DRONE TECHNOLOGY AND RUBBLE MOUND STRUCTURES

ST. LUCIE INLET SOUTH JETTY CASE STUDY

Presented By: Andrew Wycklendt, P.E.

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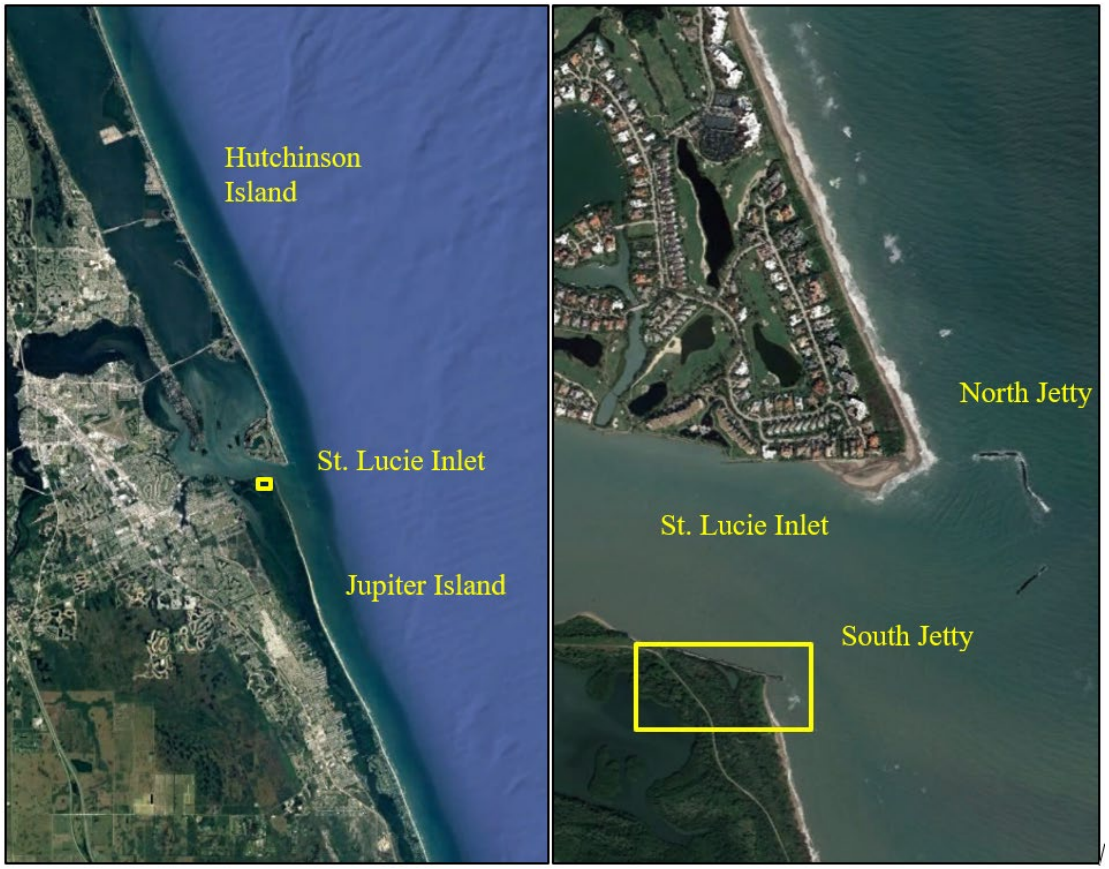
PROJECT LOCATION



PROBLEM IDENTIFICATION

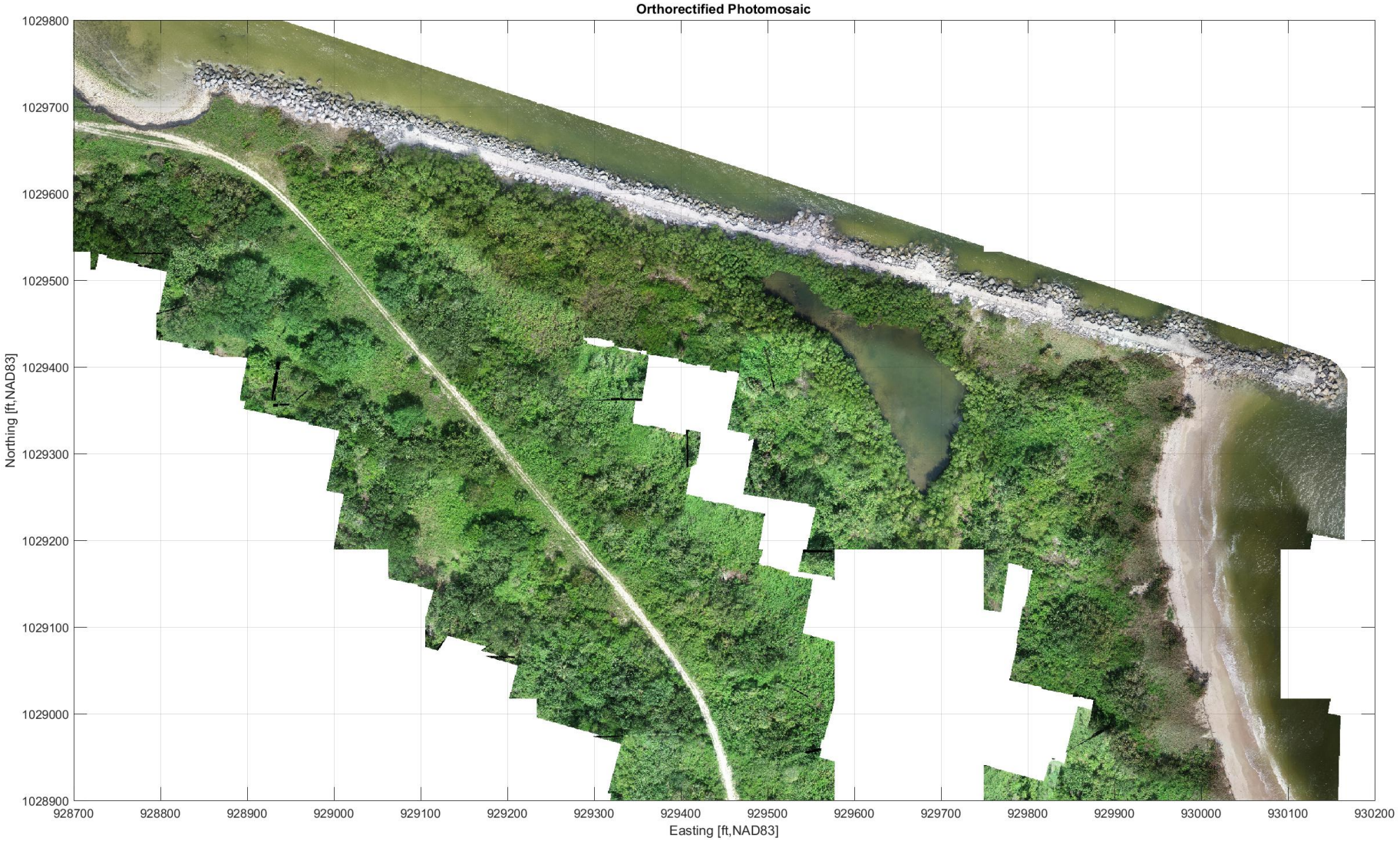
- June 2019 Engineering Investigation
  - Level 1 Evaluation – 100% Structure
  - Level 2 Evaluation – 10% Structure (i.e. profiles every 100 feet)
  - Condition Rating = Fair; primary structure elements are sound, but minor to moderate defects or deterioration was observed
- March 2020 Post-Dorian Drone Assessment
  - Negligible change to breach, crest elevation, and side slopes

AVAILABLE DATA

- Geophysical
  - Various LiDAR Surveys (USACE, FEMA, NASA, NOAA, NGS, USGS)
  - April 2019 Jetty Assessment Surveys (RTK, Drone, and Laser Scan)
  - October 2019 Post-Storm (i.e. Hurricane Dorian) Drone Survey
- Oceanographic
  - NOAA Water Level Observation Network
  - FEMA Flood Insurance Study
  - USACE Wave Information Studies
- Engineering
  - Design Drawings (1978)
  - As-Built Drawings (1984)

DESIGN CONDITIONS

- Navigation Channel
  - Authorized Depth = -10 ft MLW
  - Required Overdepth = -12 ft MLW
- Depth Limited Breaking
  - Breaking Height = 11.5 ft @ MHW
  - Equivalent to Annual Wave Height
- Design Template
  - No Curve
  - Baseline = Maintenance Road
  - Crest = 10 ft @ 5.65 ft NAVD (8.0 ft MLW)
  - 5 Platforms (Width = 25', Protrusion = 15')
  - Slope = 1V:2H
- Armor Stone Size
  - Hudson (1974) Stability Equation
    - Irregular head-on waves
  - Stability Coefficient = 2.0
    - Rough angular stone shape
    - Random Placement
    - Breaking waves
  - Waves Breaking on Crest
    - Crest Elevation = 5.65 ft NAVD
  - Armor Stone Size
    - 5.6 to 9.3 tons (7.4 tons)
    - 4.1 to 4.8 feet (4.5 feet)
  - Core Stone Size
    - 0.56 to 0.93 tons (0.74 tons)
    - 1.9 to 2.2 feet (2.1 feet)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Easting [ft,NAD83]

