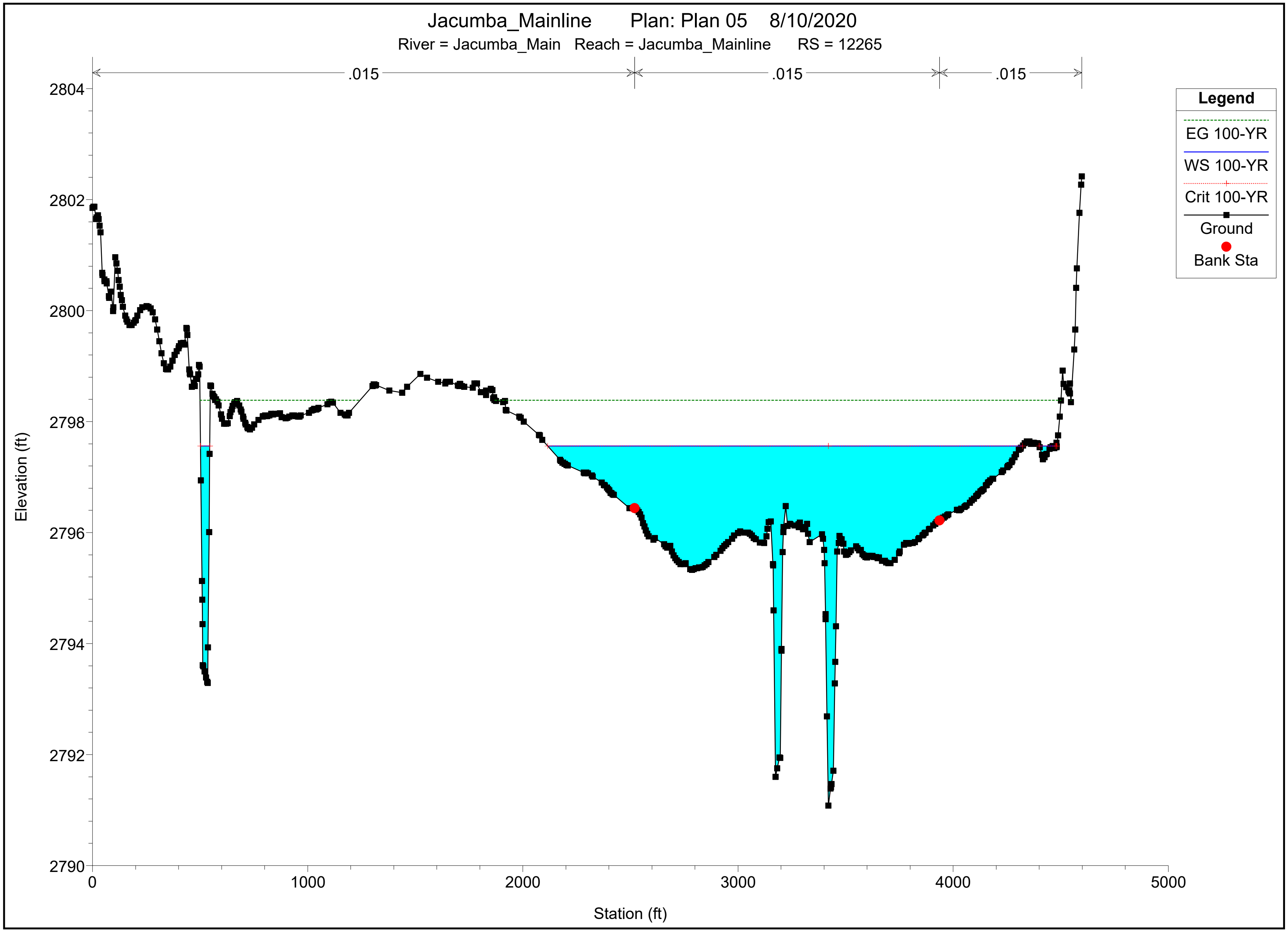
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12320
.015
.015
.015
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2804
2802
2800
2798
2796
2794
2792
0
1000
2000
3000
4000
5000
Station (ft)



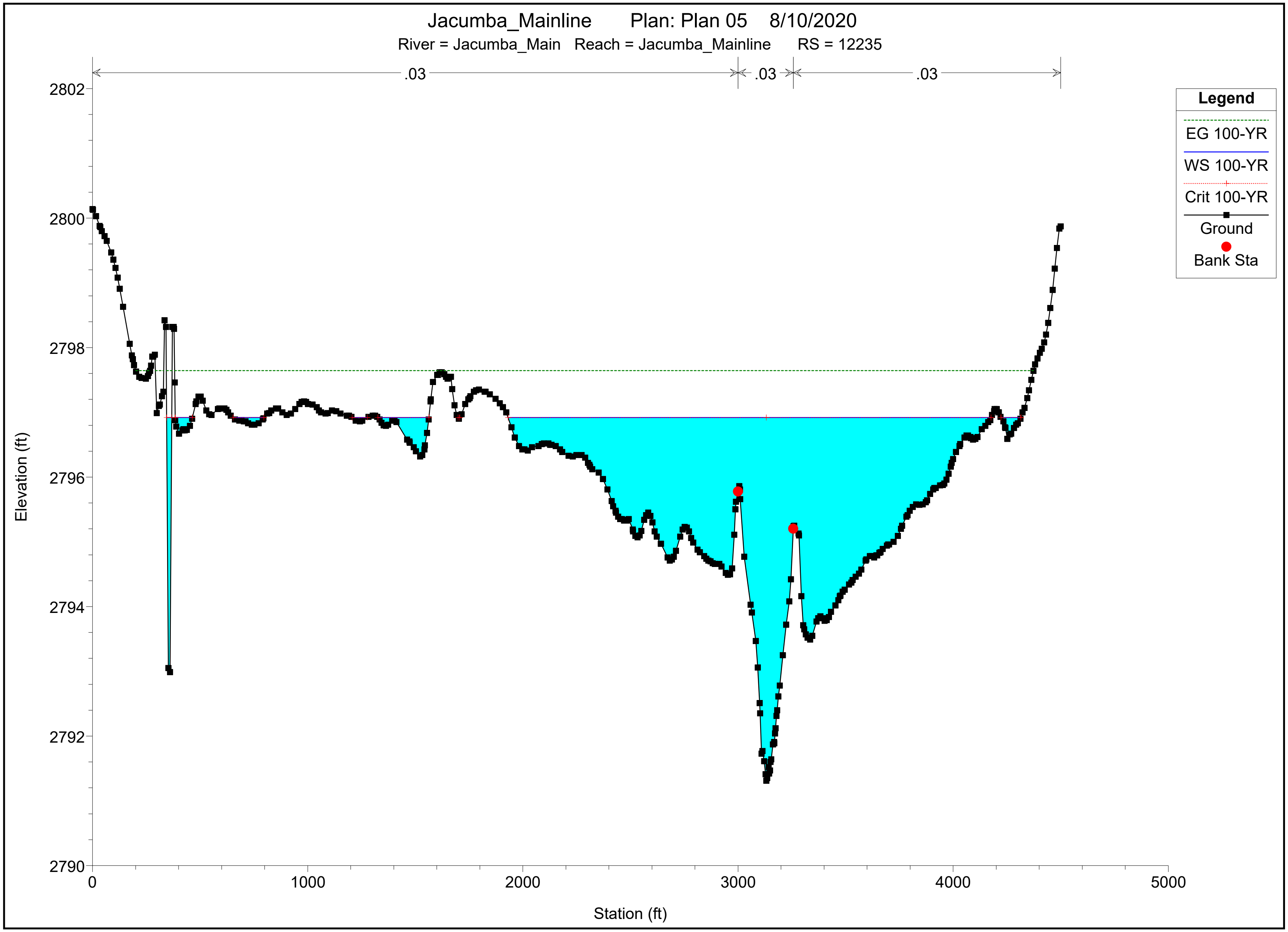
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12300 Culv
.015
.015
.015
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2804
2802
2800
2798
2796
2794
2792
2790
0
1000
2000
3000
4000
5000
Station (ft)



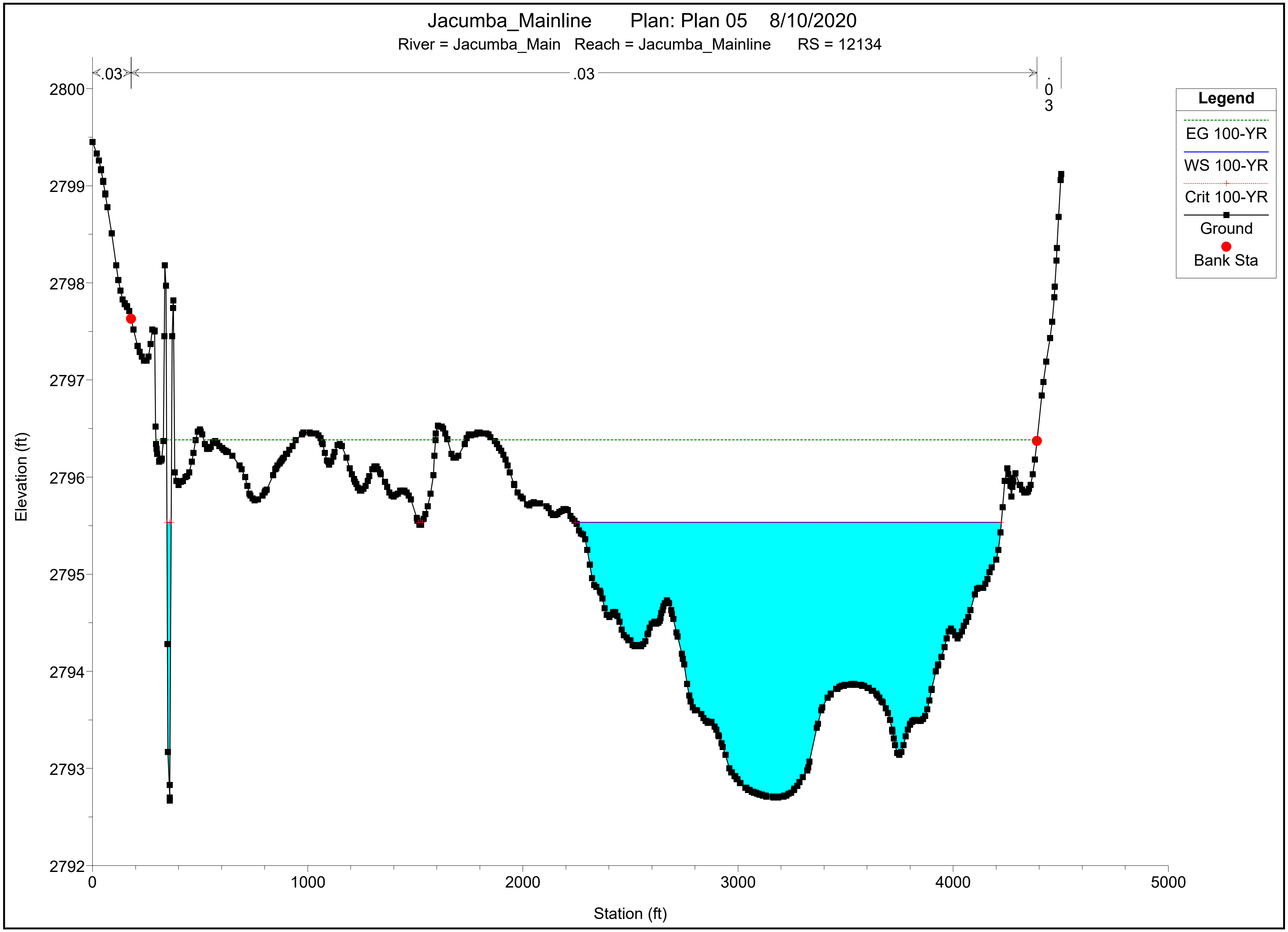
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12300 Culv
.015
.015
.015
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2804
2802
2800
2798
2796
2794
2792
2790
0
1000
2000
3000
4000
5000



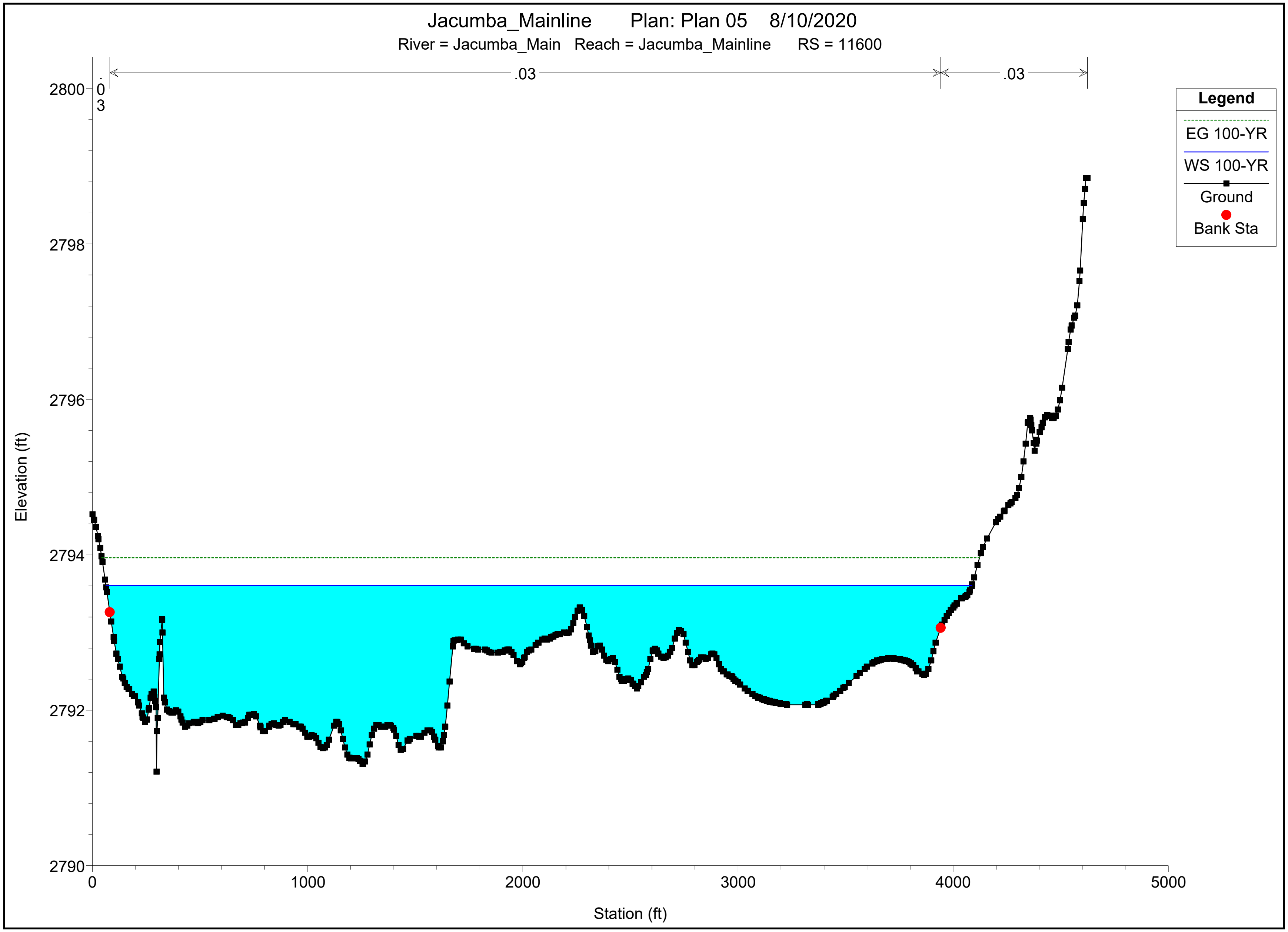
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12265
.015
.015
.015
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2804
2802
2800
2798
2796
2794
2792
2790
0
1000
2000
3000
4000
5000
Station (ft)



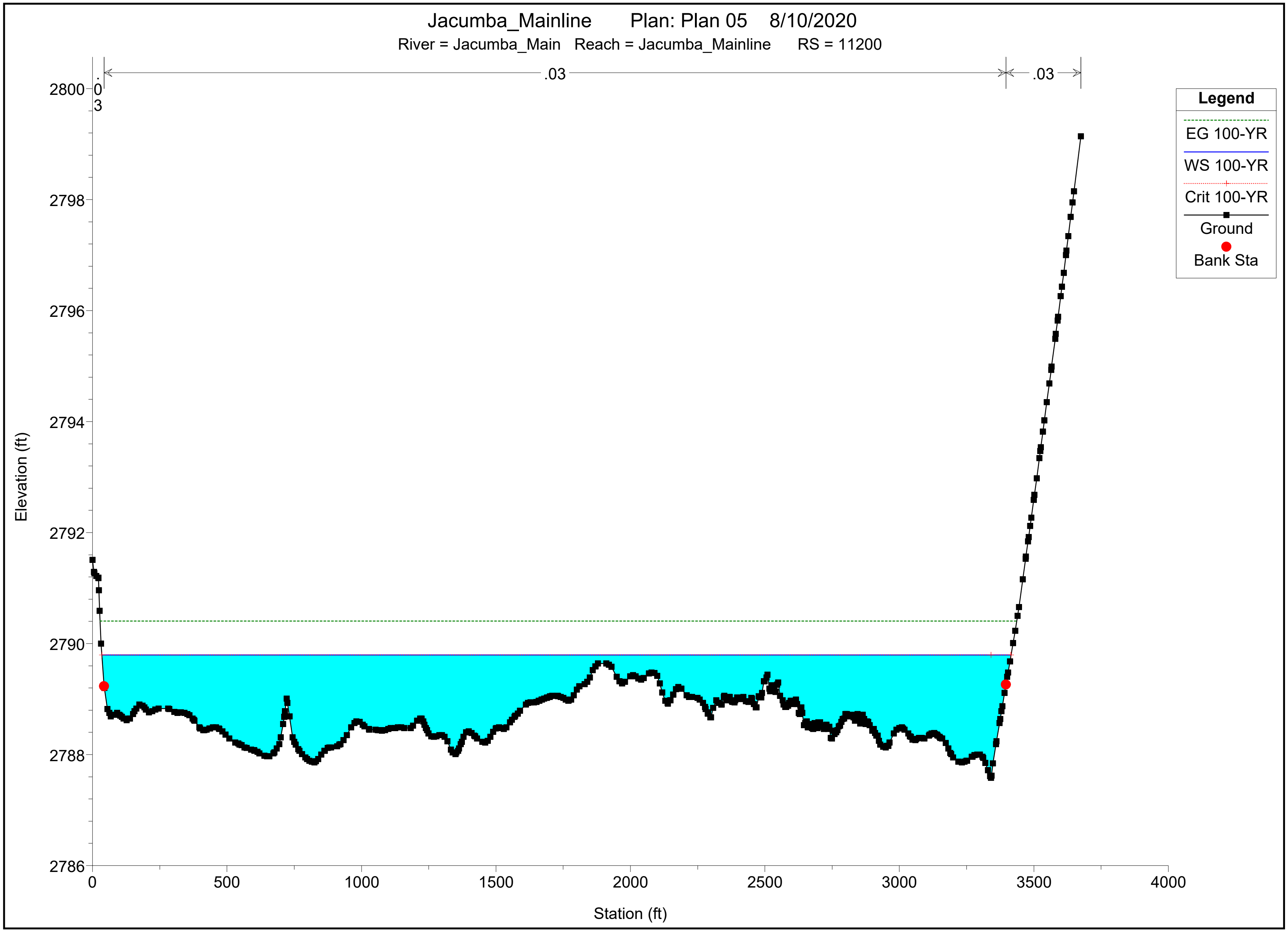
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12235
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2802
2800
2798
2796
2794
2792
2790
0
1000
2000
3000
4000
5000



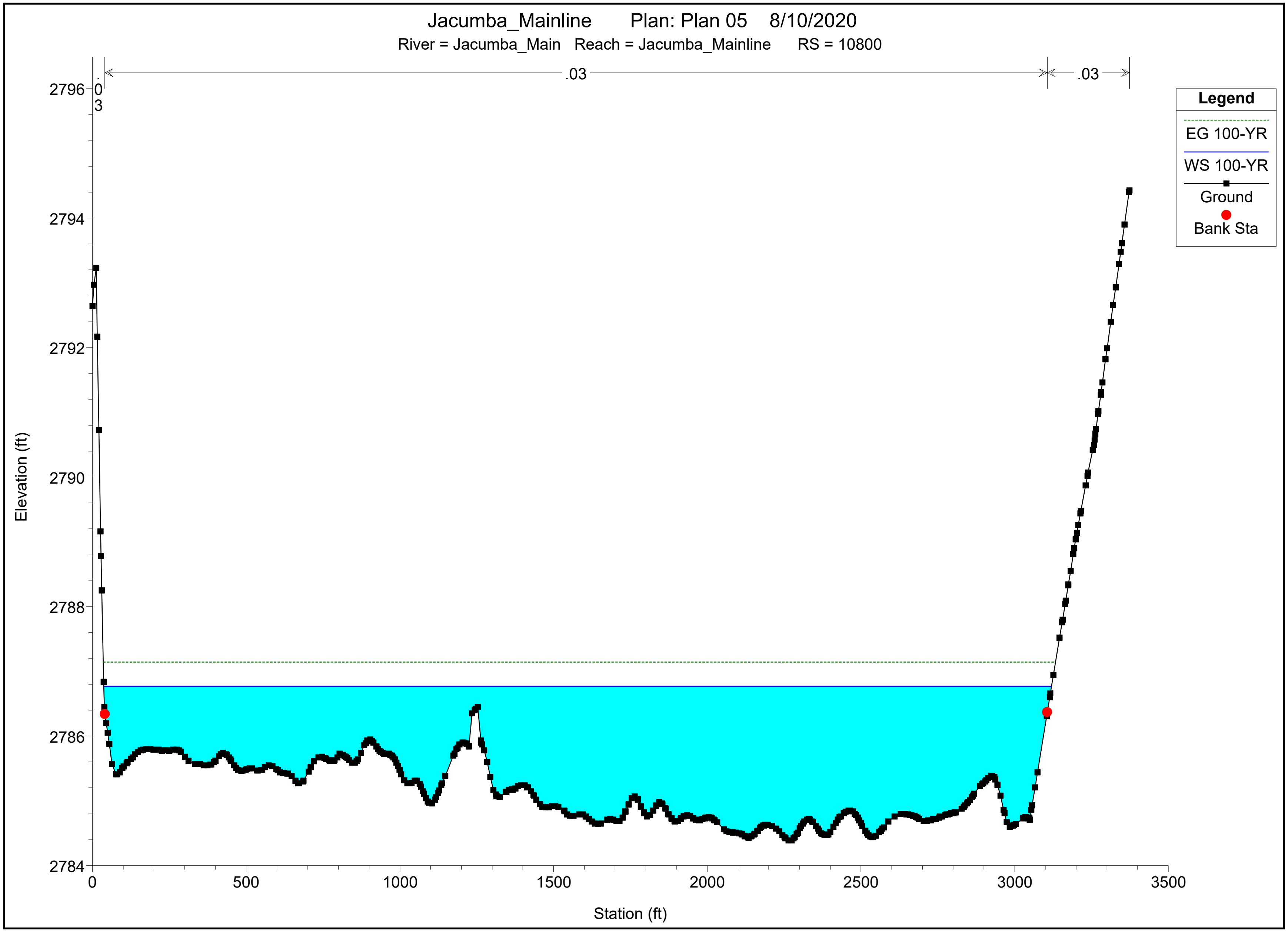
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 12134
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2800
2799
2798
2797
2796
2795
2794
2793
2792
0
1000
2000
3000
4000
5000
Station (ft)



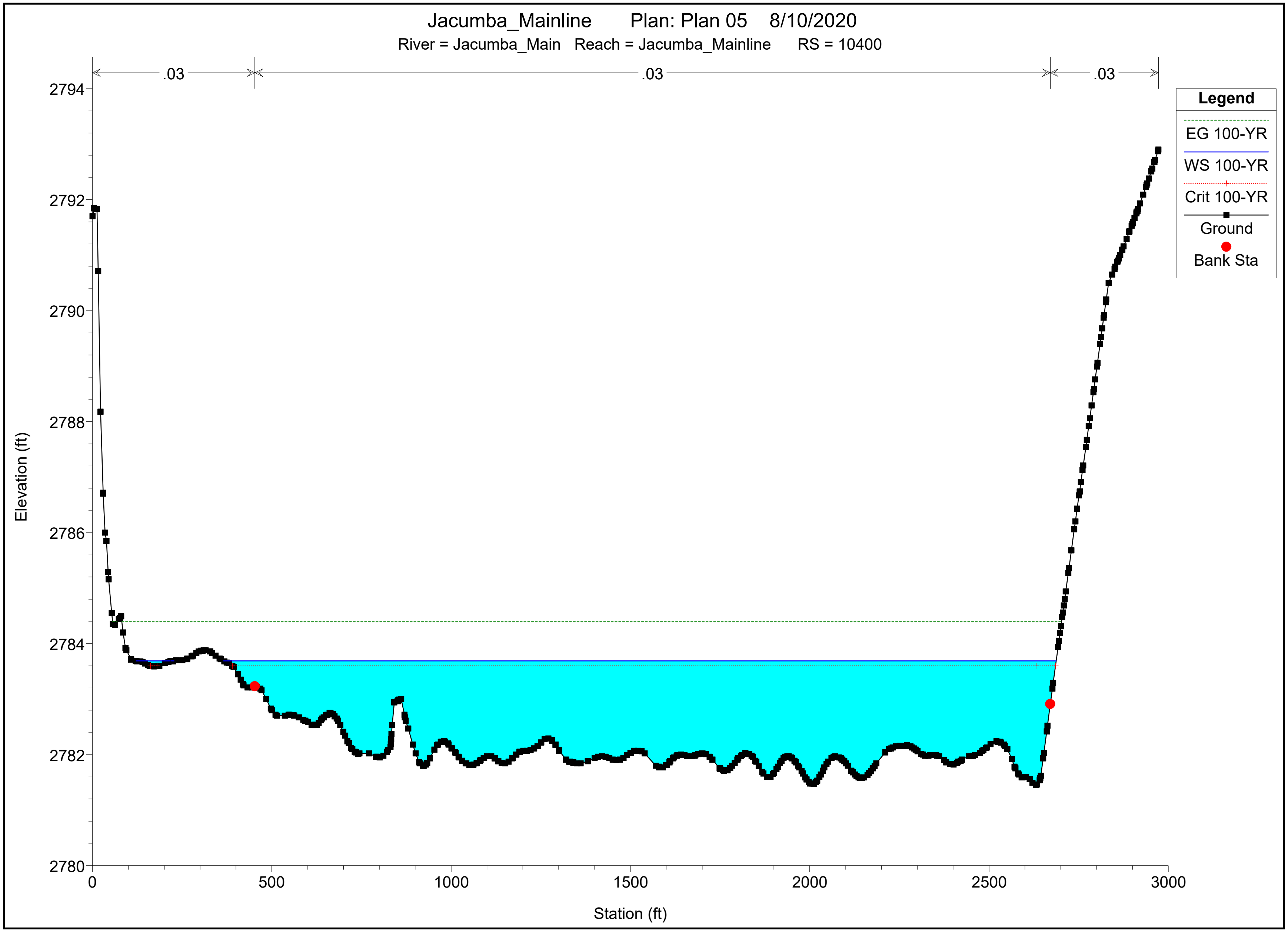
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 11600
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2800
2798
2796
2794
2792
2790
0
1000
2000
3000
4000
5000
Station (ft)



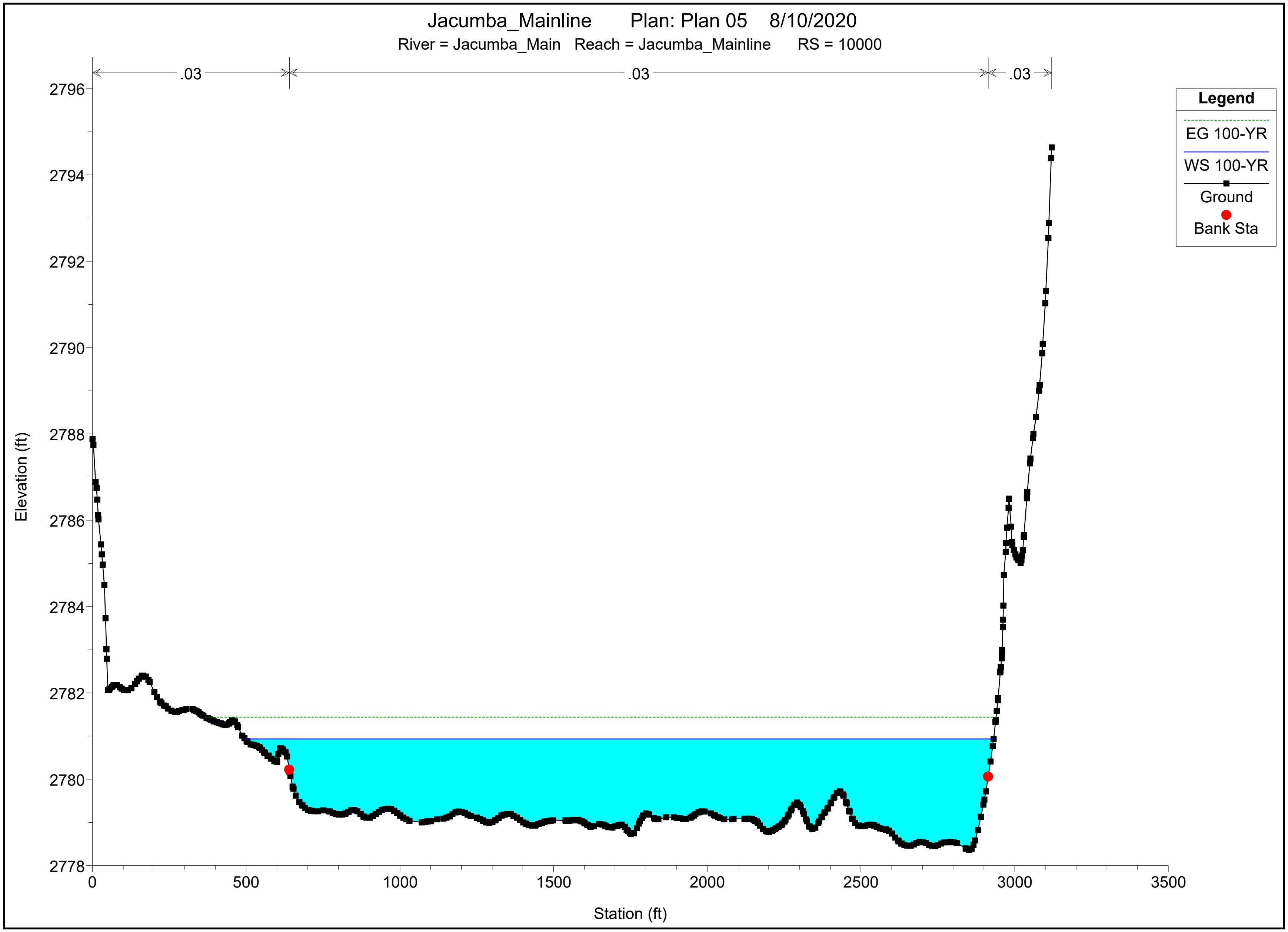
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 11200
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2786
2788
2790
2792
2794
2796
2798
2800
0
500
1000
1500
2000
2500
3000
3500
4000