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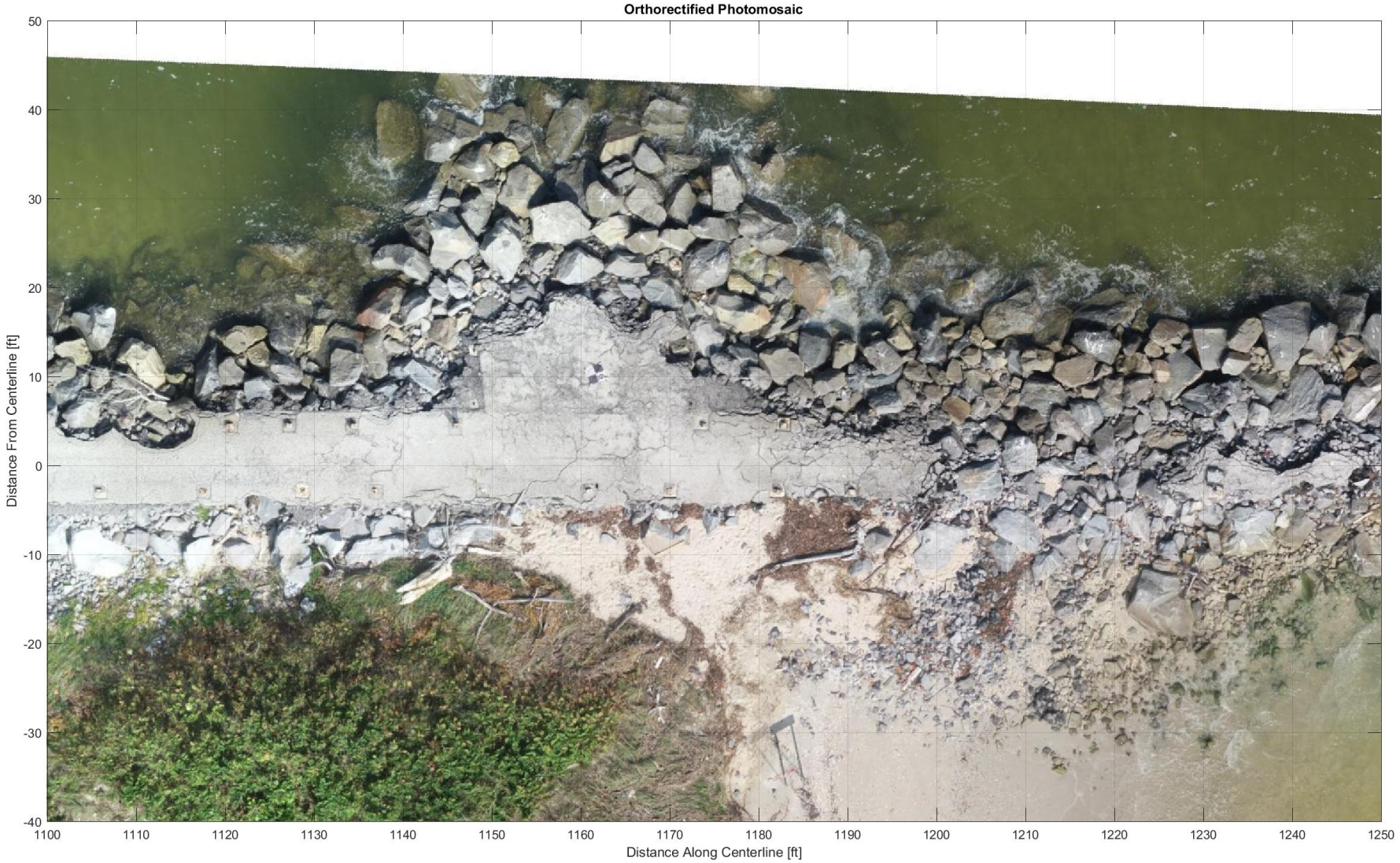
Distance Along Centerline [ft]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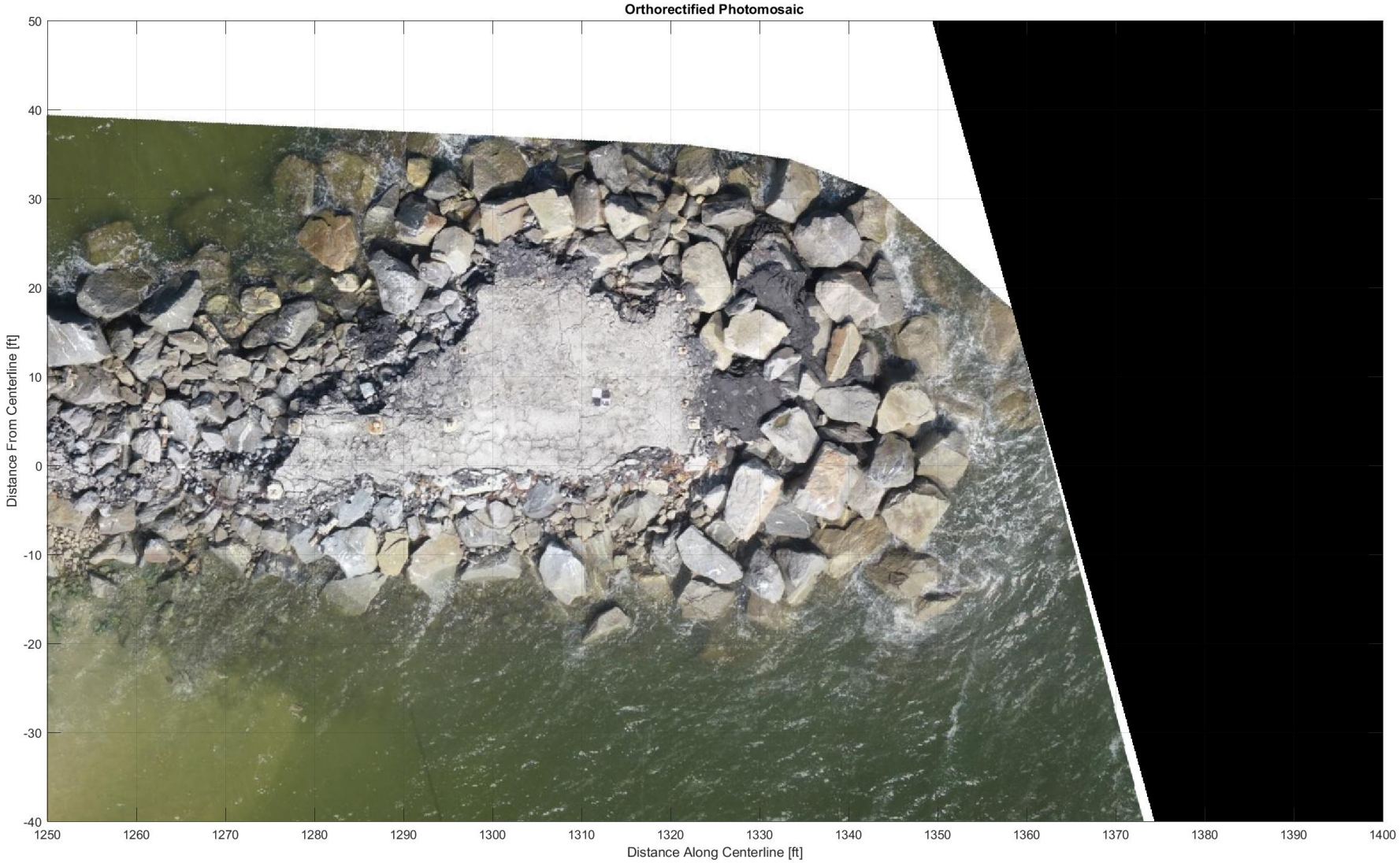
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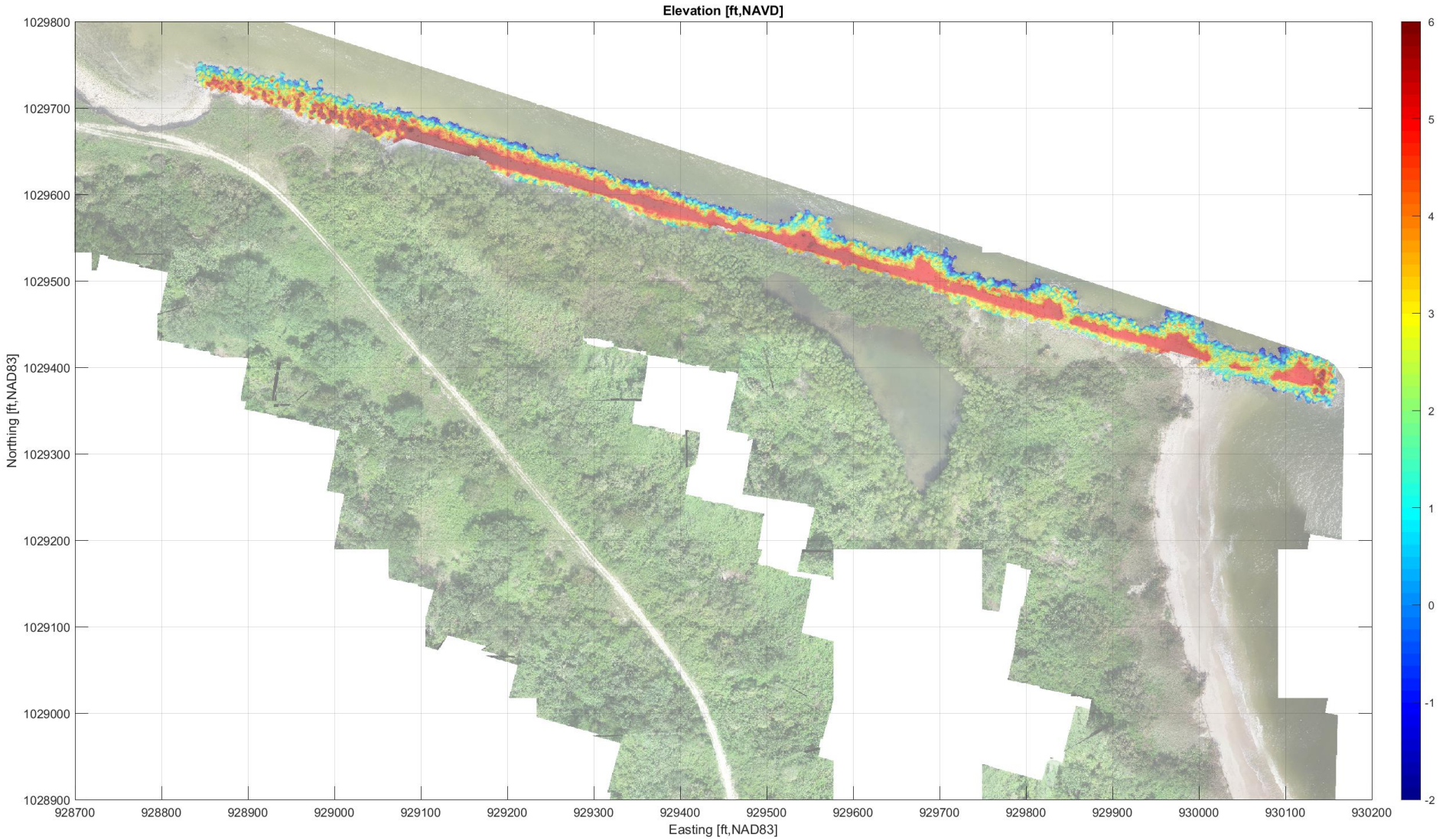
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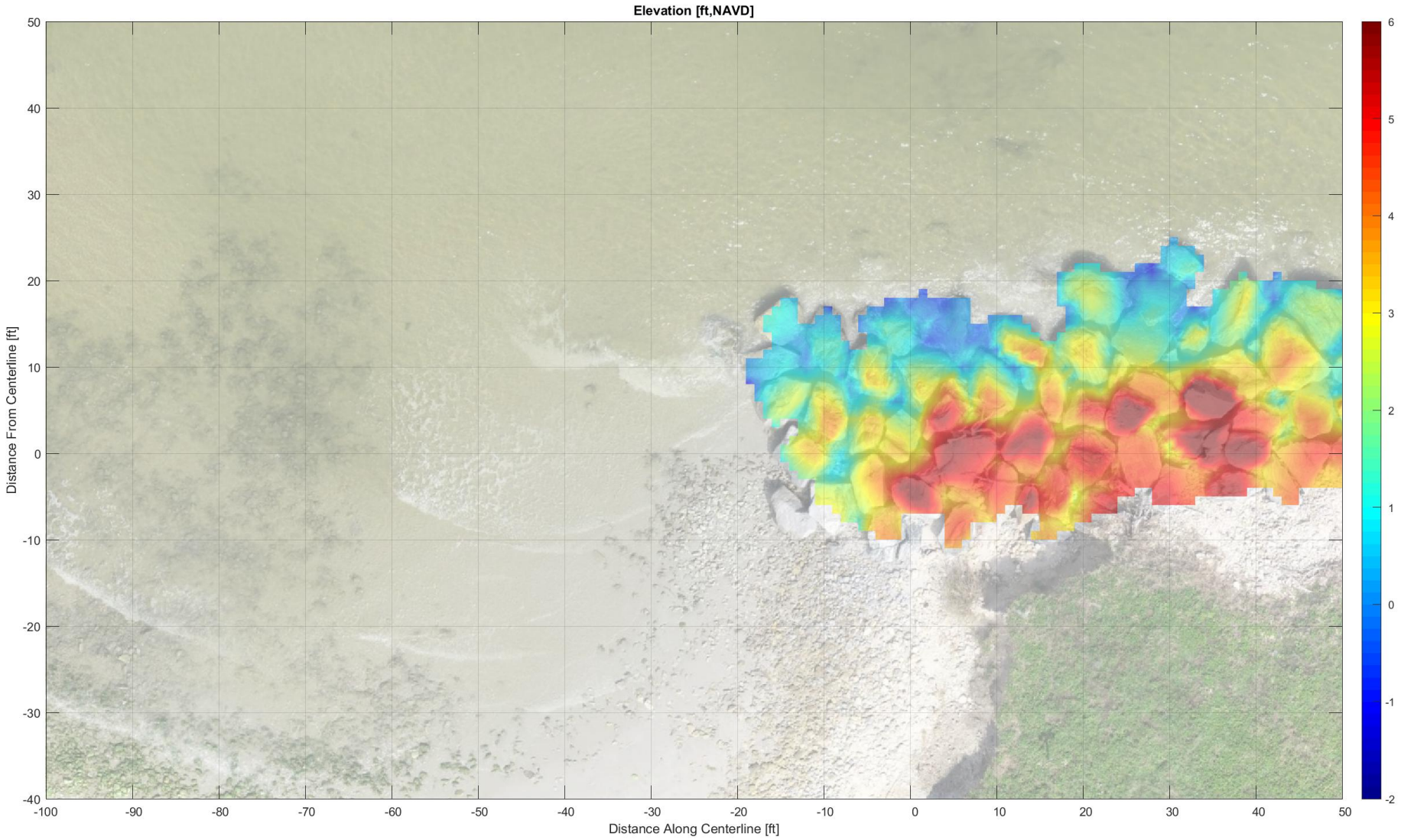
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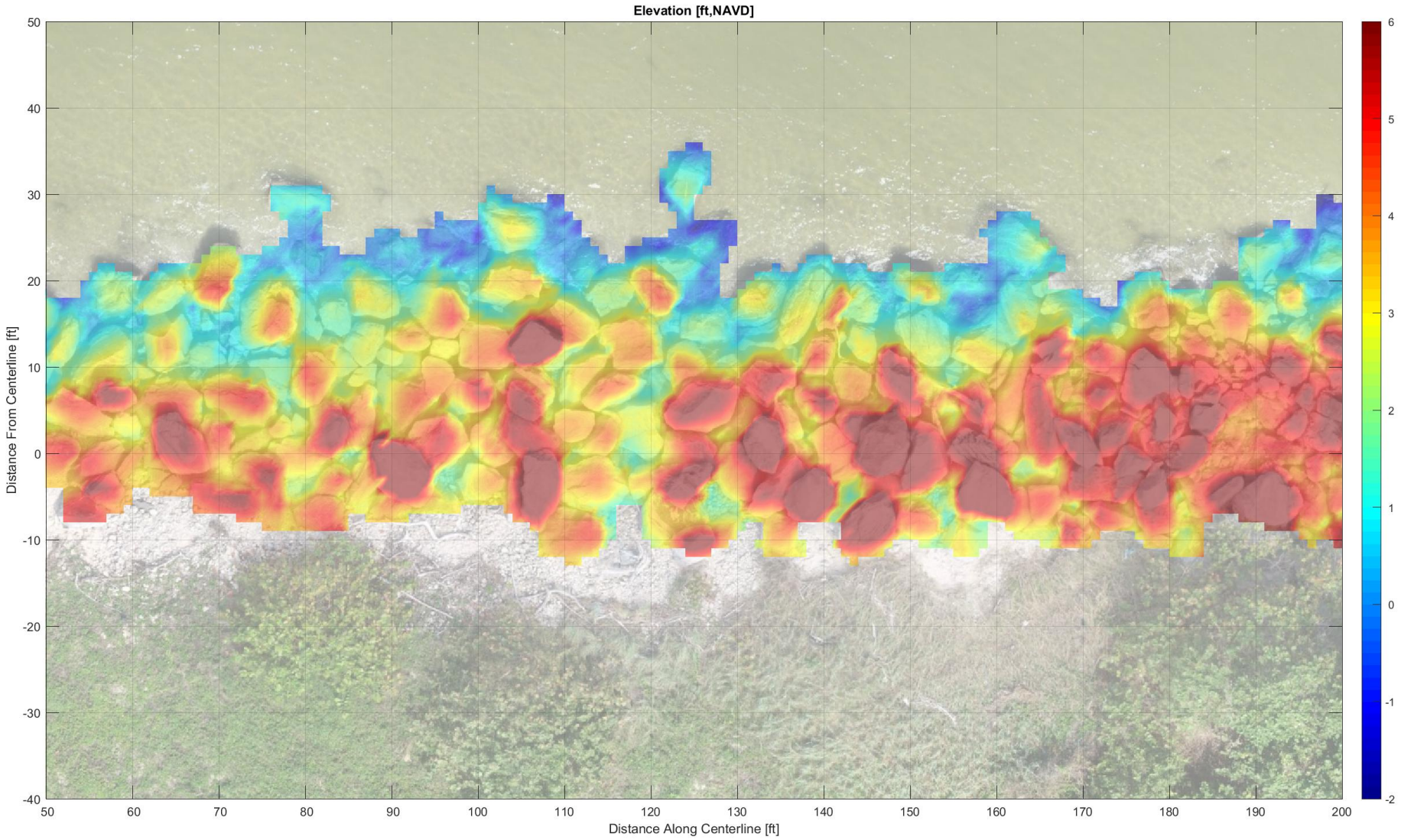
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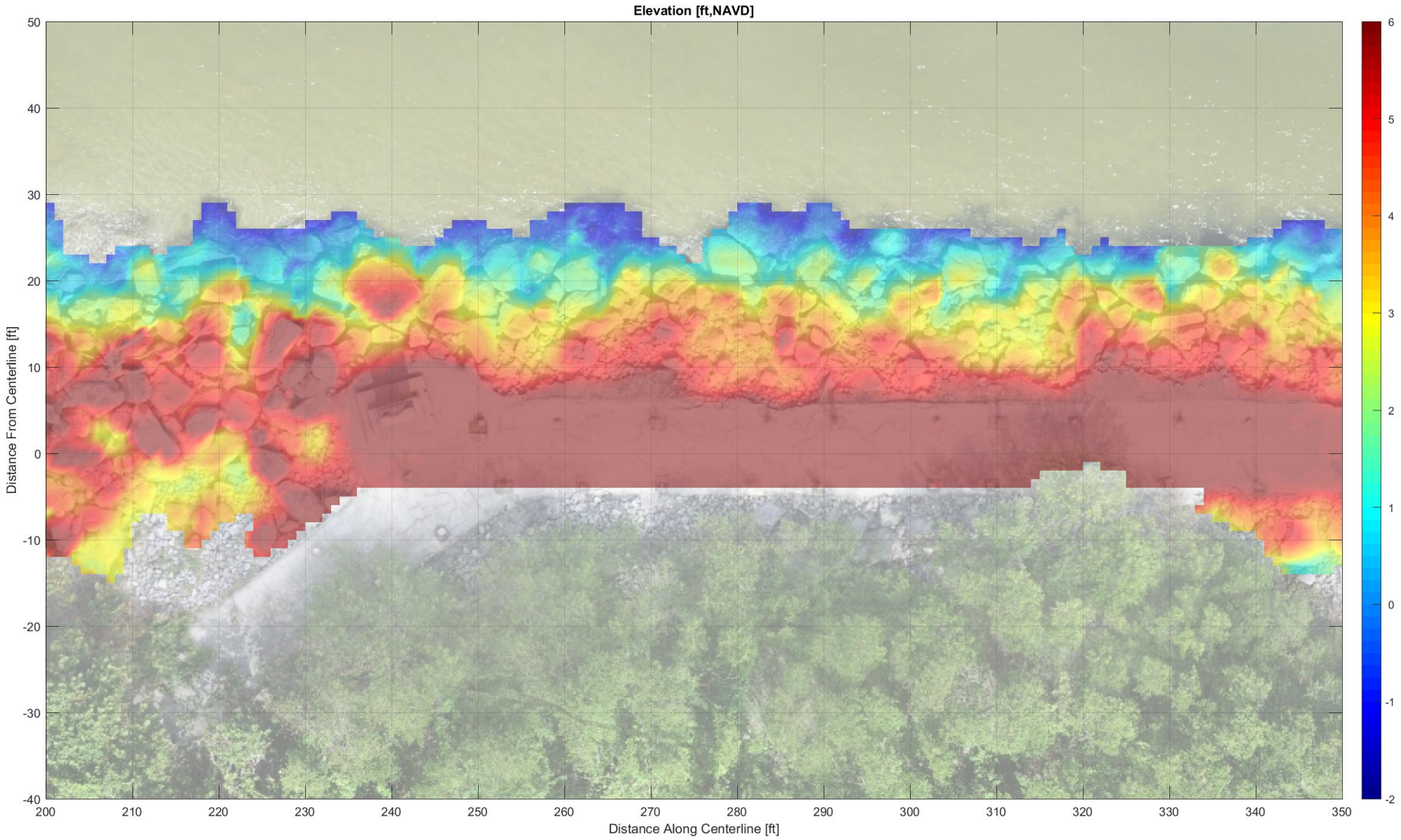
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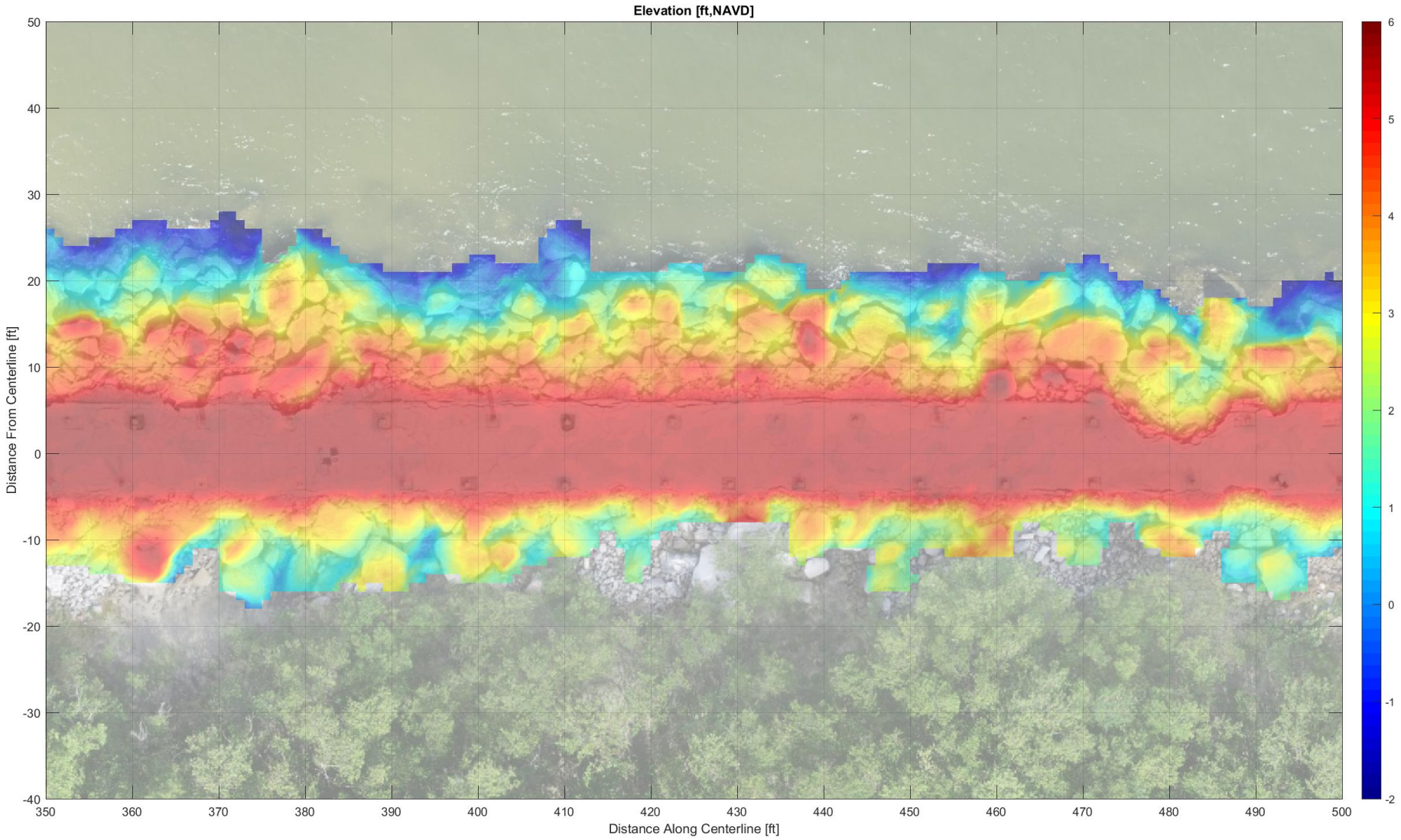
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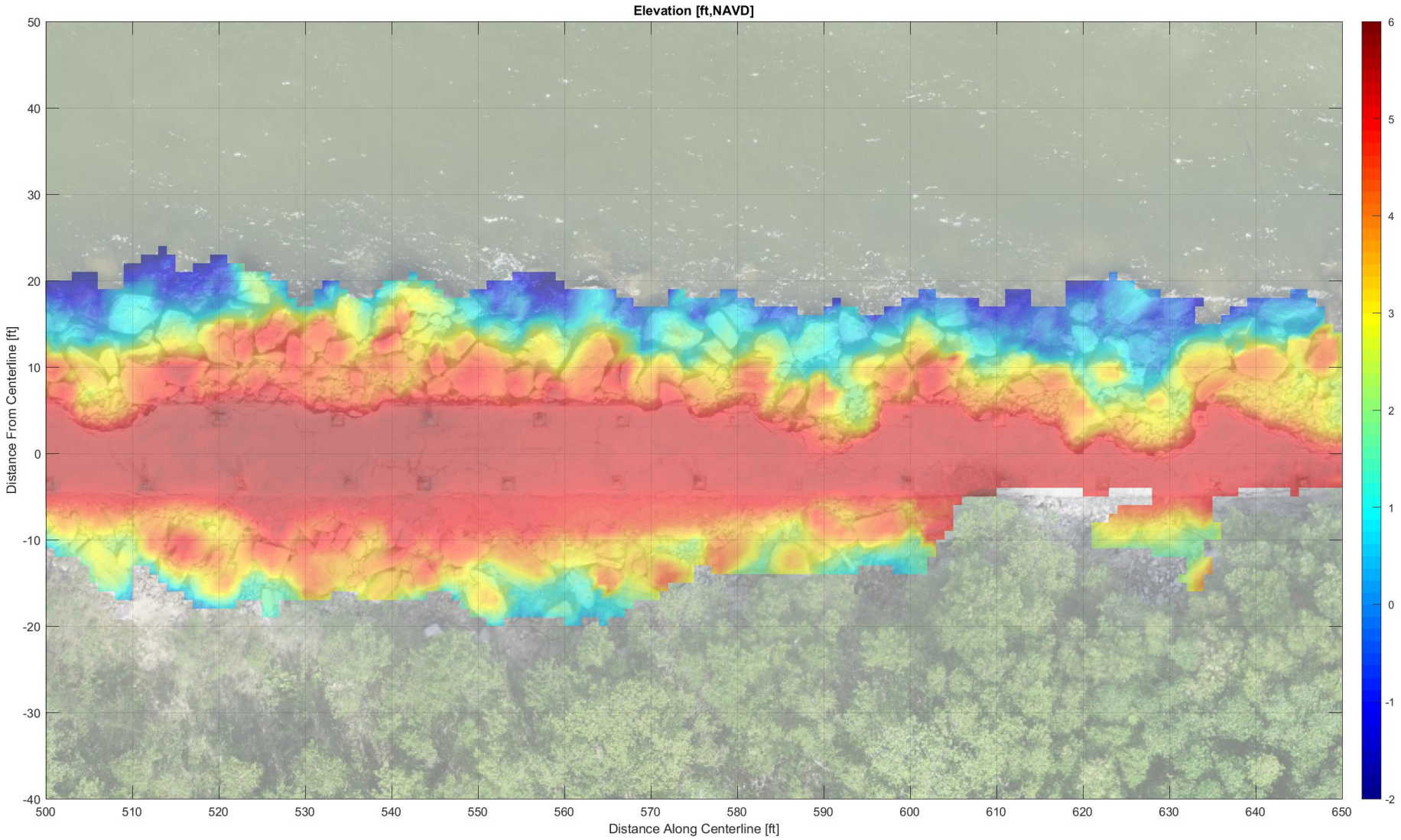
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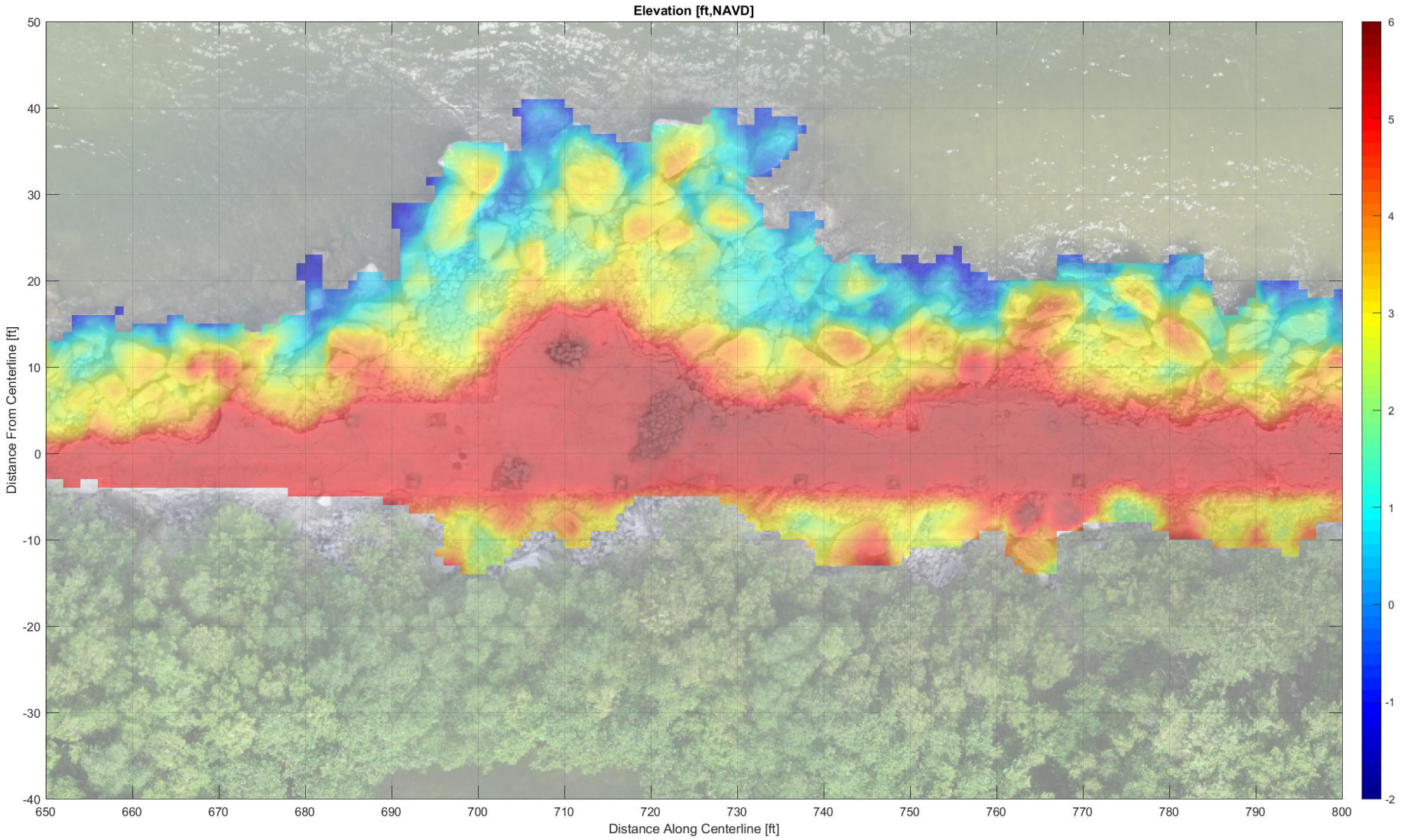
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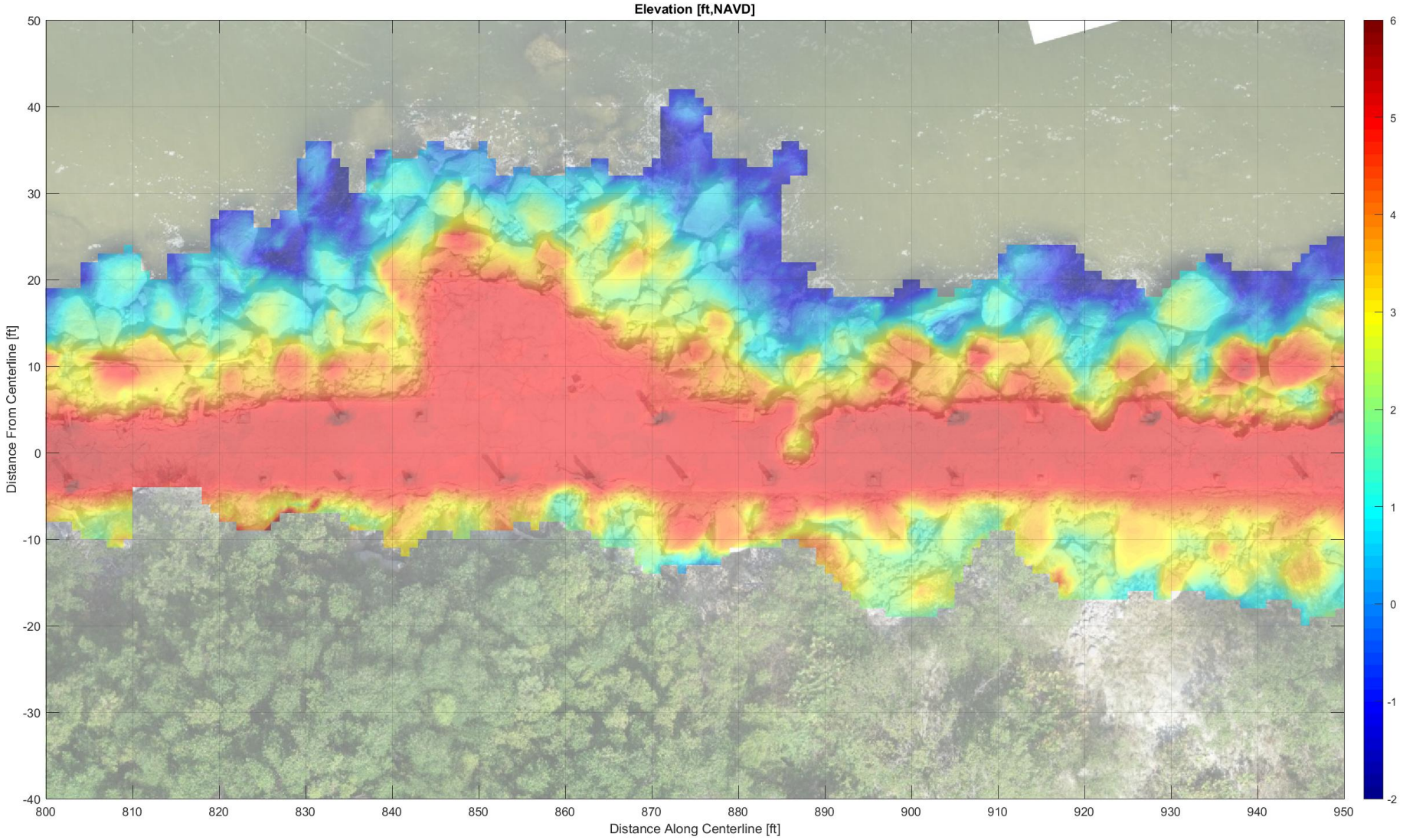
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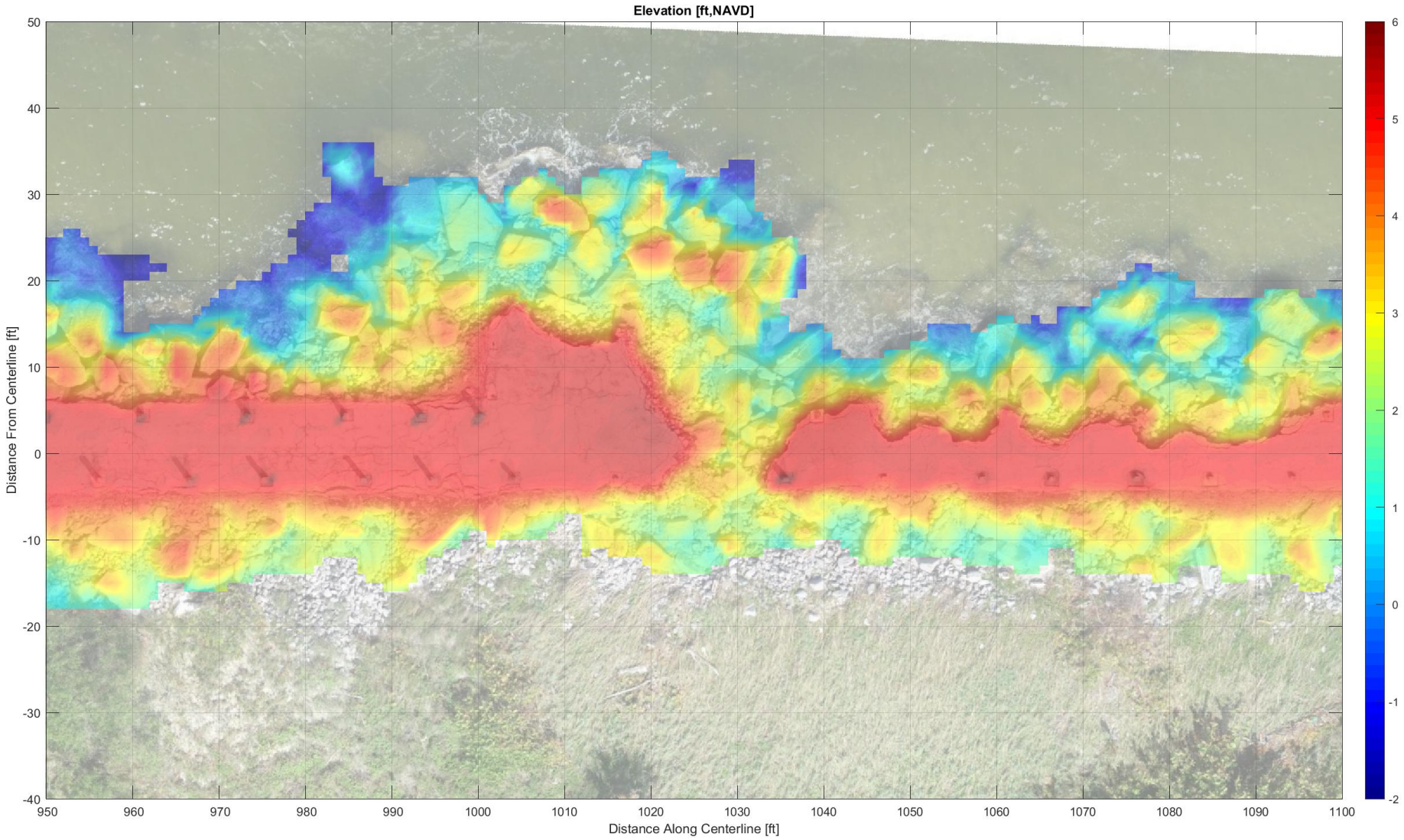
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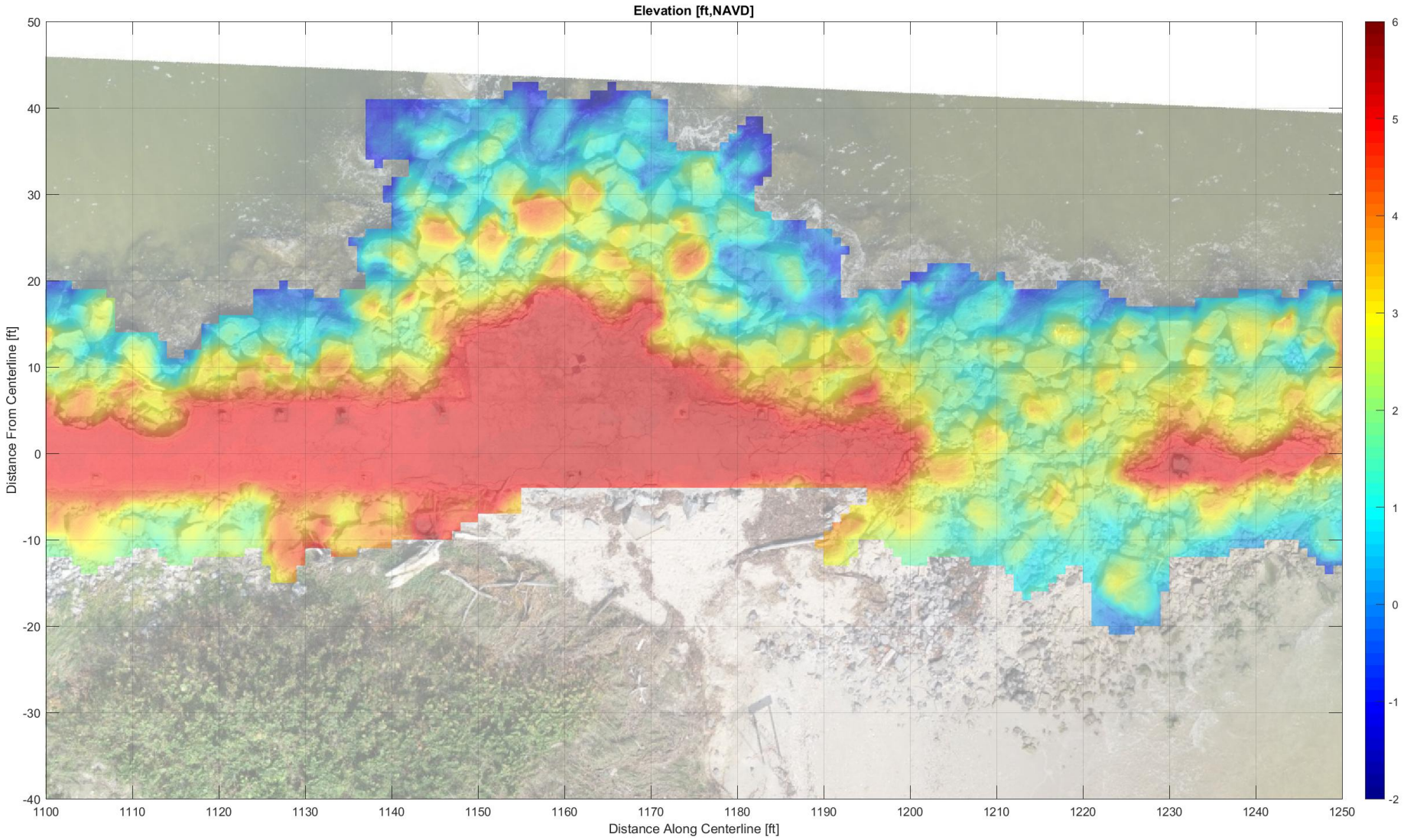
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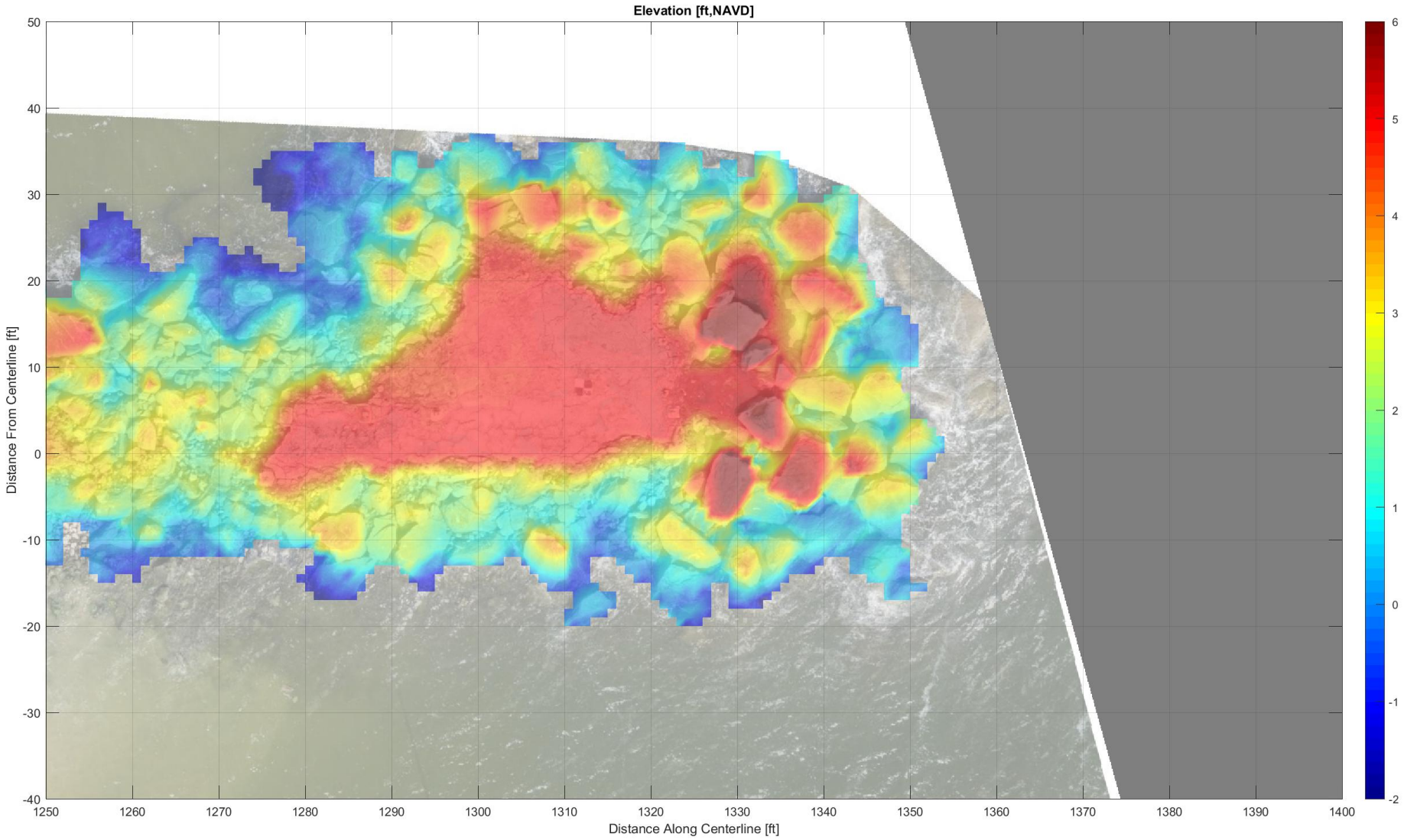
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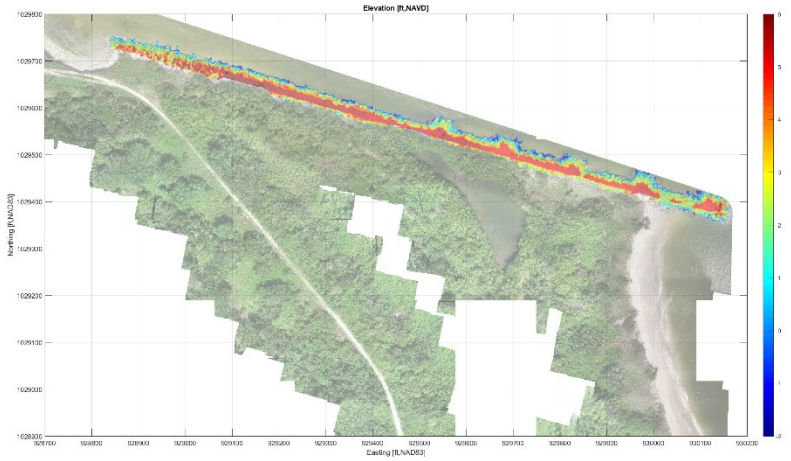
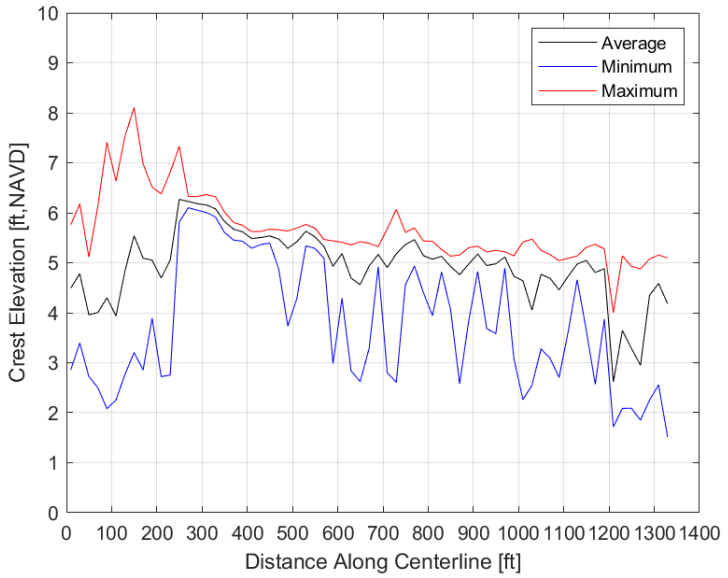
JETTY CREST ELEVATION

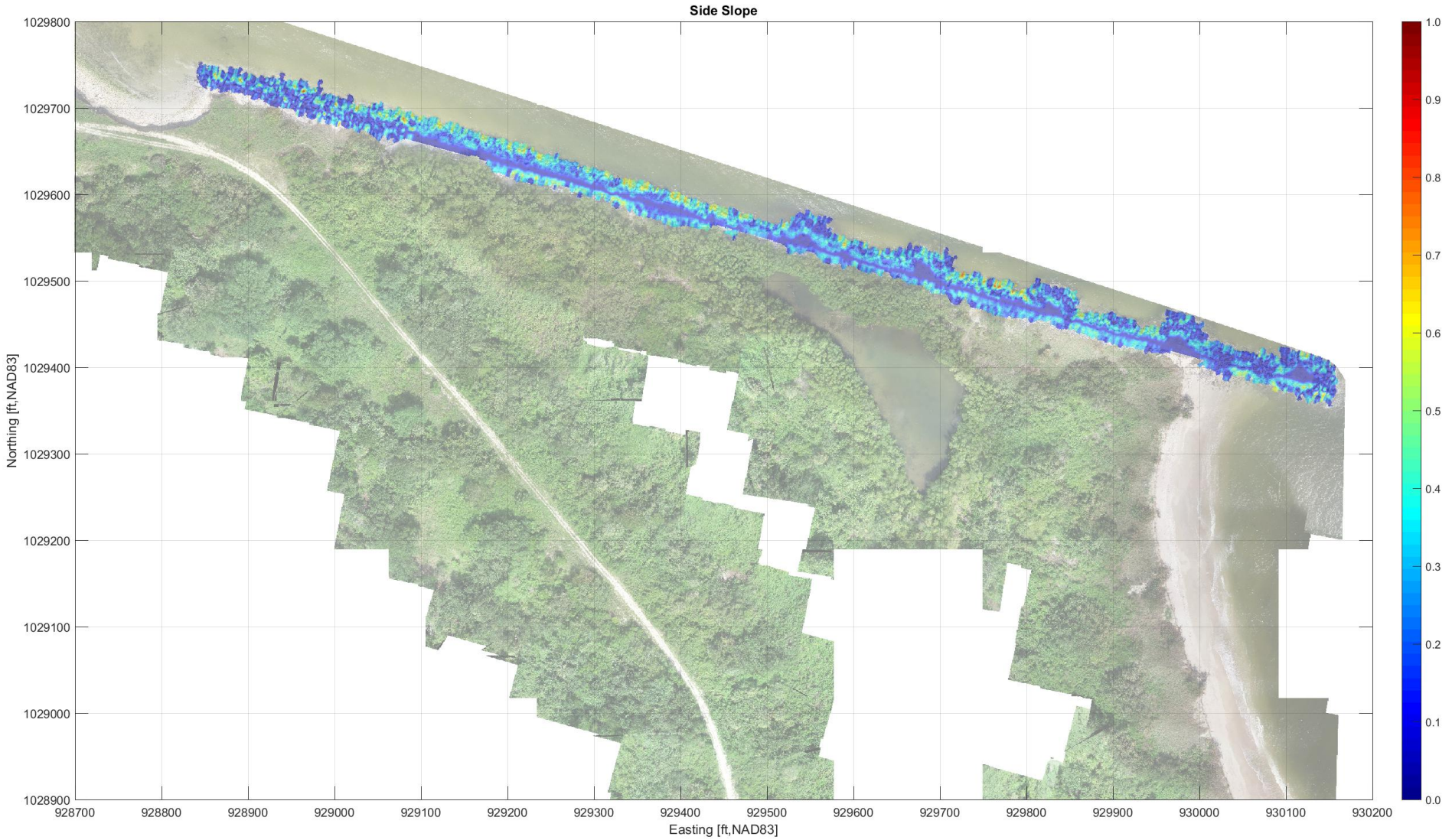


› Crest Elevation (ft,NAVD)

Face	Min	Max	Avg
Crest	1.5	8.1	4.9

› Minimum, maximum, and average crest elevations were calculated for each 20-foot segment along the jetty.