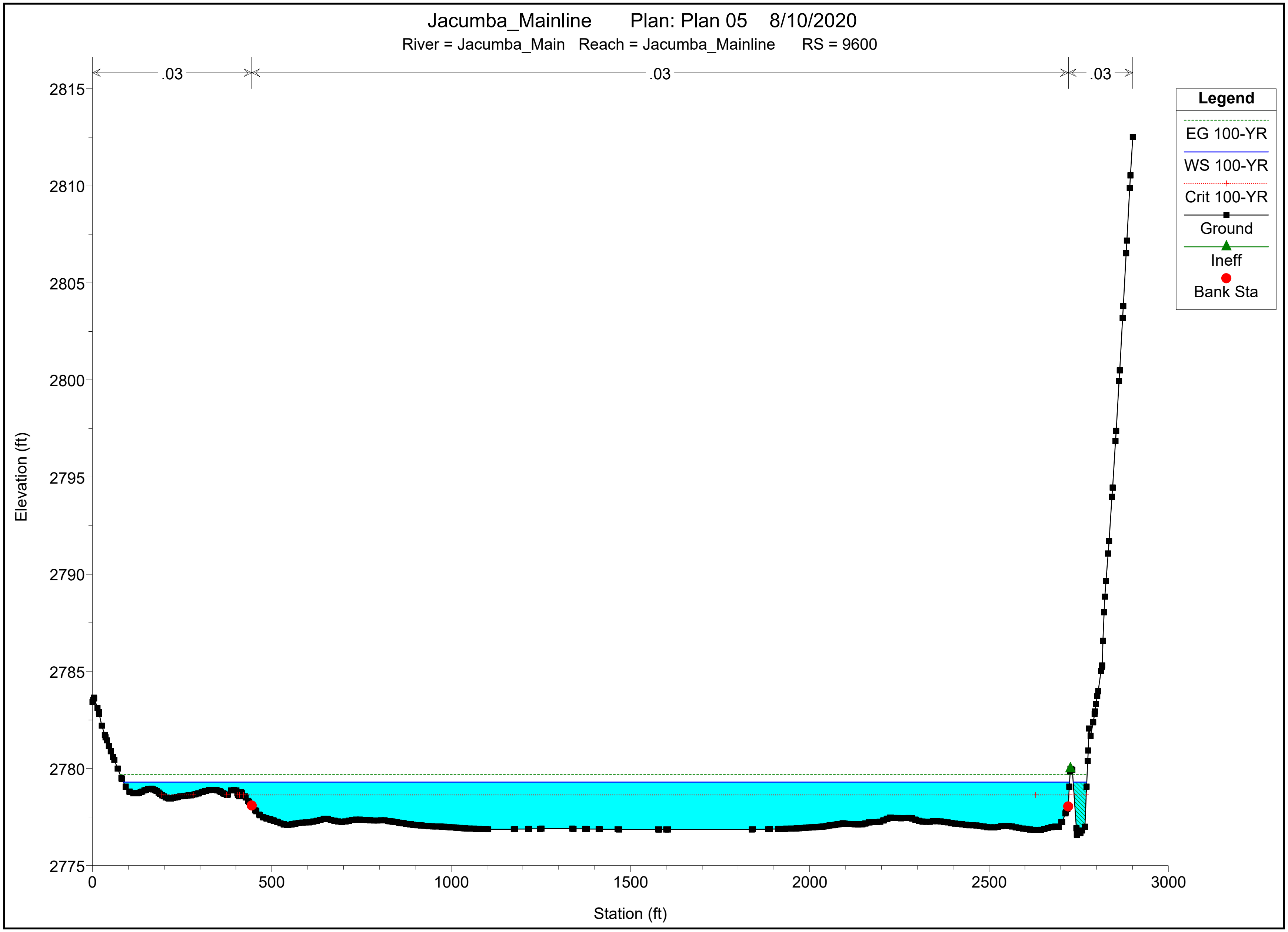
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 10800
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2796
2794
2792
2790
2788
2786
2784
Station (ft)
0
500
1000
1500
2000
2500
3000
3500

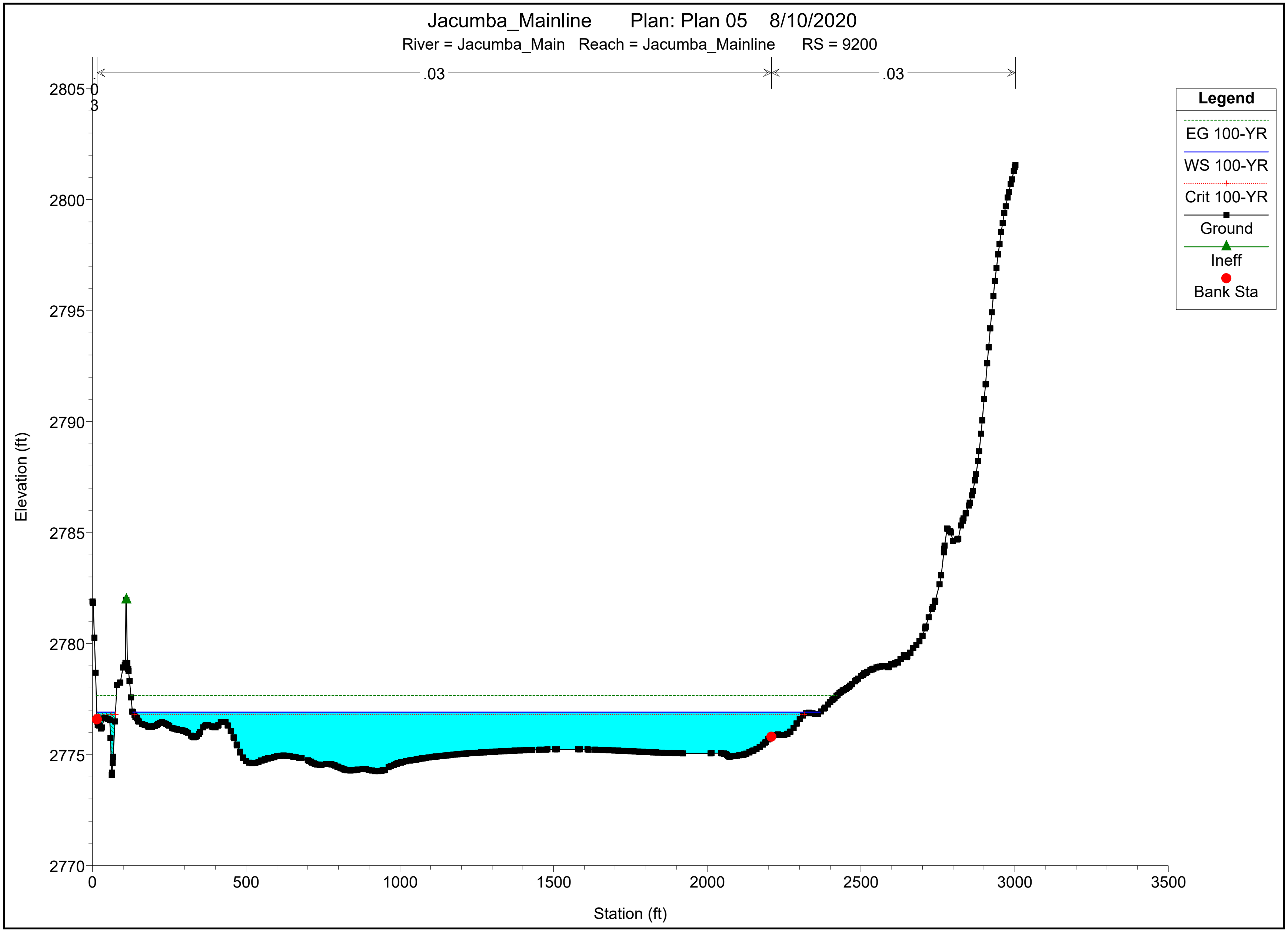


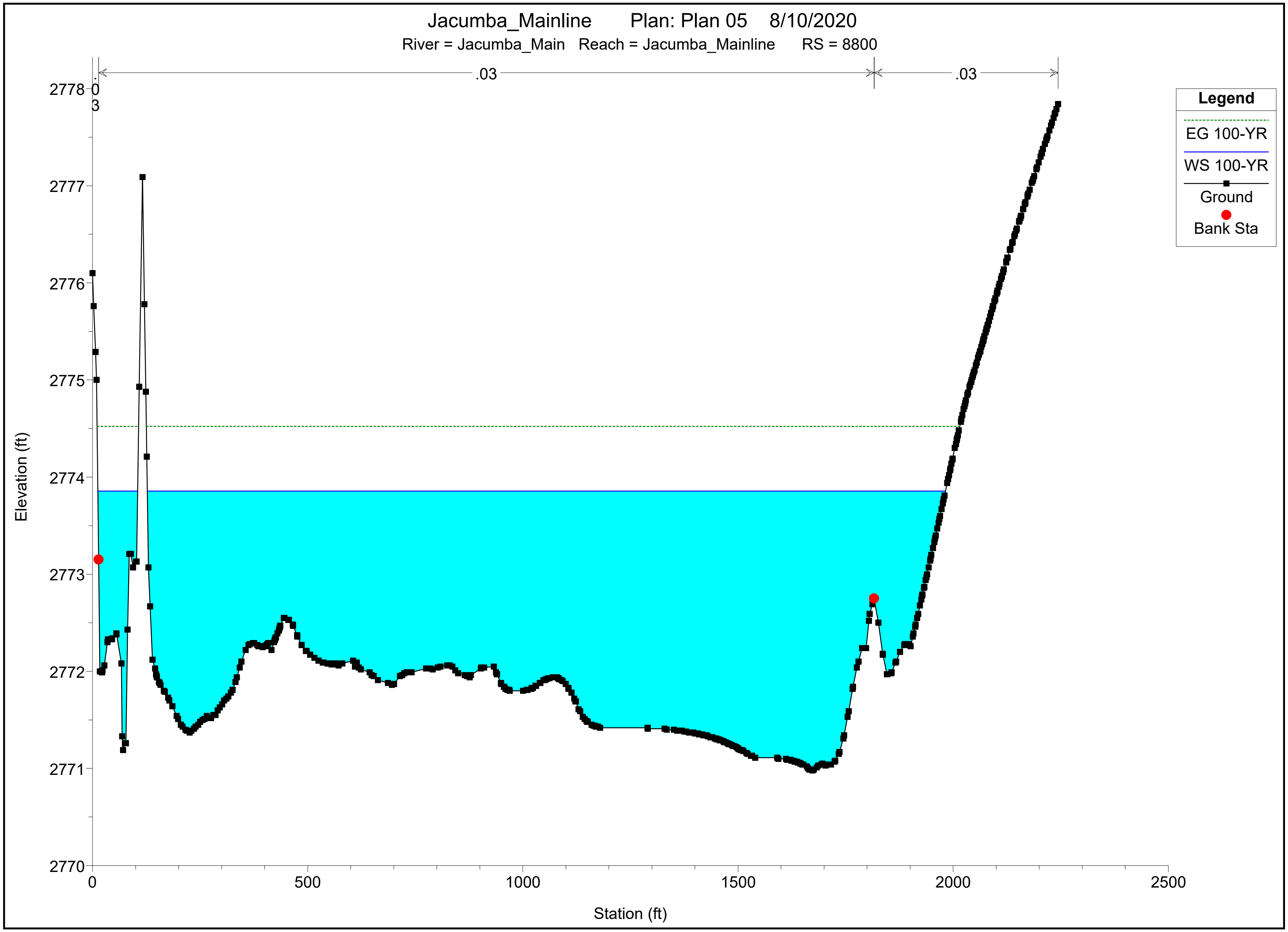
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 10400
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2794
2792
2790
2788
2786
2784
2782
2780
0
500
1000
1500
2000
2500
3000
Station (ft)



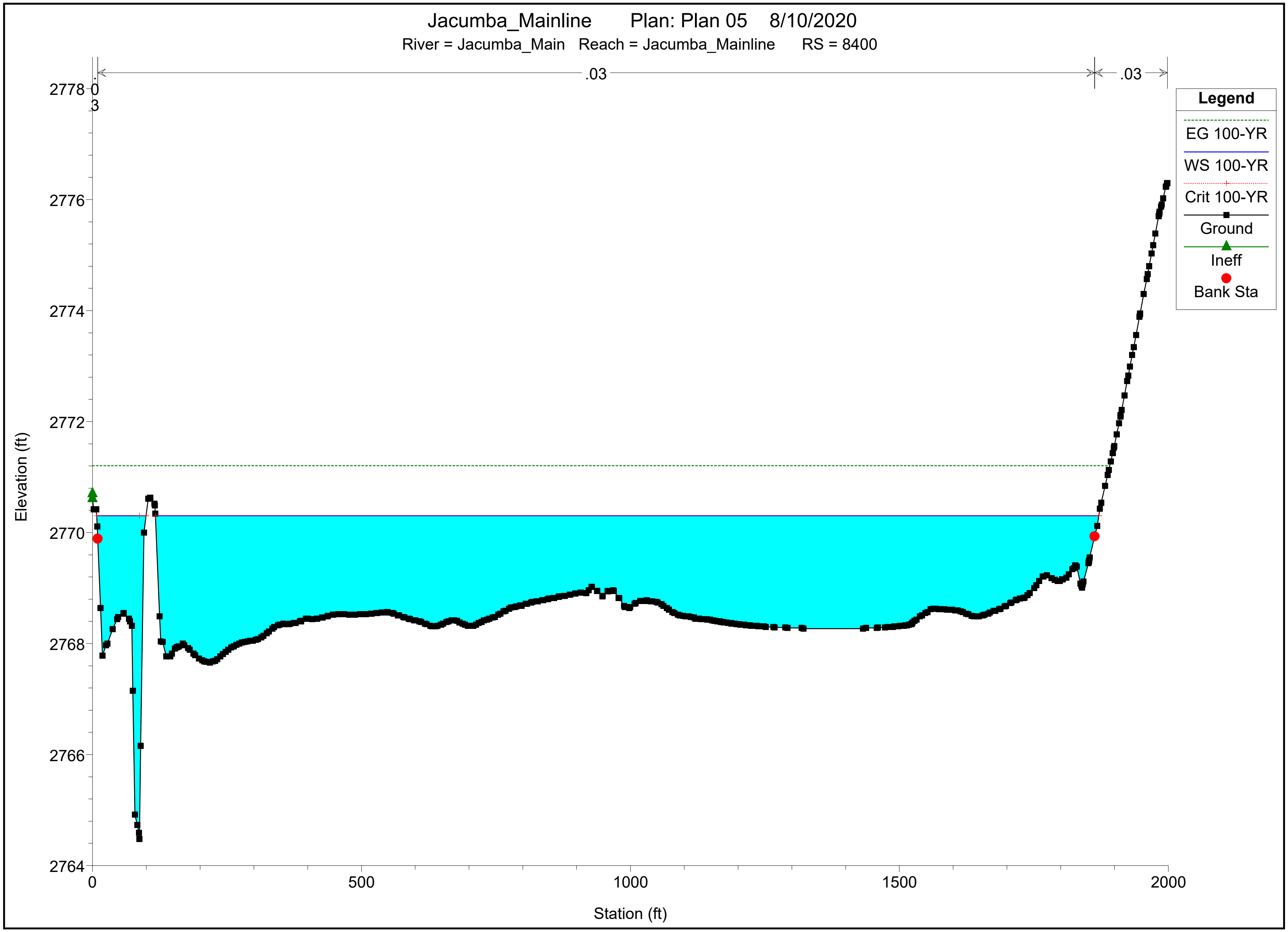
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 10000
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2796
2794
2792
2790
2788
2786
2784
2782
2780
2778
0
500
1000
1500
2000
2500
3000
3500
Station (ft)


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 9600
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2775
2780
2785
2790
2795
2800
2805
2810
2815
Station (ft)
0
500
1000
1500
2000
2500
3000

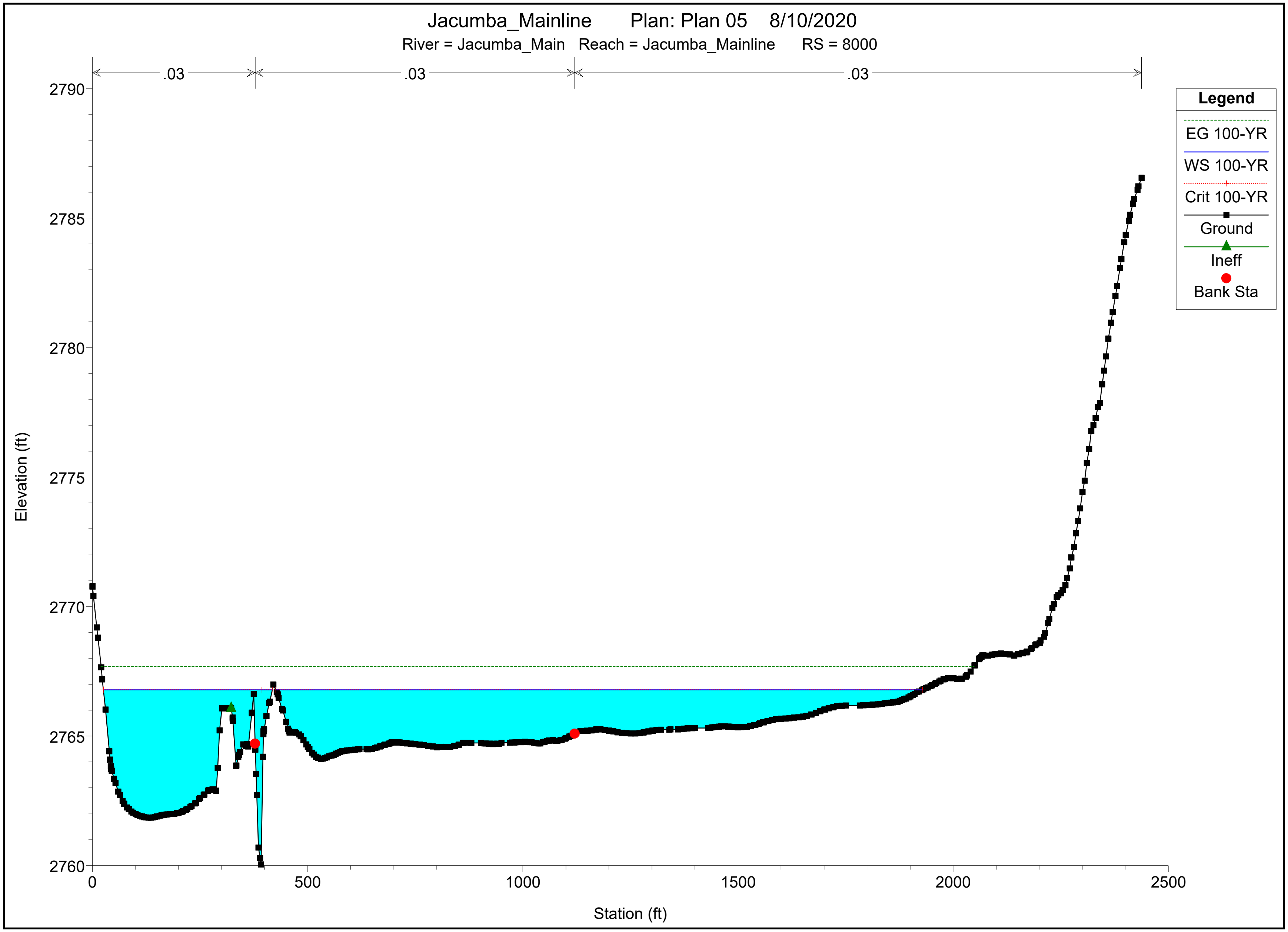

Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 9200
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2770
2775
2780
2785
2790
2795
2800
2805
0
500
1000
1500
2000
2500
3000
3500



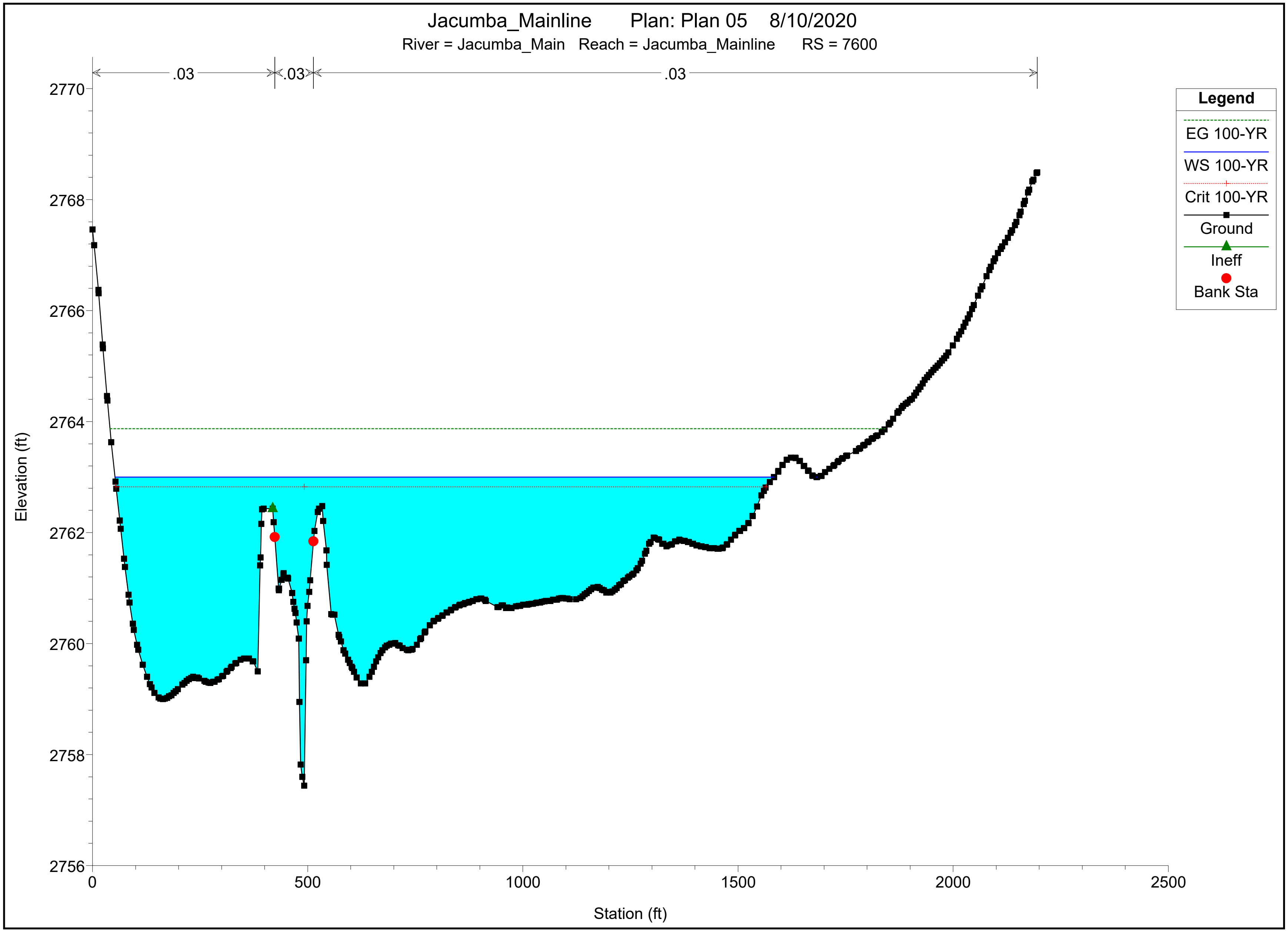
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 8800
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2778
2777
2776
2775
2774
2773
2772
2771
2770
0
500
1000
1500
2000
2500



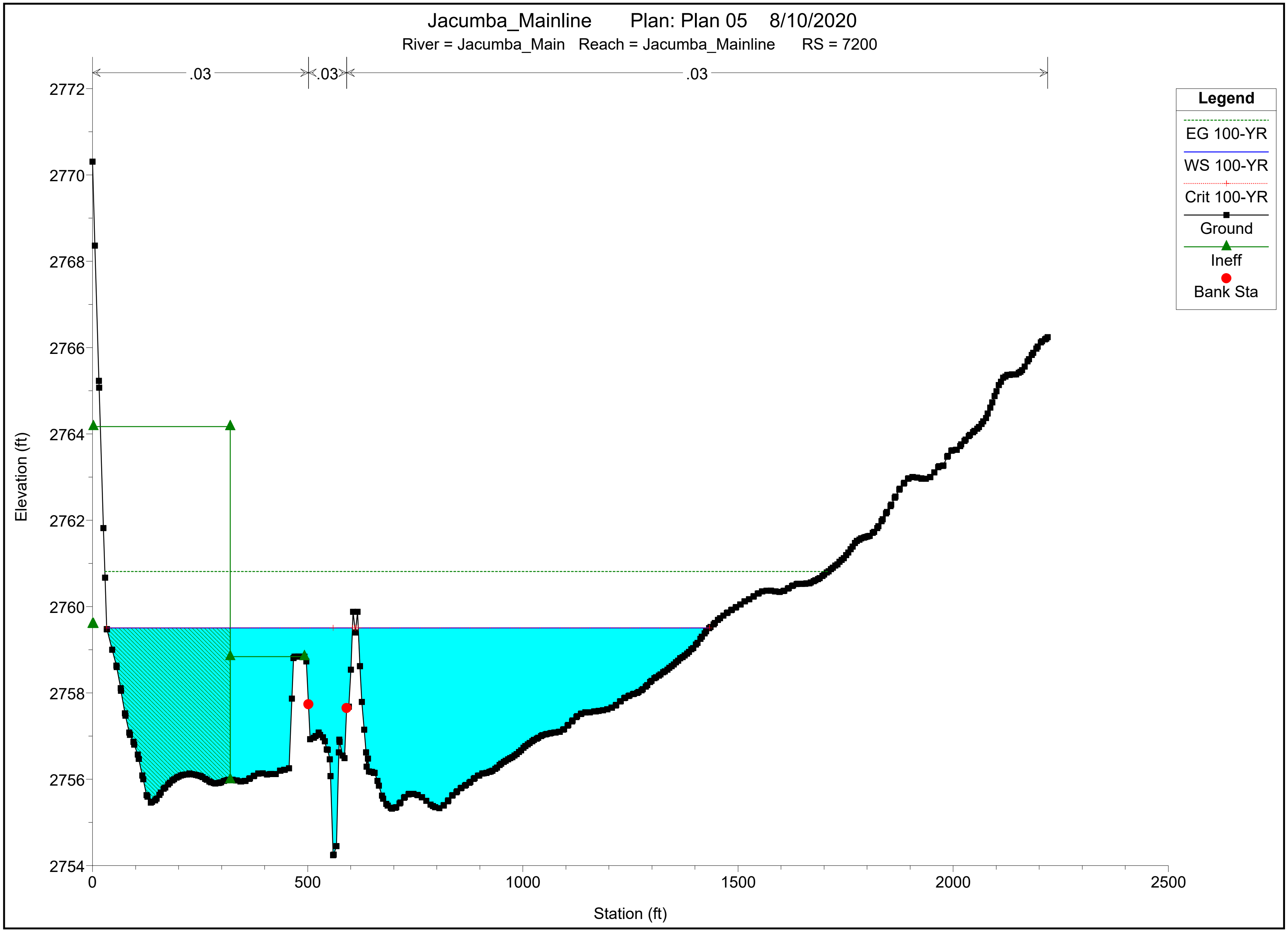
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 8400
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2778
2776
2774
2772
2770
2768
2766
2764
0
500
1000
1500
2000
Station (ft)



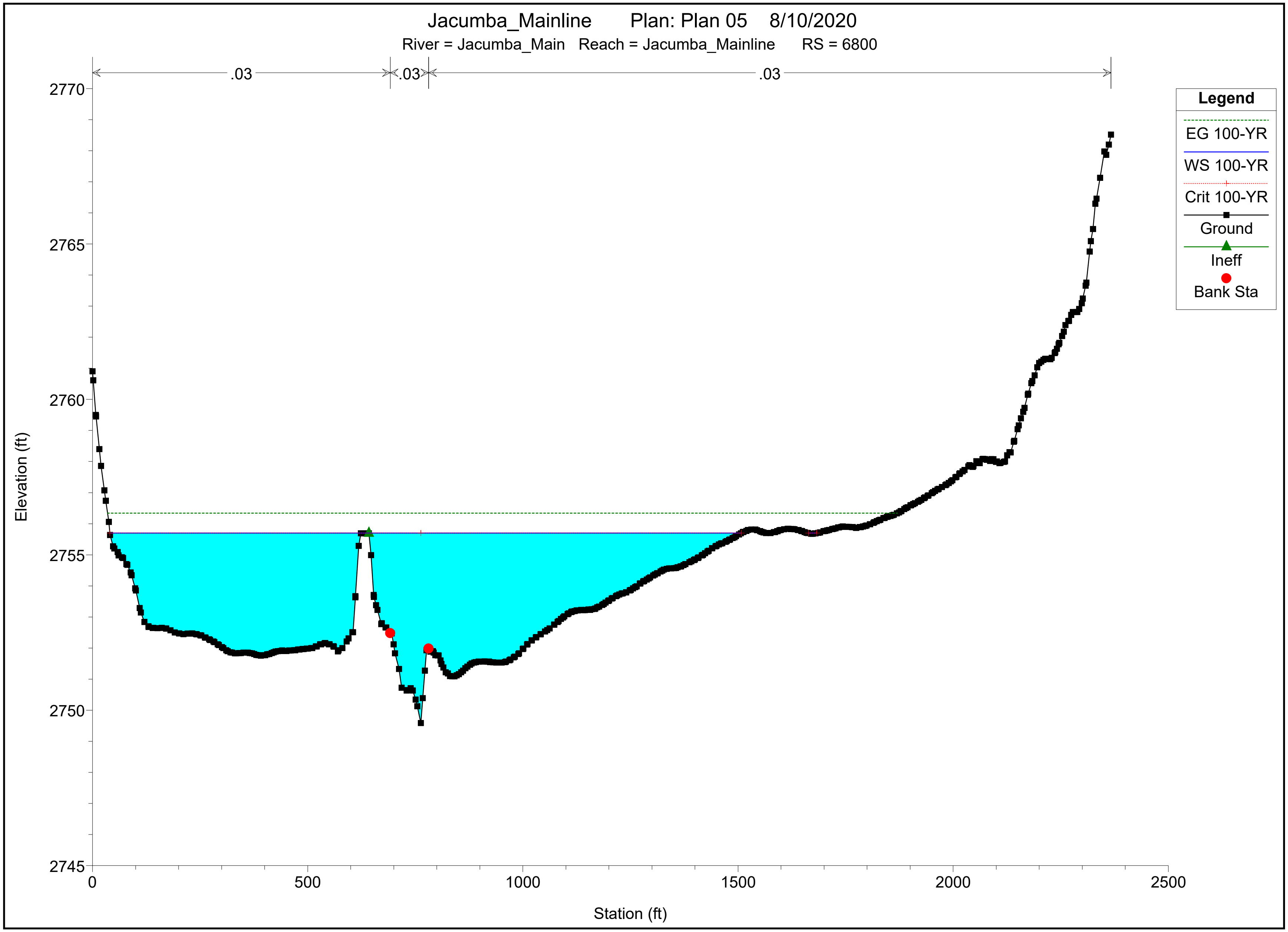
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 8000
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2760
2765
2770
2775
2780
2785
2790
0
500
1000
1500
2000
2500
Station (ft)



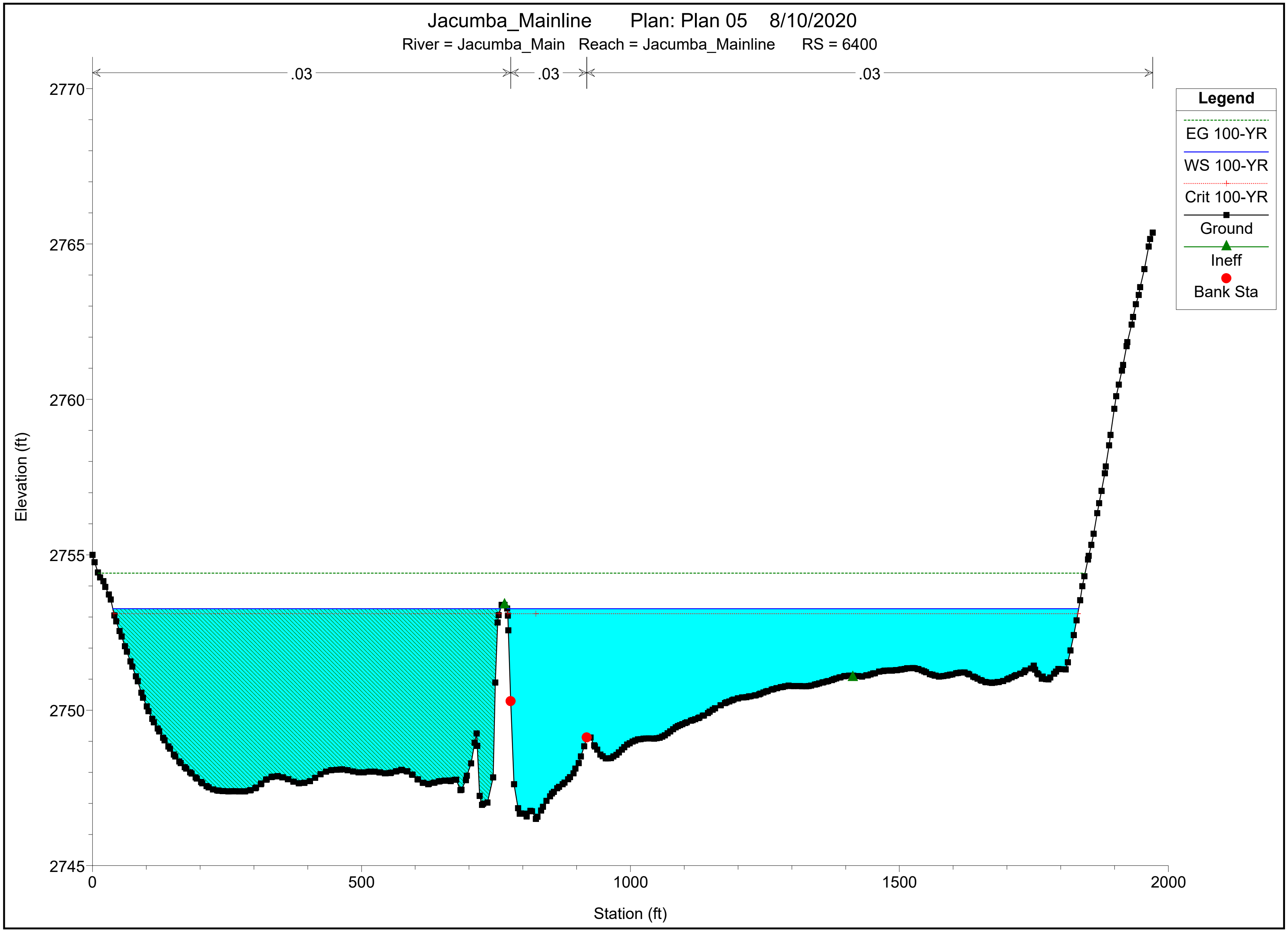
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 7600
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2756
2758
2760
2762
2764
2766
2768
2770
0
500
1000
1500
2000
2500



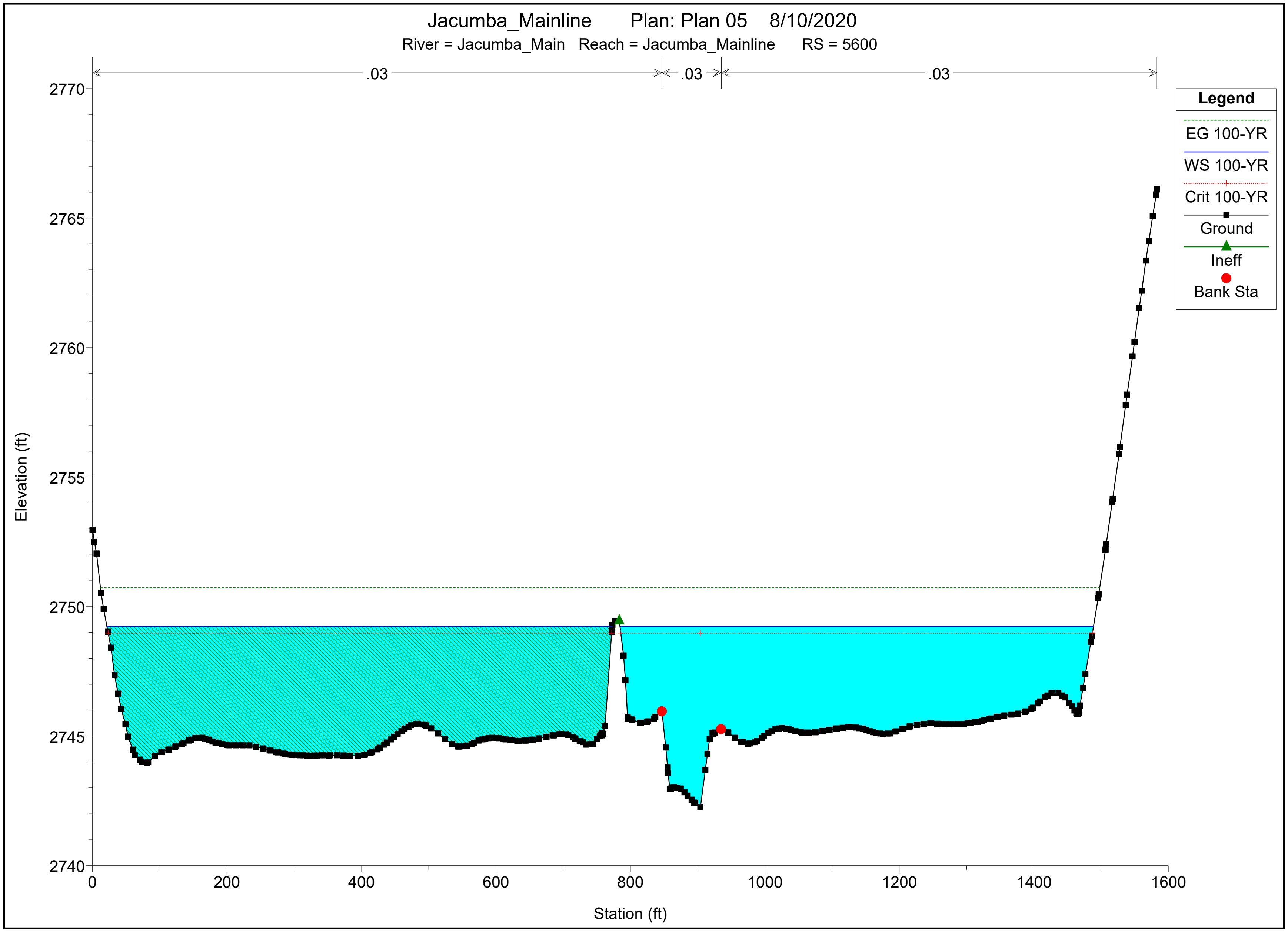
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 7200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2772
2770
2768
2766
2764
2762
2760
2758
2756
2754
0
500
1000
1500
2000
2500
Station (ft)



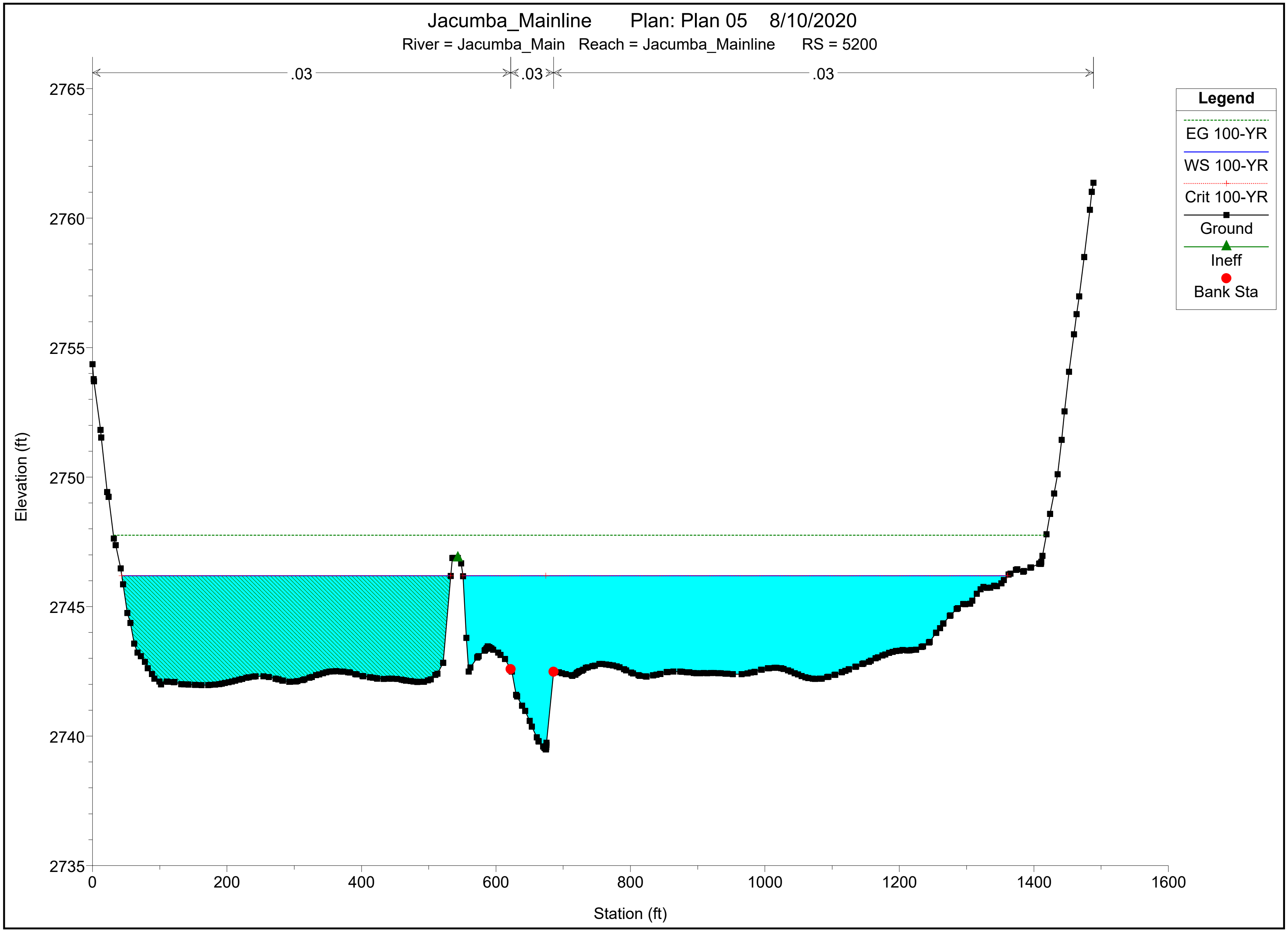
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 6800
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2770
2765
2760
2755
2750
2745
0
500
1000
1500
2000
2500
Station (ft)

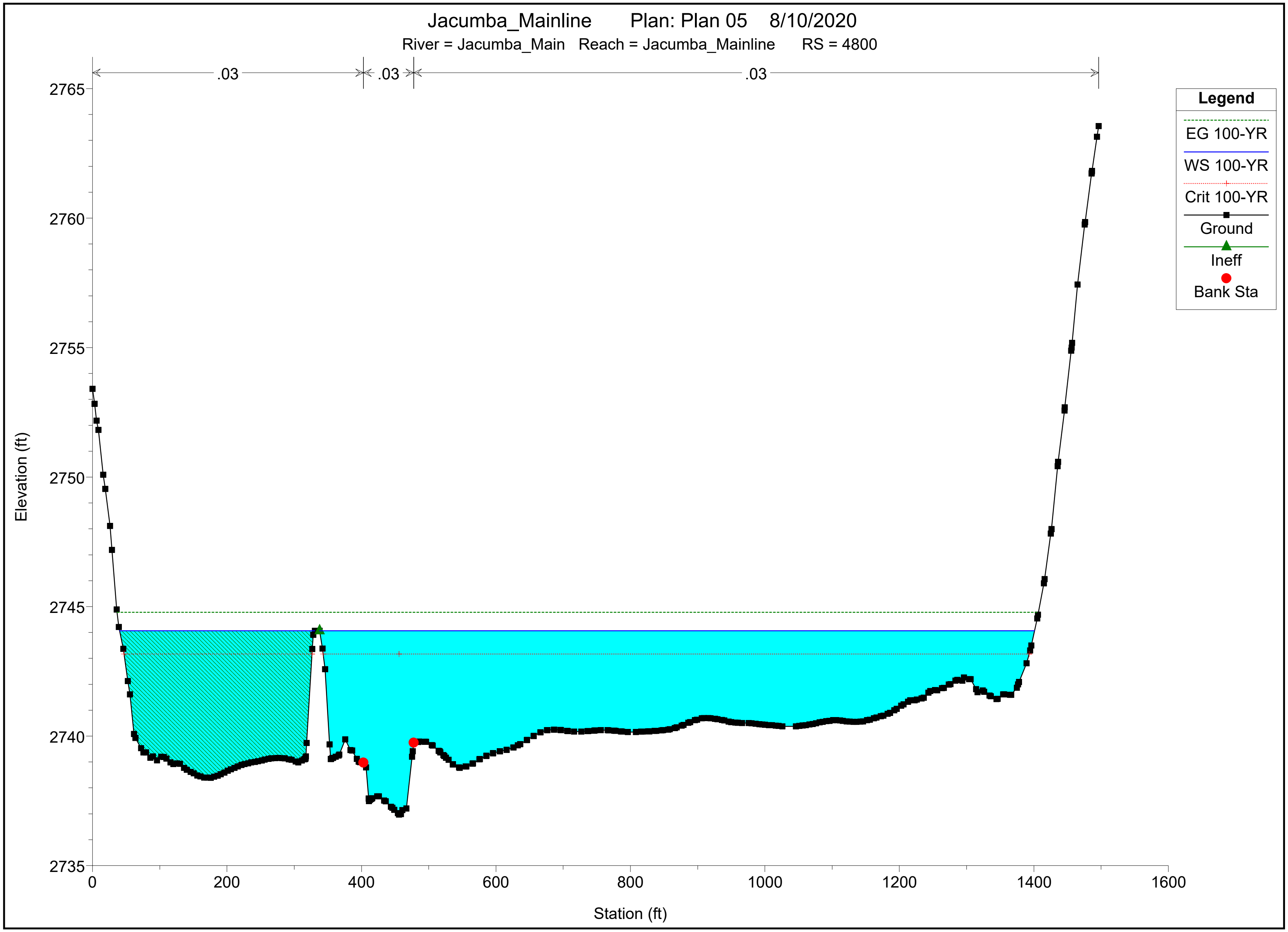


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 6400
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2770
2765
2760
2755
2750
2745
0
500
1000
1500
2000
Station (ft)

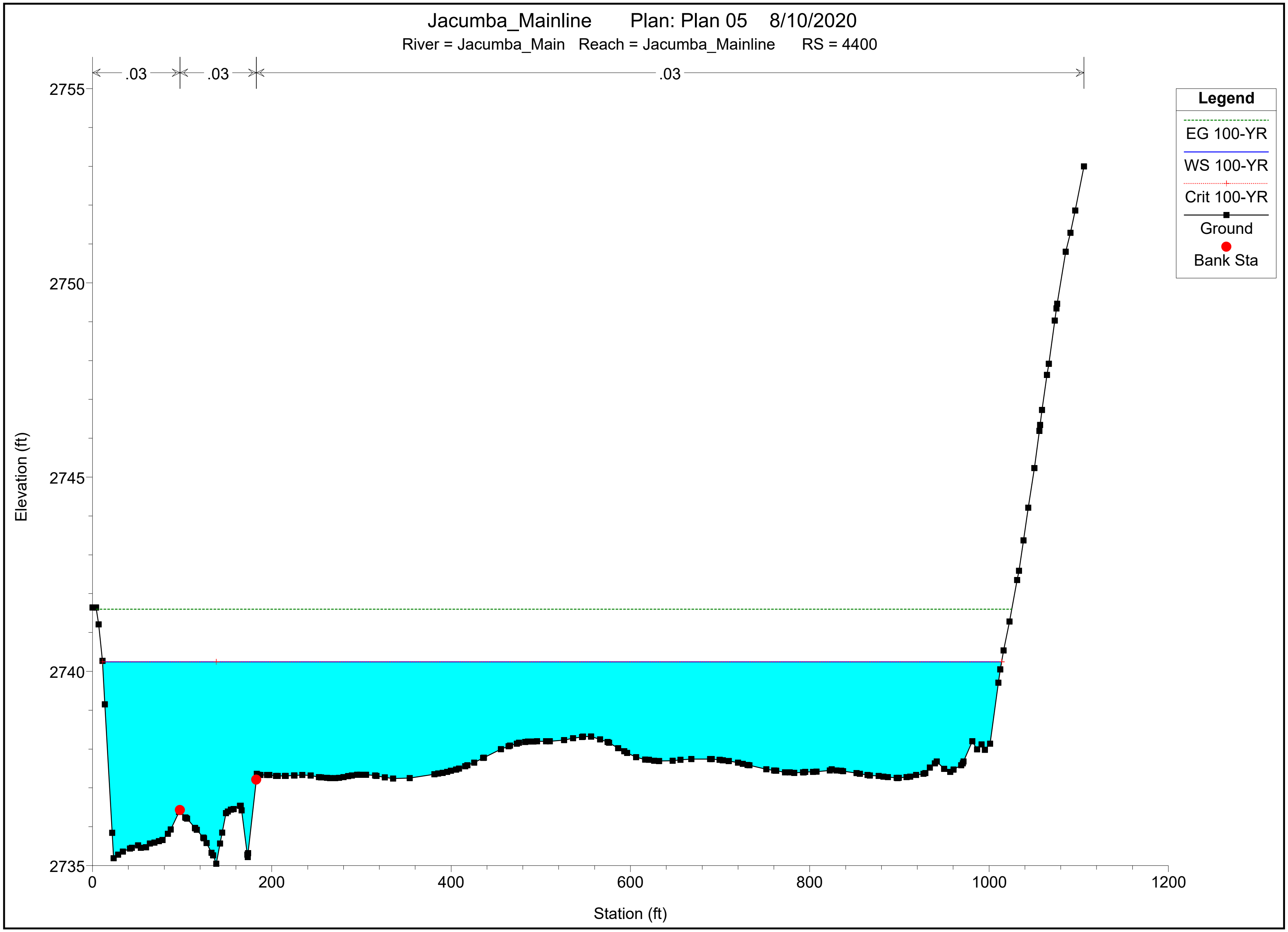


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 5600
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2740
2745
2750
2755
2760
2765
2770
Station (ft)
0
200
400
600
800
1000
1200
1400
1600

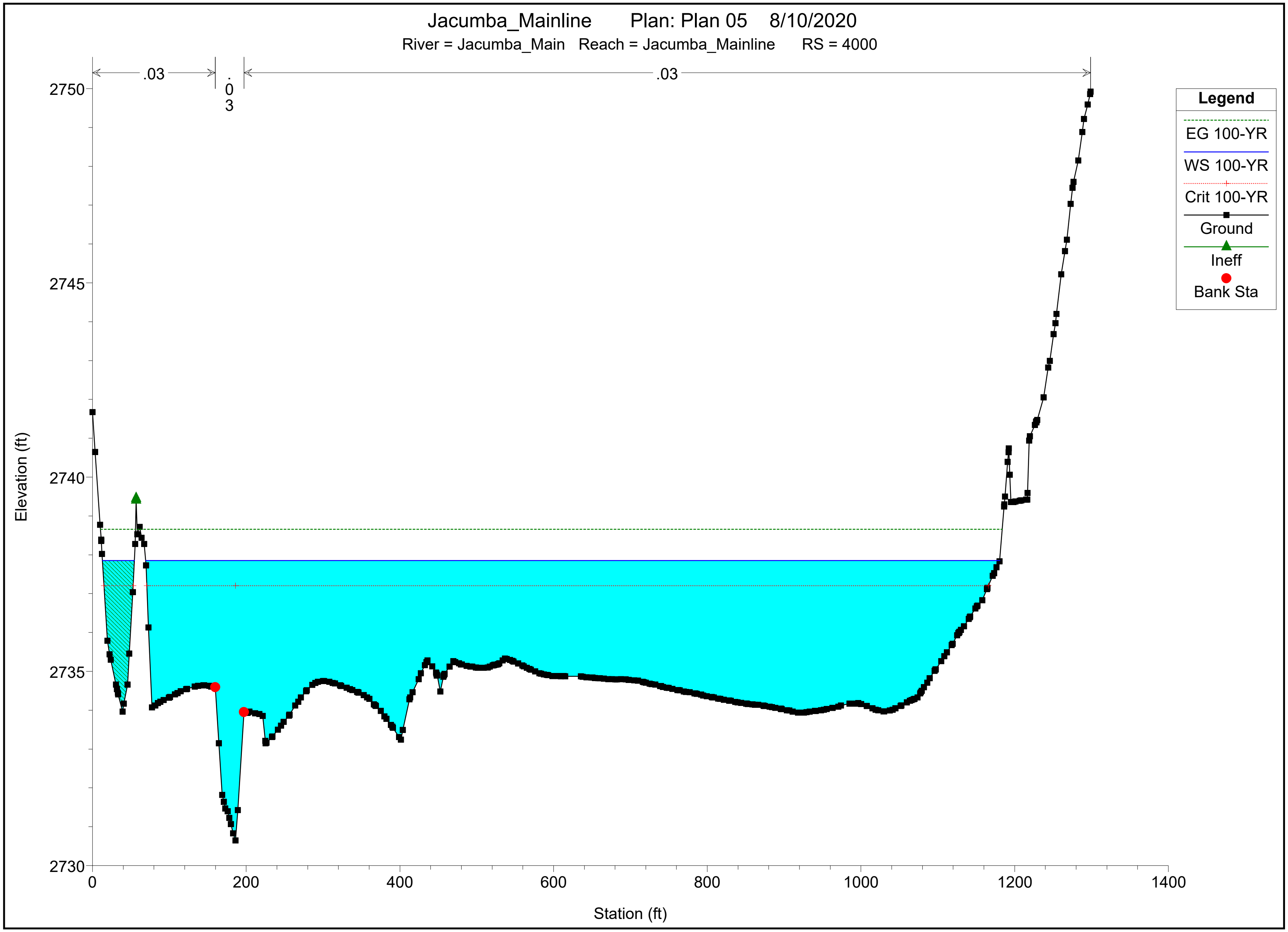

Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 5200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2735
2740
2745
2750
2755
2760
2765
0
200
400
600
800
1000
1200
1400
1600
Station (ft)

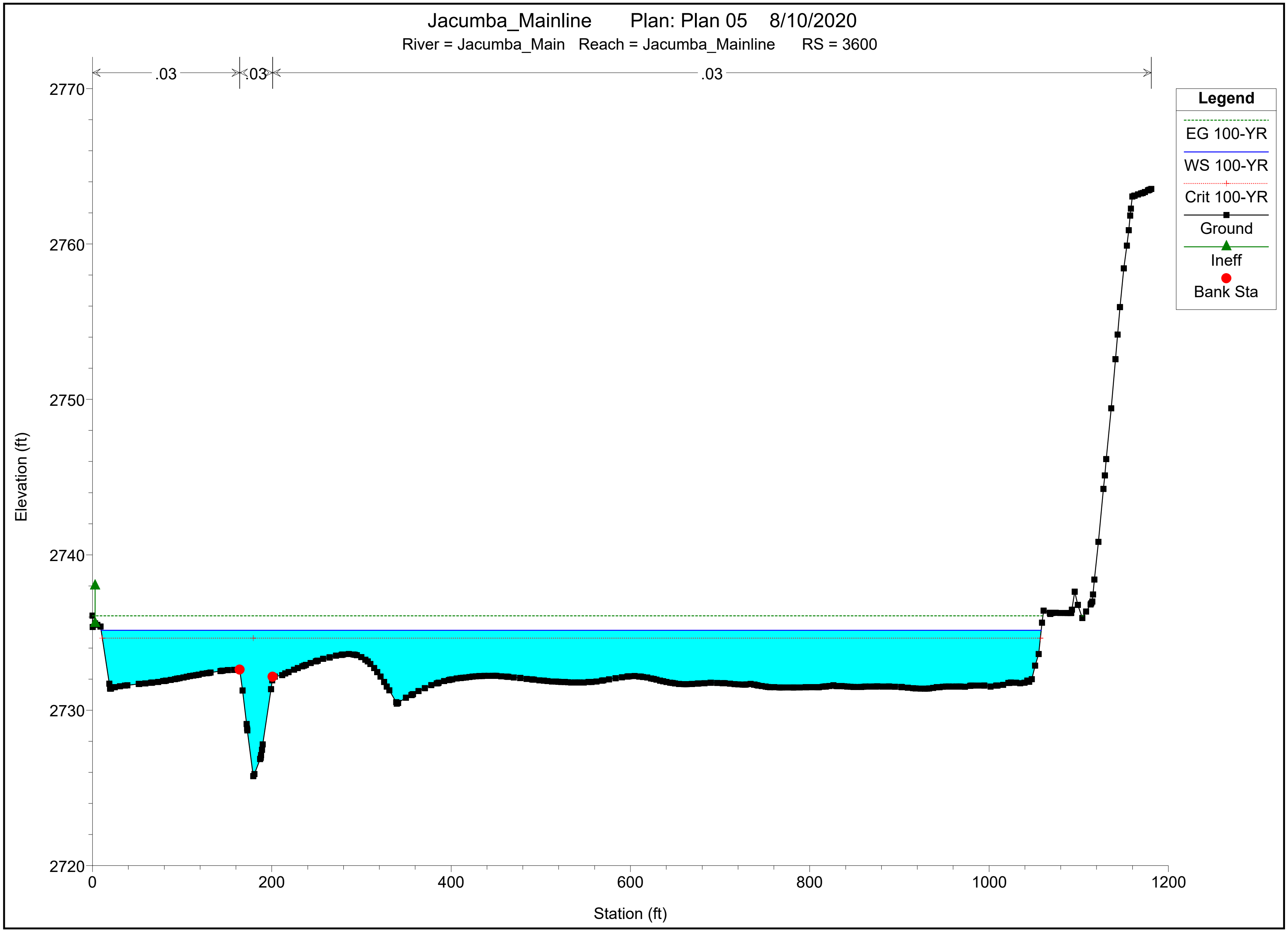


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 4800
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2765
2760
2755
2750
2745
2740
2735
0
200
400
600
800
1000
1200
1400
1600
Station (ft)