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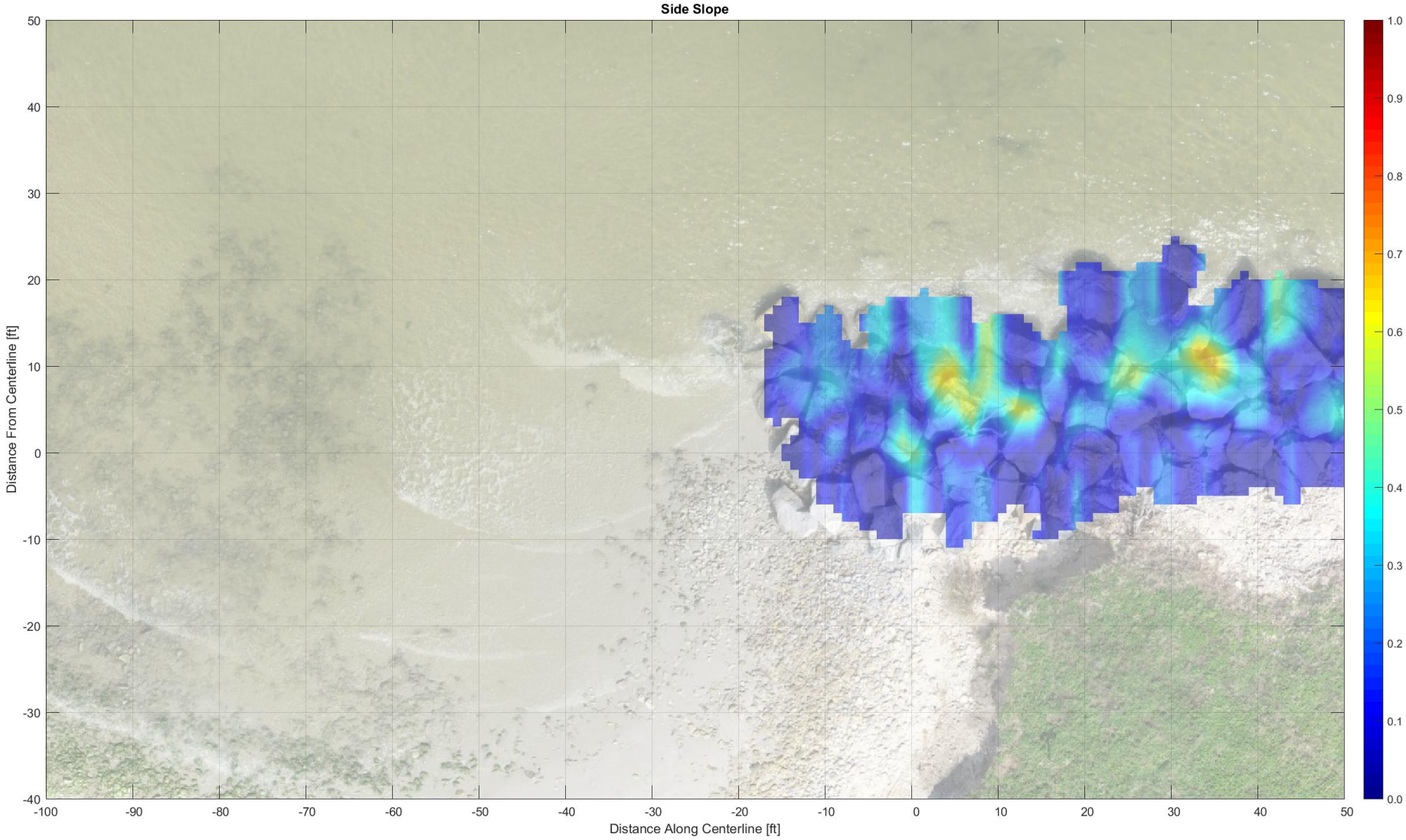
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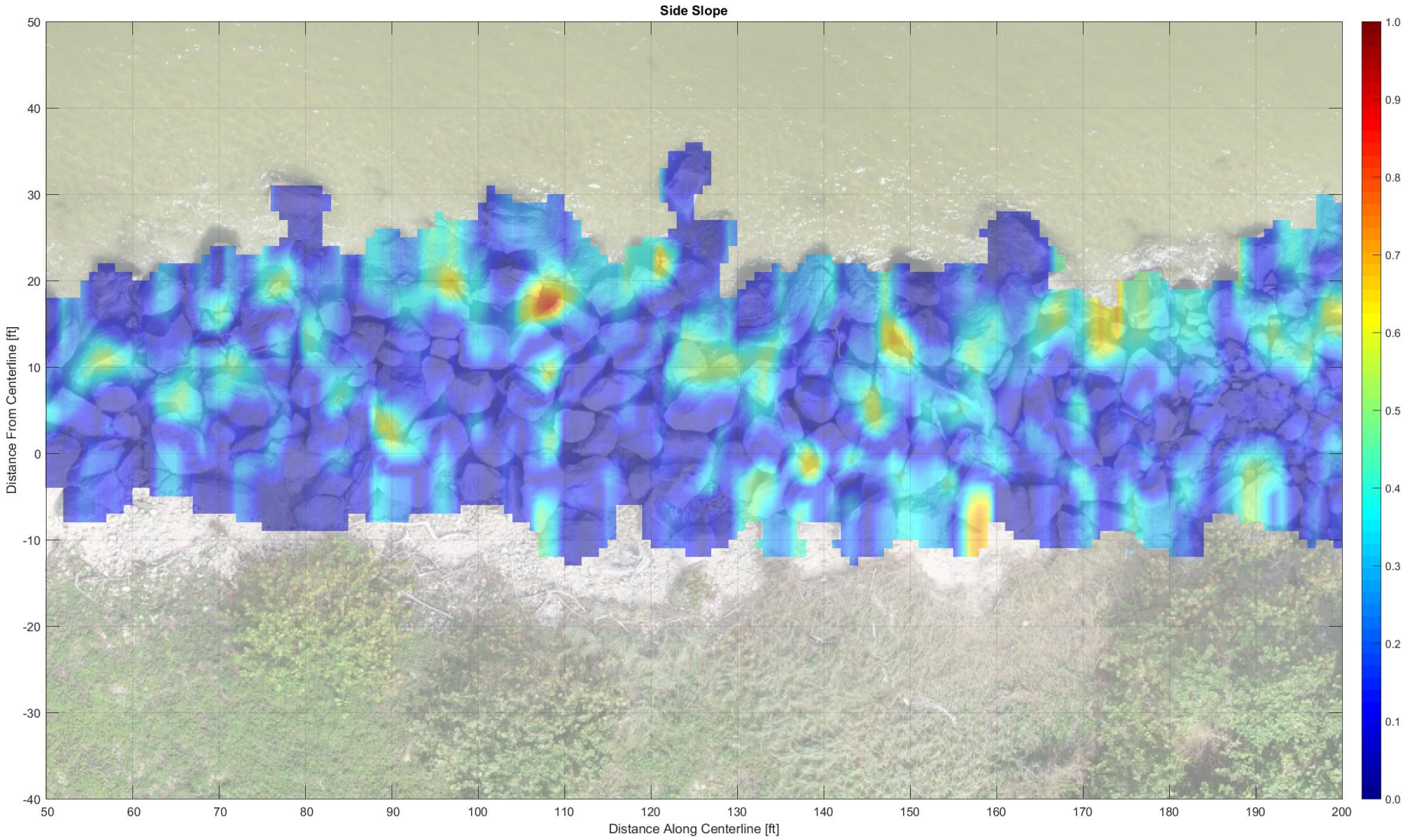
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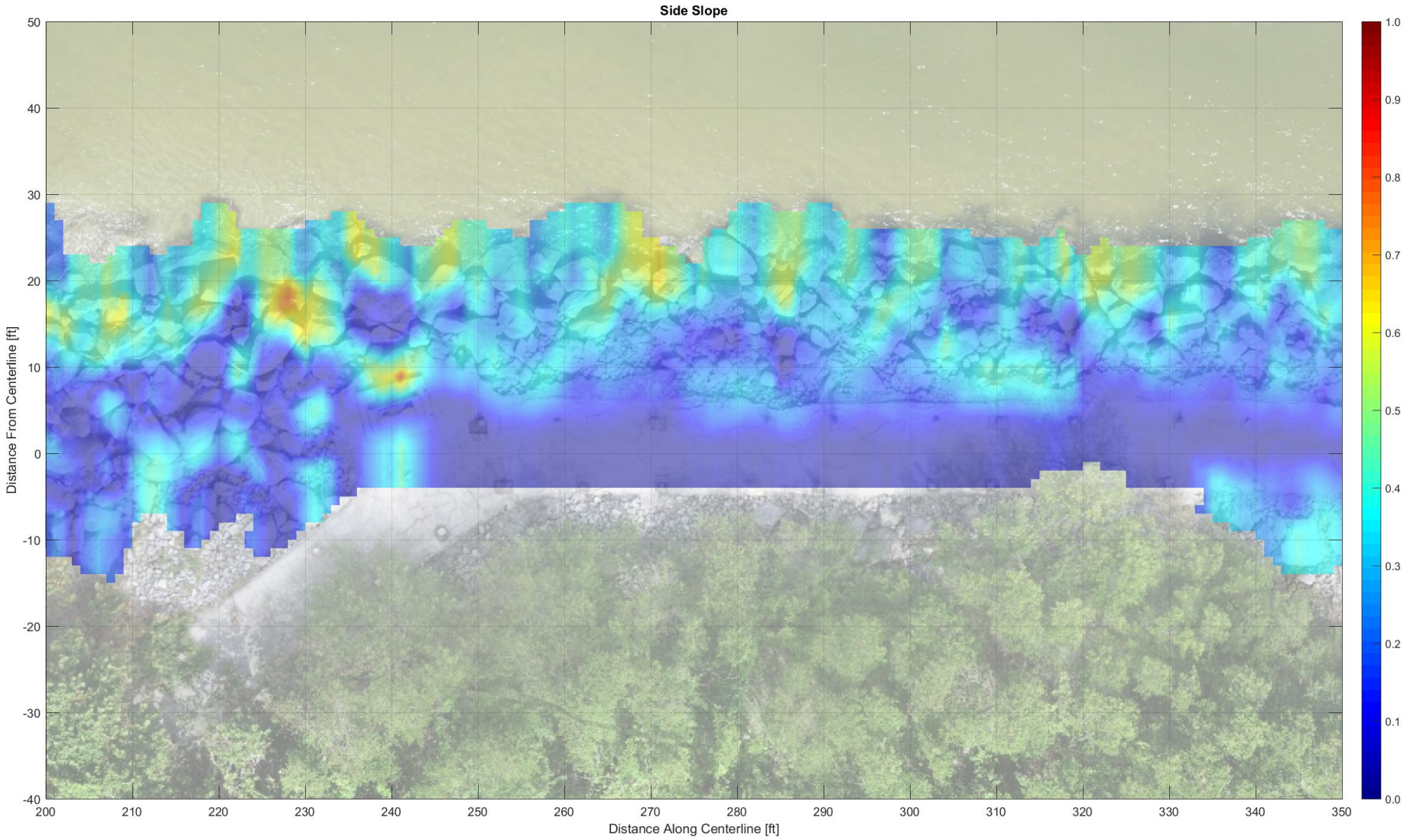
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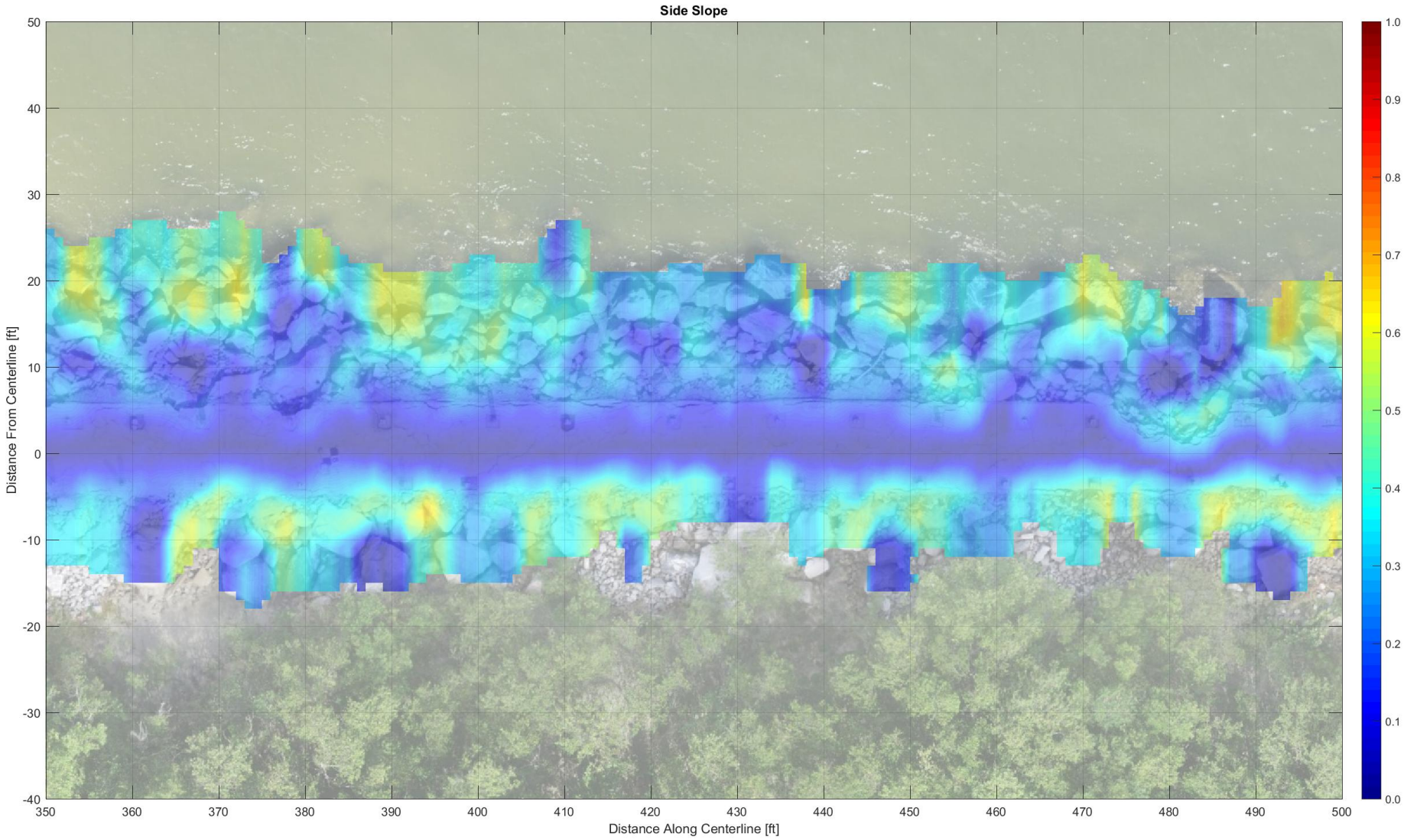
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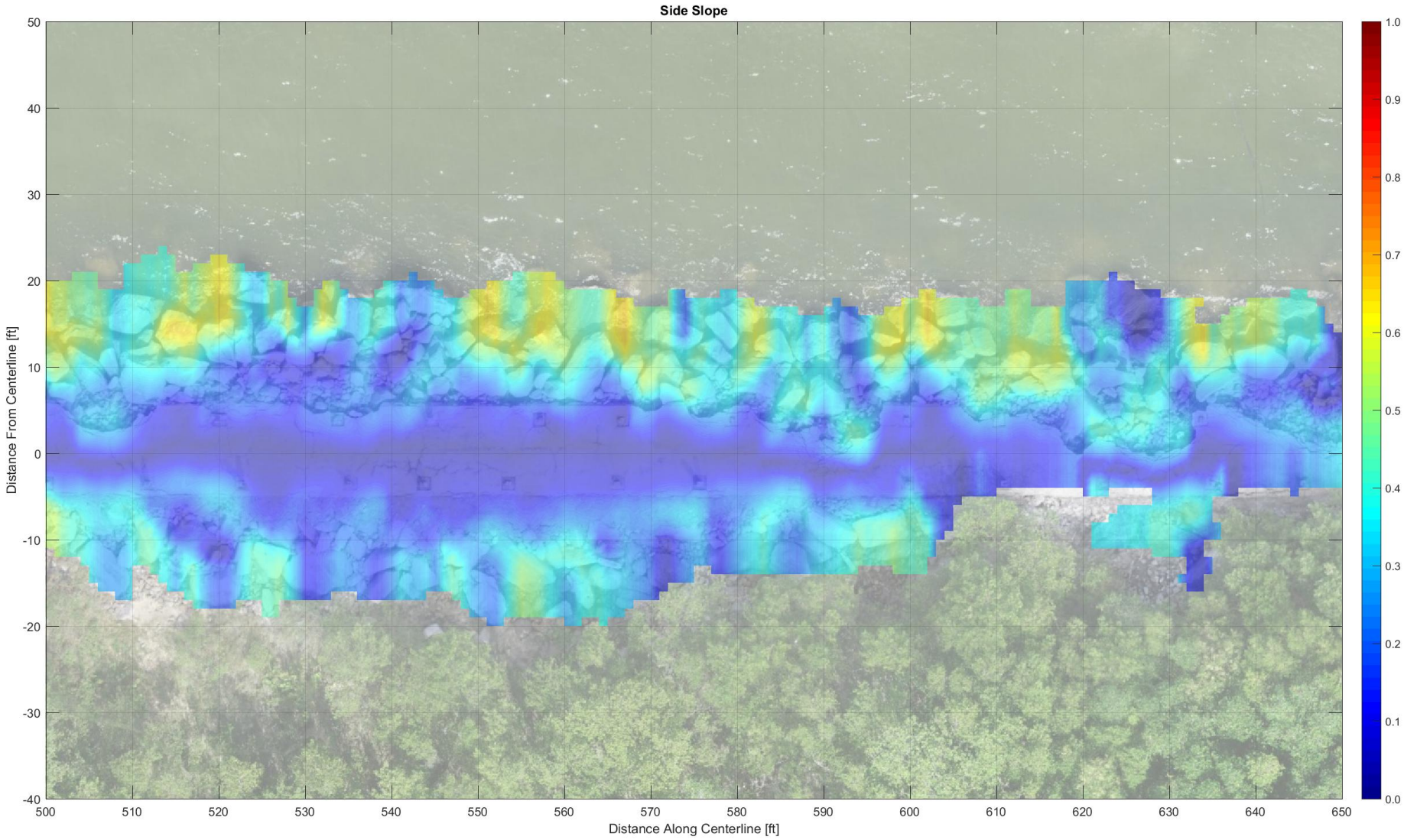
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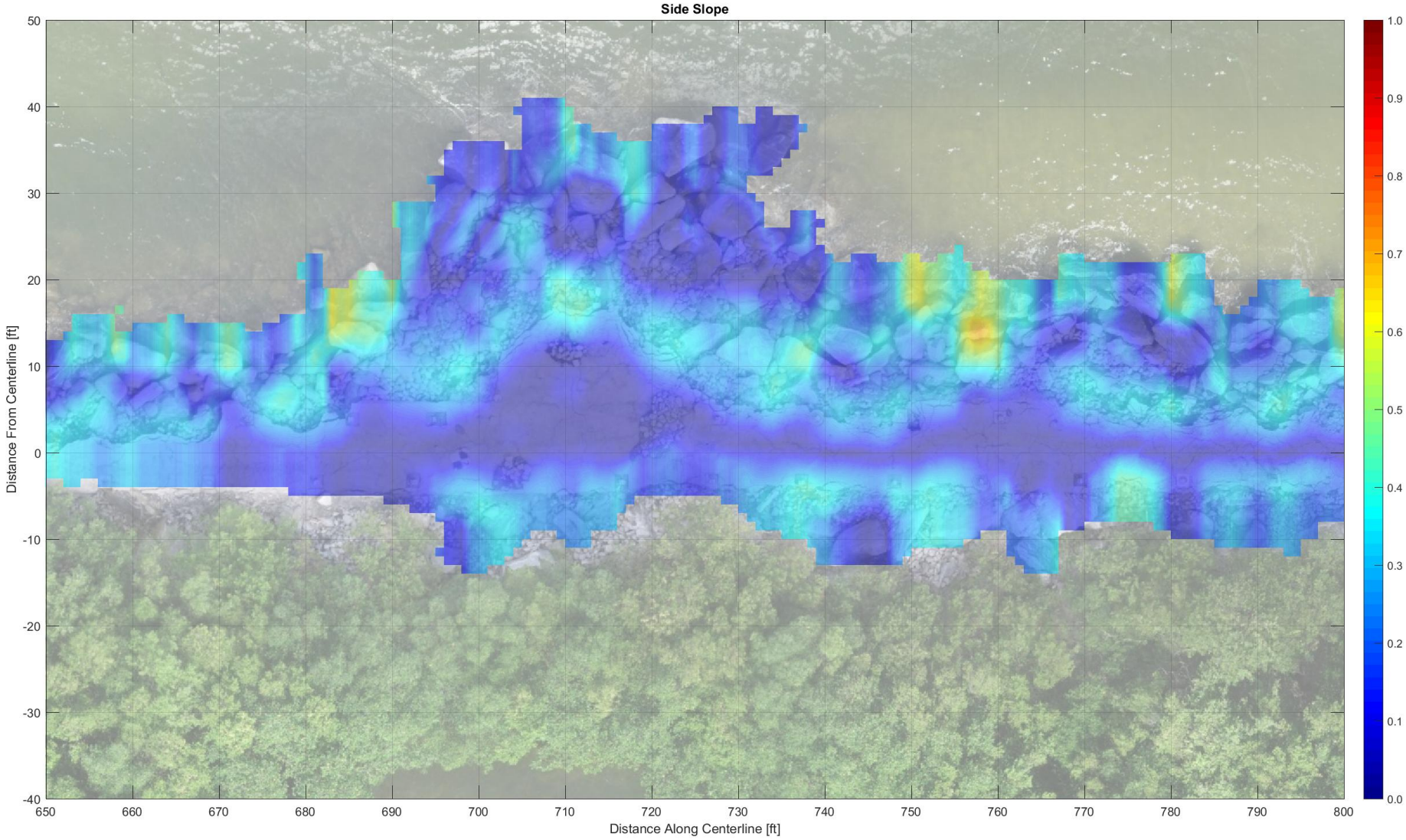
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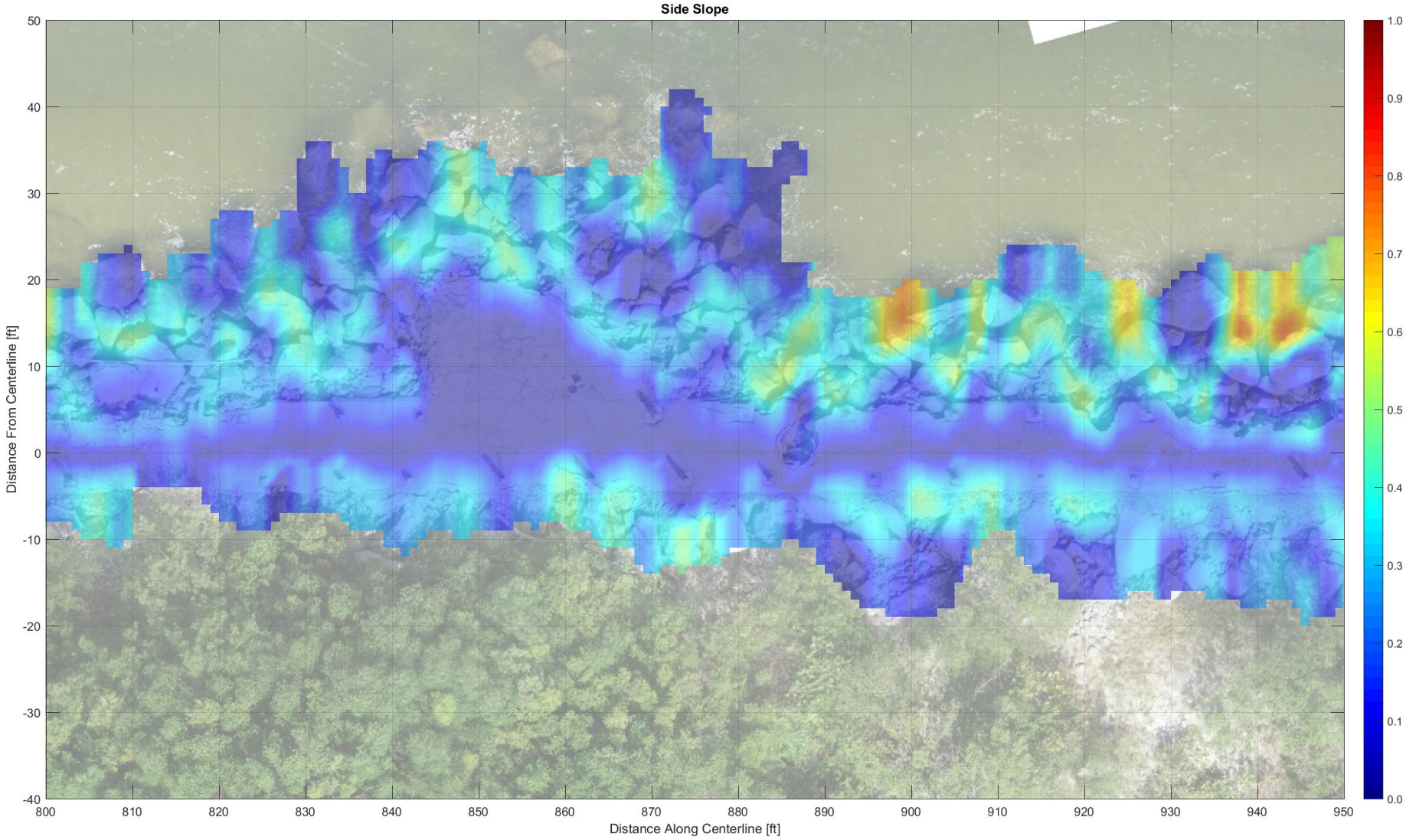
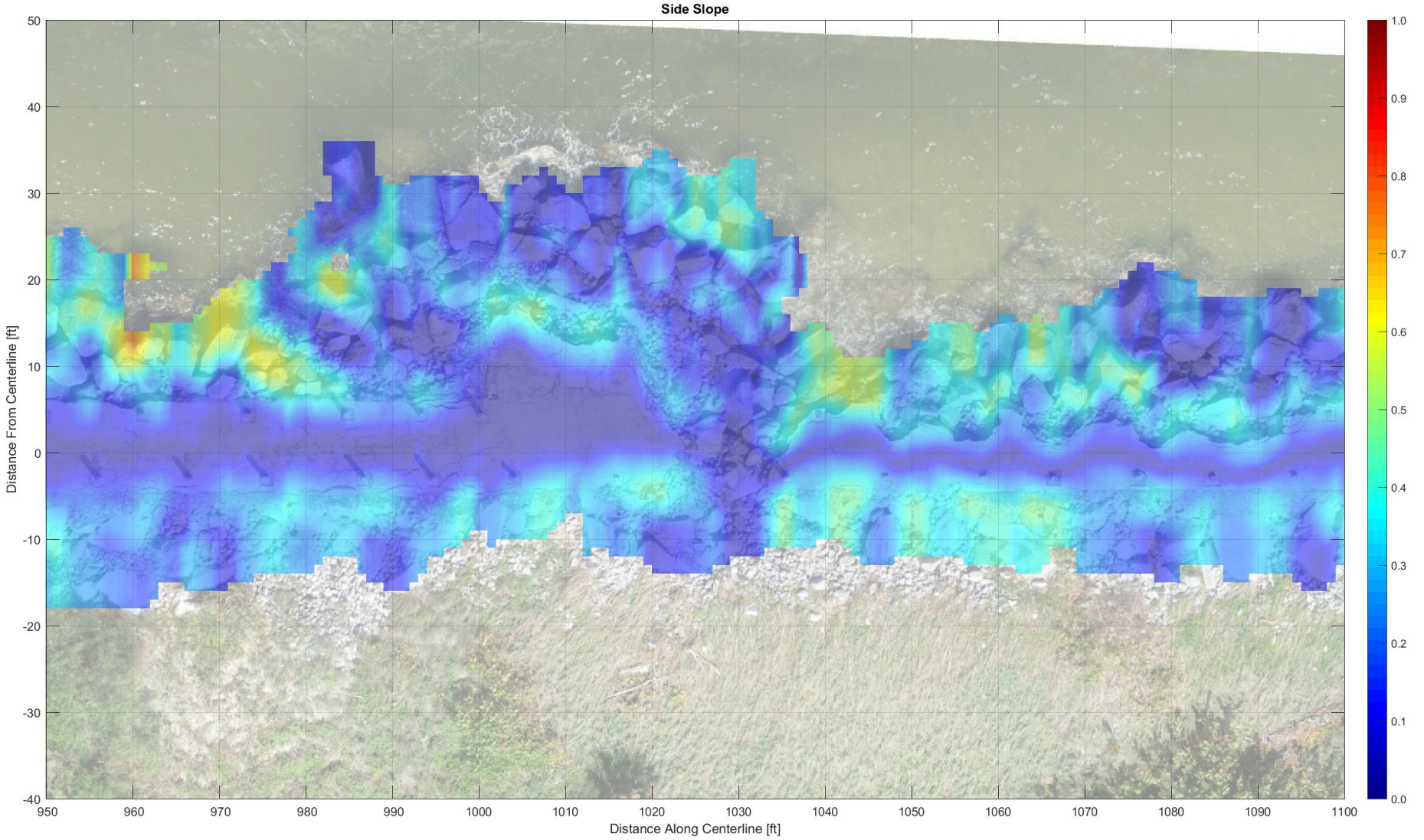
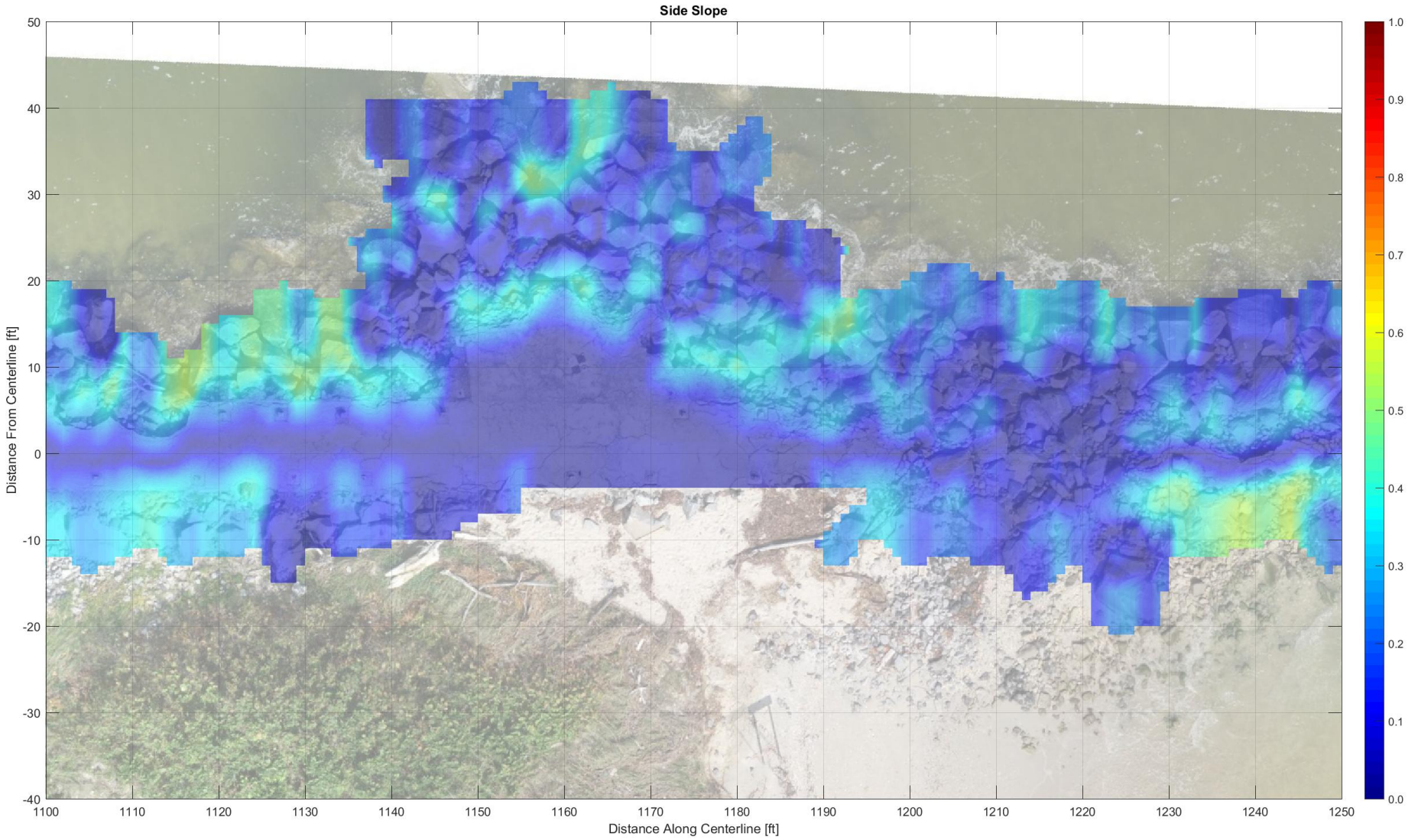
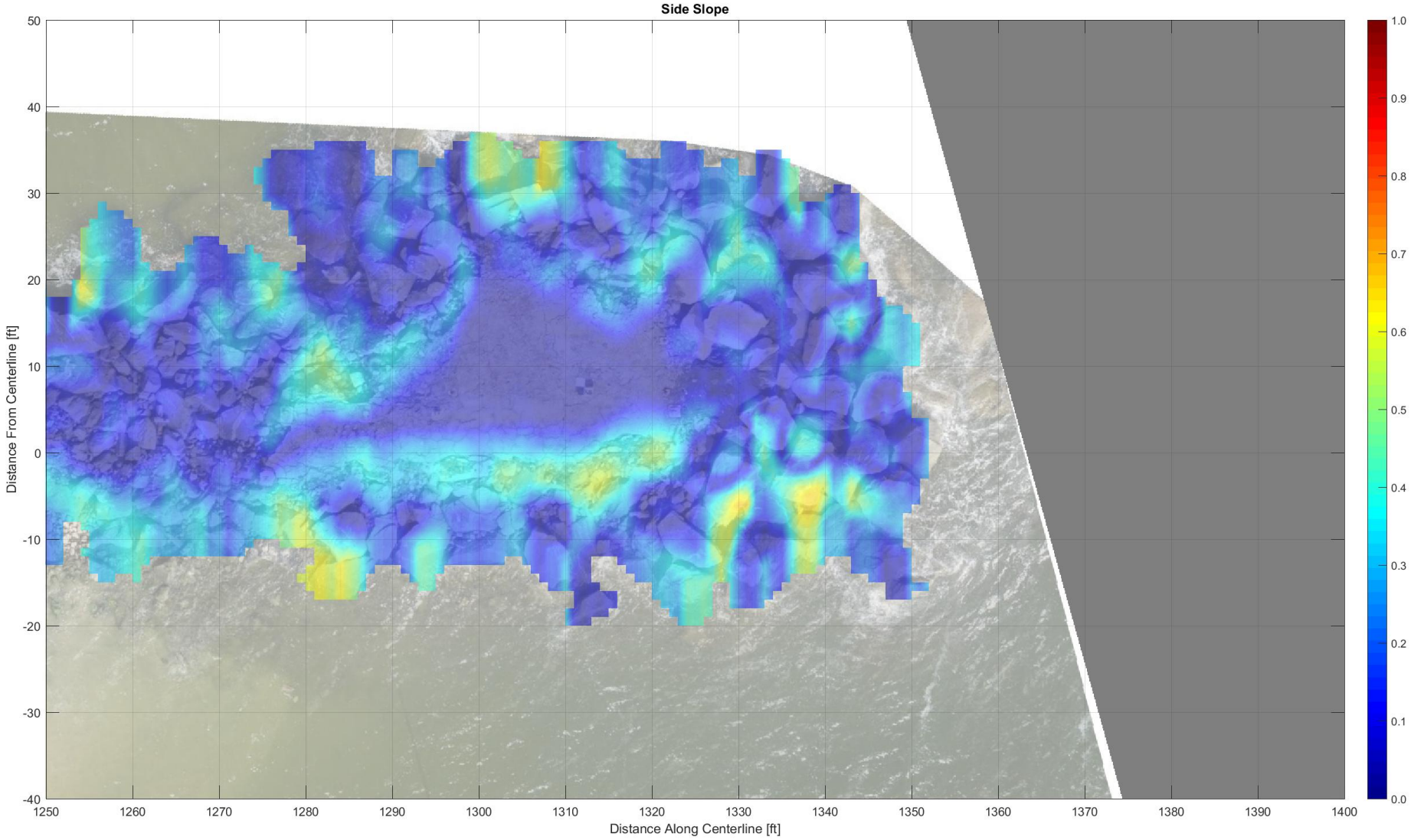
0.2
0.1
0.0