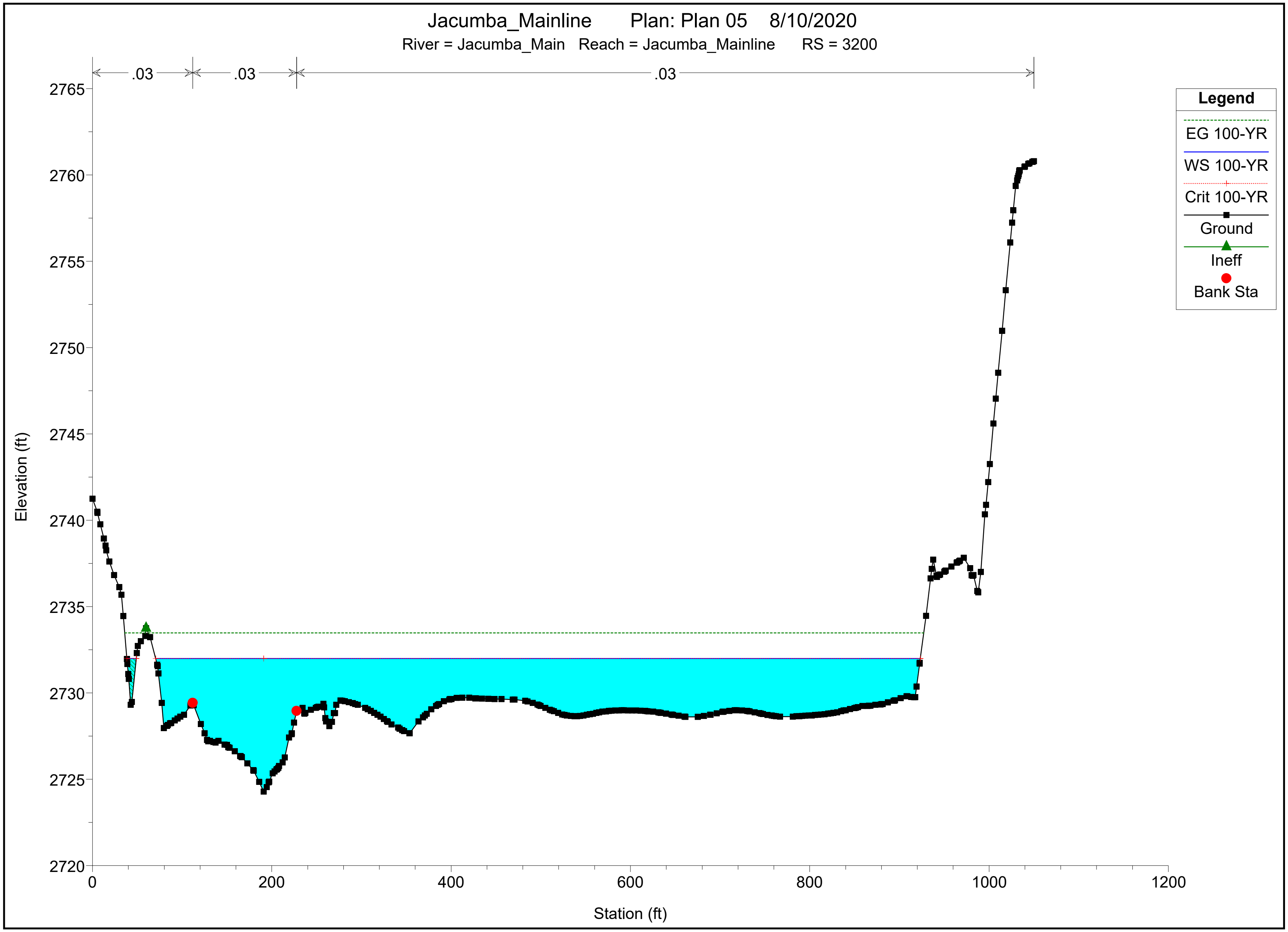


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 4400
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2735
2740
2745
2750
2755
Station (ft)
0
200
400
600
800
1000
1200

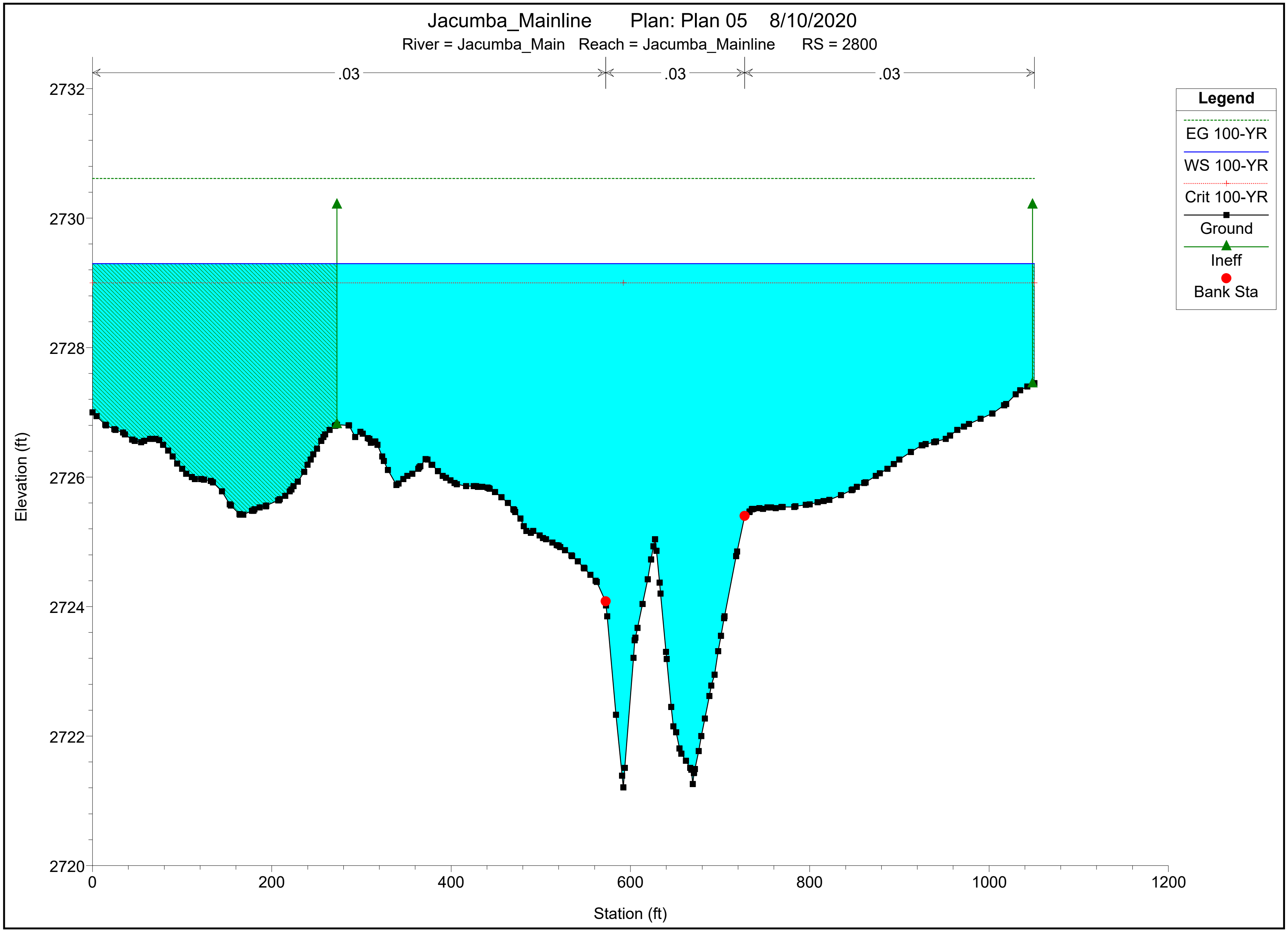

Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 4000
.03
.
0
3
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2750
2745
2740
2735
2730
0
200
400
600
800
1000
1200
1400
Station (ft)

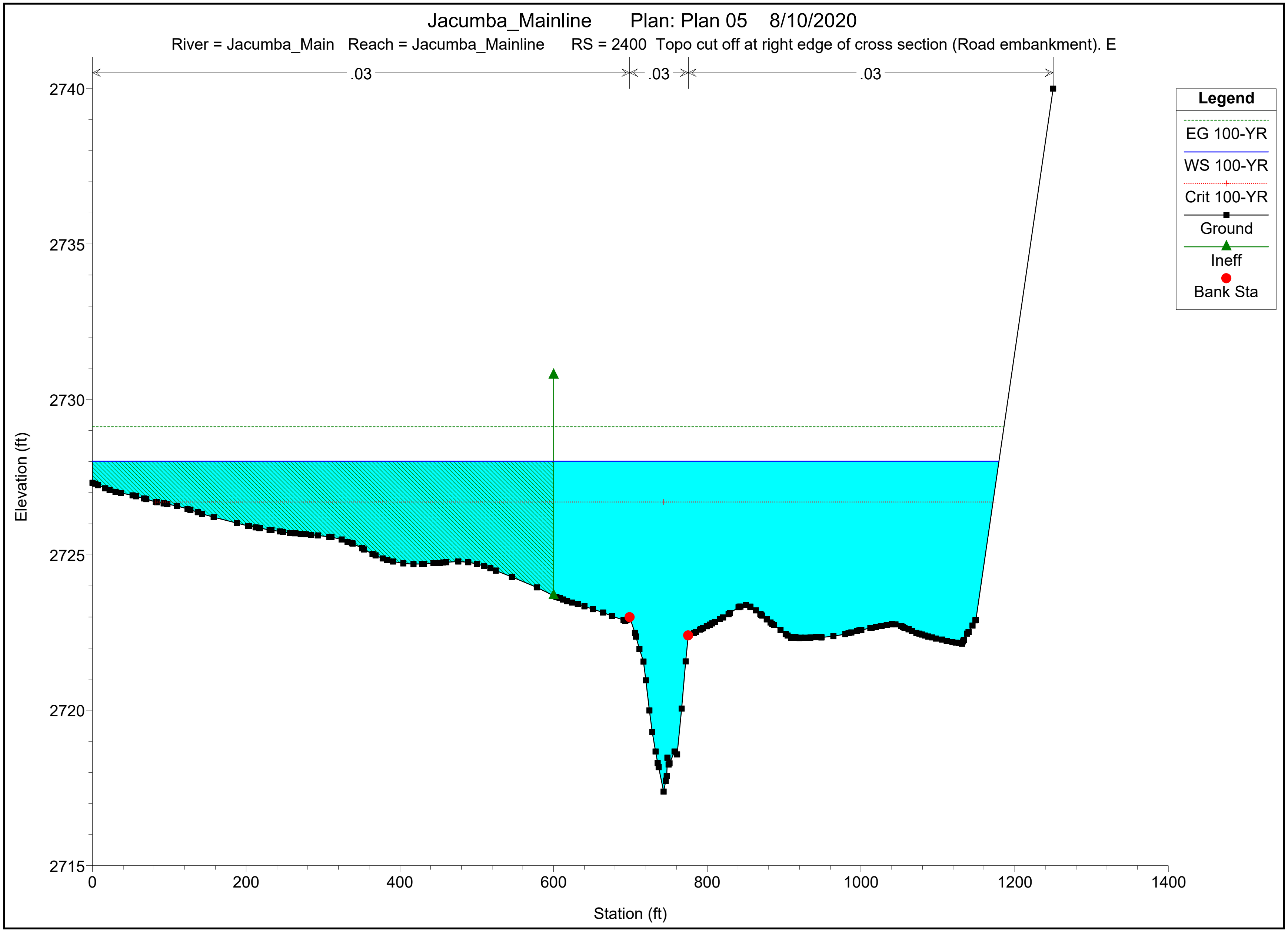


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 3600
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2770
2760
2750
2740
2730
2720
0
200
400
600
800
1000
1200
Station (ft)

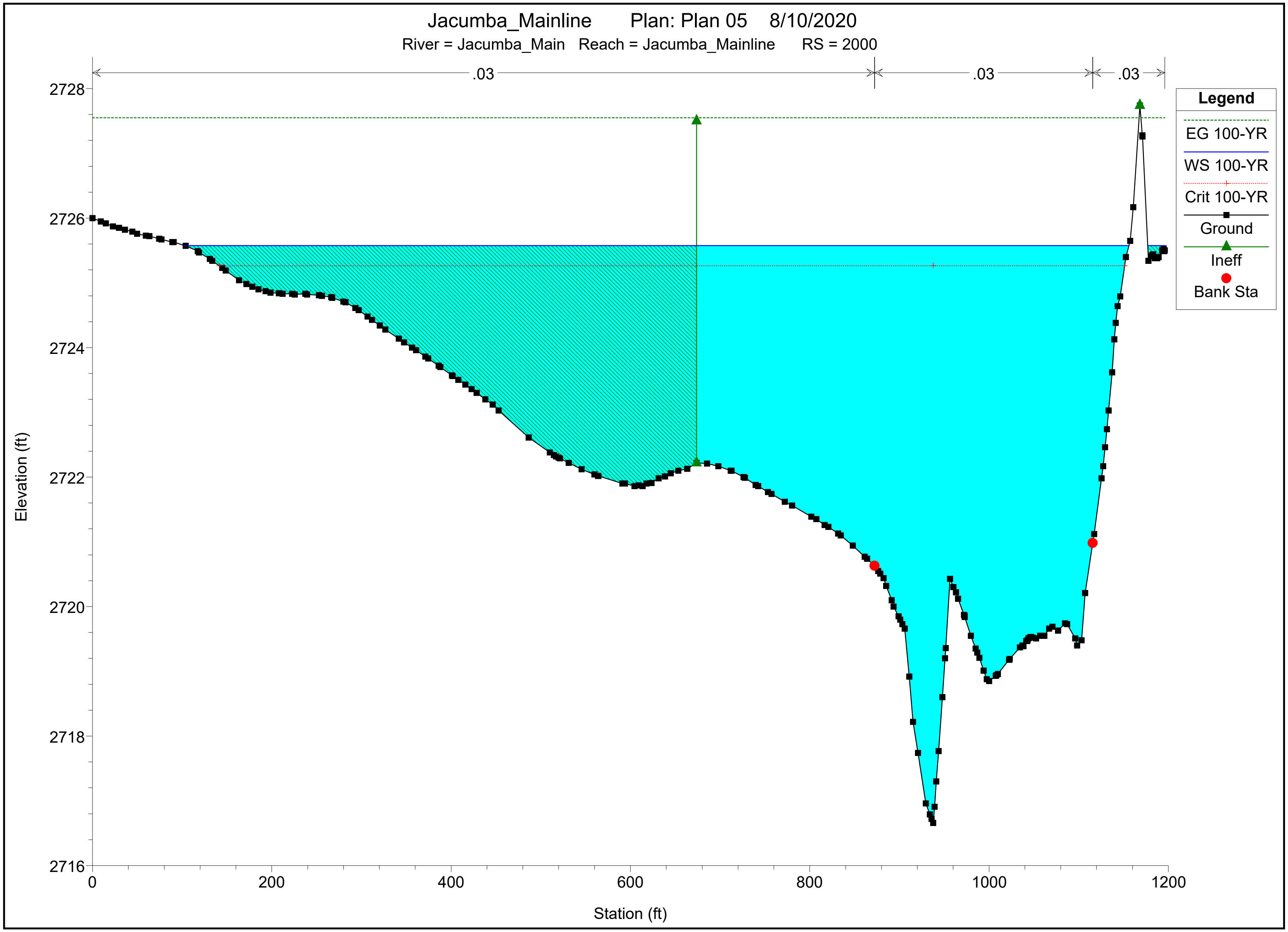


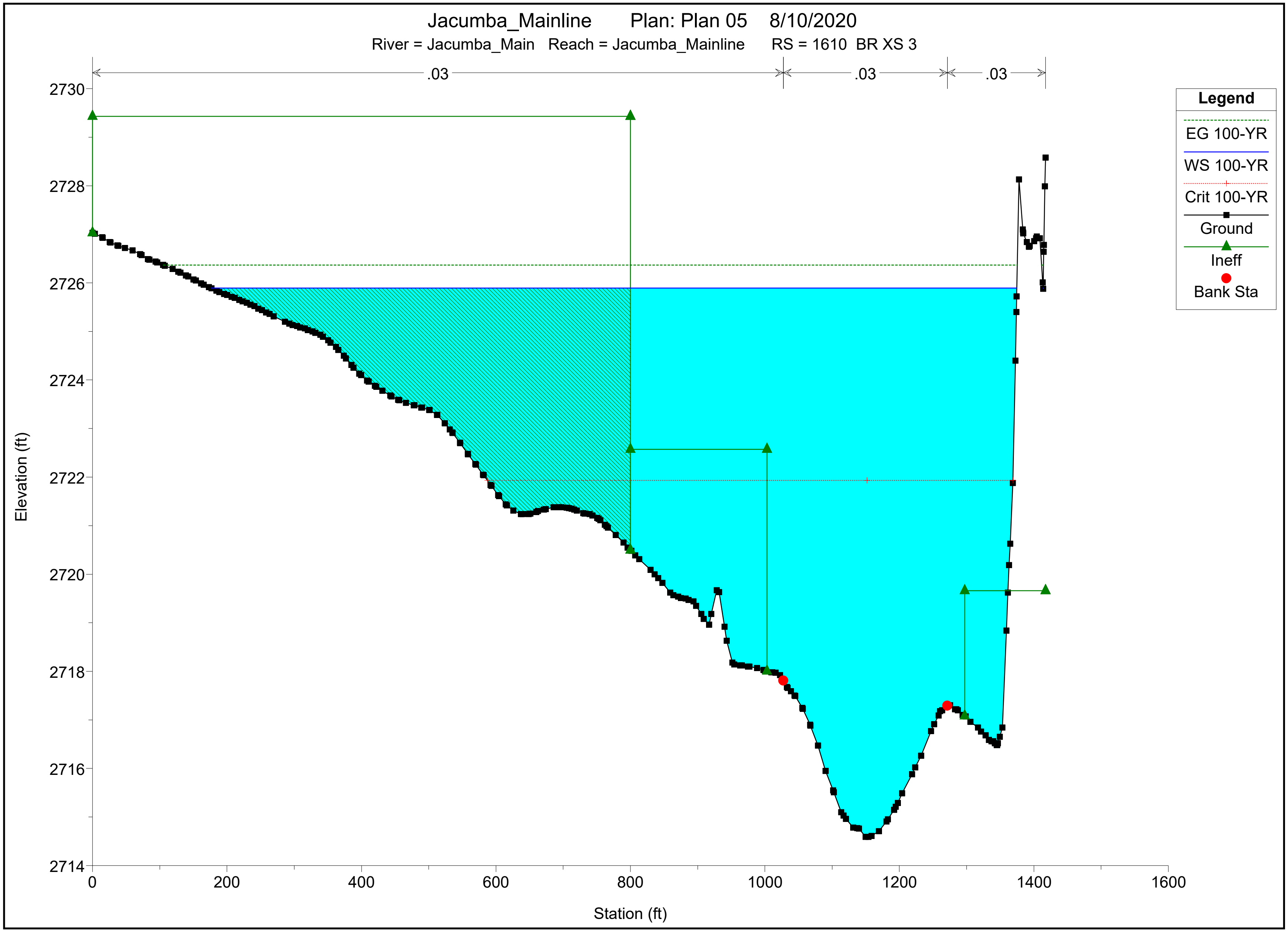
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 3200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2765
2760
2755
2750
2745
2740
2735
2730
2725
2720
0
200
400
600
800
1000
1200
Station (ft)

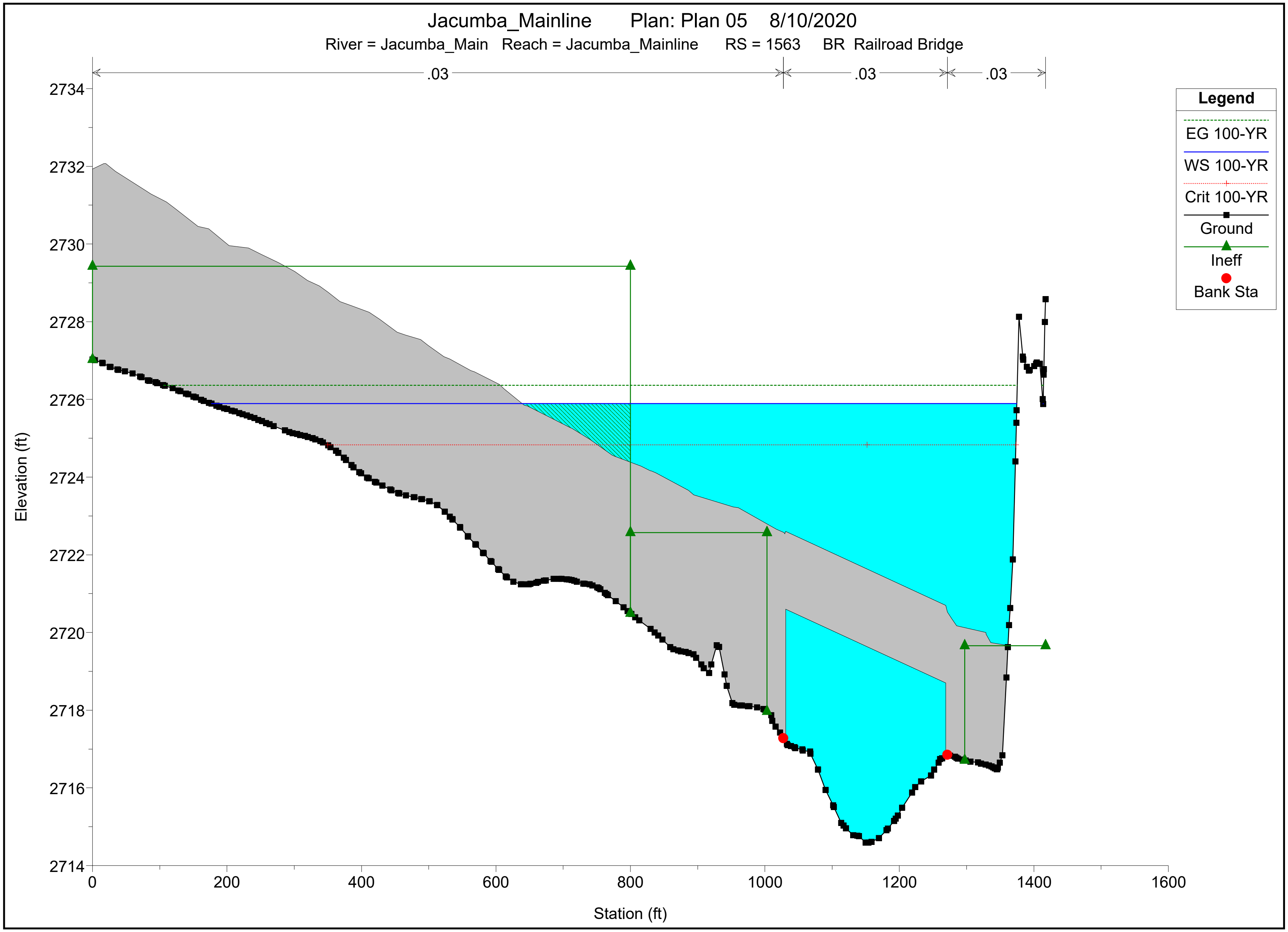

Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 2800
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2732
2730
2728
2726
2724
2722
2720
0
200
400
600
800
1000
1200
Station (ft)



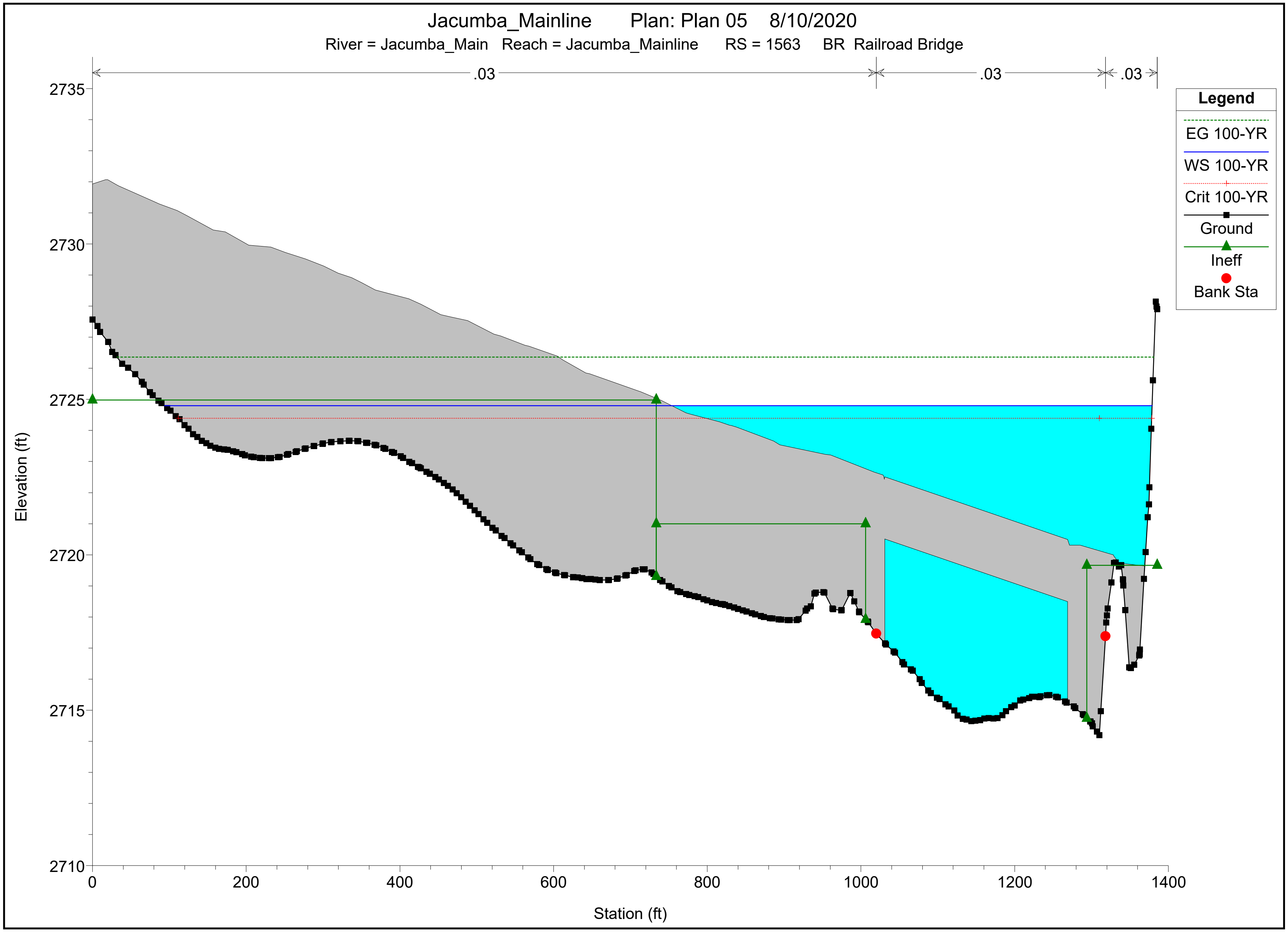
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 2400 Topo cut off at right edge of cross section (Road embankment). E
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2740
2735
2730
2725
2720
2715
0
200
400
600
800
1000
1200
1400


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 2000
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2728
2726
2724
2722
2720
2718
2716
Station (ft)
0
200
400
600
800
1000
1200

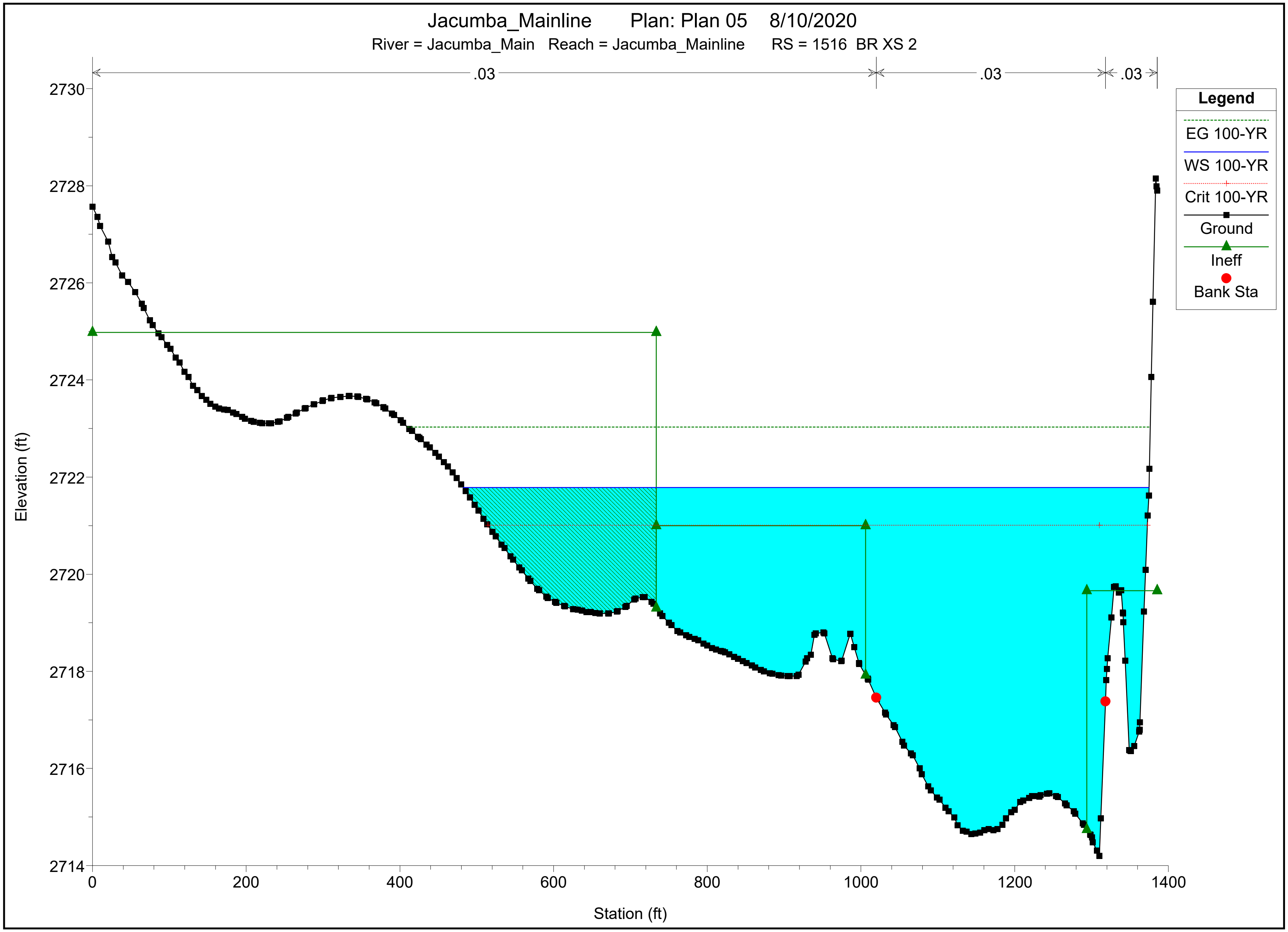

Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1610 BR XS 3
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2730
2728
2726
2724
2722
2720
2718
2716
2714
0
200
400
600
800
1000
1200
1400
1600