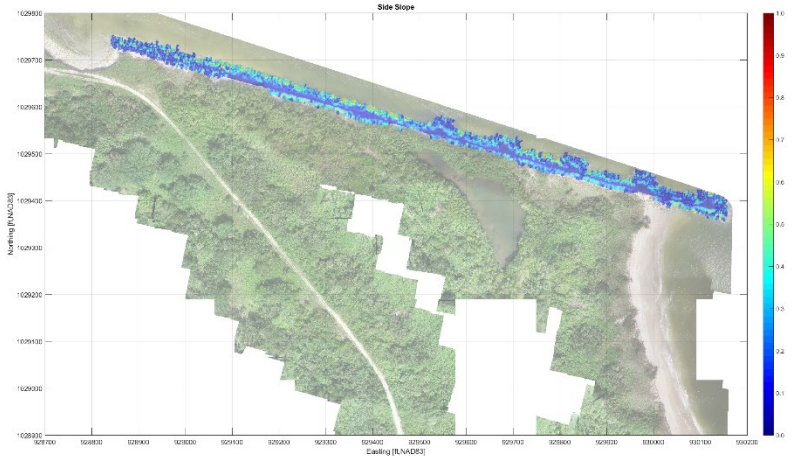

Side Slope
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
800
810
820
830
840
850
860
870
880
890
900
910
920
930
940
950
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0


Side Slope
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
950
960
970
980
990
1000
1010
1020
1030
1040
1050
1060
1070
1080
1090
1100
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0


Side Slope
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
1100
1110
1120
1130
1140
1150
1160
1170
1180
1190
1200
1210
1220
1230
1240
1250
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0


Side Slope
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
1250
1260
1270
1280
1290
1300
1310
1320
1330
1340
1350
1360
1370
1380
1390
1400
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

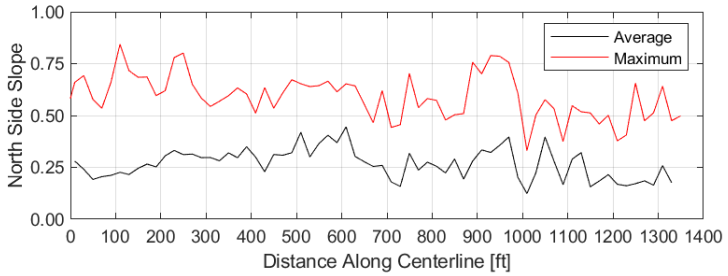
JETTY SIDE SLOPES

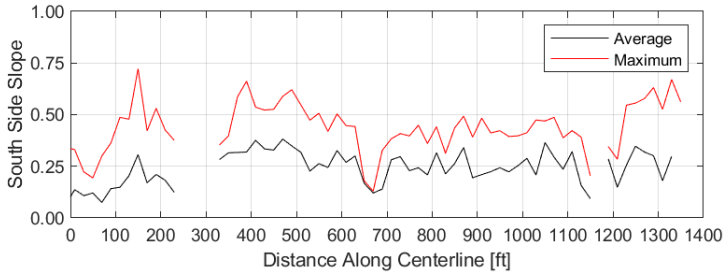


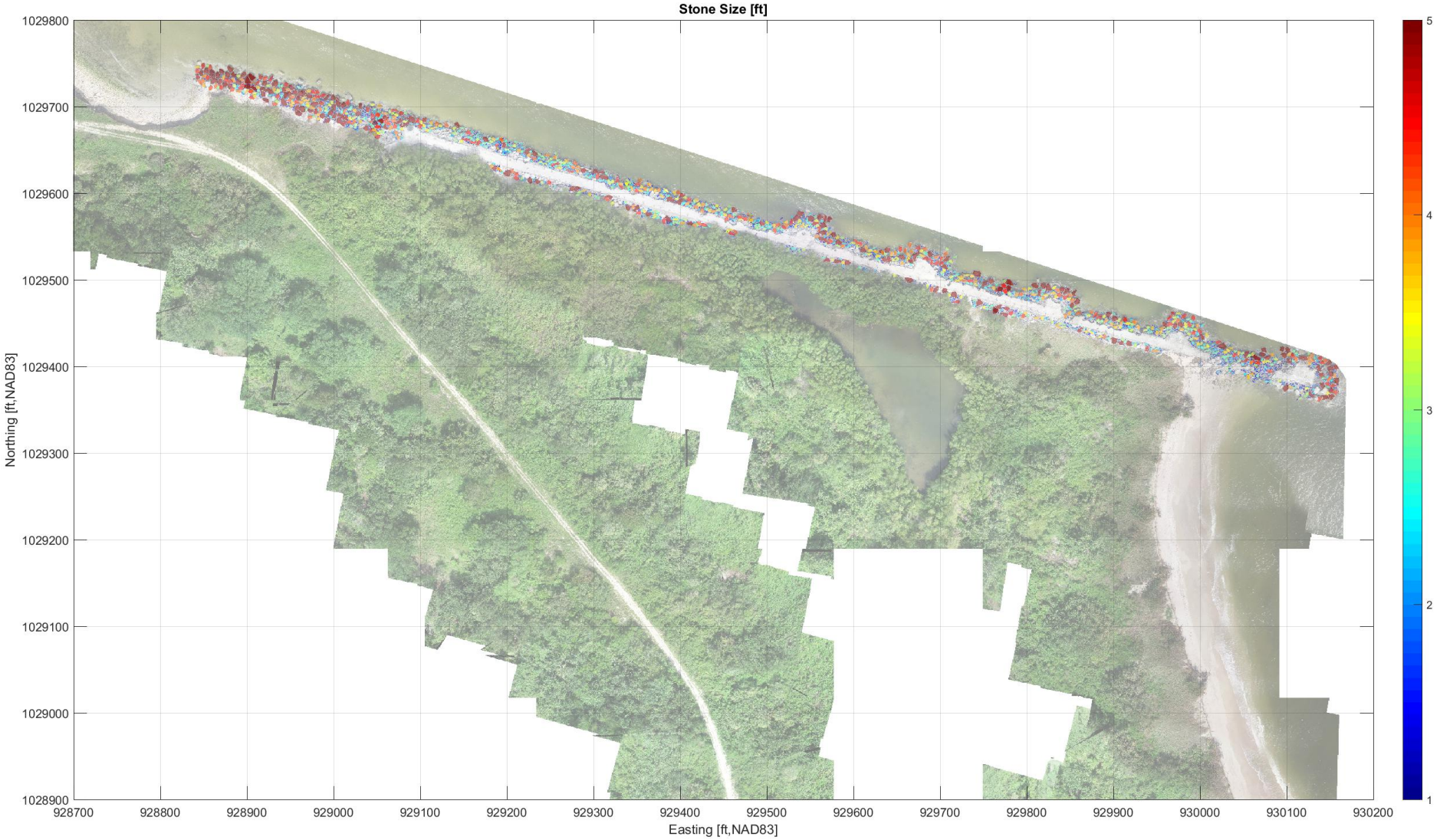
Side Slope

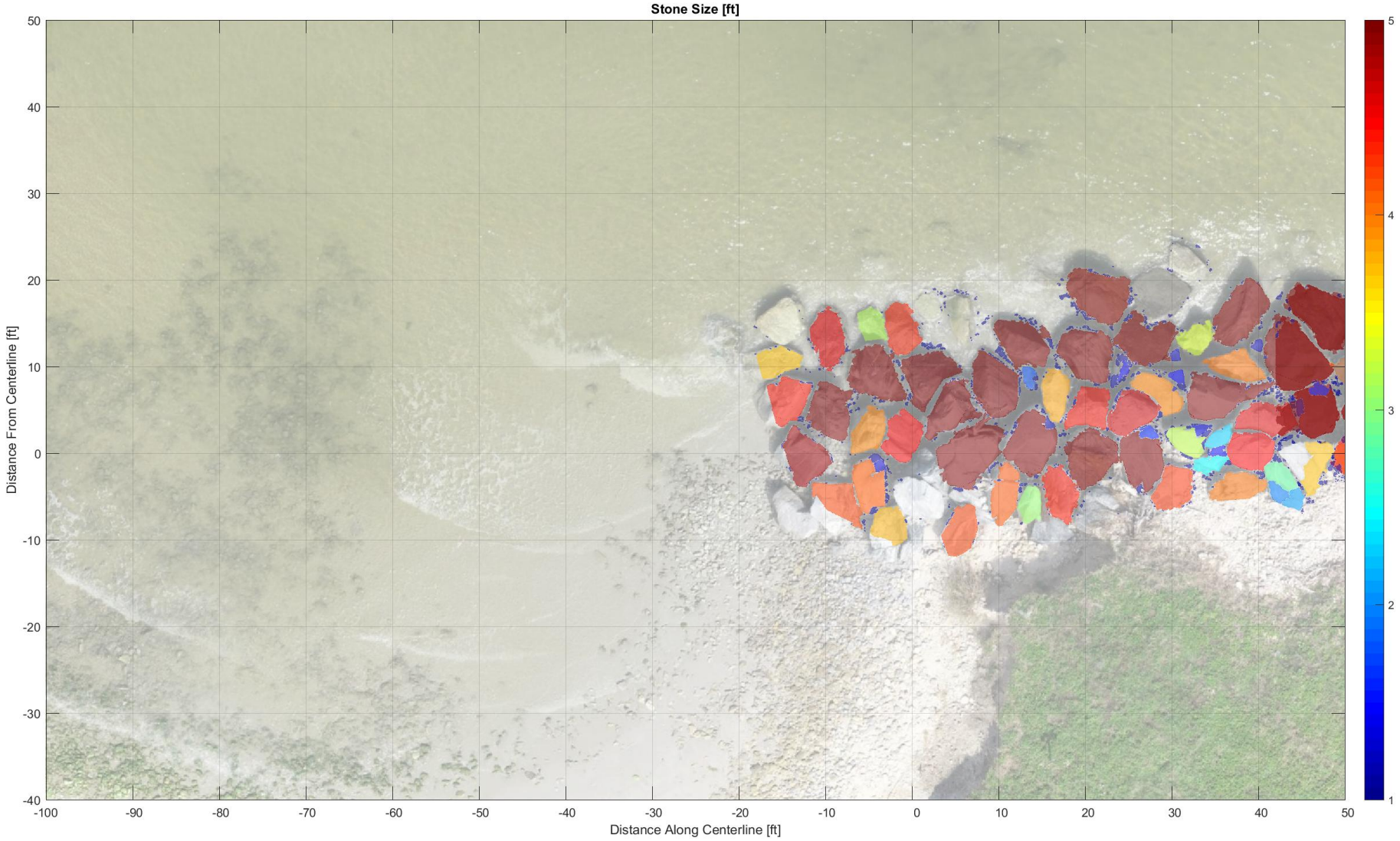
Face	Min	Max	Avg
North	1V:3.0H	1V:1.2H	1V:3.7H
South	1V:7.7H	1V:1.4H	1V:4.1H

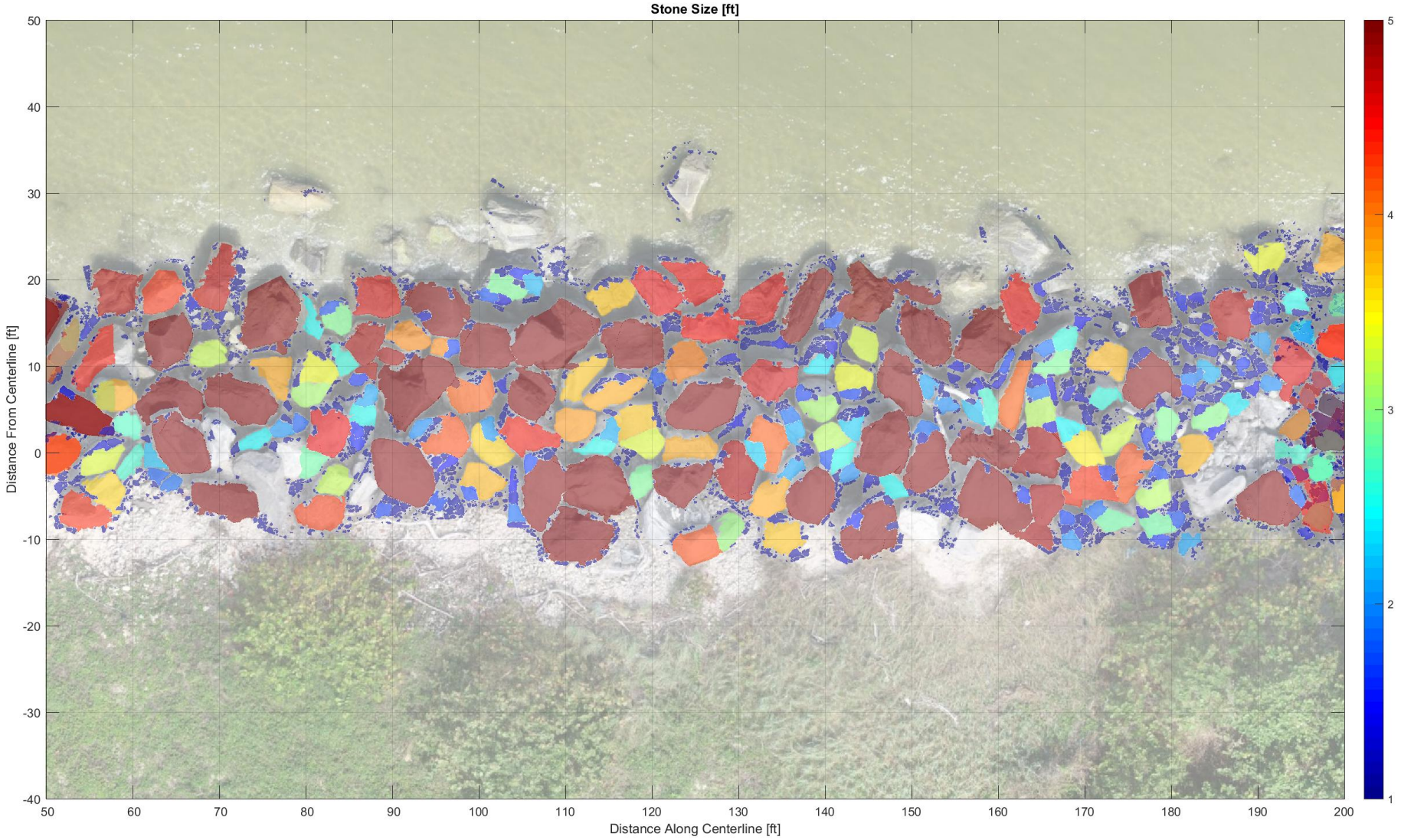
- Average and maximum side slopes were calculated for each 20-foot segment along the north and south jetty faces.

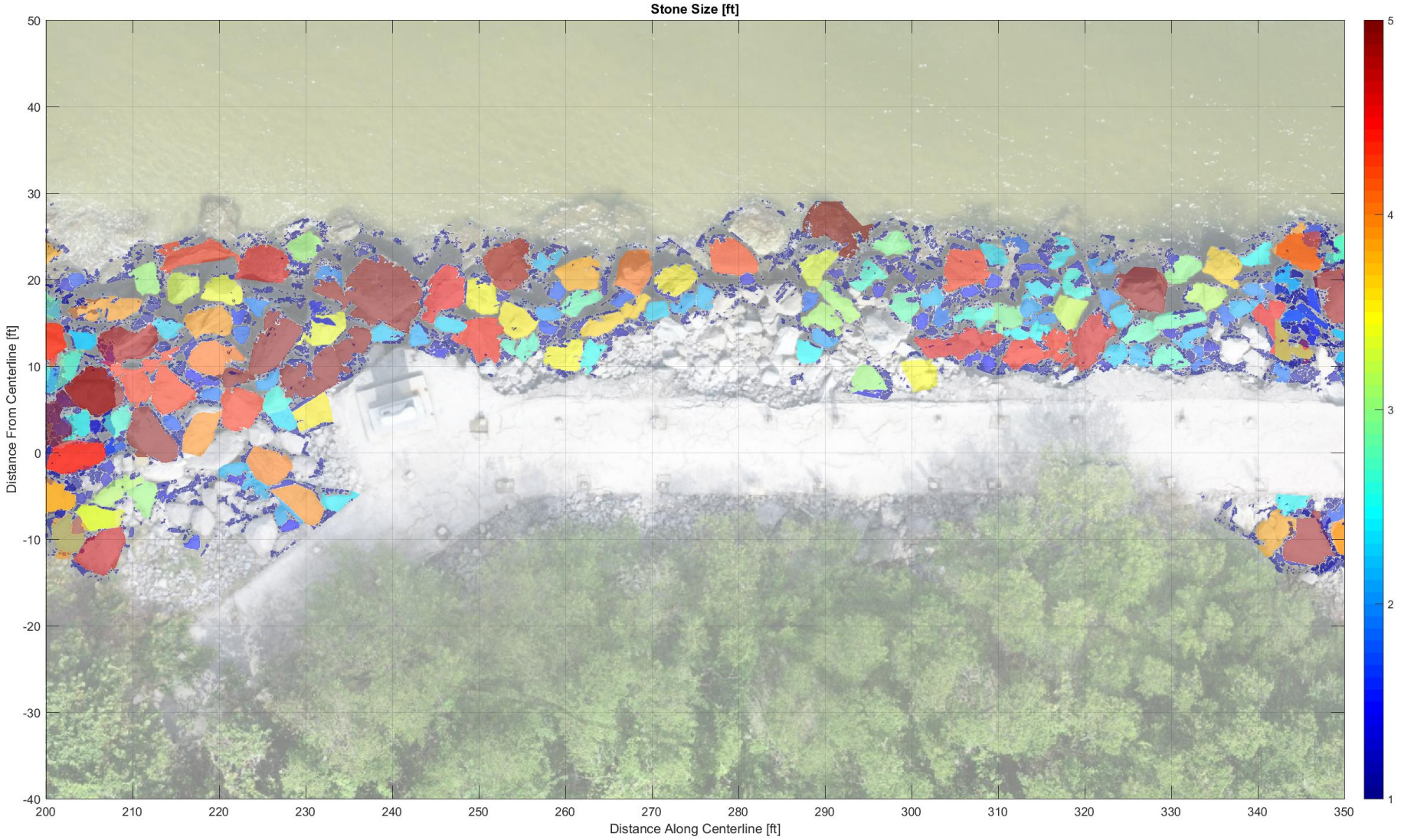


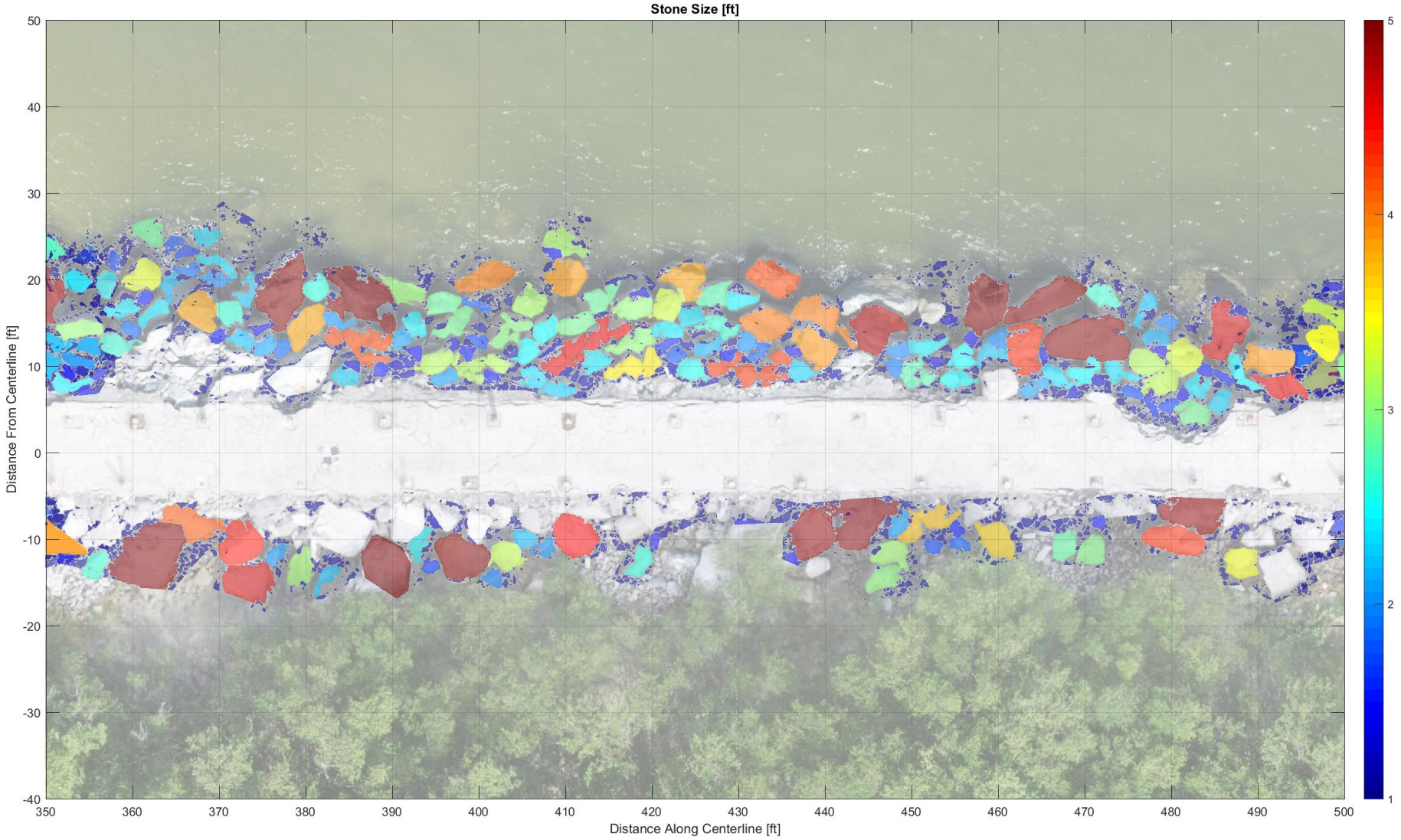


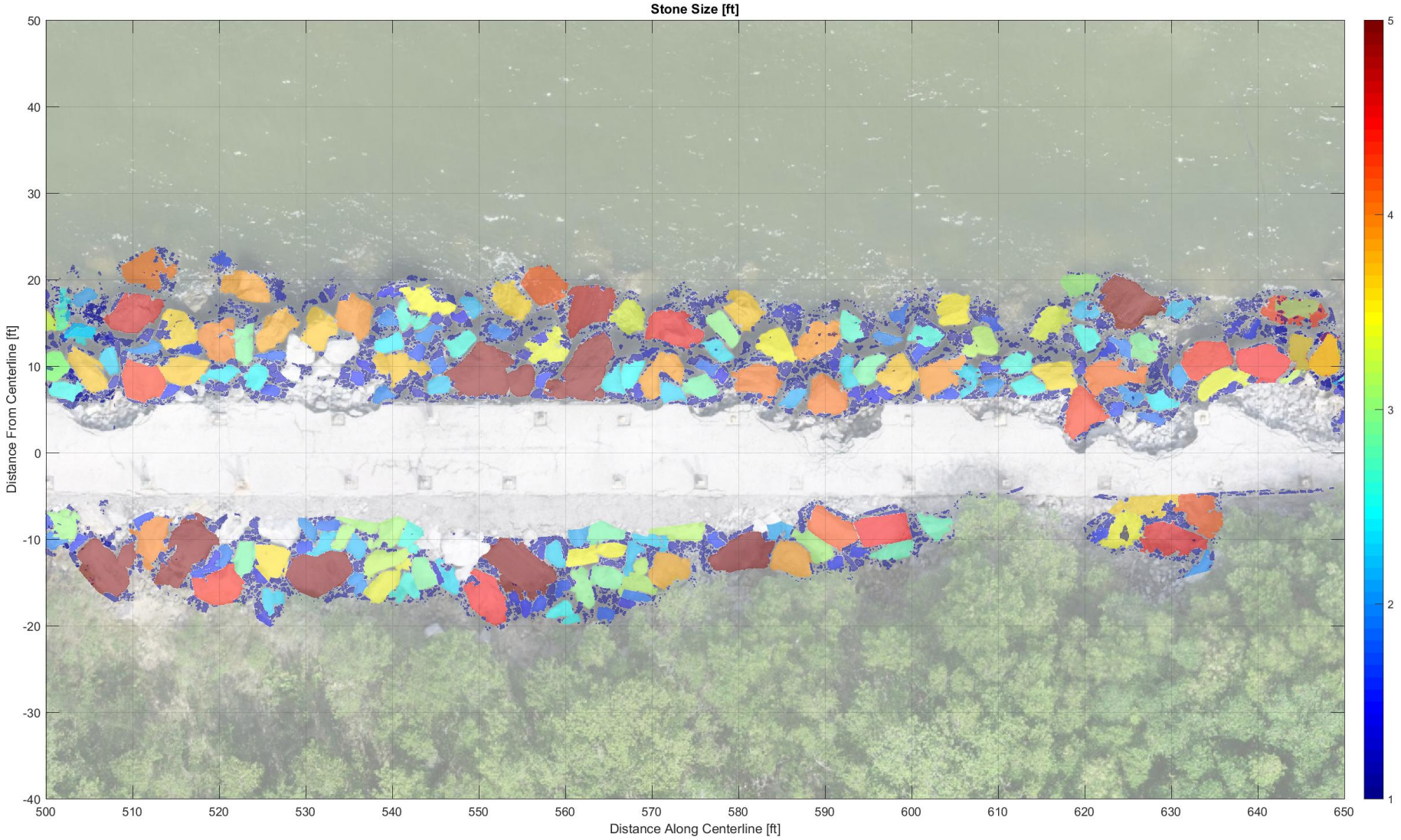

Stone Size [ft]
Northing [ft,NAD83]
Easting [ft,NAD83]
1029800
1029700
1029600
1029500
1029400
1029300
1029200
1029100
1029000
1028900
928700
928800
928900
929000
929100
929200
929300
929400
929500
929600
929700
929800
929900
930000
930100
930200
5
4
3
2
1

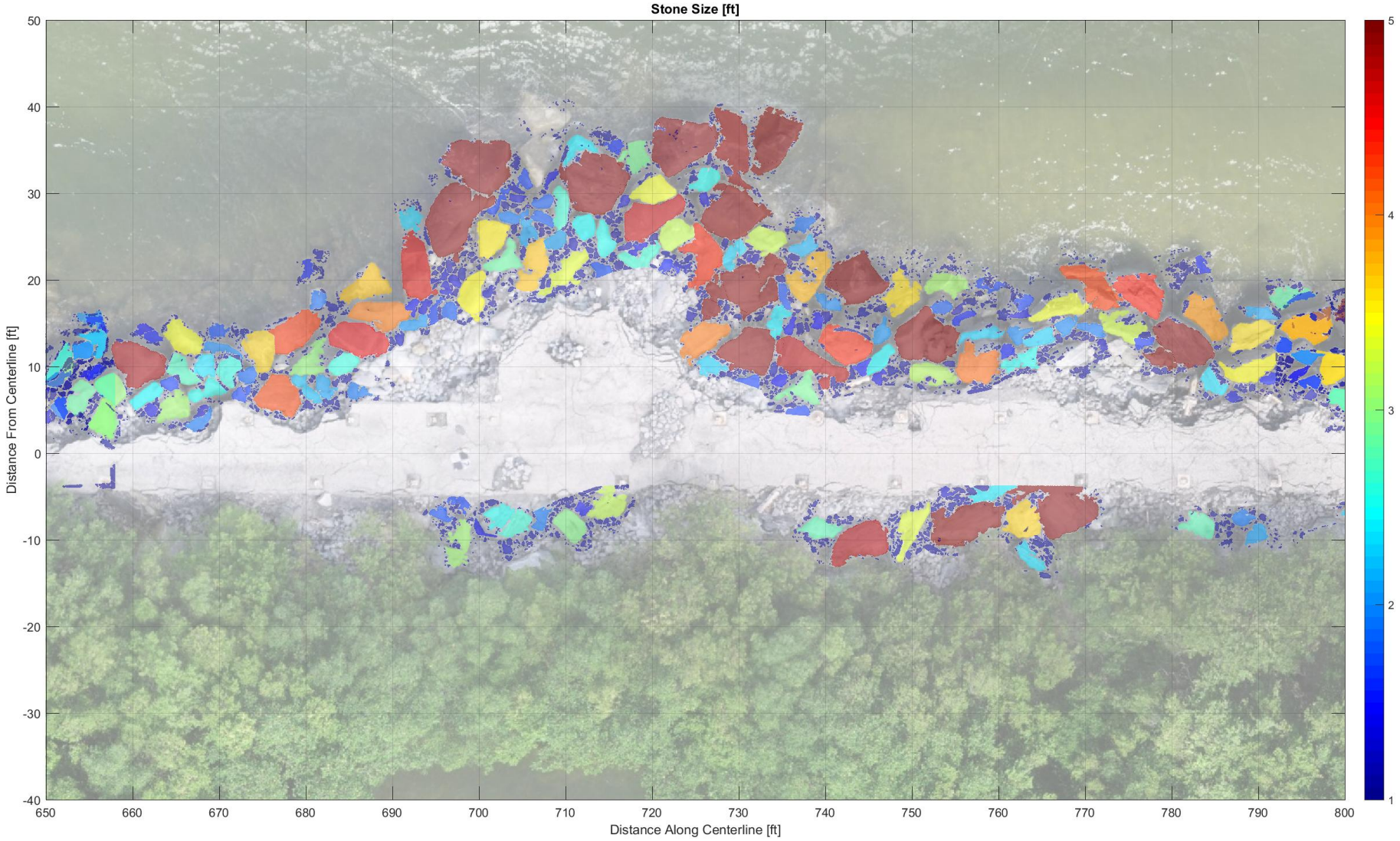

Stone Size [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
5
4
3
2
1

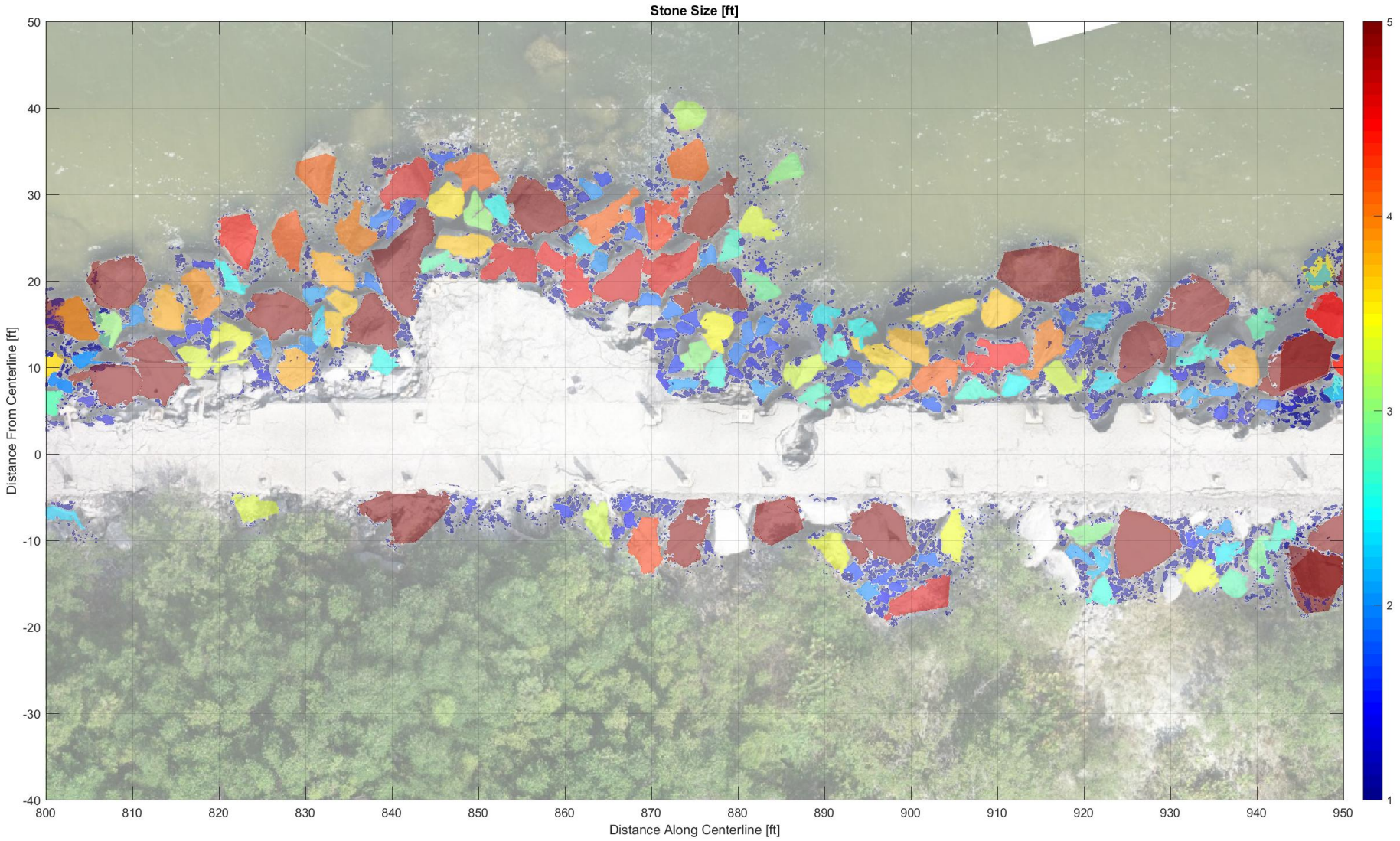

Stone Size [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
5
4
3
2
1

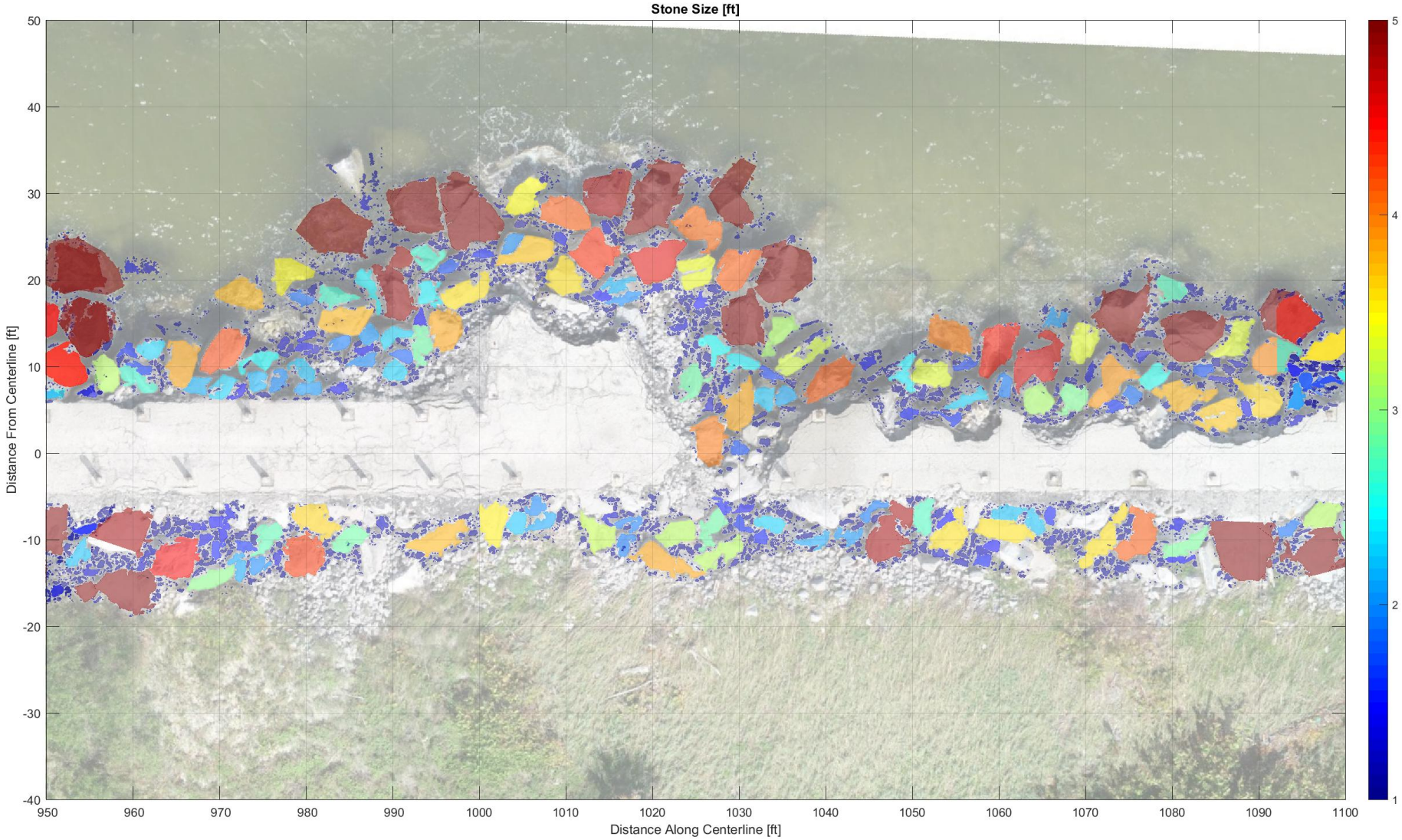

Stone Size [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
5
4
3
2
1

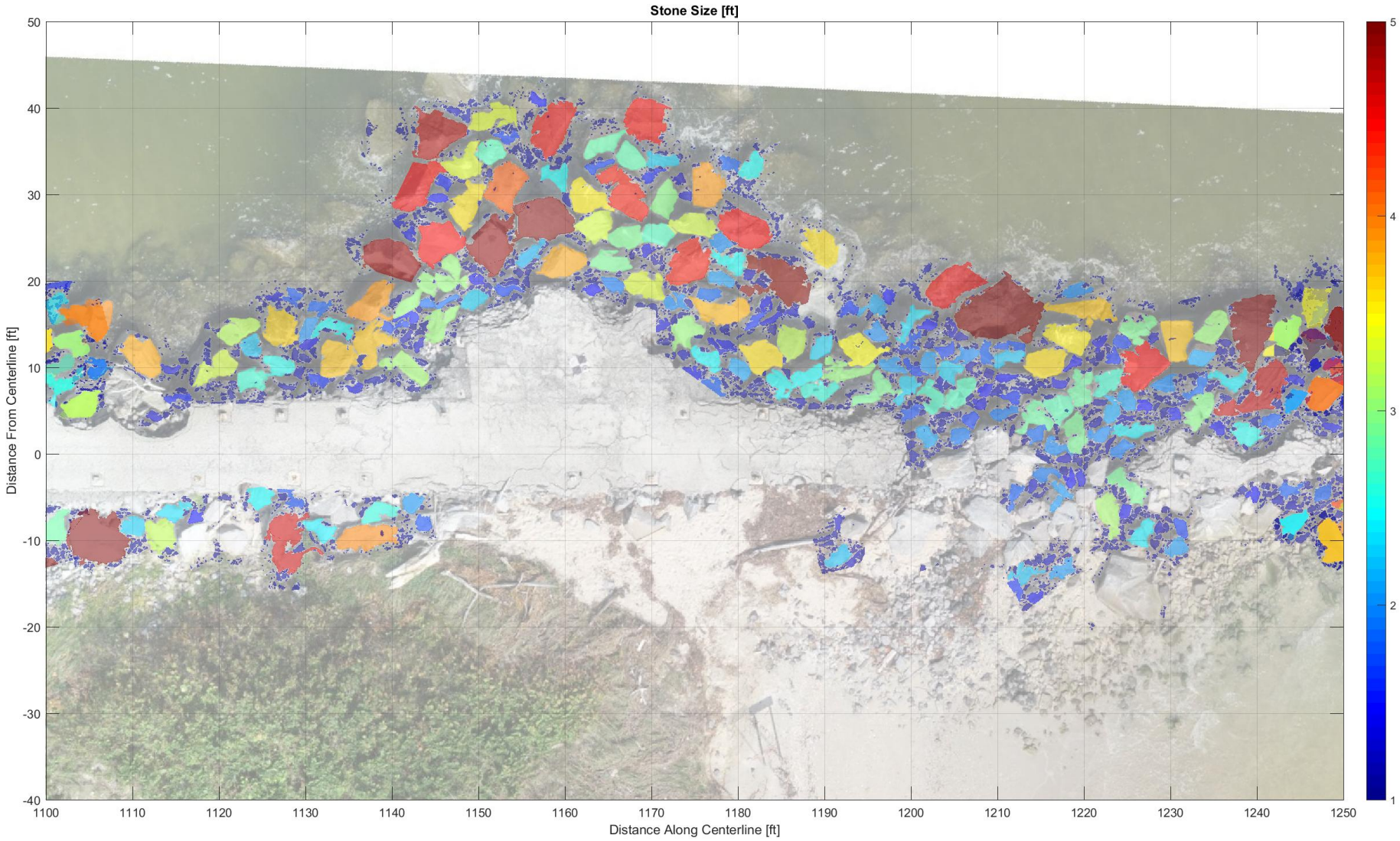

Stone Size [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
350
360
370
380
390
400
410
420
430
440
450
460
470
480
490
500
5
4
3
2
1

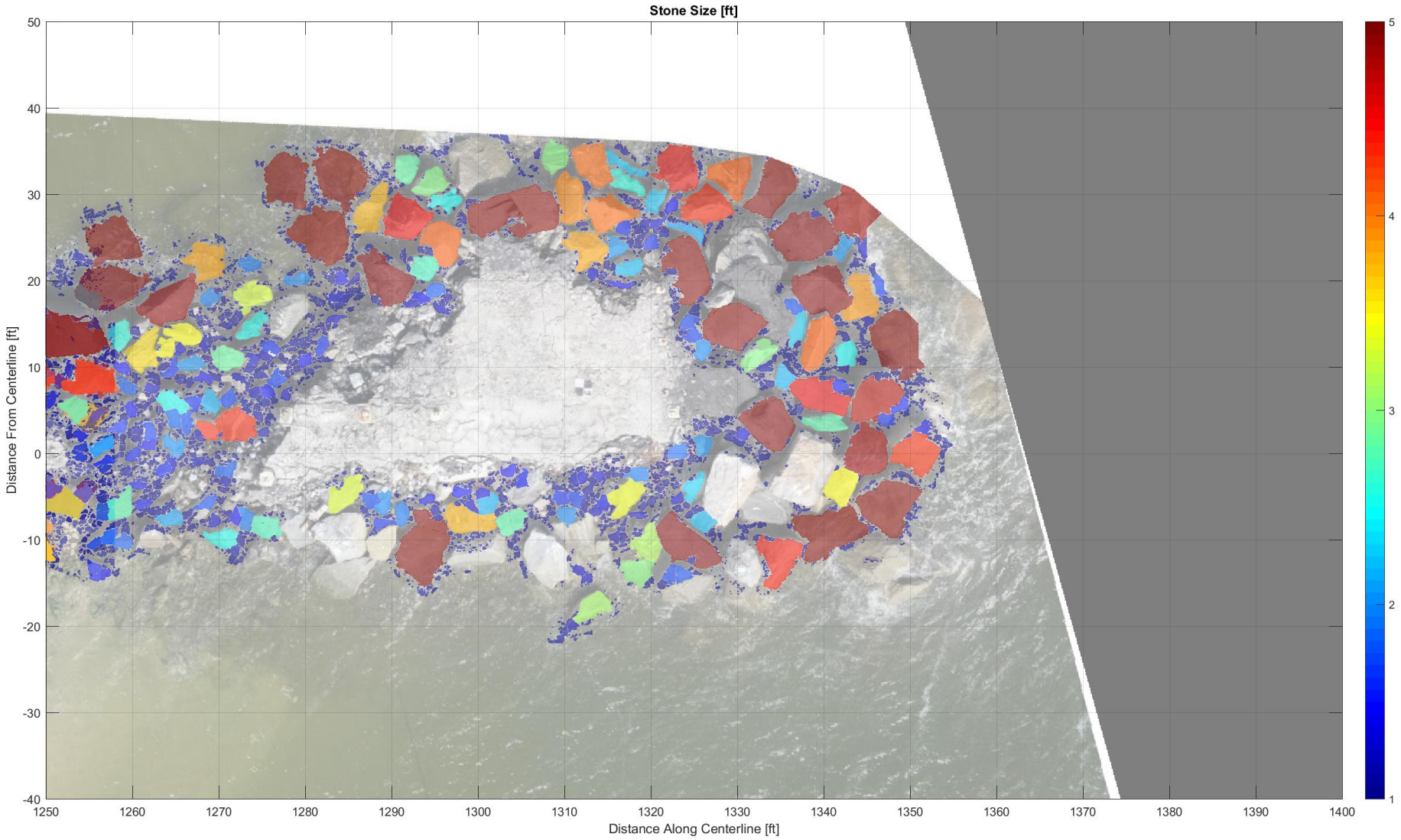

Stone Size [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
500
510
520
530
540
550
560
570
580
590
600
610
620
630
640
650
5
4
3
2
1