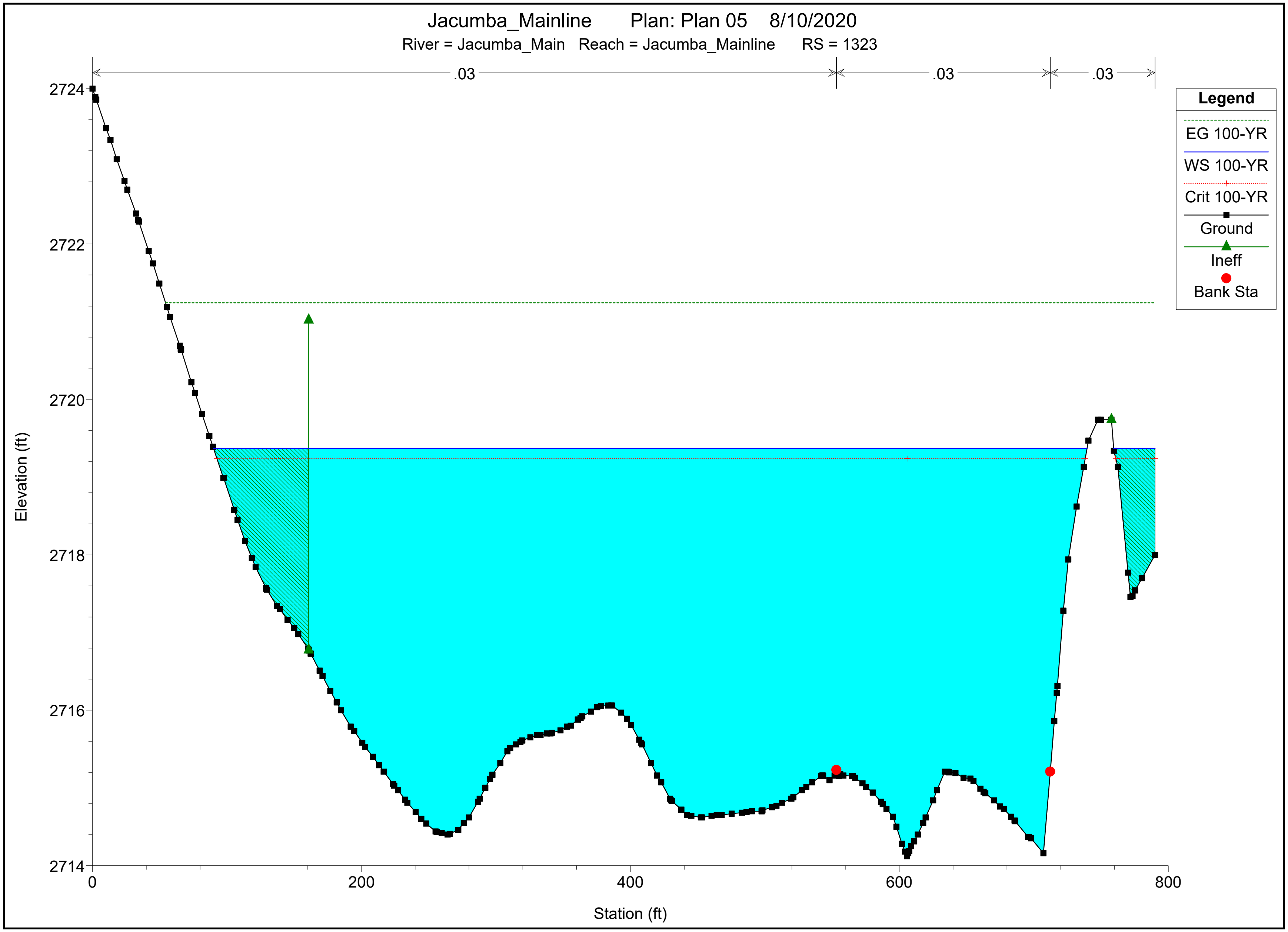


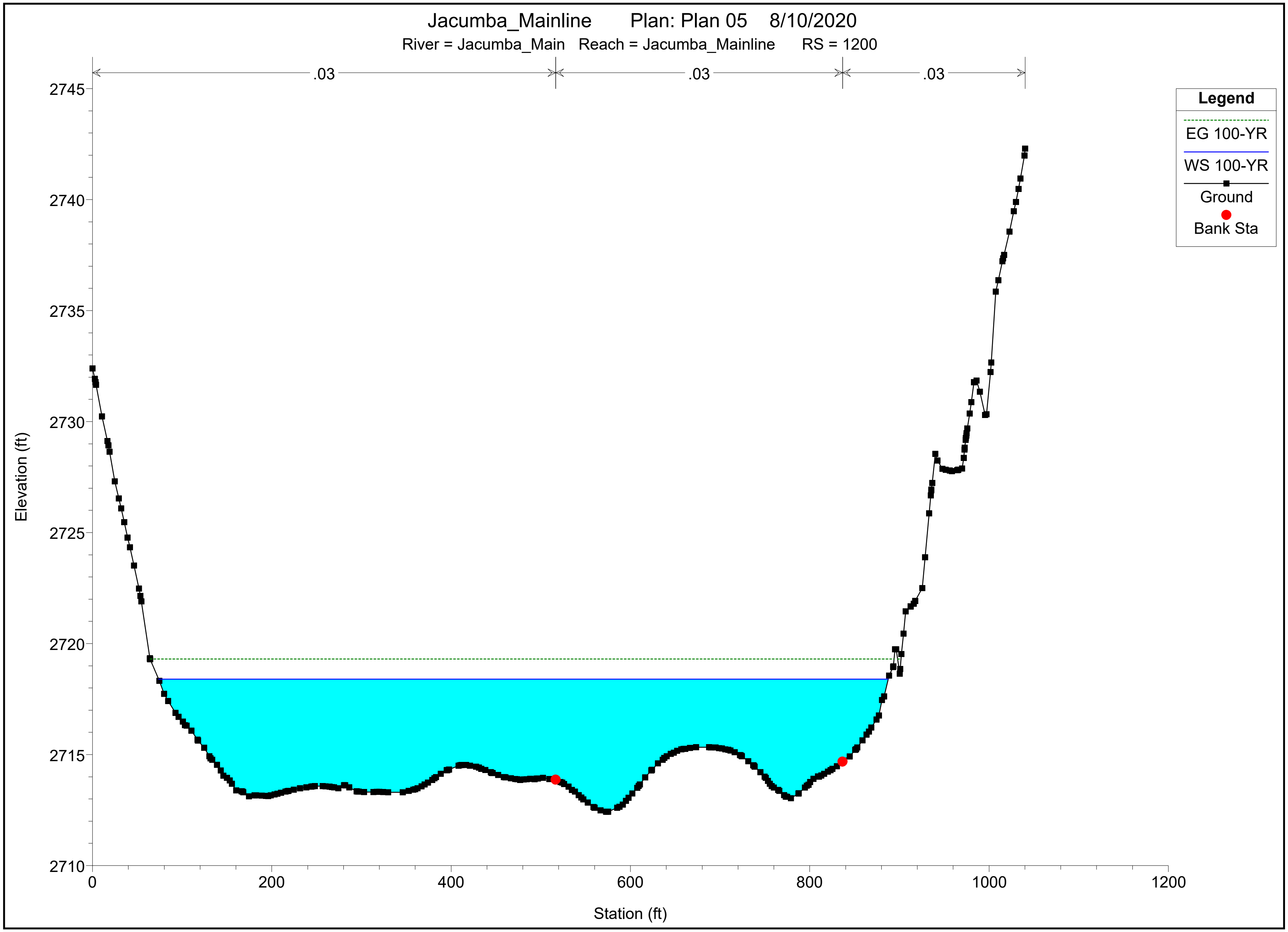
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1563 BR Railroad Bridge
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2714
2716
2718
2720
2722
2724
2726
2728
2730
2732
2734
Station (ft)
0
200
400
600
800
1000
1200
1400
1600



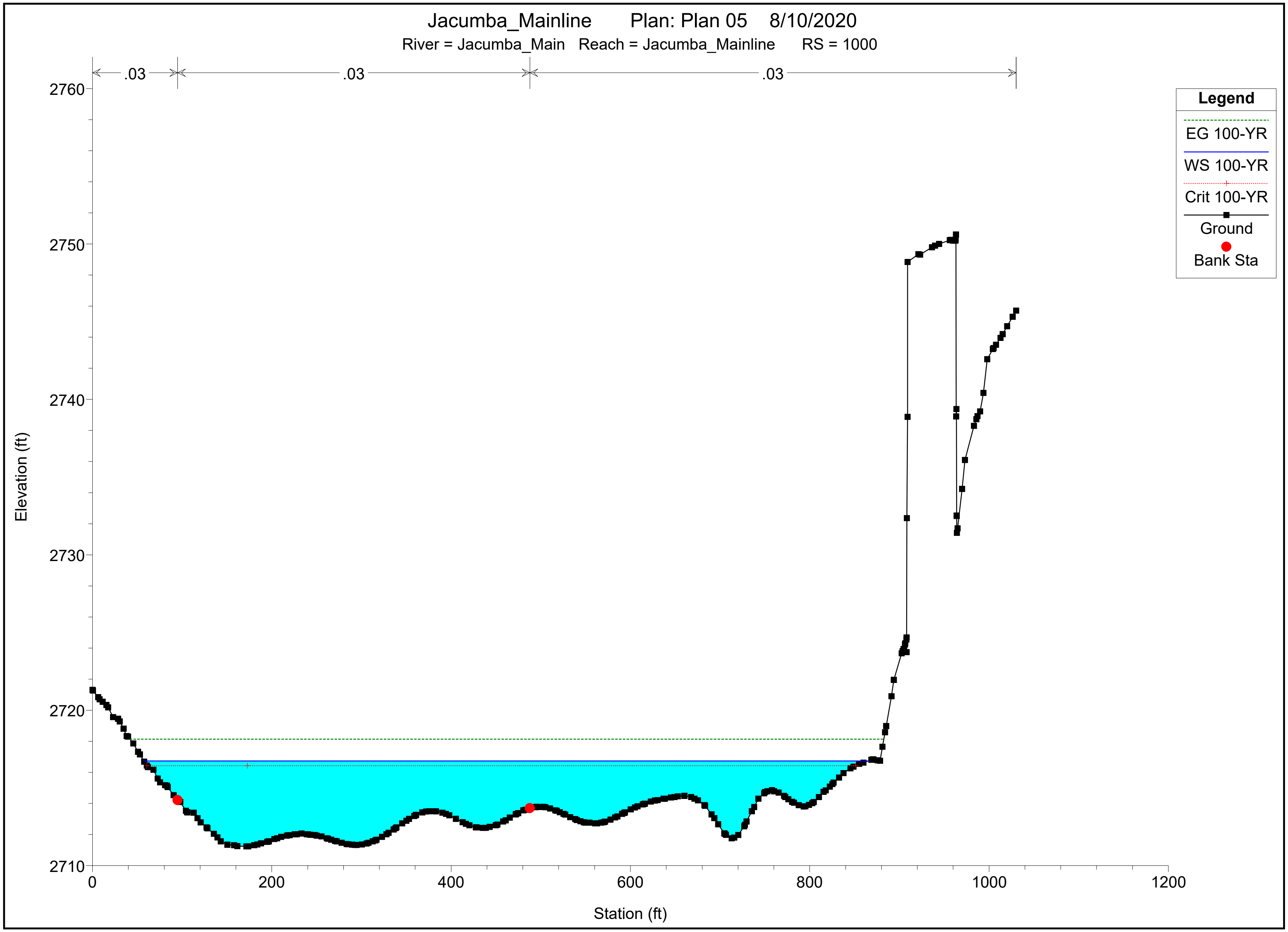
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1563 BR Railroad Bridge
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2735
2730
2725
2720
2715
2710
0
200
400
600
800
1000
1200
1400
Station (ft)


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1516 BR XS 2
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2730
2728
2726
2724
2722
2720
2718
2716
2714
0
200
400
600
800
1000
1200
1400
Station (ft)


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1323
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Ineff
Bank Sta
Elevation (ft)
2724
2722
2720
2718
2716
2714
0
200
400
600
800
Station (ft)



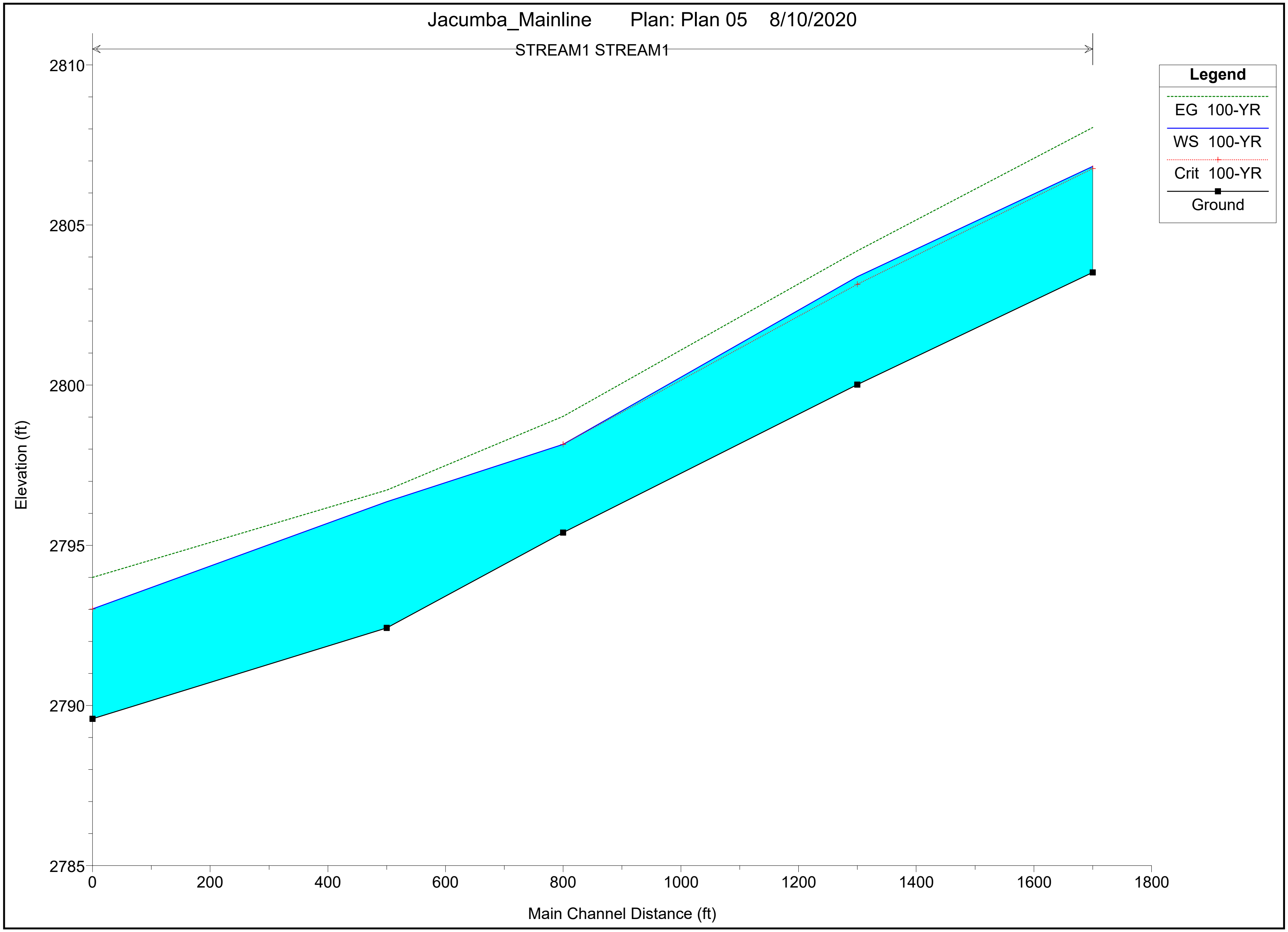
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1200
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2745
2740
2735
2730
2725
2720
2715
2710
0
200
400
600
800
1000
1200
Station (ft)



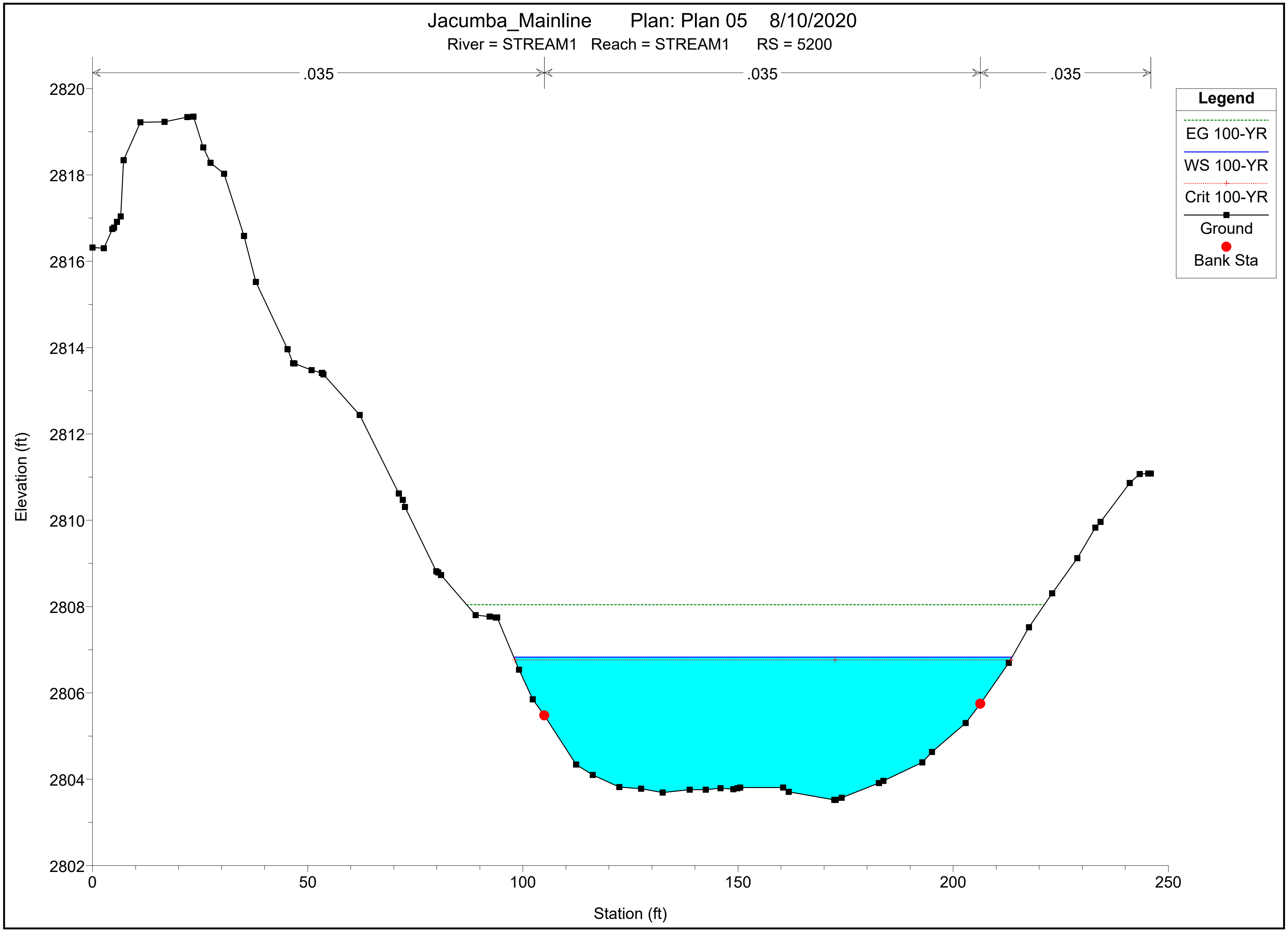
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = Jacumba_Main Reach = Jacumba_Mainline RS = 1000
.03
.03
.03
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2760
2750
2740
2730
2720
2710
0
200
400
600
800
1000
1200
Station (ft)

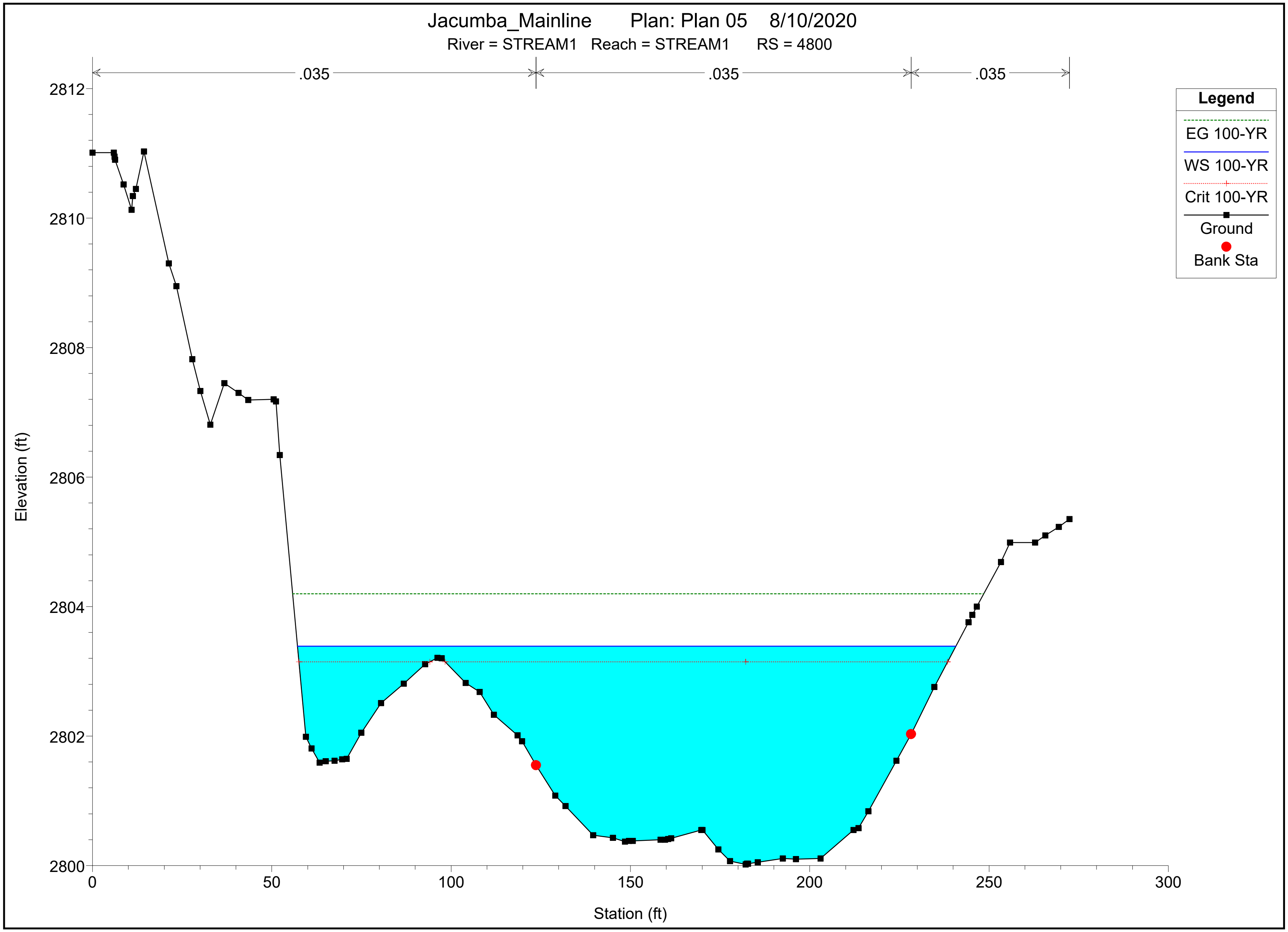
HEC-RAS Plan:

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
STREAM1	5200	100-YR	2522.00	2803.52	2806.83	2806.76	2808.05	0.011367	8.90	289.20	115.74	0.94
STREAM1	4800	100-YR	2522.00	2800.02	2803.39	2803.15	2804.20	0.007777	7.53	373.62	183.60	0.79
STREAM1	4300	100-YR	2522.00	2795.40	2798.15	2798.15	2799.03	0.014392	7.54	338.22	194.85	0.99
STREAM1	4000	100-YR	2522.00	2792.42	2796.36		2796.72	0.002883	5.26	551.44	210.95	0.49
STREAM1	3500	100-YR	2522.00	2789.58	2793.01	2793.01	2794.00	0.012950	8.08	322.62	164.04	0.97

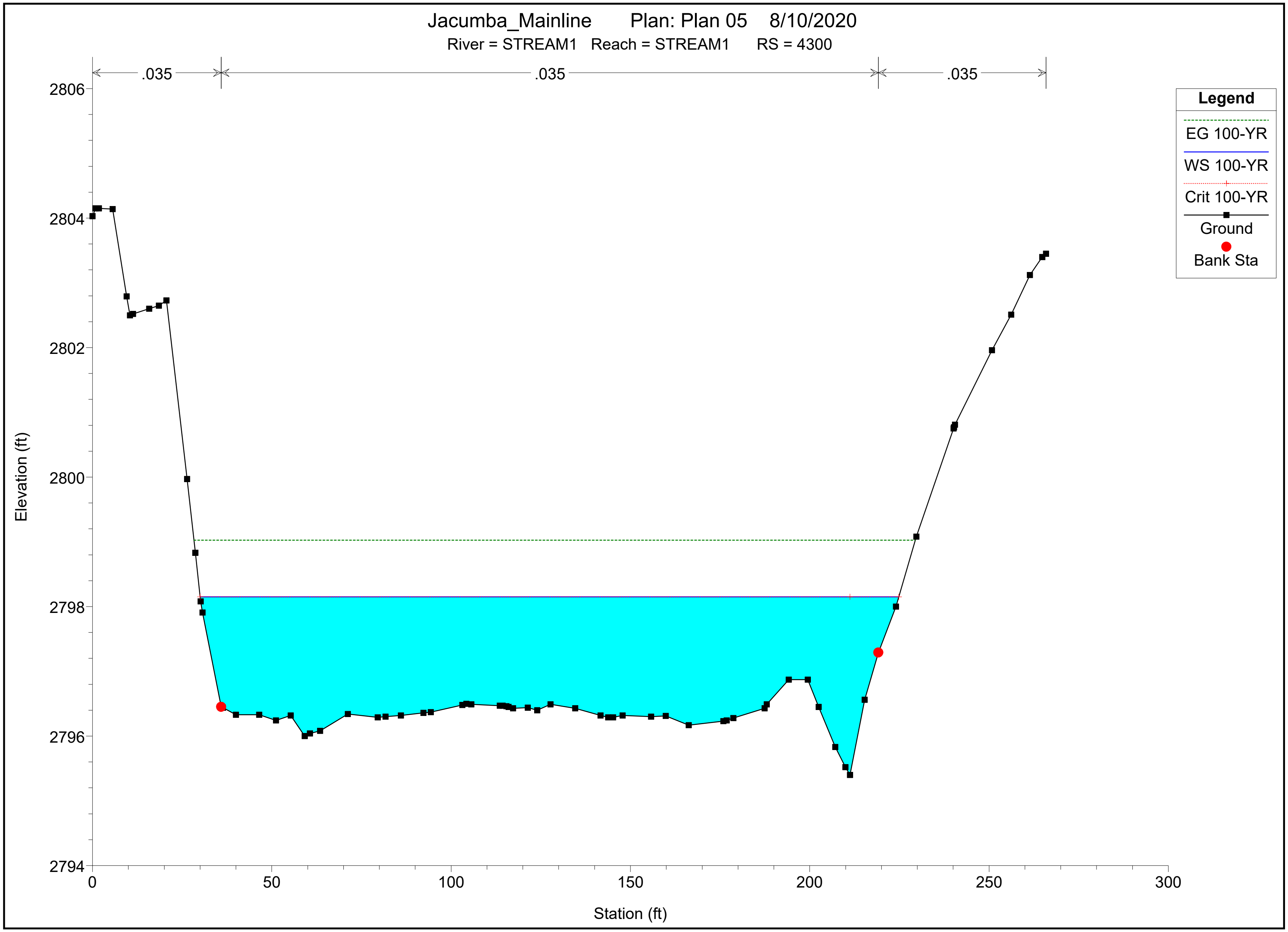


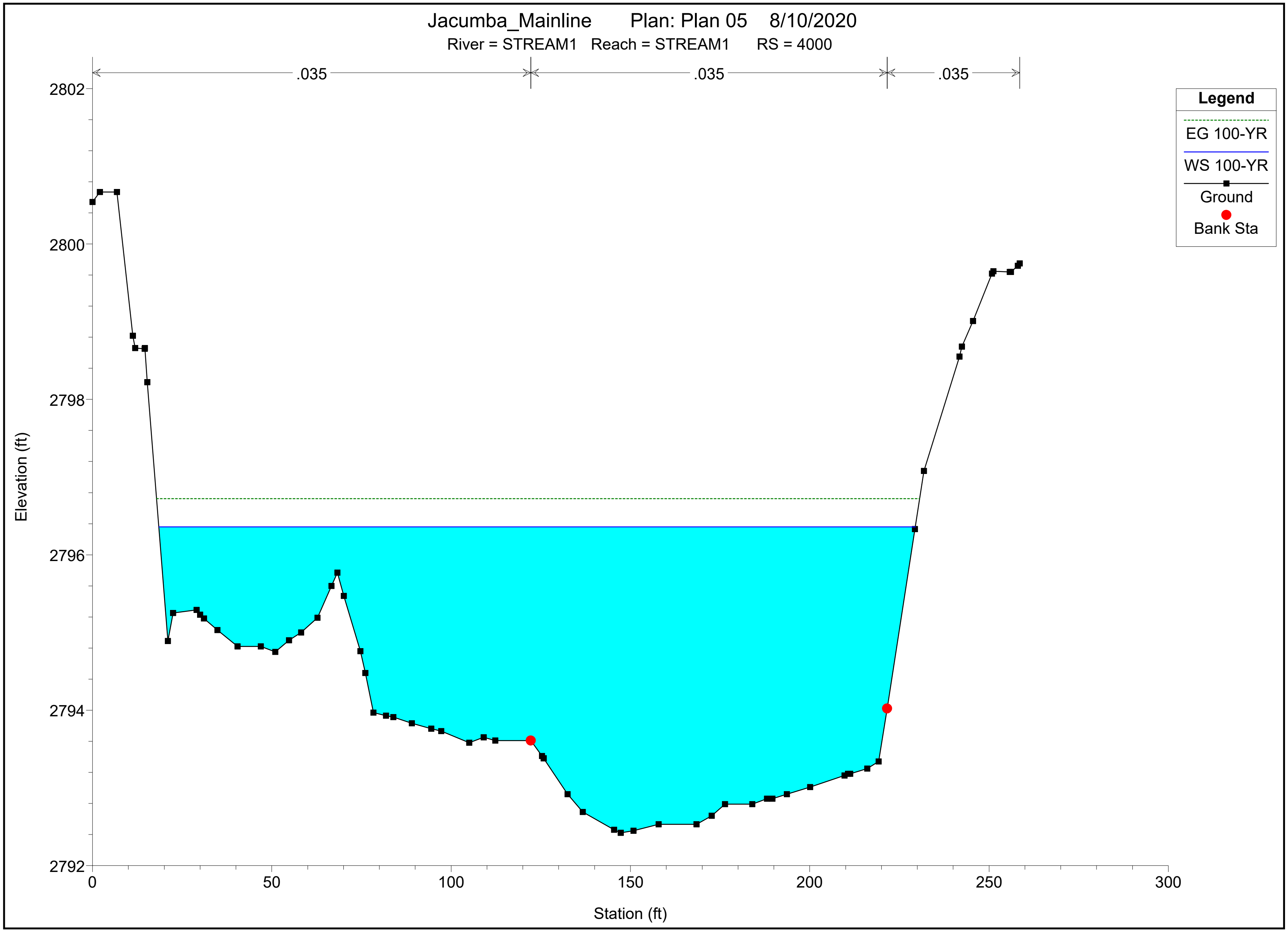
Jacumba_Mainline Plan: Plan 05 8/10/2020
STREAM1 STREAM1
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Elevation (ft)
2810
2805
2800
2795
2790
2785
0
200
400
600
800
1000
1200
1400
1600
1800
Main Channel Distance (ft)


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM1 Reach = STREAM1 RS = 5200
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2802
2804
2806
2808
2810
2812
2814
2816
2818
2820
0
50
100
150
200
250
Station (ft)

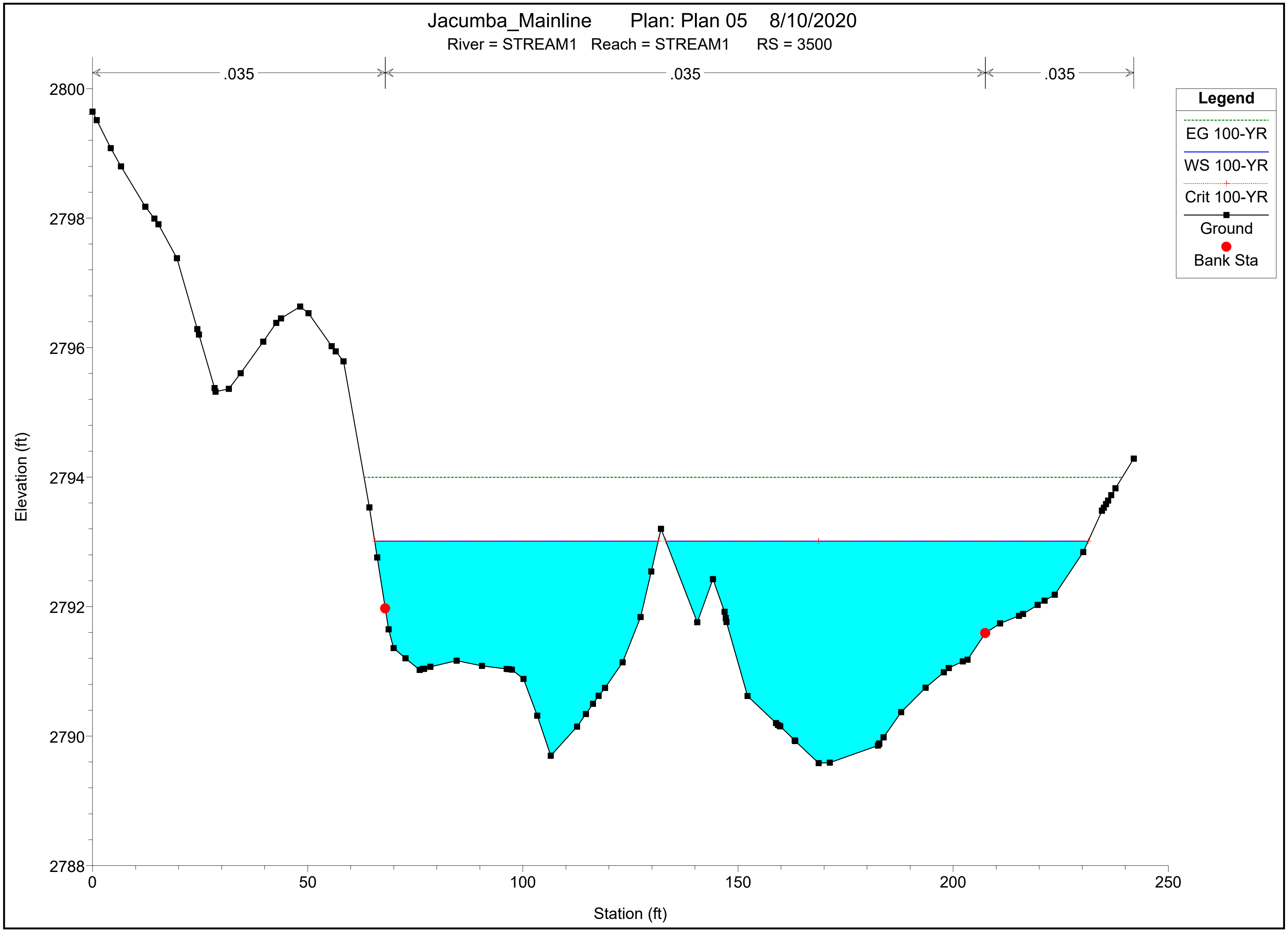


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM1 Reach = STREAM1 RS = 4800
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2812
2810
2808
2806
2804
2802
2800
0
50
100
150
200
250
300
Station (ft)


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM1 Reach = STREAM1 RS = 4300
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2806
2804
2802
2800
2798
2796
2794
0
50
100
150
200
250
300
Station (ft)



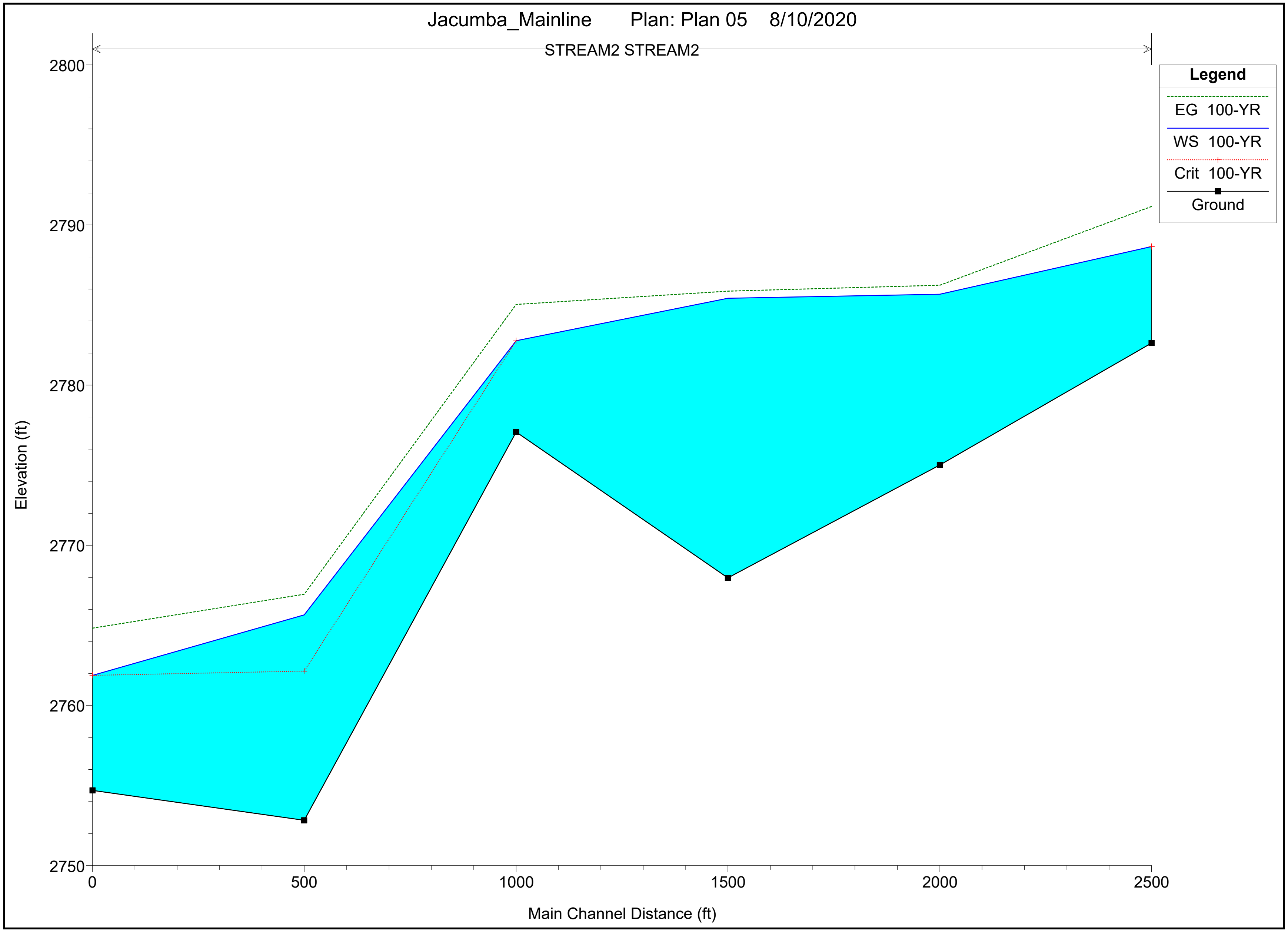
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM1 Reach = STREAM1 RS = 4000
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2802
2800
2798
2796
2794
2792
0
50
100
150
200
250
300
Station (ft)



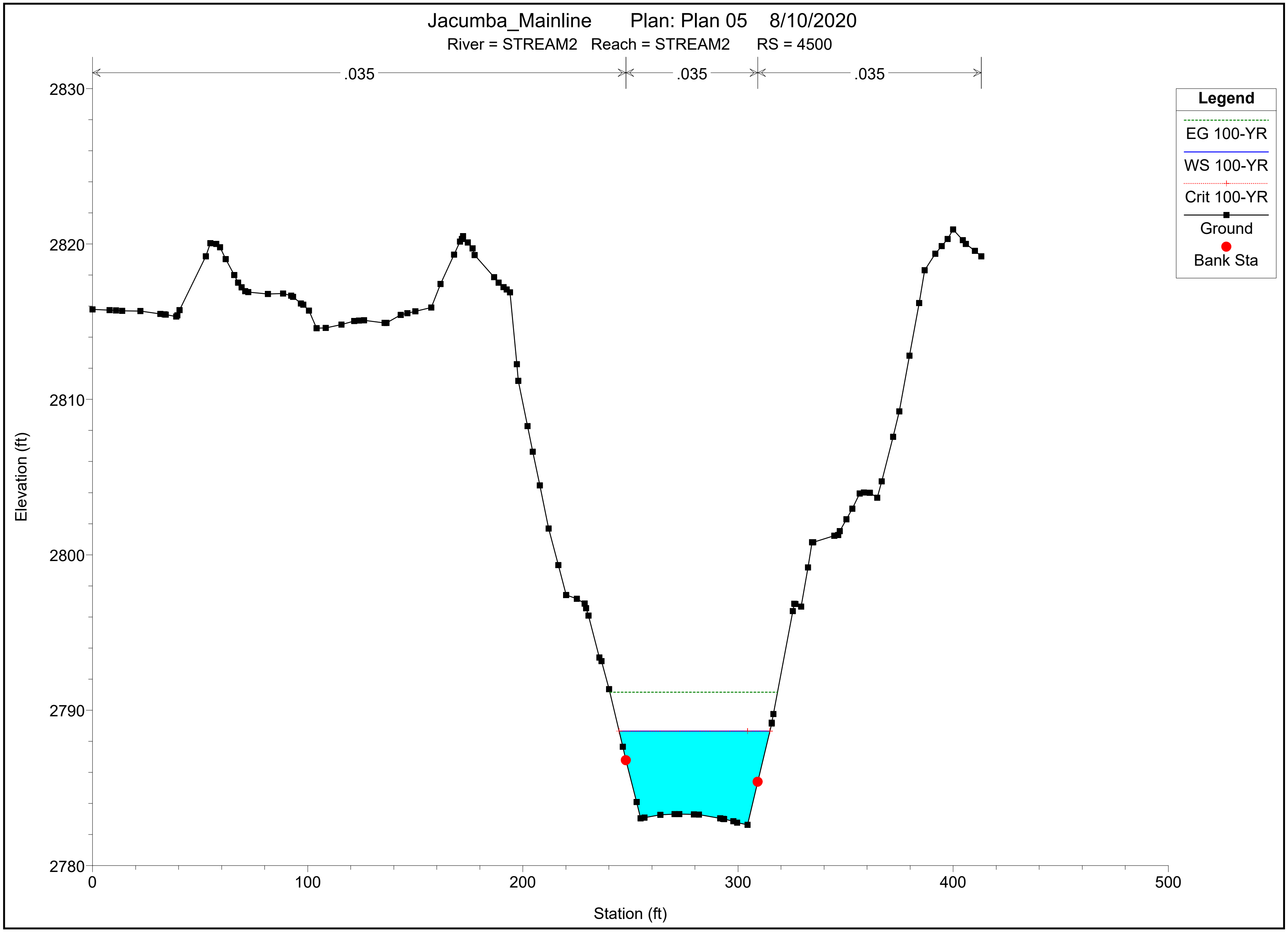
Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM1 Reach = STREAM1 RS = 3500
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2800
2798
2796
2794
2792
2790
2788
0
50
100
150
200
250
Station (ft)

HEC-RAS Plan:

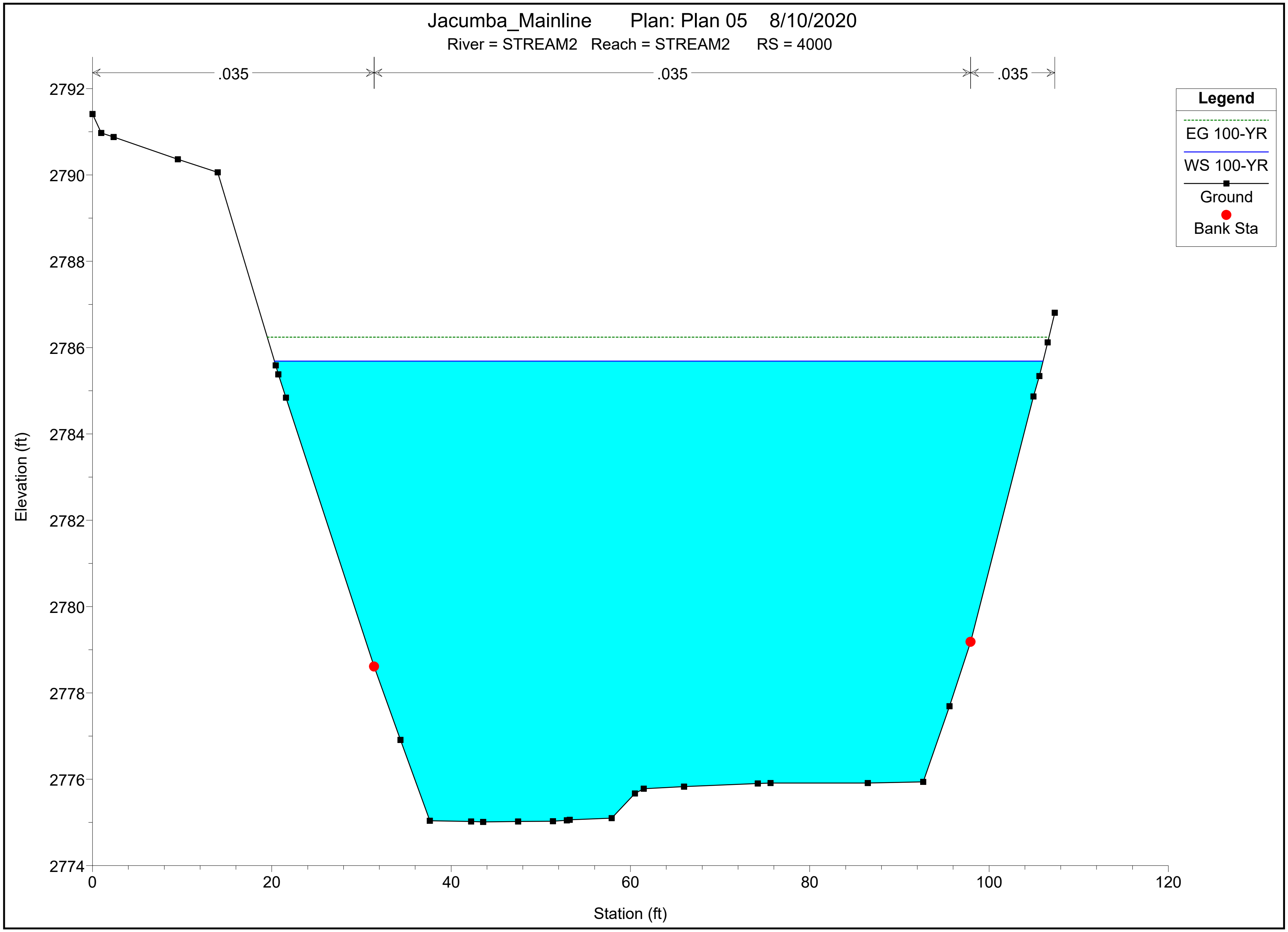
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
STREAM2	4500	100-YR	4181.00	2782.63	2788.66	2788.66	2791.16	0.010247	12.77	334.89	70.13	0.98
STREAM2	4000	100-YR	4181.00	2775.01	2785.68		2786.24	0.001016	6.10	721.55	85.73	0.34
STREAM2	3500	100-YR	4181.00	2767.97	2785.43		2785.87	0.000481	5.55	844.20	76.86	0.25
STREAM2	3000	100-YR	4181.00	2777.08	2782.77	2782.77	2785.04	0.010161	12.23	353.55	79.69	0.98
STREAM2	2500	100-YR	4181.00	2752.83	2765.65	2762.15	2766.94	0.002169	9.49	490.36	58.02	0.50
STREAM2	2000	100-YR	4181.00	2754.70	2761.88	2761.88	2764.82	0.008980	14.00	314.74	55.86	0.95



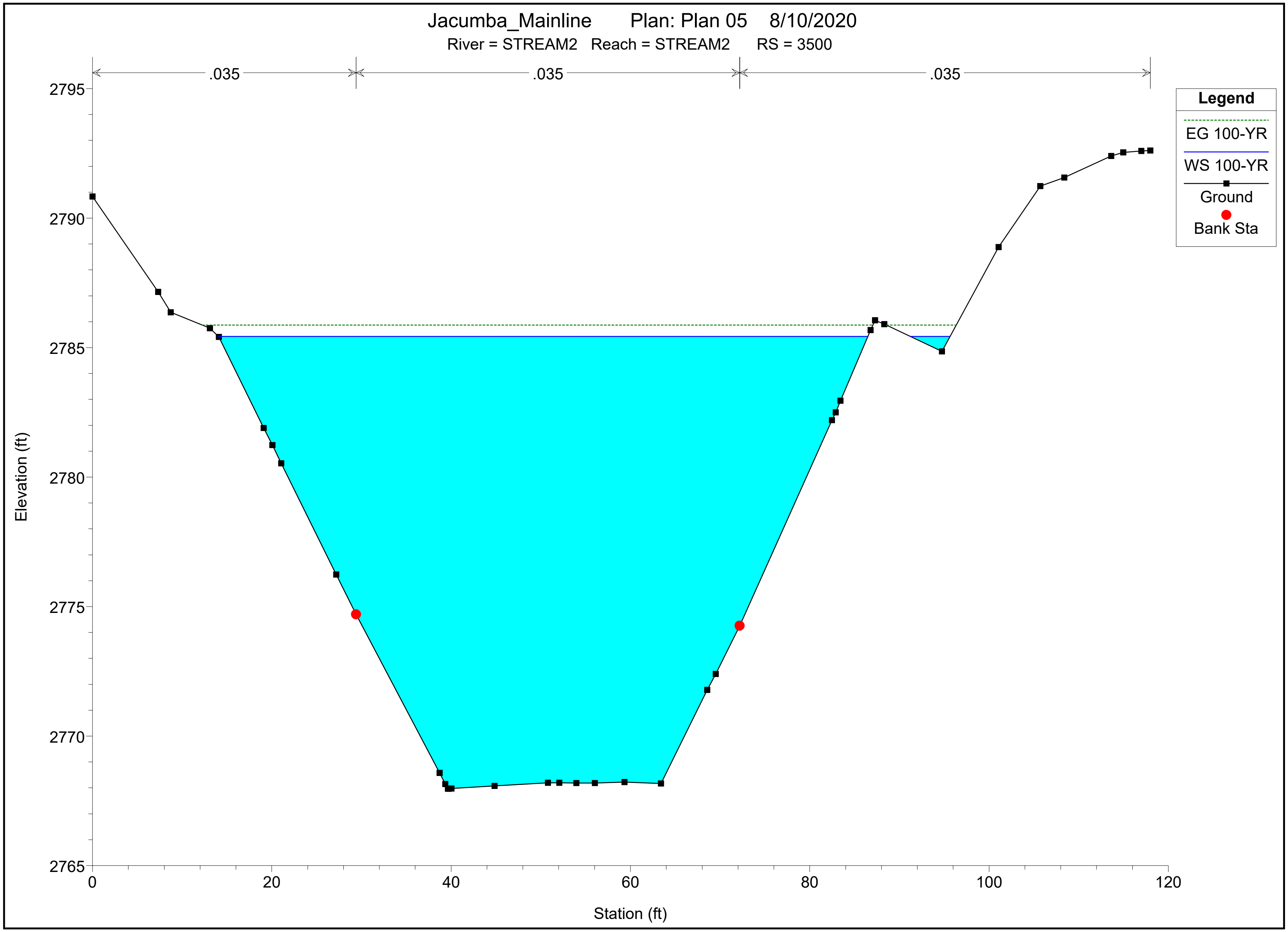
Jacumba_Mainline Plan: Plan 05 8/10/2020
STREAM2 STREAM2
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Elevation (ft)
2800
2790
2780
2770
2760
2750
0
500
1000
1500
2000
2500
Main Channel Distance (ft)

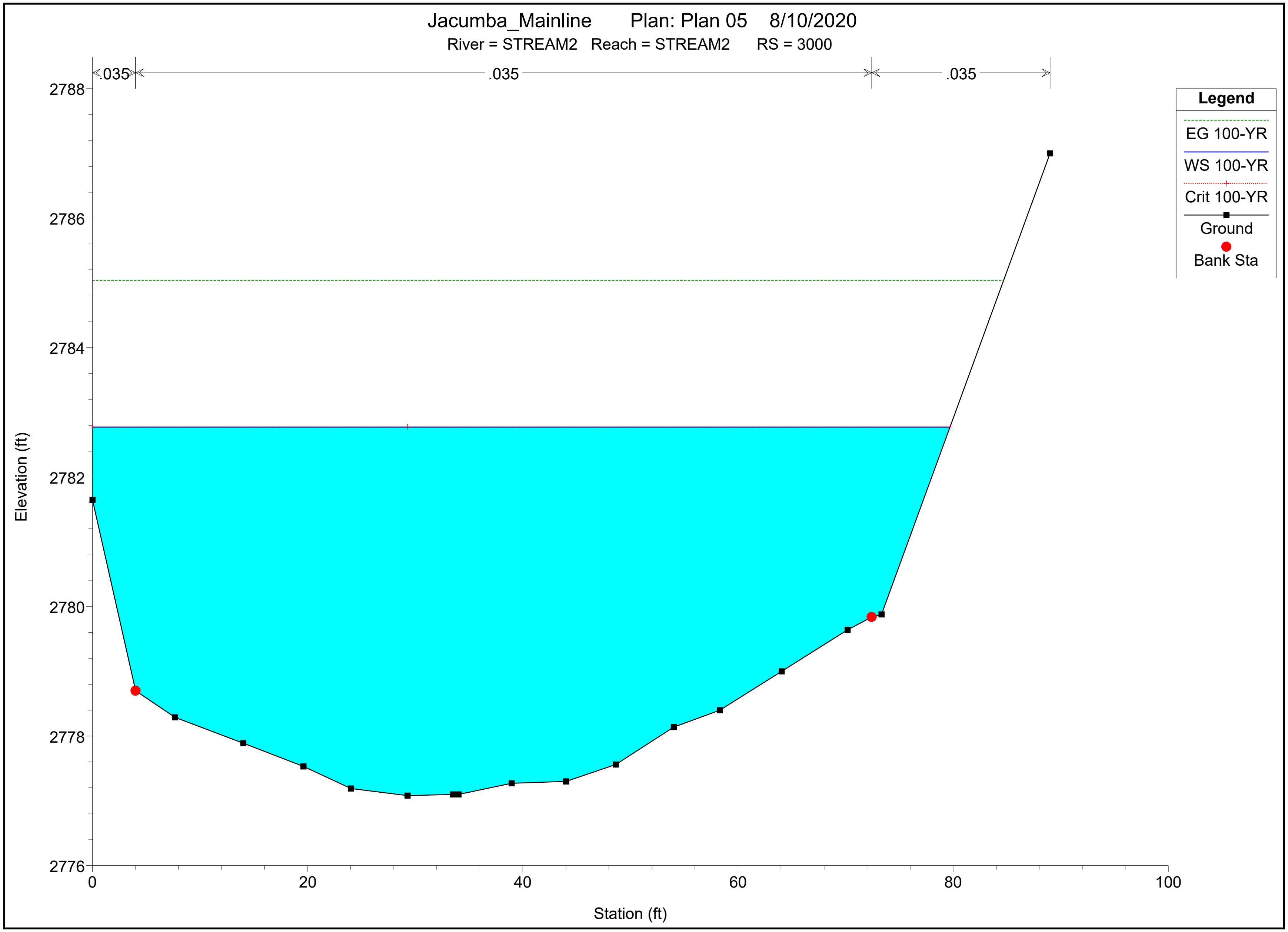


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM2 Reach = STREAM2 RS = 4500
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2830
2820
2810
2800
2790
2780
0
100
200
300
400
500
Station (ft)

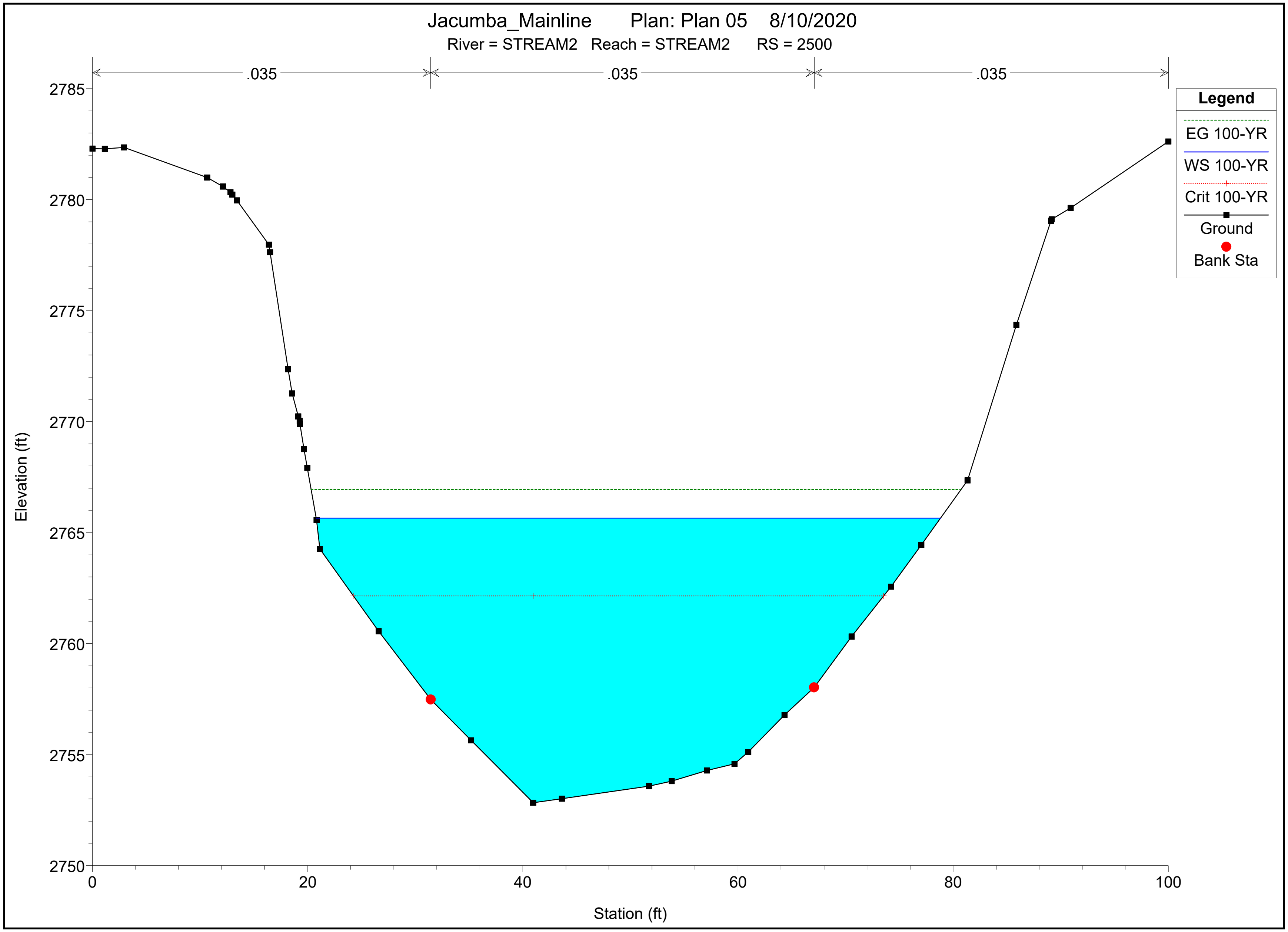


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM2 Reach = STREAM2 RS = 4000
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
2792
2790
2788
2786
2784
2782
2780
2778
2776
2774
0
20
40
60
80
100
120
Station (ft)

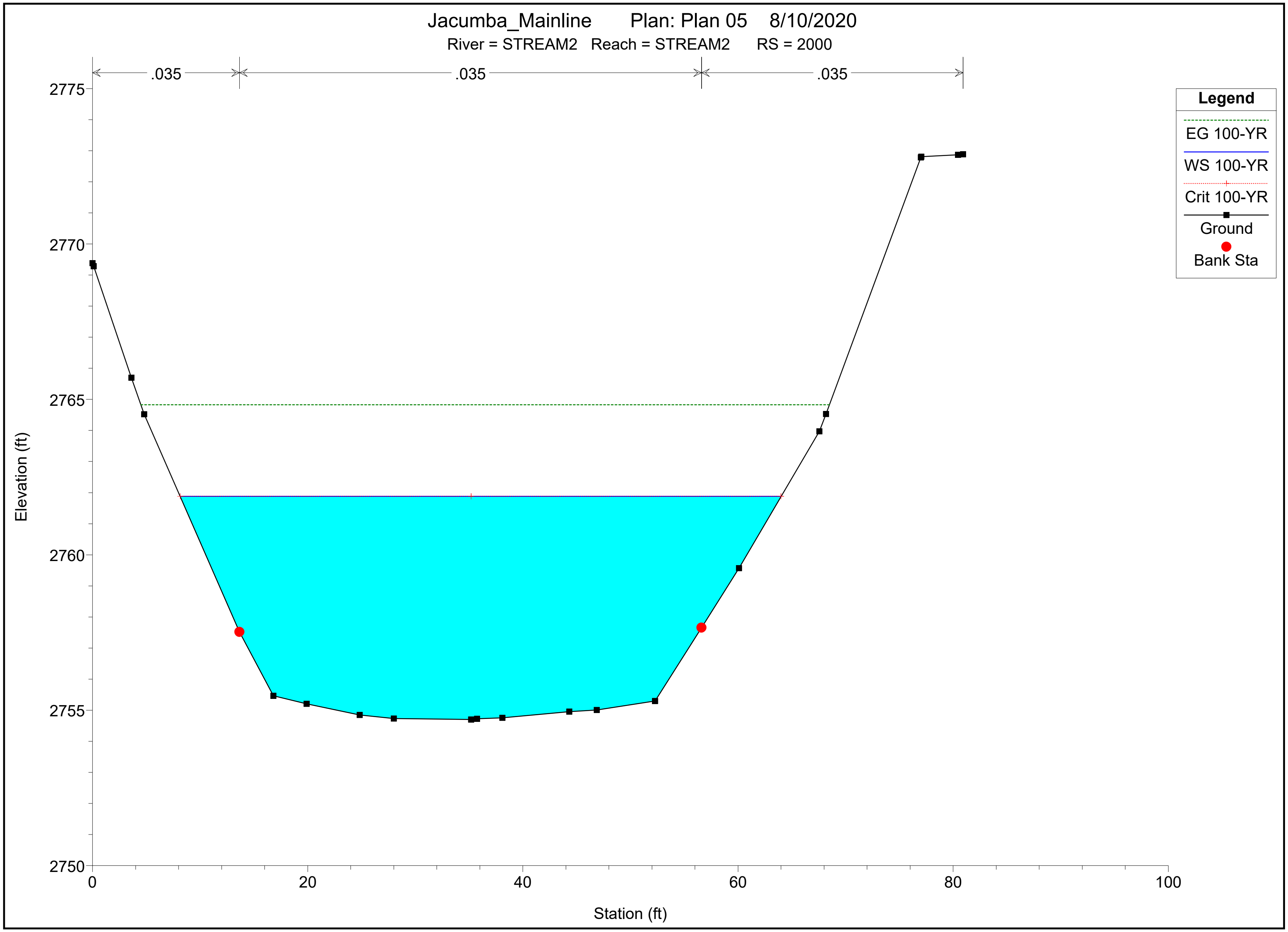

Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM2 Reach = STREAM2 RS = 3500
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2795
2790
2785
2780
2775
2770
2765
0
20
40
60
80
100
120



Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM2 Reach = STREAM2 RS = 3000
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2788
2786
2784
2782
2780
2778
2776
0
20
40
60
80
100
Station (ft)

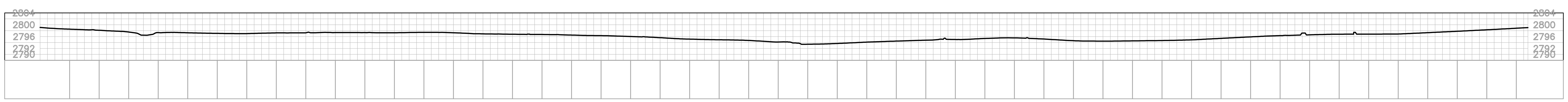


Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM2 Reach = STREAM2 RS = 2500
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2785
2780
2775
2770
2765
2760
2755
2750
0
20
40
60
80
100
Station (ft)



Jacumba_Mainline Plan: Plan 05 8/10/2020
River = STREAM2 Reach = STREAM2 RS = 2000
.035
.035
.035
Legend
EG 100-YR
WS 100-YR
Crit 100-YR
Ground
Bank Sta
Elevation (ft)
2775
2770
2765
2760
2755
2750
0
20
40
60
80
100
Station (ft)

Old Hwy 80 TOPO
Cross-section Exhibit



ROADWAY CROS-SECTION TOPO EXHIBIT

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Appendix D – Hydrologic Data Sources

National Flood Hazard Layer FIRMette

FEMA

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/25/2018 at 10:58:31 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Definitions of FEMA Flood Zone Designations

Flood zones are geographic areas that the FEMA has defined according to varying levels of flood risk. These zones are depicted on a community's Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map. Each zone reflects the severity or type of flooding in the area.