Stone Size [ft]
Distance From Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
650
660
670
680
690
700
710
720
730
740
750
760
770
780
790
800
Distance Along Centerline [ft]
5
4
3
2
1


Stone Size [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
800
810
820
830
840
850
860
870
880
890
900
910
920
930
940
950
5
4
3
2
1


Stone Size [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
950
960
970
980
990
1000
1010
1020
1030
1040
1050
1060
1070
1080
1090
1100
5
4
3
2
1


Stone Size [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
1100
1110
1120
1130
1140
1150
1160
1170
1180
1190
1200
1210
1220
1230
1240
1250
5
4
3
2
1


Stone Size [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
1250
1260
1270
1280
1290
1300
1310
1320
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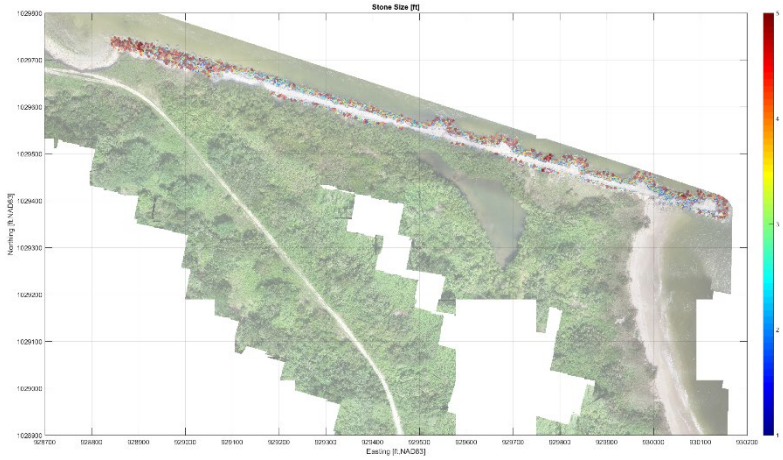
1350
1360
1370
1380
1390
1400
5
4
3
2
1

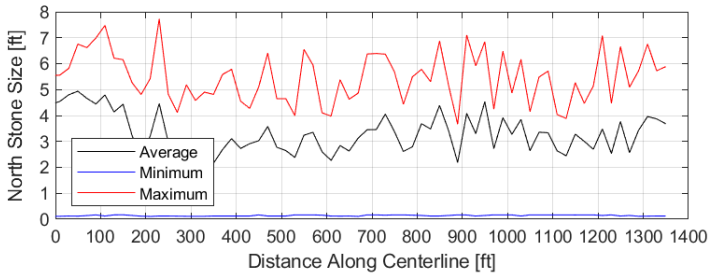
JETTY STONE SIZES

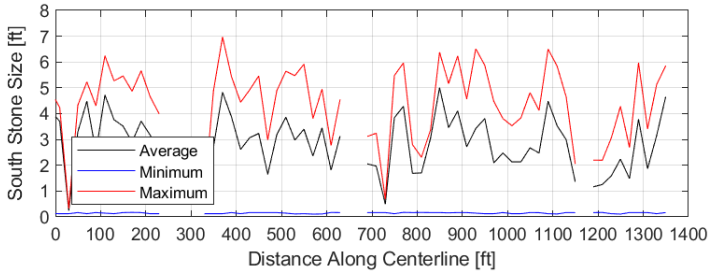


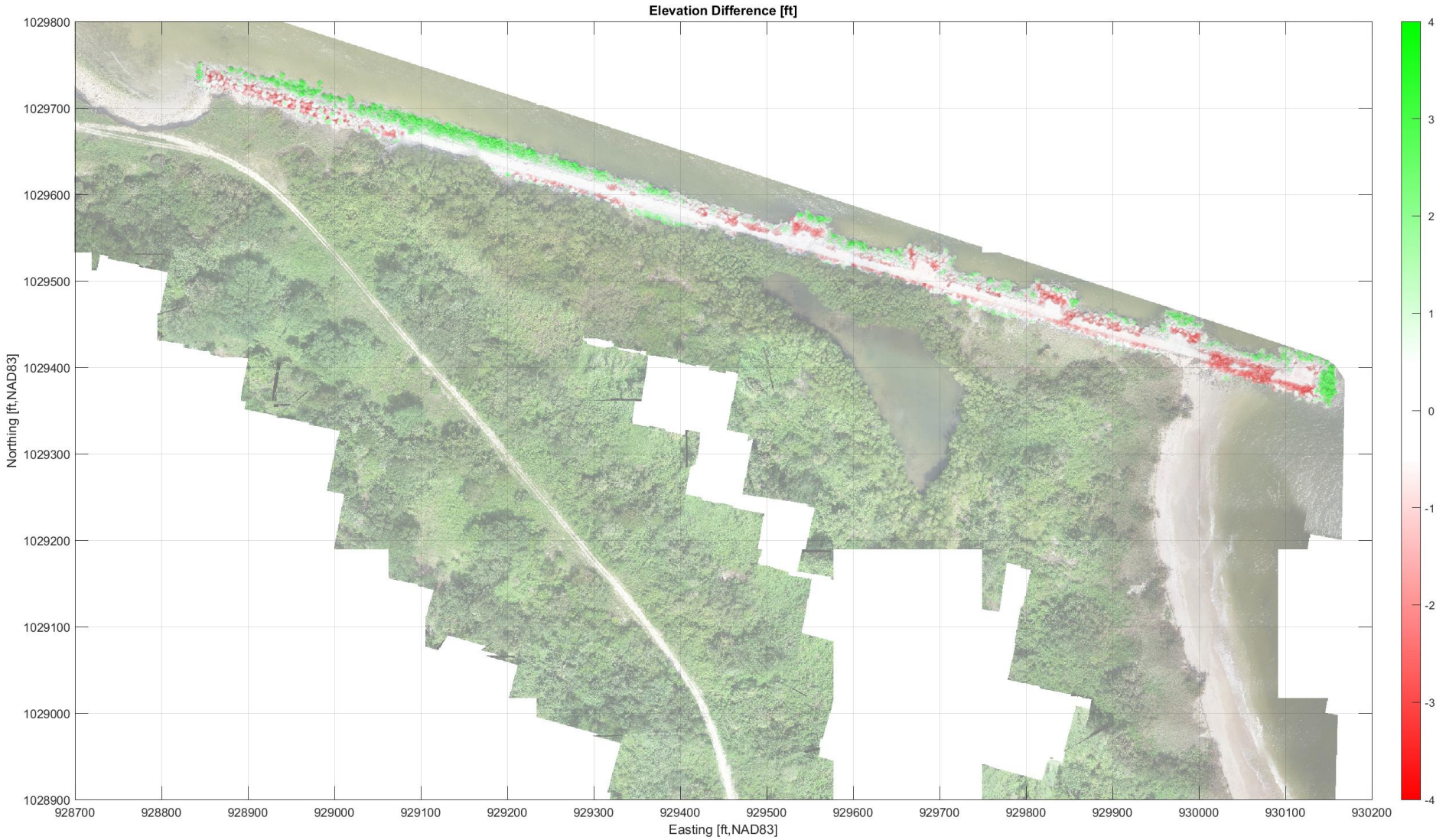
› Stone Size (ft)

Face	Min	Max	Avg
North	1.8	4.8	3.1
South	0.5	6.1	2.9

› Minimum, maximum, and average stone sizes were calculated for each 20-foot segment along the north and south jetty faces.






Elevation Difference [ft]
Northing [ft,NAD83]
Easting [ft,NAD83]
1029800
1029700
1029600
1029500
1029400
1029300
1029200
1029100
1029000
1028900
928700
928800
928900
929000
929100
929200
929300
929400
929500
929600
929700
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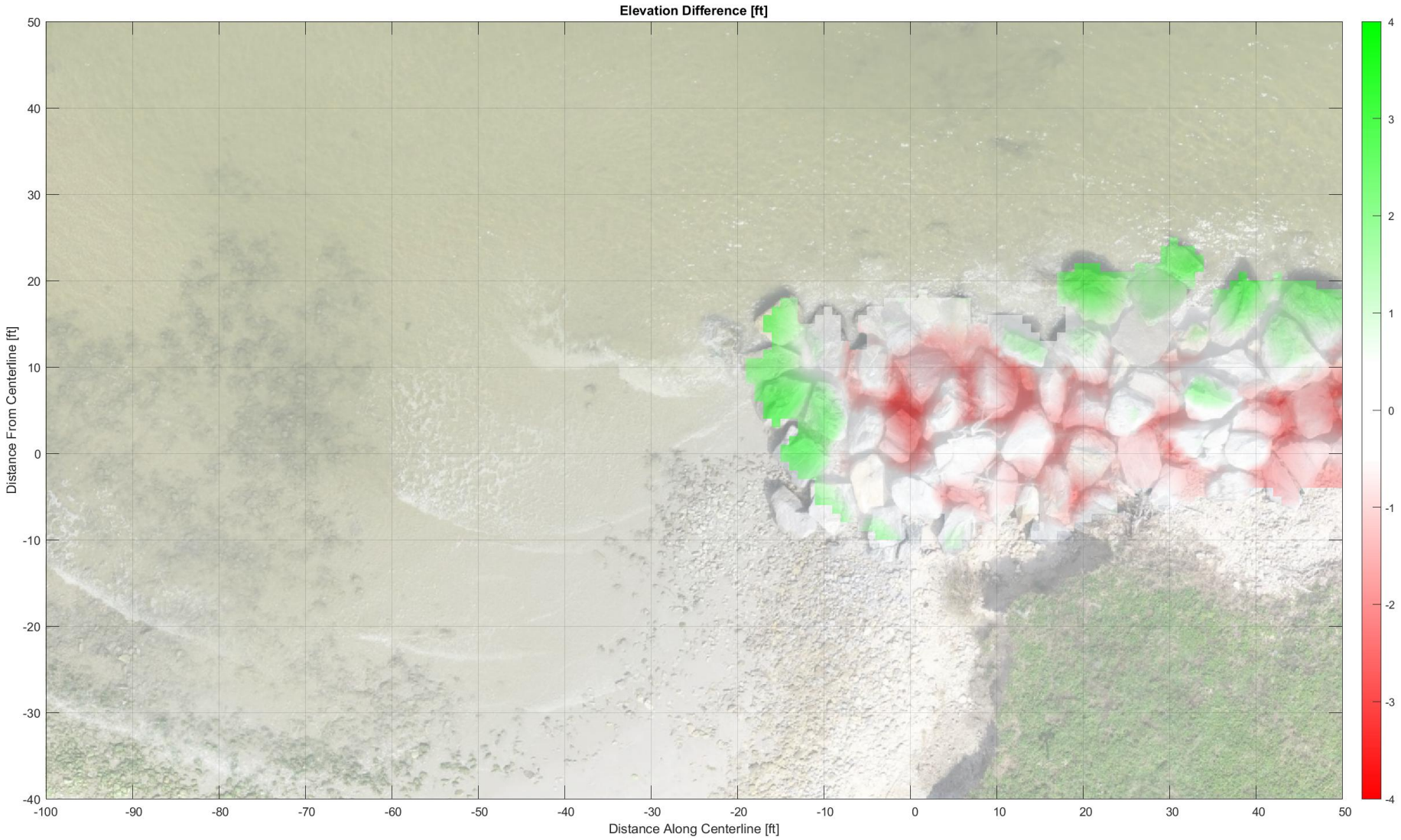
929900
930000
930100
930200
4
3
2
1
0
-1
-2
-3
-4


Elevation Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
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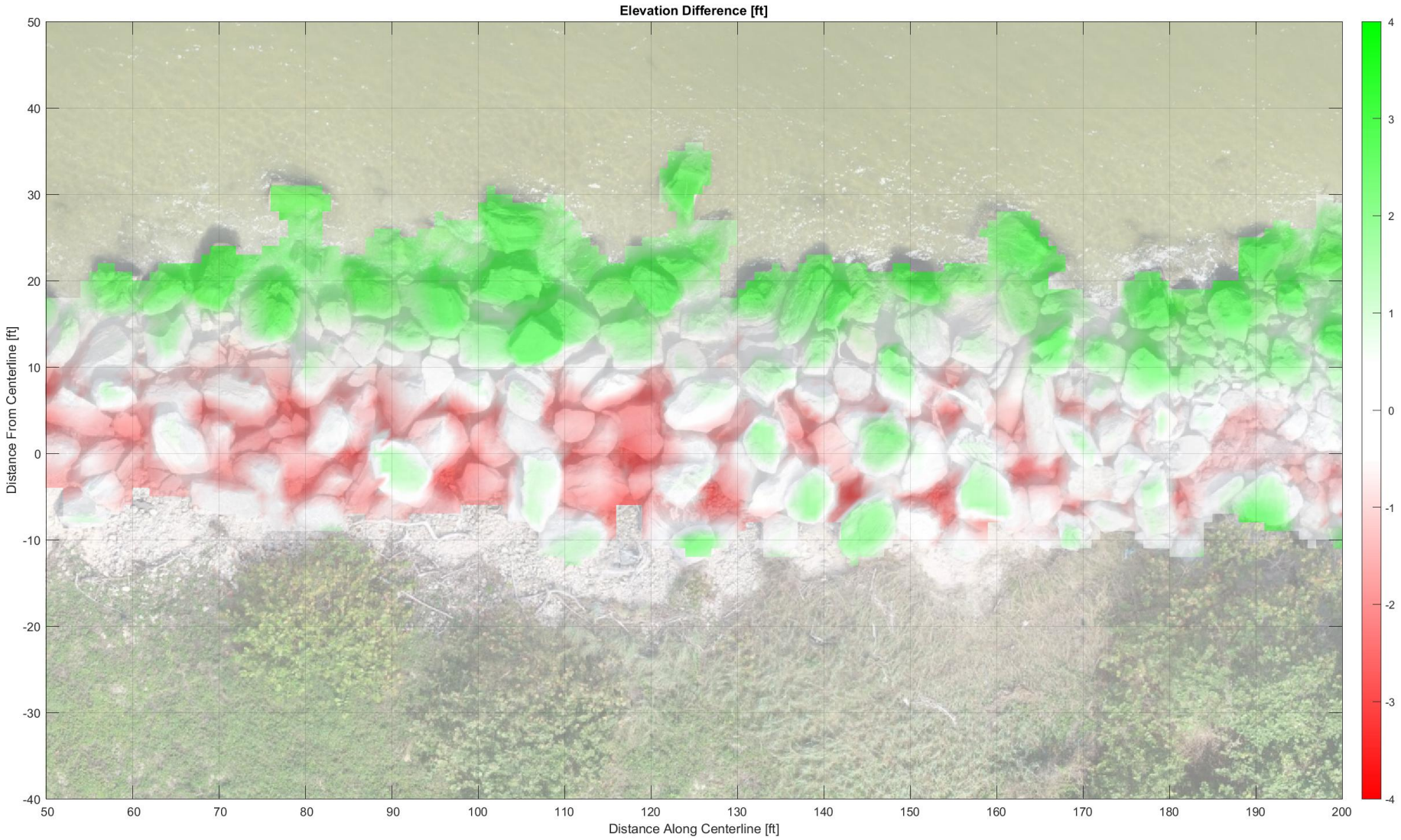
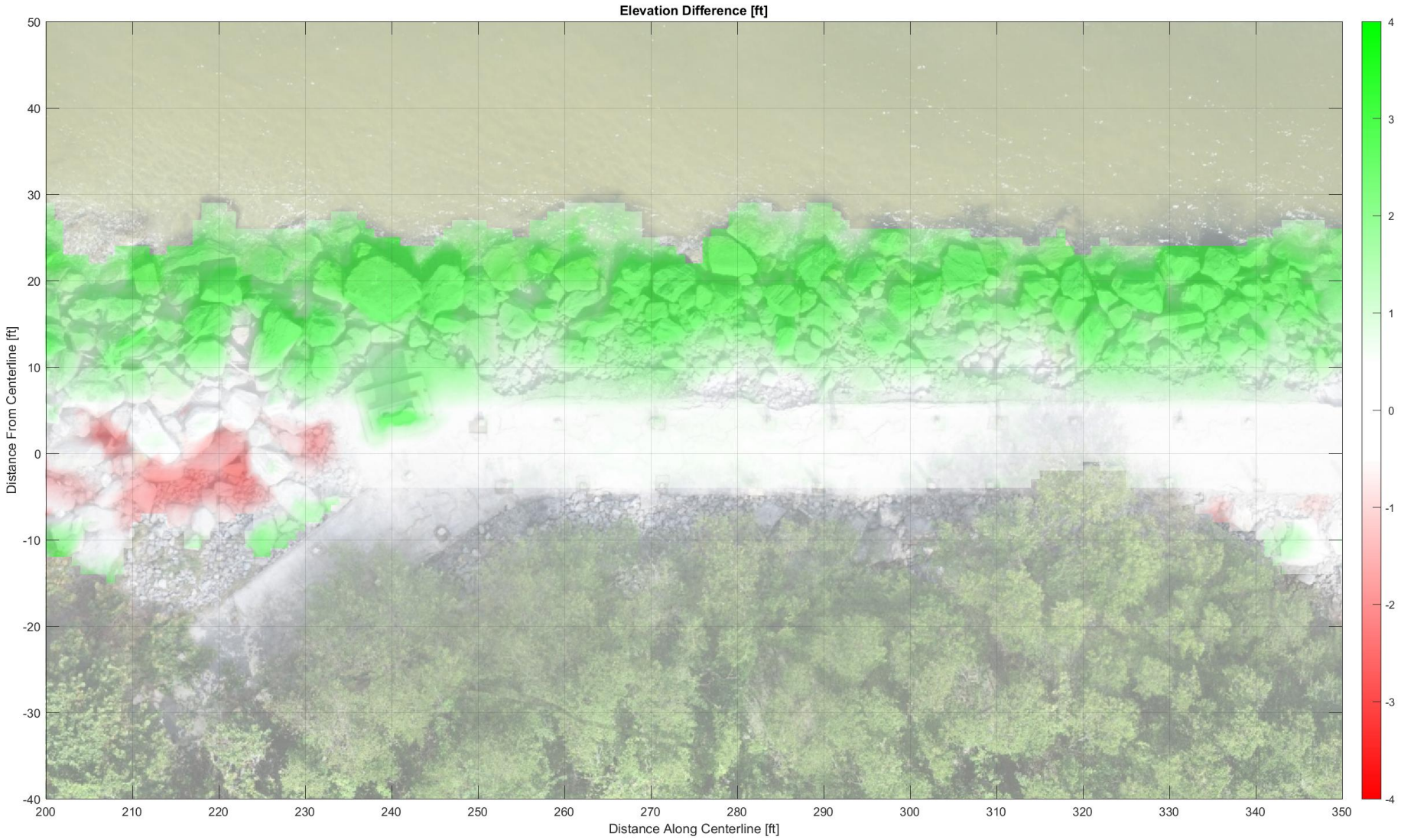
40
30
20
10
0
-10
-20
-30
-40
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
4
3
2
1
0
-1
-2
-3
-4


Elevation Difference [ft]
Distance From Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance Along Centerline [ft]
4
3
2
1
0
-1
-2
-3
-4


Elevation Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
4
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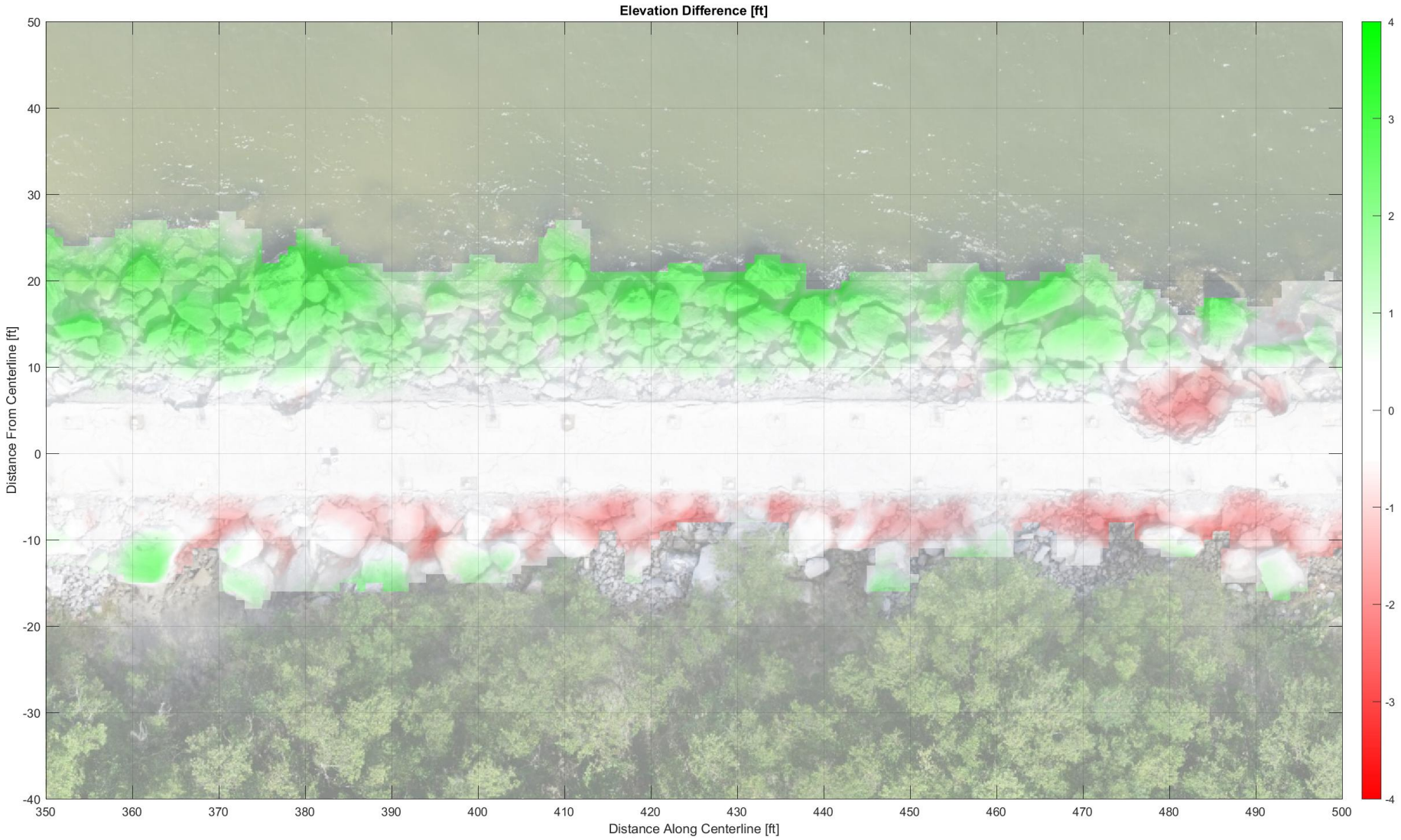
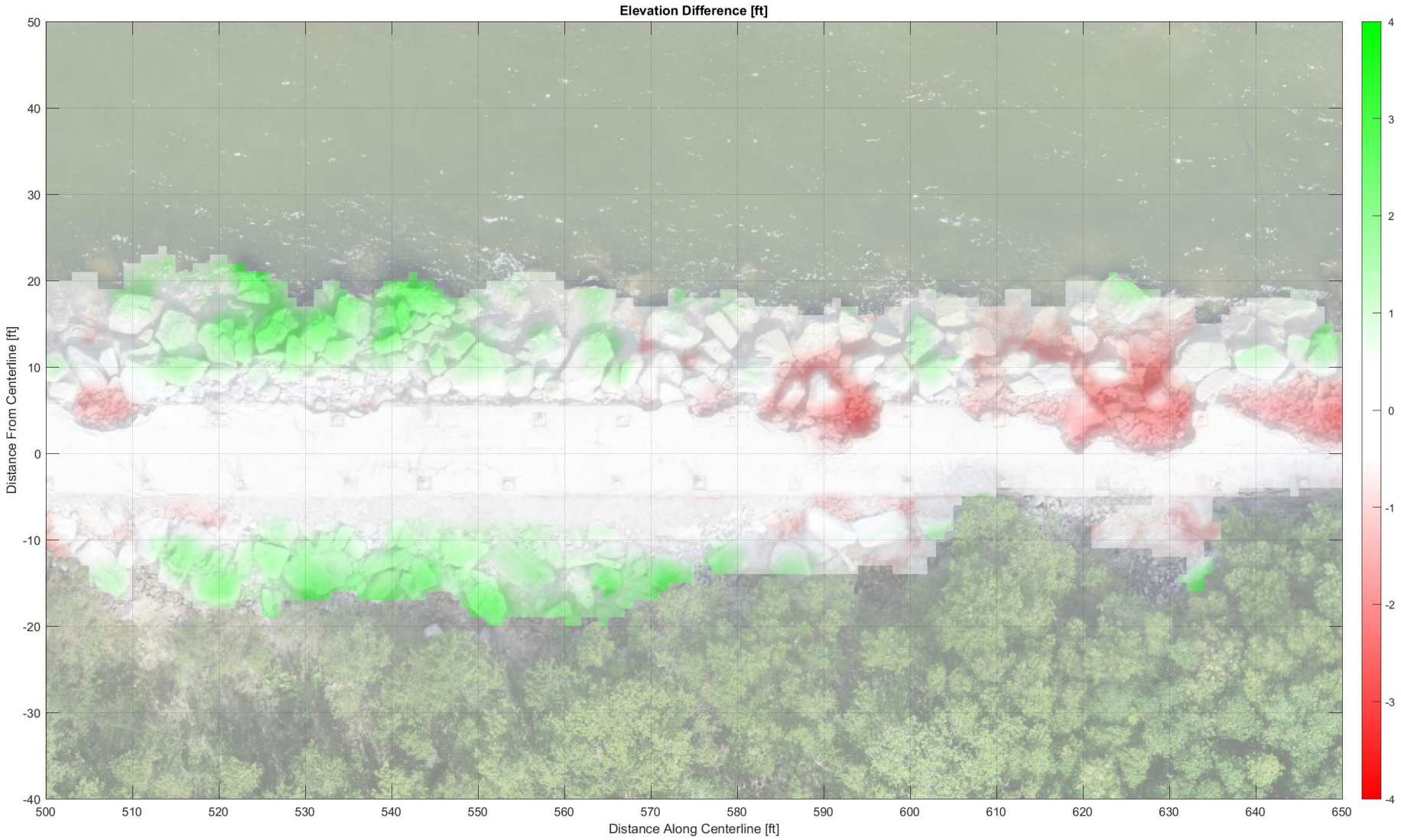
2
1
0
-1
-2
-3
-4