Moderate to Low Risk Areas

In communities that participate in the NFIP, flood insurance is available to all property owners and renters in these zones:

ZONE	DESCRIPTION
B and X (shaded)	Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. B Zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than 1 square mile.
C and X (unshaded)	Area of minimal flood hazard, usually depicted on FIRMs as above the 500-year flood level. Zone C may have ponding and local drainage problems that don't warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood and protected by levee from 100-year flood.

High Risk Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones:

ZONE	DESCRIPTION
A	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas; no depths or base flood elevations are shown within these zones.
AE	The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones.
A1-30	These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format).
AH	Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
AO	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
AR	Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A zones if the structure is built or restored in compliance with Zone AR floodplain management regulations.
A99	Areas with a 1% annual chance of flooding that will be protected by a Federal flood control system where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones.

High Risk - Coastal Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones.

ZONE	DESCRIPTION
V	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.
VE, V1 - 30	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.

Undetermined Risk Areas

ZONE	DESCRIPTION
D	Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk.

From FEMA Map Service Center:
http://msc.fema.gov/webapp/wcs/stores/servlet/info?storeId=10001&catalogId=10001&langId=-1&content=floodZones&title=FEMA%20Flood%20Zone%20Designations

Appendix B Synthetic Rainfall Distributions and Rainfall Data Sources

The highest peak discharges from small watersheds in the United States are usually caused by intense, brief rainfalls that may occur as distinct events or as part of a longer storm. These intense rainstorms do not usually extended over a large area and intensities vary greatly. One common practice in rainfall-runoff analysis is to develop a synthetic rainfall distribution to use in lieu of actual storm events. This distribution includes maximum rainfall intensities for the selected design frequency arranged in a sequence that is critical for producing peak runoff.

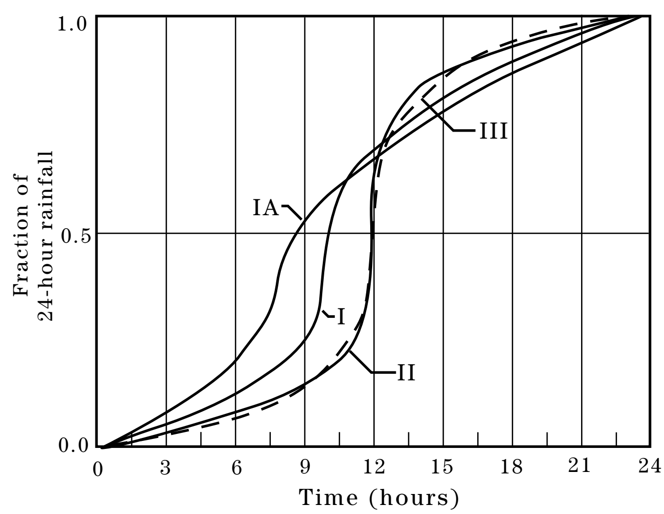
Synthetic rainfall distributions

The length of the most intense rainfall period contributing to the peak runoff rate is related to the time of concentration (T_c) for the watershed. In a hydrograph created with NRCS procedures, the duration of rainfall that directly contributes to the peak is about 170 percent of the T_c. For example, the most intense 8.5-minute rainfall period would contribute to the peak discharge for a watershed with a T_c of 5 minutes. The most intense 8.5-hour period would contribute to the peak for a watershed with a 5-hour T_c.

Different rainfall distributions can be developed for each of these watersheds to emphasize the critical rainfall duration for the peak discharges. However, to avoid the use of a different set of rainfall intensities for each drainage area size, a set of synthetic rainfall distributions having “nested” rainfall intensities was developed. The set “maximizes” the rainfall intensities by incorporating selected short duration intensities within those needed for longer durations at the same probability level.

For the size of the drainage areas for which NRCS usually provides assistance, a storm period of 24 hours was chosen the synthetic rainfall distributions. The 24-hour storm, while longer than that needed to determine peaks for these drainage areas, is appropriate for determining runoff volumes. Therefore, a single storm duration and associated synthetic rainfall distribution can be used to represent not only the peak discharges but also the runoff volumes for a range of drainage area sizes.

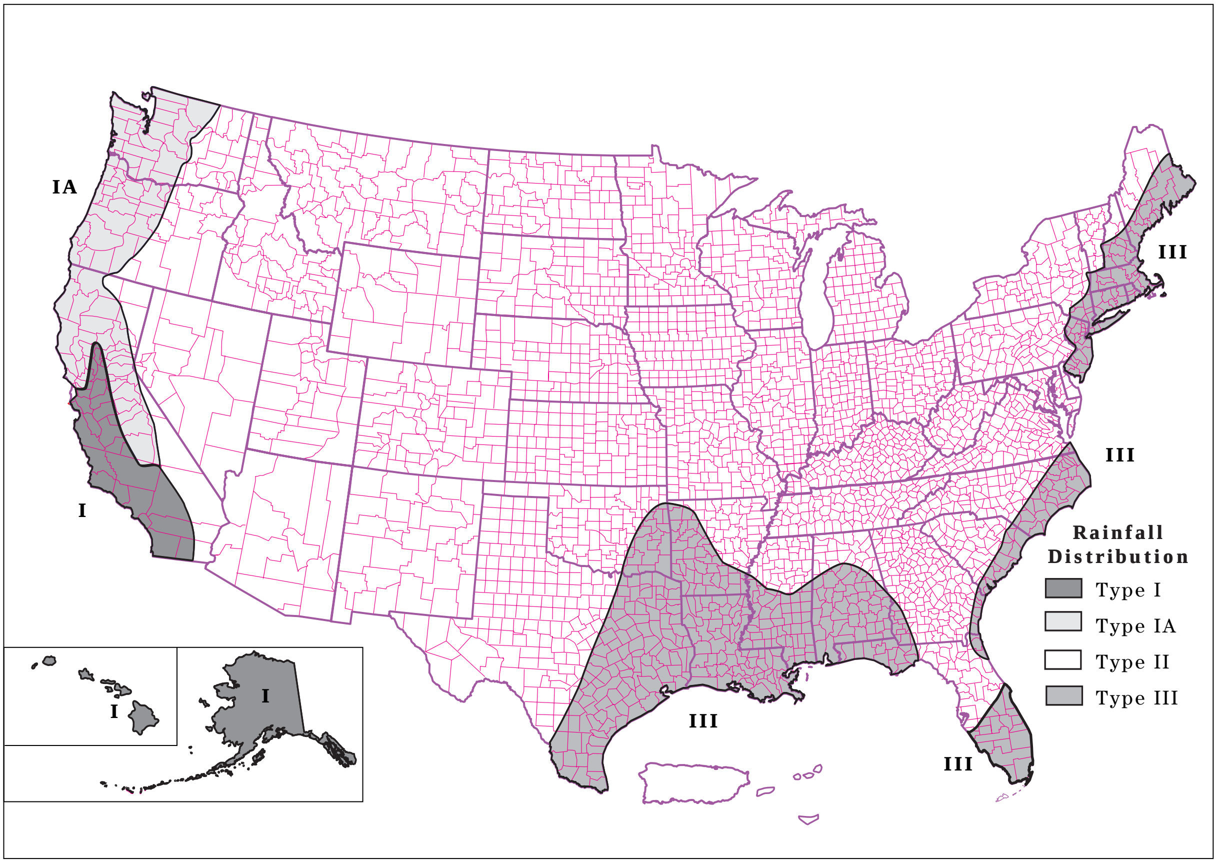
Figure B-1 SCS 24-hour rainfall distributions



The intensity of rainfall varies considerably during a storm as well as geographic regions. To represent various regions of the United States, NRCS developed four synthetic 24-hour rainfall distributions (I, IA, II, and III) from available National Weather Service (NWS) duration-frequency data (Hershfield 1061; Frederick et al., 1977) or local storm data. Type IA is the least intense and type II the most intense short duration rainfall. The four distributions are shown in figure B-1, and figure B-2 shows their approximate geographic boundaries.

Types I and IA represent the Pacific maritime climate with wet winters and dry summers. Type III represents Gulf of Mexico and Atlantic coastal areas where tropical storms bring large 24-hour rainfall amounts. Type II represents the rest of the country. For more precise distribution boundaries in a state having more than one type, contact the NRCS State Conservation Engineer.

Figure B-2 Approximate geographic boundaries for NRCS (SCS) rainfall distributions



Rainfall data sources

This section lists the most current 24-hour rainfall data published by the National Weather Service (NWS) for various parts of the country. Because NWS Technical Paper 40 (TP-40) is out of print, the 24-hour rainfall maps for areas east of the 105th meridian are included here as figures B-3 through B-8. For the area generally west of the 105th meridian, TP-40 has been superseded by NOAA Atlas 2, the Precipitation-Frequency Atlas of the Western United States, published by the National Ocean and Atmospheric Administration.

East of 105th meridian

Hershfield, D.M. 1961. Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 40. Washington, DC. 155 p.

West of 105th meridian

Miller, J.F., R.H. Frederick, and R.J. Tracey. 1973. Precipitation-frequency atlas of the Western United States. Vol. I Montana; Vol. II, Wyoming; Vol III, Colorado; Vol. IV, New Mexico; Vol V, Idaho; Vol. VI, Utah; Vol. VII, Nevada; Vol. VIII, Arizona; Vol. IX, Washington; Vol. X, Oregon; Vol. XI, California. U.S. Dept. of Commerce, National Weather Service, NOAA Atlas 2. Silver Spring, MD.

Alaska

Miller, John F. 1963. Probable maximum precipitation and rainfall-frequency data for Alaska for areas to 400 square miles, durations to 24 hours and return periods from 1 to 100 years. U.S. Dept. of Commerce, Weather Bur. Tech. Pap. No. 47. Washington, DC. 69 p.

Hawaii

Weather Bureau. 1962. Rainfall-frequency atlas of the Hawaiian Islands for areas to 200 square miles, durations to 24 hours and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 43. Washington, DC. 60 p.

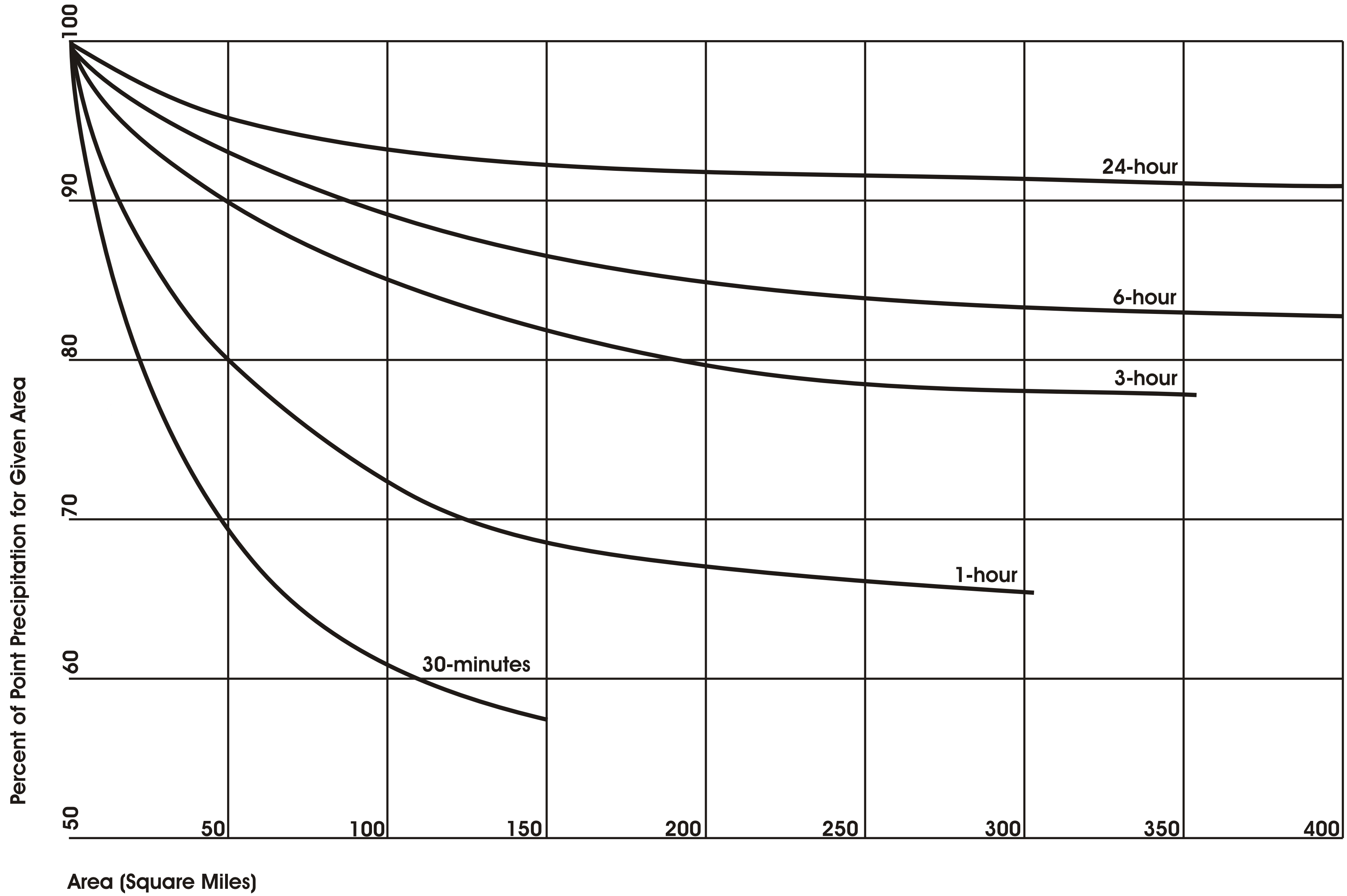
Puerto Rico and Virgin Islands

Weather Bureau. 1961. Generalized estimates of probable maximum precipitation and rainfall-frequency data for Puerto Rico and Virgin Islands for areas to 400 square miles, durations to 24 hours, and return periods from 1 to 100 years. U.S. Dept. Commerce, Weather Bur. Tech. Pap. No. 42. Washington, DC. 94 P.

watersheds (Hromadka, 1987) to determine the effect of these two storm distributions on peak flow rates. It was concluded that a reasonable variation of the design storm pattern shape would have a negligible effect on the modeling output of peak flow rate. However, the distribution of runoff volume varies within the runoff hydrograph depending upon the design storm pattern rainfall distribution. In reservoir or detention basin design the impacts on total storage volume required would be significant. This is the reason the (2/3, 1/3) distribution was adopted for this manual. Figure 4-1 shows the (2/3, 1/3) distribution nested about hour 16 of the 24-hour storm.

4.1.1.3 Rainfall Depth-Area Adjustment

The rainfall values on the isopluvial maps provided in Appendix B and the rainfall values that must be computed to create the ordinates of the nested storm pattern hyetograph represent point rainfall. However, the average rainfall over a given area will be less than the maximum point value in the area. NOAA Atlas 2 establishes a rainfall depth-area adjustment that may be applied to the point rainfall values. Figure 4-2 gives the adjustment to the point rainfall value for various rainfall durations as a function of watershed area. Table 4-1 provides the depth-area adjustment data points that are built in to the San Diego Unit Hydrograph (SDUH) Peak Discharge Program that is provided with this manual (the SDUH Peak Discharge Program is discussed in Section 4.3). These data points were obtained from Figure 4-2. For consistency between studies, it is recommended that the depth-area adjustment factors be interpolated from Table 4-1. The depth-area adjustment may be applied for watershed approximately 1 square mile or greater in size. The depth-area adjustment should be applied to the incremental rainfall amounts prior to arranging the incremental rainfall amounts in the (2/3, 1/3) distribution.



Source: NOAA Atlas 2 Precipitation-Frequency Atlas of the Western United States Volume IX-California, 1973

FIGURE

4-2

Rainfall Depth-Area Adjustment Curves

Table 4-1
RAINFALL DEPTH-AREA ADJUSTMENT DATA POINTS

Watershed Area (square miles)	Rainfall Depth-Area Adjustment for Duration				
	30-Minute	1-Hour	3-Hour	6-Hour	24-Hour
0	1.000	1.000	1.000	1.000	1.000
5	0.942	0.970	0.980	0.985	0.990
10	0.900	0.947	0.970	0.980	0.985
20	0.834	0.900	0.952	0.963	0.975
30	0.768	0.858	0.932	0.950	0.964
40	0.730	0.830	0.915	0.940	0.958
50	0.692	0.800	0.900	0.928	0.952
60	0.663	0.778	0.883	0.920	0.948
70	0.645	0.760	0.872	0.912	0.945
80	0.630	0.746	0.862	0.904	0.942
90	0.620	0.735	0.853	0.896	0.938
100	0.610	0.722	0.845	0.890	0.935
111					0.933
125	0.588	0.700	0.830	0.878	0.930
150	0.572	0.685	0.818	0.865	0.925
175	0.572	0.672	0.808	0.858	0.922
200	0.572	0.666	0.798	0.851	0.918
225	0.572	0.660	0.790	0.845	0.915
250	0.572	0.655	0.787	0.842	0.914
300	0.572	0.652	0.782	0.838	0.912
350	0.572	0.652	0.780	0.830	0.910
400	0.572	0.652	0.780	0.828	0.908

4.1.2 Runoff Curve Number

The hydrograph of storm runoff from a drainage area is also based in part on the physical characteristics of the watershed. The principal physical watershed characteristics affecting the relationship between rainfall and runoff are land use, land treatment, soil types, and land slope. The NRCS method uses a combination of soil conditions and land uses (ground cover) and land treatment (generally agricultural practices) to assign a runoff factor to an area. These runoff factors, called runoff curve numbers (CNs), indicate the runoff potential of an area. The higher the CN, the higher the runoff potential. The CN does not account for land slope. However, in the NRCS hydrologic method land slope is accounted for in the determination of watershed lag time (see Section 4.1.3).

The CN values in Table 4-2 are suitable for preparing hydrographs in accordance with the methods shown in Chapters 10 and 16 of NEH-4 and summarized in Section 4.2 of this manual. The CN values are based on hydrologic soil group and land use/land treatment. Tables 4-3, 4-4, and 4-5 provide descriptions of some of the terms used in Table 4-2, including vegetative condition and cover density. See the glossary for descriptions of land uses and hydrologic conditions listed in Tables 4-2 through 4-5. When a drainage area has more than one land use, a composite CN can be calculated and used in the analysis (see Section 4.2.3). It should be noted that when composite CNs are used, the analysis does not take into account the location of the specific land uses but treats the drainage area as a uniform land use represented by the composite CN.

Note: The CN values in Table 4-2 are unadjusted for PZN Condition. These are suitable where the PZN adjustment factor = 2.0, which represents the average PZN Condition. The PZN Condition and PZN adjustment factor are discussed in Section 4.1.2.4.

Table 4-2
RUNOFF CURVE NUMBERS[1] FOR PZN CONDITION = 2.0

Cover Description	Cover Treatment or Practice[2]	Hydrologic Condition[3]	Average Percent Impervious Area[4]	Curve Numbers for Hydrologic Soil Groups: A	B	C	D
Developing urban areas and newly graded areas (pervious areas only, no vegetation)				77	86	91	94
Impervious areas: Paved parking lots, roofs, and driveways (excluding right-of-way)				98	98	98	98
Residential districts by average lot size:[4]							
1/8 acre or less (town houses)			65%	77	85	90	92
1/4 acre			38%	61	75	83	87
1/3 acre			30%	57	72	81	86
1/2 acre			25%	54	70	80	85
1 acre			20%	51	68	79	84
2 acres			12%	46	65	77	82
Streets and roads	Paved; curbs and storm drains (excluding right-of-way)			98	98	98	98
	Paved; open ditches (including right-of-way)			83	89	92	93
	Gravel (including right-of-way)			76	85	89	91
	Hard surface (including right-of-way)			74	84	90	92
	Dirt (including right-of-way)			72	82	87	89
Urban districts[4]	Commercial and business		85%	89	92	94	95
	Industrial		72%	81	88	91	93
Western desert urban areas:							
Natural desert landscaping (pervious areas only)[5]				63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)				96	96	96	96

Table 4-2 (Continued)
RUNOFF CURVE NUMBERS[1] FOR PZN CONDITION = 2.0

Cover Description	Cover Treatment or Practice[2]	Hydrologic Condition[3]	Average Percent Impervious Area[4]	Curve Numbers for Hydrologic Soil Groups: A	B	C	D
Close-seeded legumes or rotated pasture	Straight row	Poor		66	77	85	89
		Good		58	72	81	85
	Contoured	Poor		64	75	83	85
		Good		55	69	78	83
	Contoured and terraced	Poor		63	73	80	83
		Good		51	67	76	80
Cultivated land	Without conservation treatment			72	81	88	91
	With conservation treatment			62	71	78	81
Fallow	Bare soil			77	86	91	94
	Crop residue cover	Poor		76	85	90	92
		Good		74	83	88	90
Farmsteads (buildings, lanes, driveways, and surrounding lots)				59	74	82	86
Irrigated pasture		Poor		58	74	83	87
		Fair		44	65	77	82
		Good		33	58	72	79
Orchards (deciduous)		(see glossary description)					
Orchards (evergreen)		Poor		57	73	82	86
		Fair		44	65	77	82
		Good		33	58	72	79
Row crops	Straight row	Poor		72	81	88	91
		Good		67	78	85	89
	Contoured	Poor		70	79	84	88
		Good		65	75	82	86

Table 4-2 (Continued)
RUNOFF CURVE NUMBERS[1] FOR PZN CONDITION = 2.0

Cover Description	Cover Treatment or Practice[2]	Hydrologic Condition[3]	Average Percent Impervious Area[4]	Curve Numbers for Hydrologic Soil Groups: A	B	C	D
Small grain	Straight row	Poor		65	76	84	88
		Good		63	75	83	87
	Contoured	Poor		63	74	82	85
		Good		61	73	81	84
Vineyards[6]	Disked			76	85	90	92
	Annual grass or legume cover	Poor		65	78	85	89
		Fair		50	69	79	84
		Good		38	61	74	80
Annual grass (Dryland pasture)		Poor		67	78	86	89
		Fair		50	69	79	84
		Good		38	61	74	80
Barren				78	86	91	93
Meadow		Poor		63	77	85	88
		Fair		51	70	80	84
		Good		30	58	72	78
Open space (lawns, parks, golf courses, cemeteries, etc.)[7]	Grass cover <50%	Poor		68	79	86	89
	Grass cover 50% to 75%	Fair		49	69	79	84
	Grass cover >75%	Good		39	61	74	80
Pasture or range land		Poor		68	79	86	89
		Fair		49	69	79	84
		Good		39	61	74	80
Perennial grass		Poor		67	79	86	89
		Fair		50	69	79	84
		Good		38	61	74	80

Table 4-2 (Continued)
RUNOFF CURVE NUMBERS[1] FOR PZN CONDITION = 2.0

Cover Description	Cover Treatment or Practice[2]	Hydrologic Condition[3]	Average Percent Impervious Area[4]	Curve Numbers for Hydrologic Soil Groups: A	B	C	D
Turf[8]		Poor		58	74	83	87
		Fair		44	65	77	82
		Good		33	58	72	79
Water surfaces (during floods)				97	98	99	99
Broadleaf chaparral		Poor		53	70	80	85
		Fair		40	63	75	81
		Good		31	57	71	78
Desert shrub–major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus		Poor		63	77	85	88
		Fair		55	72	81	86
		Good		49	68	79	84
Herbaceous–mixture of grass, weeds, and low-growing brush, with brush the minor element		Poor		[9]	80	87	93
		Fair		[9]	71	81	89
		Good		[9]	62	74	85
Narrowleaf chaparral		Poor		71	82	88	91
		Fair		55	72	81	86
Oak-aspen–mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush		Poor		[9]	66	74	79
		Fair		[9]	48	57	63
		Good		[9]	30	41	48
Open brush		Poor		62	76	84	88
		Fair		46	66	77	83
		Good		41	63	75	81

Table 4-2 (Continued)
RUNOFF CURVE NUMBERS[1] FOR PZN CONDITION = 2.0

Cover Description	Cover Treatment or Practice[2]	Hydrologic Condition[3]	Average Percent Impervious Area[4]	Curve Numbers for Hydrologic Soil Groups: A	B	C	D
Pinyon-juniper–pinyon, juniper, or both; grass understory		Poor		[9]	75	85	89
		Fair		[9]	58	73	80
		Good		[9]	41	61	71
Sagebrush with grass understory		Poor		[9]	67	80	85
		Fair		[9]	51	63	70
		Good		[9]	35	47	55
Wood or forest land		Thin stand, poor cover		45	66	77	83
		Good cover		25	55	70	77
Woods (woodland)		Poor		45	66	77	83
		Fair		36	60	73	79
		Good		28	55	70	77
Woodland-grass combination		Poor		57	73	82	86
		Fair		44	65	77	82
		Good		33	58	72	79

1 Average runoff condition, and $I_a = 0.2S$.
2 Hydrologic practices described as "straight row" and "contoured" are defined in the glossary.
3 For definition of hydrologic condition, see Tables 4-3, 4-4, and 4-5.
4 The average percent impervious area shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. If the impervious area is not directly connected, the NRCS method has an adjustment to reduce the effect.
5 Composite CNs for natural desert landscaping should be computed based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CNs are assumed equivalent to desert shrub in poor hydrologic condition.
6 See glossary.
7 CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space cover type.
8 Includes lawns, cemeteries, golf courses and parks with ground cover of mowed and irrigated perennial grass.
9 CNs for Group A have not been developed.

4.2.4 PZN Condition

The CNs provided in Table 4-2 are for PZN Condition 2.0 (PZN adjustment factor = 2.0). After the CN has been calculated for the study area, it must be adjusted for PZN Condition. This adjustment is required for NRCS hydrologic method studies. The PZN adjustment factors (described in Section 4.1.3 and provided in Table 4-6) are based on the storm frequency and the precipitation zone that the watershed is located in. To adjust the CN for PZN Condition, first determine the appropriate PZN adjustment factor for the combination of storm duration and precipitation zone for the study. For precipitation zone numbers not equal to 1.0, 2.0, 3.0, and 4.0 (Coast, Foothills, Mountains, and Desert), interpolate the PZN adjustment factor between the zones. Interpolation, if necessary, is linear. For example, for a 100-year storm duration for a study area with a PZN of 1.5, the PZN adjustment factor interpolated from the values in Table 4-6 is 2.5. After determining the appropriate PZN adjustment factor, use Table 4-10 to determine the adjusted CN for the study area for the appropriate PZN Condition. If the appropriate PZN Condition for the study area based on the storm duration and PZN is 2.0 (PZN adjustment factor = 2.0), no adjustment is necessary because the CNs provided in Table 4-2 are for PZN Condition 2.0. For PZN adjsutment factor equal to 1.0 or 3.0, locate the CN value for PZN Condition 2.0 and read the adjusted CN value for PZN Condition 1.0 or 3.0 from the same row of the table. For PZN adjsutment factor not equal to 1.0, 2.0, or 3.0, interpolate the CN between the value for PZN Condition 2.0 and the value for the appropriate PZN Condition in the same row of the table. Interpolation, if necessary, is linear.

Table 4-10

RUNOFF CURVE NUMBERS FOR PZN CONDITIONS 1.0, 2.0, AND 3.0

CN For:			CN For:		
PZN Condition = 1.0	PZN Condition = 2.0	PZN Condition = 3.0	PZN Condition = 1.0	PZN Condition = 2.0	PZN Condition = 3.0
100	100	100	40	60	78
97	99	100	39	59	77
94	98	99	38	58	76
91	97	99	37	57	75
89	96	99	37	56	75
87	95	98	34	55	73
85	94	98	34	54	73
83	93	98	33	53	72
81	92	97	32	52	71
80	91	97	31	51	70
78	90	96	31	50	70
76	89	96	30	49	69
75	88	95	29	48	68
73	87	95	28	47	67
72	86	94	27	46	66
70	85	94	26	45	65
68	84	93	25	44	64
67	83	93	25	43	63
66	82	92	24	42	62
64	81	92	23	41	61
63	80	91	22	40	60
62	79	91	21	39	59
60	78	90	21	38	58
59	77	89	20	37	57
58	76	89	19	36	56
57	75	88	18	35	55
55	74	88	18	34	54
54	73	87	17	33	53
53	72	86	16	32	52
52	71	86	16	31	51
51	70	85	15	30	50
50	69	84			
48	68	84	12	25	43
47	67	83	9	20	37
46	66	82	6	15	30
45	65	82	4	10	22
44	64	81	2	5	13
43	63	80	0	0	0
42	62	79			
41	61	78			

The adjustment for PZN Condition may be made to the composite CN for the watershed. It is not necessary to make the PZN Condition adjustment to each of the CNs for the different combinations of ground cover and soil group within the watershed before calculating the composite CN.

Table 4-6

PZN ADJUSTMENT FACTORS FOR FLOW COMPUTATIONS
(San Diego County)

Storm Frequency	Coast (PZN = 1.0)	Foothills (PZN = 2.0)	Mountains (PZN = 3.0)	Desert (PZN = 4.0)
Less than 35-year return period	1.5	2.5	2.0	1.5
Greater than or equal to 35-year return period	2.0	3.0	3.0	2.0

Notes: PZN is the precipitation zone number (see Map, Appendix C). The PZN adjustment factor represents the PZN Condition that the CN for the watershed should be adjusted to.

4.1.3 Rainfall-Runoff Relationship

A relationship between accumulated rainfall and accumulated runoff was derived by NRCS from experimental plots for numerous soils and vegetative cover conditions. The following NRCS runoff equation is used to estimate direct runoff from 24-hour or 6-hour storm rainfall. The equation is:

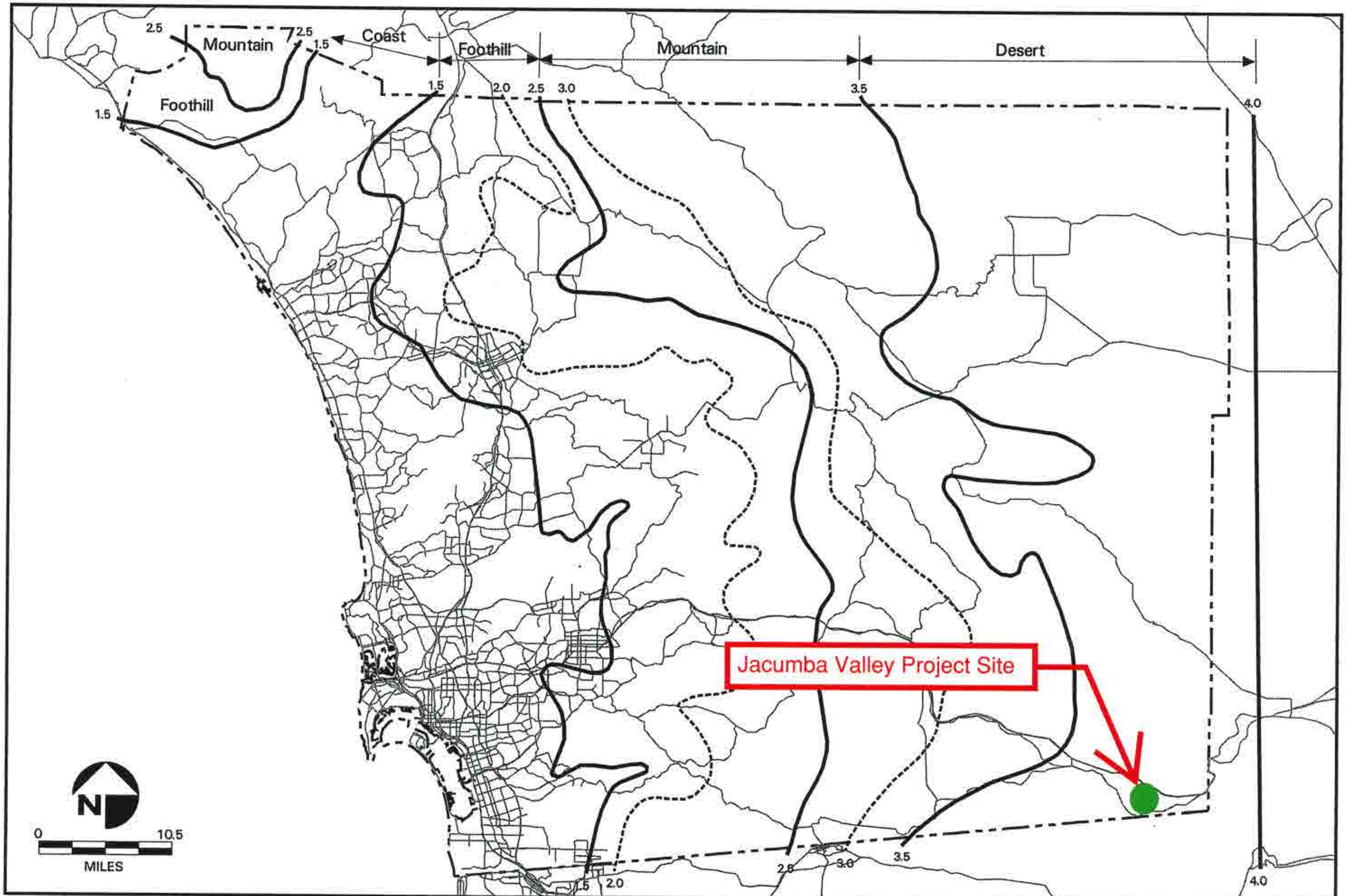
$$Q_a = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \text{(Eq. 4-1)}$$

where: Q_a = accumulated direct runoff (in)

P = accumulated rainfall (potential maximum runoff) (in)

I_a = initial abstraction including surface storage, interception, evaporation, and infiltration prior to runoff (in)

S = potential maximum soil retention (in)



County of San Diego Hydrology Manual

Precipitation Zone Numbers (PZN)

FIGURE

C-1

Raw CN Values by Covertype

CoverType	A	B	C	D	Reference From SDCHM Table 4-2
Barren Land	78	86	91	93	Page 4-12, "Barren"
Cultivated Crops	44	65	77	82	Page 4-11 "Cultivated Land"
Deciduous Forest					
Developed, High Intensity	89	92	94	95	Page 4-10 "Urban Districts - Commercial and
Developed, Low Intensity	61	75	83	87	Page 4-10 "Residential Districts - 1/4 Acre Lot
Developed, Medium Intensity	77	85	90	92	Page 4-10 "Residential Districts - 1/8 Acre Lot
Developed, Open Space	49	69	79	84	Page 4-12 "Open Space - Grass Cover 50%-75
Emergent Herbaceous Wetlands	97	98	99	99	Page 4-13 "Water Surfaces (During Floods)"
Evergreen Forest	44	65	77	82	Page 4-11 "Orchards (Evergreen) - Fair"
Grassland / Herbaceous	50	69	79	84	Page 4-12 "Annual Grass (Dryland Pasture)"
Open Water	97	98	99	99	Page 4-13 "Water Surfaces (During Floods)"
Pasture / Hay	49	69	79	84	Page 4-12 "Paster or Range Land - Fair"
Shrub / Scrub	55	72	81	86	Page 4-13 "Desert Shrub - Fair"
Woody Wetlands	97	98	99	98	Page 4-13 "Water Surfaces (During Floods)"
Mixed Forest	36	60	73	79	Page 4-14 "Woods(Woodland) - Fair"

PZN Adjusted CN Values by Covertype

CoverType	A	B	C	D
Barren Land	80	88	92	94
Cultivated Crops	48	68	79	84
Deciduous Forest	0	0	0	0
Developed, High Intensity	90	93	95	96
Developed, Low Intensity	64	78	85	89
Developed, Medium Intensity	79	87	91	93
Developed, Open Space	53	72	81	86
Emergent Herbaceous Wetlands	97	98	99	99
Evergreen Forest	48	68	79	84
Grassland / Herbaceous	54	72	81	86
Open Water	97	98	99	99
Pasture / Hay	53	72	81	86
Shrub / Scrub	59	75	83	88
Woody Wetlands	97	98	99	98
Mixed Forest	40	64	76	81

Manning's N
Support using Ven T Chow and
the USGS Paper 2339

Table 1. Base values of Manning's *n*

[Modified from Aldridge and Garrett, 1973, table 1; —, no data]

Bed material	Median size of bed material (in millimeters)	Base *n* value: Straight uniform channel[1]	Base *n* value: Smooth channel[2]
Sand channels			
Sand[3]	0.2	0.012	—
	.3	.017	—
	.4	.020	—
	.5	.022	—
	.6	.023	—
	.8	.025	—
	1.0	.026	—
Stable channels and flood plains			
Concrete	—	0.012–0.018	0.011
Rock cut	—	—	.025
Firm soil	—	0.025–0.032	.020
Coarse sand	1–2	0.026–0.035	—
Fine gravel	—	—	.024
Gravel	2–64	0.028–0.035	—
Coarse gravel	—	—	.026
Cobble	64–256	0.030–0.050	—
Boulder	>256	0.040–0.070	—

[1] Benson and Dalrymple (1967).
[2] For indicated material; Chow (1959).
[3] Only for upper regime flow where grain roughness is predominant.

moves easily and takes on different configurations or bed forms. Bed form is a function of velocity of flow, grain size, bed shear, and temperature. The flows that produce the bed forms are classified as lower regime flow and upper regime flow, according to the relation between depth and discharge (fig. 2). The lower regime flow occurs during low discharges, and the upper regime flow occurs during high discharges. An unstable discontinuity, called a transitional zone, appears between the two regimes in the depth to discharge relation (fig. 3). In lower regime flow, the bed may have a plane surface and no movement of sediment, or the bed may be deformed and have small uniform waves or large irregular saw-toothed waves formed by sediment moving downstream. The smaller waves are known as ripples, and the larger waves are known as dunes. In upper regime flow, the bed may have a plane surface and sediment movement or long, smooth sand waves that are in phase with the surface waves. These waves are known as standing waves and antidunes. Bed forms on dry beds are remnants of the bed forms that existed during receding flows and may not represent flood stages.

The flow regime is governed by the size of the bed materials and the stream power, which is a measure of energy transfer. Stream power (*SP*) is computed by the formula:

$$SP = 62\, R S_w V \qquad (4)$$

where

62 = specific weight of water, in pounds per cubic foot,
R = hydraulic radius, in feet,
S_w = water-surface slope, in feet per foot, and
V = mean velocity, in feet per second.

The values in table 1 for sand channels are for upper regime flows and are based on extensive laboratory and field data obtained by the U.S. Geological Survey. When using these values, a check must be made to ensure that the stream power is large enough to produce upper regime flow (fig. 2). Although the base *n* values given in table 1 for stable channels are from verification studies, the values have a wide range because the effects of bed roughness are extremely difficult to separate from the effects of other roughness factors. The choice of *n* values selected from table 1 will be influenced by personal judgment and experience. The *n* values for lower and transitional-regime flows are much larger generally than the values given in table 1 for upper regime flow. Simons, Li, and Associates (1982) give a range of *n* values commonly found for different bed forms.

The *n* value for a sand channel is assigned for upper regime flow by using table 1, which shows the relation between median grain size and the *n* value. The flow regime is checked by computing the velocity and stream power that correspond to the assigned *n* value. The computed stream power is compared with the value that is necessary to cause upper regime flow (see fig. 2, from Simons and Richardson, 1966, fig. 28). If the computed stream power is not large enough to produce upper regime flow (an indication of lower regime or transitional-zone flow), a reliable value of *n* cannot be assigned. The evaluation of *n* is complicated by bed-form drag. Different equations are needed to describe the bed forms. The total *n* value for lower and transitional-regime flows can vary greatly and depends on the bed forms present at a particular time. Figure 3 illustrates how the total resistance in a channel varies for different bed forms.

Limerinos (1970) related *n* to hydraulic radius and particle size on the basis of samples from 11 stream channels having bed material ranging from small gravel to medium-sized boulders. Particles have three dimensions—length, width, and thickness—and are oriented so that length and width are parallel to the plane of the streambed. Limerinos related *n* to minimum diameter (thickness) and to intermediate diameter (width). His equation using intermediate diameter appears to be the most useful because this dimension is the most easy to measure in the field and to estimate from photographs.

The equation for *n* using intermediate diameter is

$$n = \frac{(0.0926)\, R^{1/6}}{1.16 + 2.0 \log\left(\frac{R}{d_{84}}\right)} \qquad (5)$$

Mountain Streams

where

R = hydraulic radius, in feet, and

d_{84} = the particle diameter, in feet, that equals or exceeds the diameter of 84 percent of the particles (determined from a sample of about 100 randomly distributed particles).

Limerinos selected reaches having a minimum amount of roughness, other than that caused by bed material, and corresponding to the average base values given by Benson and Dalrymple (1967) shown in table 1.

Burkham and Dawdy (1976) showed that equation 5 applies to upper regime flow in sand channels. If a measured d_{84} is available or can be estimated, equation 5 may be used to obtain a base *n* for sand channels in lieu of using table 1.

Adjustment Factors for Channel *n* Values

The n_b values selected from table 1 or computed from the Limerinos equation are for straight channels of nearly uniform cross-sectional shape. Channel irregularities, alignment, obstructions, vegetation, and meandering increase the roughness of a channel. The value for *n* must be adjusted accordingly by adding increments of roughness to the base value, n_b, for each condition that increases the roughness. The adjustments apply to stable and sand channels. Table 2, modified from Aldridge and Garrett (1973), gives ranges of adjustments for the factors that affect channel roughness for the prevailing channel conditions. The average base values of Benson and Dalrymple (1967) from table 1 and the values computed from equation 5 apply to near-average conditions and, therefore, require smaller adjustments than do the smooth-channel base values of Chow (1959). Likewise, the adjustments (from table 2) made to base values of Benson and Dalrymple (1967) should be reduced slightly.

Depth of flow must be considered when selecting *n* values for channels. If the depth of flow is shallow in relation to the size of the roughness elements, the *n* value can be large. The *n* value decreases with increasing depth, except where the channel banks are much rougher than the bed or where dense brush overhangs the low-water channel.

Irregularity (n_1)

Where the ratio of width to depth is small, roughness caused by eroded and scalloped banks, projecting points, and exposed tree roots along the banks must be accounted for by fairly large adjustments. Chow (1959) and Benson and Dalrymple (1967) showed that severely eroded and scalloped banks can increase *n* values by as much as 0.02. Larger adjustments may be required for very large, irregular banks that have projecting points.

Variation in Channel Cross Section (n_2)

The value of *n* is not affected significantly by relatively large changes in the shape and size of cross sections if the changes are gradual and uniform. Greater roughness is associated with alternating large and small cross sections and sharp bends, constrictions, and side-to-side shifting of the low-water channel. The degree of the effect of changes in the size of the channel depends primarily on the number of alternations of large and small sections and secondarily on the magnitude of the changes. The effects of abrupt changes may extend downstream for several hundred feet. The *n* value for a reach below a disturbance may require adjustment, even though none of the roughness-producing factors are apparent in the study reach. A maximum increase in *n* of 0.003 will result from the usual amount of channel curvature found in designed channels and in the reaches of natural channels used to compute discharge (Benson and Dalrymple, 1967).

Obstructions (n_3)

Obstructions—such as logs, stumps, boulders, debris, pilings, and bridge piers—disturb the flow pattern in the channel and increase roughness. The amount of increase depends on the shape of the obstruction; the size of the obstruction in relation to that of the cross section; and the number, arrangement, and spacing of obstructions. The effect of obstructions on the roughness coefficient is a function of the flow velocity. When the flow velocity is high, an obstruction exerts a sphere of influence that is much larger than the obstruction because the obstruction affects the flow pattern for considerable distances on each side. The sphere of influence for velocities that generally occur in channels that have gentle to moderately steep slopes is about three to five times the width of the obstruction. Several obstructions can create overlapping spheres of influence and may cause considerable disturbance, even though the obstructions may occupy only a small part of a channel cross section. Chow (1959) assigned adjustment values to four levels of obstruction: negligible, minor, appreciable, and severe (table 2).

Vegetation (n_4)

The extent to which vegetation affects *n* depends on the depth of flow, the percentage of the wetted perimeter covered by the vegetation, the density of vegetation below the high-water line, the degree to which the vegetation is flattened by high water, and the alignment of vegetation relative to the flow. Rows of vegetation that parallel the flow may have less effect than rows of vegetation that are perpendicular to the flow. The adjustment values given in

Table 2. Adjustment values for factors that affect the roughness of a channel

[Modified from Aldridge and Garrett, 1973, table 2]

Channel conditions		*n* value adjustment[1]	Example
Degree of irregularity (n_1)	Smooth	0.000	Compares to the smoothest channel attainable in a given bed material.
	Minor	0.001–0.005 0.005	Compares to carefully dredged channels in good condition but having slightly eroded or scoured side slopes.
	Moderate	0.006–0.010	Compares to dredged channels having moderate to considerable bed roughness and moderately sloughed or eroded side slopes.
	Severe	0.011–0.020	Badly sloughed or scalloped banks of natural streams; badly eroded or sloughed sides of canals or drainage channels; unshaped, jagged, and irregular surfaces of channels in rock.
Variation in channel cross section (n_2)	Gradual	0.000	Size and shape of channel cross sections change gradually.
	Alternating occasionally	0.001–0.005 0.005	Large and small cross sections alternate occasionally, or the main flow occasionally shifts from side to side owing to changes in cross-sectional shape.
	Alternating frequently	0.010–0.015	Large and small cross sections alternate frequently, or the main flow frequently shifts from side to side owing to changes in cross-sectional shape.
Effect of obstruction (n_3)	Negligible	0.000–0.004	A few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, that occupy less than 5 percent of the cross-sectional area.
	Minor	0.005–0.015 0.005	Obstructions occupy less than 15 percent of the cross-sectional area, and the spacing between obstructions is such that the sphere of influence around one obstruction does not extend to the sphere of influence around another obstruction. Smaller adjustments are used for curved smooth-surfaced objects than are used for sharp-edged angular objects.
	Appreciable	0.020–0.030	Obstructions occupy from 15 to 50 percent of the cross-sectional area, or the space between obstructions is small enough to cause the effects of several obstructions to be additive, thereby blocking an equivalent part of a cross section.
	Severe	0.040–0.050	Obstructions occupy more than 50 percent of the cross-sectional area, or the space between obstructions is small enough to cause turbulence across most of the cross section.
Amount of vegetation (n_4)	Small	0.002–0.010	Dense growths of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, cottonwood, arrowweed, or saltcedar growing where the average depth of flow is at least three times the height of the vegetation.
	Medium	0.010–0.025	Turf grass growing where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemmy grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of the vegetation; brushy, moderately dense vegetation, similar to 1- to 2-year-old willow trees in the dormant season, growing along the banks, and no significant vegetation is evident along the channel bottoms where the hydraulic radius exceeds 2 ft.
	Large	0.025–0.050 0.03	Turf grass growing where the average depth of flow is about equal to the height of the vegetation; 8- to 10-year-old willow or cottonwood trees intergrown with some weeds and brush (none of the vegetation in foliage) where the hydraulic radius exceeds 2 ft; bushy willows about 1 year old intergrown with some weeds along side slopes (all vegetation in full foliage), and no significant vegetation exists along channel bottoms where the hydraulic radius is greater than 2 ft.
	Very large	0.050–0.100	Turf grass growing where the average depth of flow is less than half the height of the vegetation; bushy willow trees about 1 year old intergrown with weeds along side slopes (all vegetation in full foliage), or dense cattails growing along channel bottom; trees intergrown with weeds and brush (all vegetation in full foliage).
Degree of meandering[2] (m)	Minor	1.00	Ratio of the channel length to valley length is 1.0 to 1.2.
	Appreciable	1.15	Ratio of the channel length to valley length is 1.2 to 1.5.
	Severe	1.30	Ratio of the channel length to valley length is greater than 1.5.

[1] Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base *n* value (table 1) before multiplying by the adjustment for meander.

[2] Adjustment values apply to flow confined in the channel and do not apply where downvalley flow crosses meanders.

$n \sum n_i = 0.071$

streams

table 2 apply to constricted channels that are narrow in width. In wide channels having small depth-to-width ratios and no vegetation on the bed, the effect of bank vegetation is small, and the maximum adjustment is about 0.005. If the channel is relatively narrow and has steep banks covered by dense vegetation that hangs over the channel, the maximum adjustment is about 0.03. The larger adjustment values given in table 2 apply only in places where vegetation covers most of the channel.

Meandering (*m*)

The degree of meandering, *m*, depends on the ratio of the total length of the meandering channel in the reach being considered to the straight length of the channel reach. The meandering is considered minor for ratios of 1.0 to 1.2, appreciable for ratios of 1.2 to 1.5, and severe for ratios of 1.5 and greater. According to Chow (1959), meanders can increase the *n* values by as much as 30 percent where flow is confined within a stream channel. The meander adjustment should be considered only when the flow is confined to the channel. There may be very little flow in a meandering channel when there is flood-plain flow.

FLOOD-PLAIN *n* VALUES

Roughness values for channels and flood plains should be determined separately. The composition, physical shape, and vegetation of a flood plain can be quite different from those of a channel.

Modified Channel Method

By altering Cowan's (1956) procedure that was developed for estimating *n* values for channels, the following equation can be used to estimate *n* values for a flood plain:

$$n=(n_b+n_1+n_2+n_3+n_4)m \qquad (6)$$

where

- n_b = a base value of *n* for the flood plain's natural bare soil surface,
- n_1 = a correction factor for the effect of surface irregularities on the flood plain,
- n_2 = a value for variations in shape and size of the flood-plain cross section, assumed to equal 0.0,
- n_3 = a value for obstructions on the flood plain,
- n_4 = a value for vegetation on the flood plain, and
- m = a correction factor for sinuosity of the flood plain, equal to 1.0.

By using equation 6, the roughness value for the flood plain is determined by selecting a base value of n_b for the natural bare soil surface of the flood plain and adding adjustment factors due to surface irregularity, obstructions, and vegetation. The selection of an n_b value is the same as outlined for channels in Channel *n* Values. See table 3 for *n* value adjustments for flood plains. The adjustment for cross-sectional shape and size is assumed to be 0.0. The cross section of a flood plain is subdivided where abrupt changes occur in the shape of the flood plain. The adjustment for meandering is assumed to be 1.0 because there may be very little flow in a meandering channel when there is flood-plain flow. In certain cases where the roughness of the flood plain is caused by trees and brush, the roughness value for the flood plain can be determined by measuring the vegetation density of the flood plain rather than by directly estimating from table 3 (see Vegetation-Density Method).

Adjustment Factors for Flood-Plain *n* Values

Surface Irregularities (n_1)

Irregularity of the surface of a flood plain causes an increase in the roughness of the flood plain. Such physical factors as rises and depressions of the land surface and sloughs and hummocks increase the roughness of the flood plain. A hummock is a low mound or ridge of earth above the level of an adjacent depression. A slough is a stagnant swamp, marsh, bog, or pond.

Shallow water depths, accompanied by an irregular ground surface in pastureland or brushland and by deep furrows perpendicular to the flow in cultivated fields, can increase the *n* values by as much as 0.02.

Obstructions (n_3)

The roughness contribution of some obstructions on a flood plain, such as debris deposits, stumps, exposed roots, logs, or isolated boulders, cannot be measured directly but must be considered. Table 3 lists values of roughness for different percentages of obstruction occurrence.

Vegetation (n_4)

Visual observation, judgment, and experience are used in selecting adjustment factors for the effects of vegetation from table 3. An adjustment factor for tree trunks and other measurable obstacles is described in the Vegetation-Density Method. Although measuring the area occupied by tree trunks and large diameter vegetation is relatively easy, measuring the area occupied by low vines, briars, grass, or crops is more difficult (table 3).

In the case of open fields and cropland on flood plains, several references are available to help determine the roughness factors. Ree and Crow (1977) conducted experiments to determine roughness factors for gently sloping earthen channels planted with wheat, sorghum, lespedeza, or grasses. The roughness factors were intended for application in the design of diversion terraces. However, the data can be applied to the design of any terrace, or they can be used to estimate the roughness of cultivated flood plains.

Floodplains

Table 3. Adjustment values for factors that affect roughness of flood plains
[Modified from Aldridge and Garrett, 1973, table 2]

Flood-plain conditions		*n* value adjustment	Example
Degree of irregularity (n_1)	Smooth	0.000	Compares to the smoothest, flattest flood plain attainable in a given bed material.
	Minor	0.001–0.005 (0.005)	Is a flood plain slightly irregular in shape. A few rises and dips or sloughs may be visible on the flood plain.
	Moderate	0.006–0.010	Has more rises and dips. Sloughs and hummocks may occur.
	Severe	0.011–0.020	Flood plain very irregular in shape. Many rises and dips or sloughs are visible. Irregular ground surfaces in pastureland and furrows perpendicular to the flow are also included.
Variation of flood-plain cross section (n_2)		0.0	Not applicable.
Effect of obstructions (n_3)	Negligible	0.000–0.004	Few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, or isolated boulders, occupy less than 5 percent of the cross-sectional area.
	Minor	(0.005) 0.005–0.019	Obstructions occupy less than 15 percent of the cross-sectional area.
	Appreciable	0.020–0.030	Obstructions occupy from 15 to 50 percent of the cross-sectional area.
Amount of vegetation (n_4)	Small	0.001–0.010	Dense growth of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation, or supple tree seedlings such as willow, cottonwood, arrowweed, or saltcedar growing where the average depth of flow is at least three times the height of the vegetation.
	Medium	0.011–0.025	Turf grass growing where the average depth of flow is from one to two times the height of the vegetation, or moderately dense stemmy grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of the vegetation; brushy, moderately dense vegetation, similar to 1- to 2-year-old willow trees in the dormant season.
	Large	0.025–0.050 (0.03)	Turf grass growing where the average depth of flow is about equal to the height of the vegetation, or 8- to 10-year-old willow or cottonwood trees intergrown with some weeds and brush (none of the vegetation in foliage) where the hydraulic radius exceeds 2 ft, or mature row crops such as small vegetables, or mature field crops where depth of flow is at least twice the height of the vegetation.
	Very large	0.050–0.100	Turf grass growing where the average depth of flow is less than half the height of the vegetation, or moderate to dense brush, or heavy stand of timber with few down trees and little undergrowth where depth of flow is below branches, or mature field crops where depth of flow is less than the height of the vegetation.
	Extreme	0.100–0.200	Dense bushy willow, mesquite, and saltcedar (all vegetation in full foliage), or heavy stand of timber, few down trees, depth of flow reaching branches.
Degree of meander (m)		1.0	Not applicable.

Chow (1959) presents a table showing minimum, normal, and maximum values of *n* for flood plains covered by pasture and crops. These values are helpful for comparing the roughness values of flood plains having similar vegetation.

Vegetation-Density Method

For a wooded flood plain, the vegetation-density method can be used as an alternative to the previous method for determining *n* values for flood plains. In a wooded flood plain, where the tree diameters can be measured, the vegetation density of the flood plain can be determined.

Determining the vegetation density is an effective way of relating plant height and density characteristics, as a function of depth of flow, to the flow resistance of vegetation. Application of the flow-resistance model presented below requires an estimate of the vegetation density as a function of depth of flow. The procedure requires a direct or indirect determination of vegetation density at a given depth. If the change in *n* value through a range in depth is required, then an estimation of vegetation density through that range is necessary.

Techniques for Determining Vegetation Density

Petryk and Bosmajian (1975) developed a method of analysis of the vegetation density to determine the rough-

$\Sigma n_i = 0.07$ Floodplain

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT *n* (*continued*)

Type of channel and description	Minimum	Normal	Maximum
C. EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
D. NATURAL STREAMS			
D-1. Minor streams (top width at flood stage <100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT *n* (*continued*)

Type of channel and description	Minimum	Normal	Maximum
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The *n* value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	.....	0.060
b. Irregular and rough section	0.035	.....	0.100

Mountain Streams

Floodplain Areas

Scour Analysis

All Calcs based on
FHWA HEC-18

Date: 23-Apr-20
Calculated/Checked by: TG
Project: Jacumba Valley Ranch Solar
Locality: Jacumba Valley, San Diego County
State California

Note: Flows based on Hydrologic and Hydraulic Calculations from Appendicies B and C

Froude Number

$$F = \frac{V}{\sqrt{gh_m}}$$

Max Flow Depth (ft)	Velocity (ft/s)	Froude #	Local Scour[1,5] (ft)
1	4	0.71	1.3
1	4.5	0.79	1.4
1.5	4.5	0.65	1.5
1.5	5	0.72	1.5
2	5	0.62	1.6
2	6	0.75	1.7
2.5	6	0.67	1.8
2.5	7	0.78	1.9

Pier Width (in)			4
Pier Length (in)			6
Pier Width (ft)		a	0.33
Pier Length (ft)		L	0.5
K1[2]	Square Nose		1.1
Angle (deg)			90
Angle (rad)			1.57
K2[3]	Square Nose		1.302
K3[4]	Plane Bed		1.1

[1] Equation 7.3 FHWA HEC 18

[2] Correction factor for pier nose shape Table 7.1

[3] Correction factor for angle of attach Equation 7.4

[4] Correction factor for bed condition Table 7.3

[5] Local scour based on maximum depth of flow