Elevation Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
350
360
370
380
390
400
410
420
430
440
450
460
470
480
490
500
4
3
2
1
0
-1
-2
-3
-4


Elevation Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
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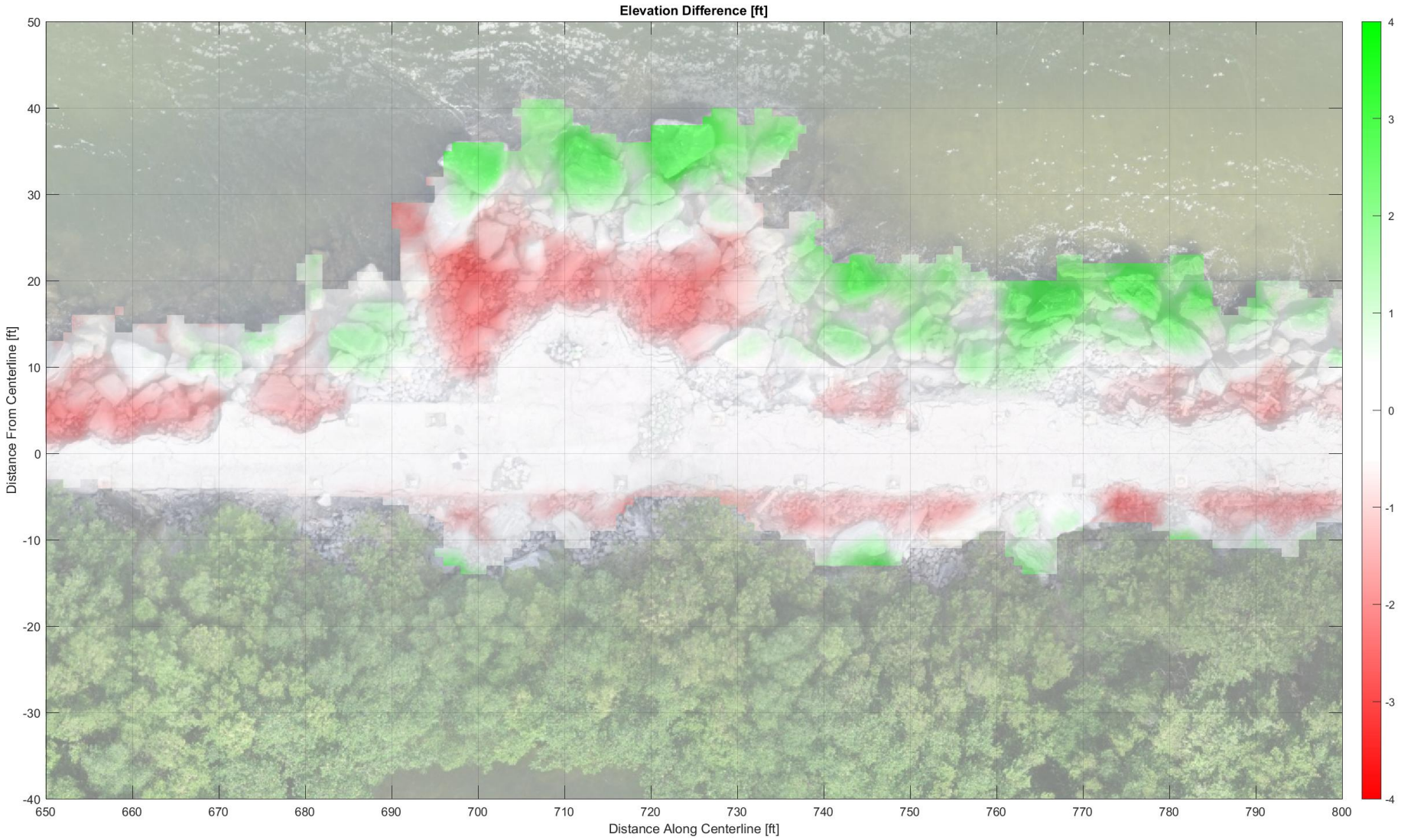
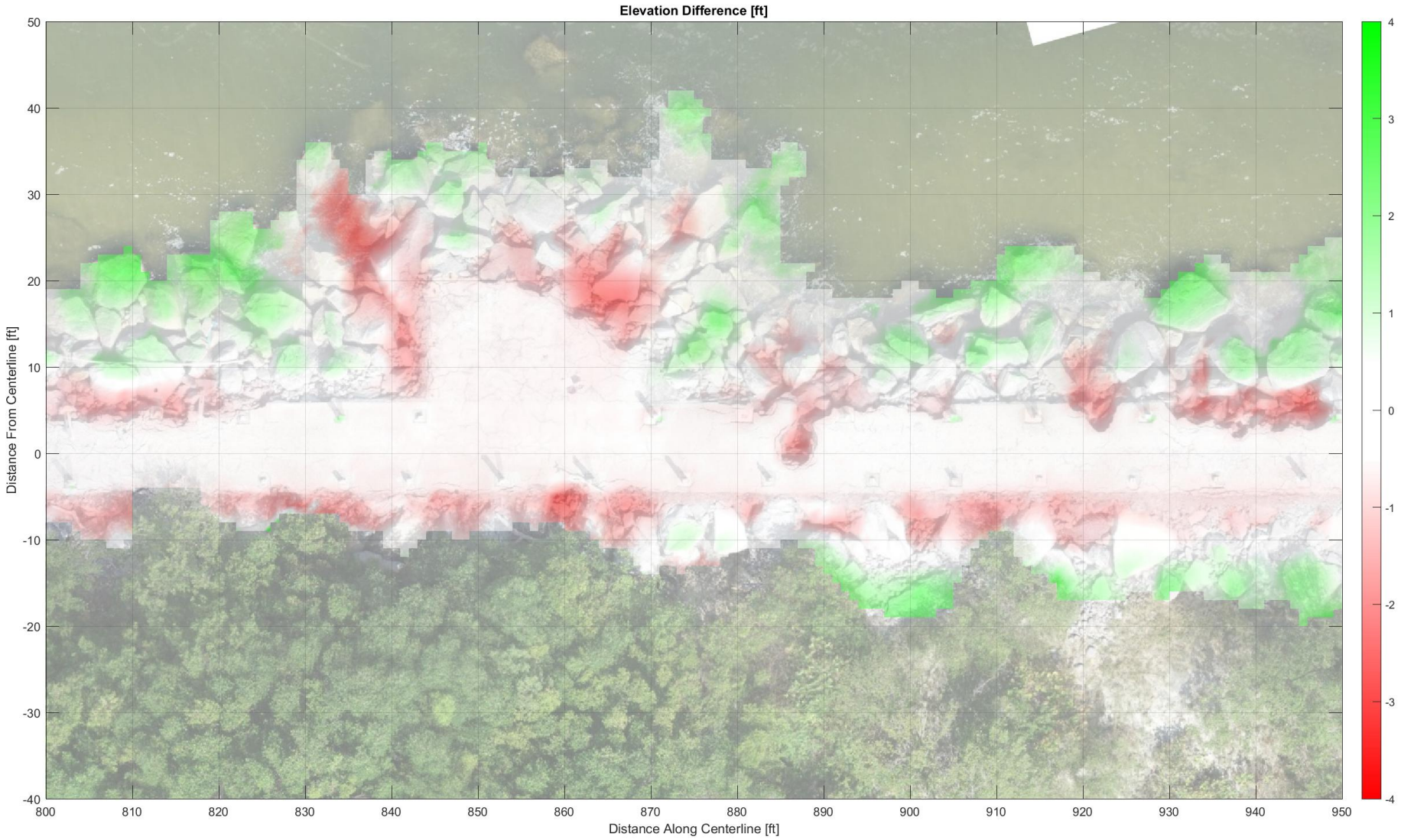
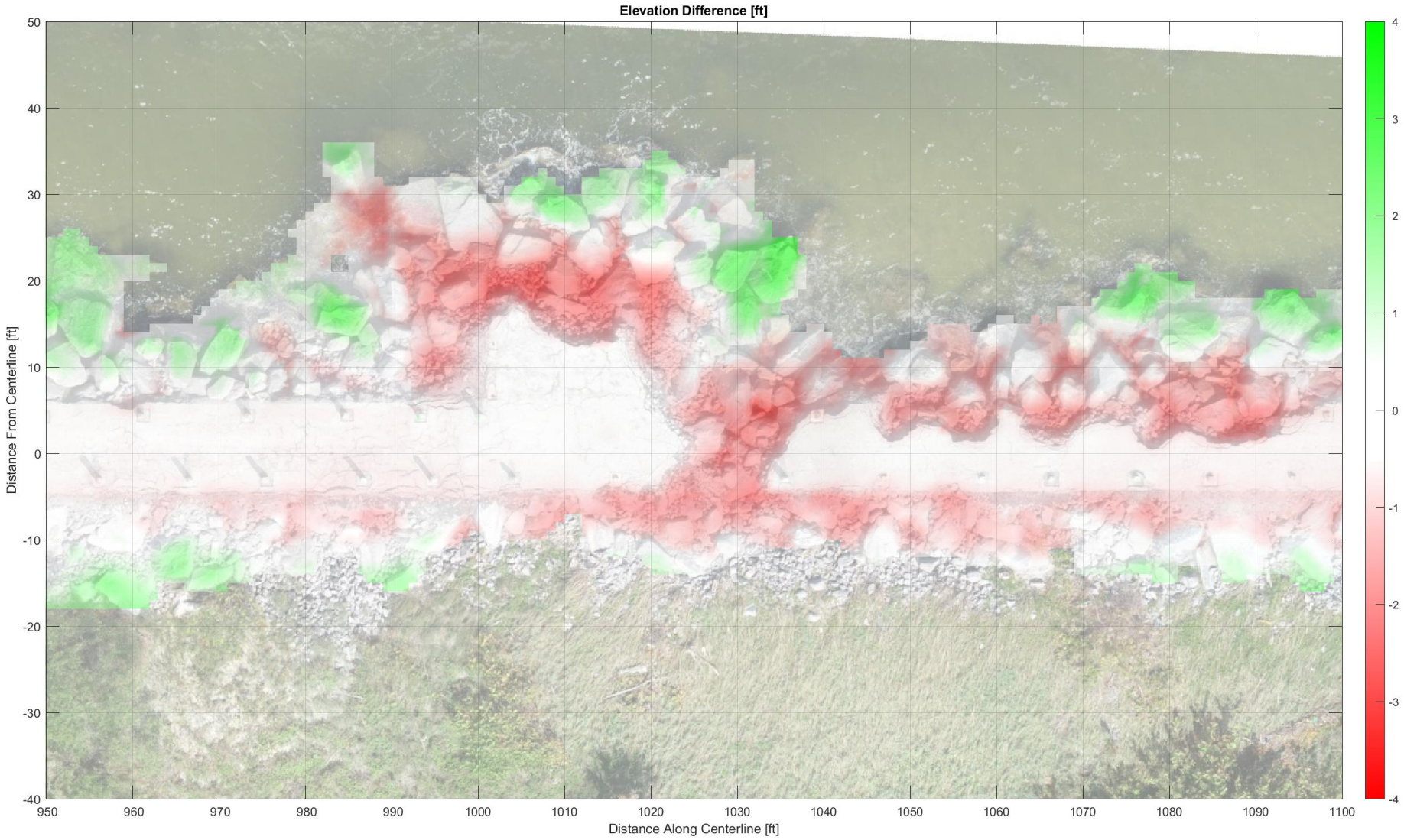
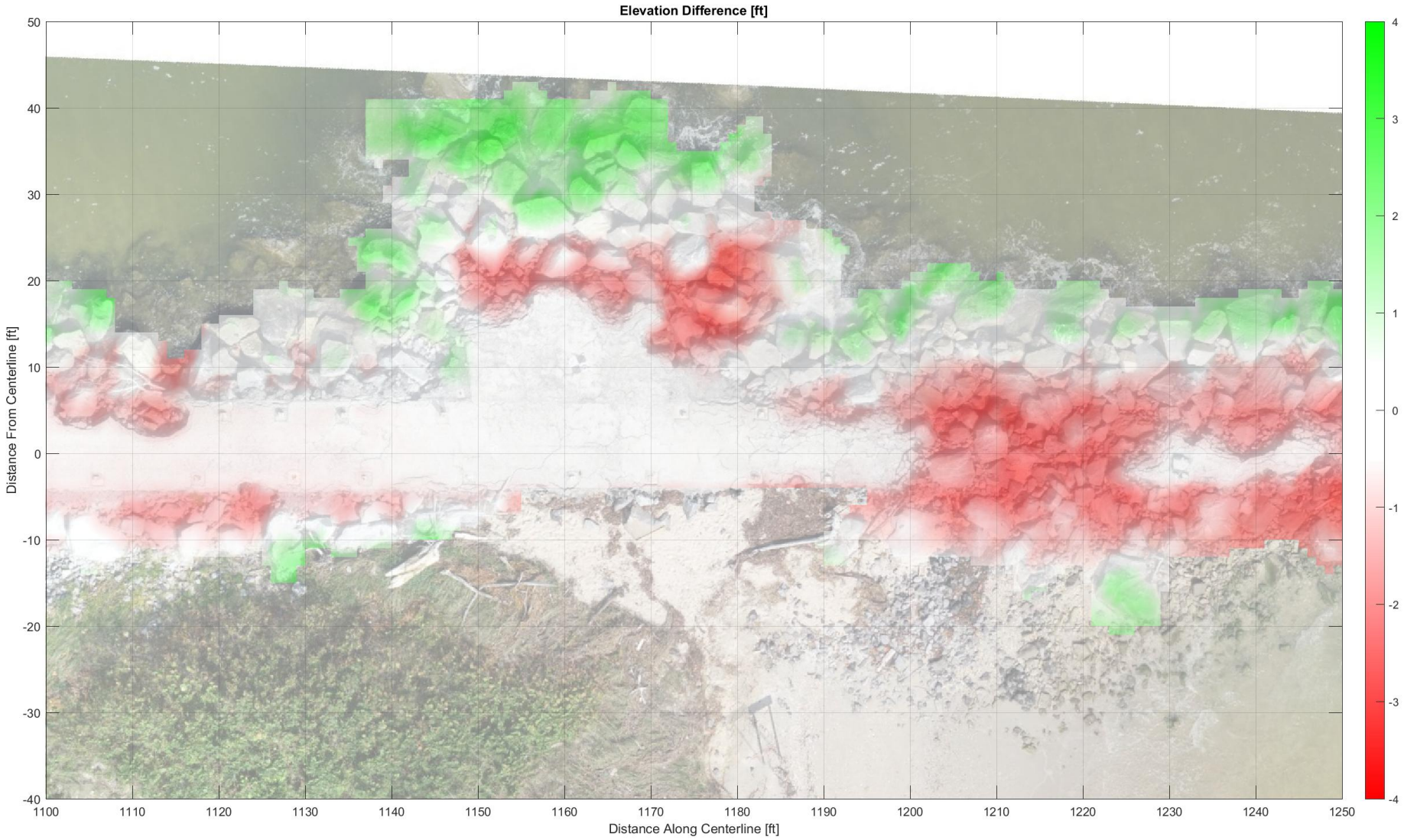
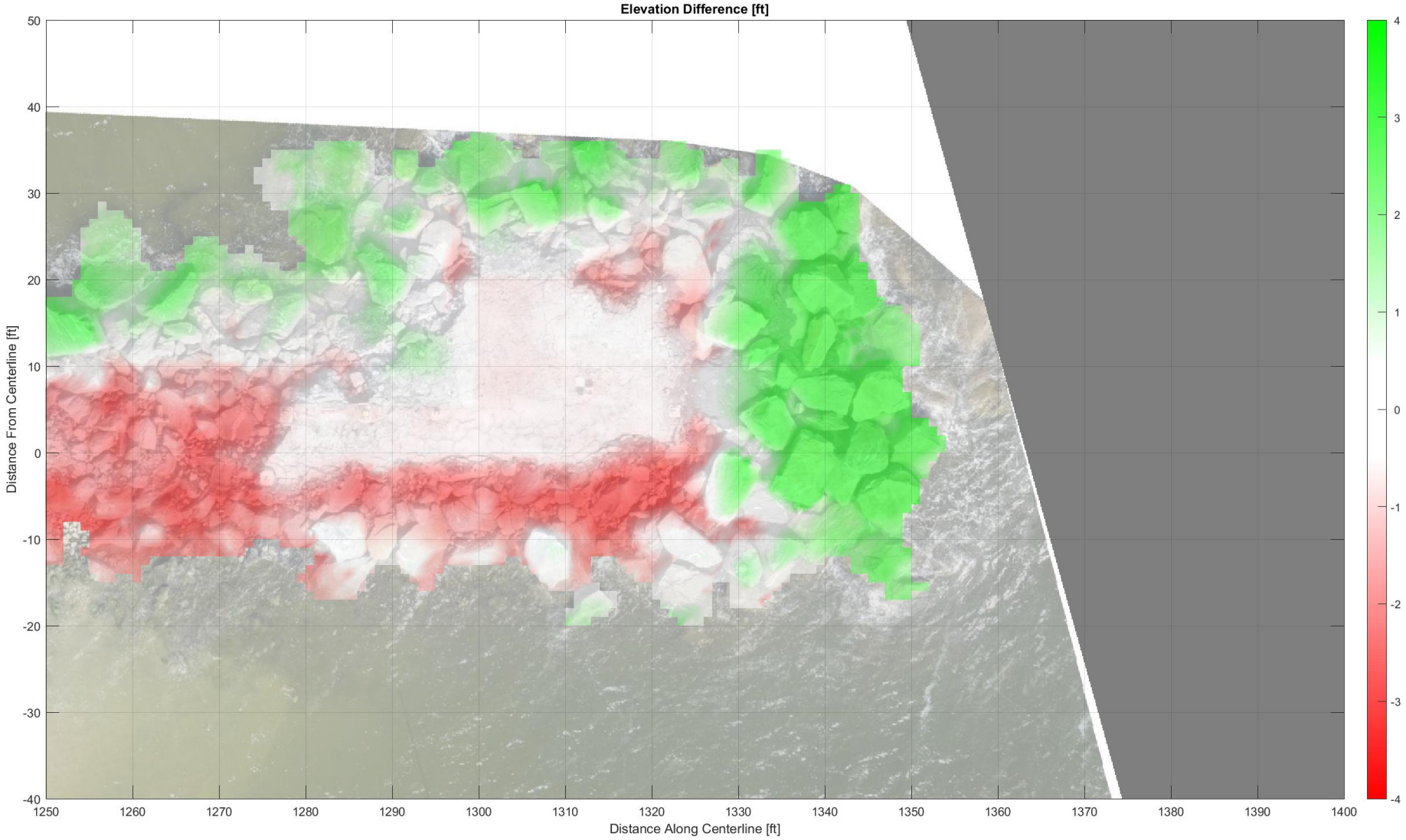
40
30
20
10
0
-10
-20
-30
-40
500
510
520
530
540
550
560
570
580
590
600
610
620
630
640
650
4
3
2
1
0
-1
-2
-3
-4


Elevation Difference [ft]
Distance From Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
650
660
670
680
690
700
710
720
730
740
750
760
770
780
790
800
Distance Along Centerline [ft]
4
3
2
1
0
-1
-2
-3
-4

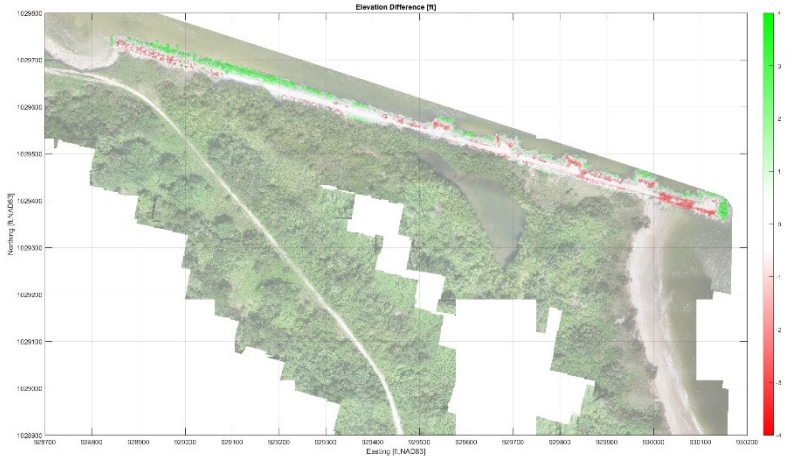

Elevation Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
800
810
820
830
840
850
860
870
880
890
900
910
920
930
940
950
4
3
2
1
0
-1
-2
-3
-4


Elevation Difference [ft]
Distance From Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
950
960
970
980
990
1000
1010
1020
1030
1040
1050
1060
1070
1080
1090
1100
Distance Along Centerline [ft]
4
3
2
1
0
-1
-2
-3
-4


Elevation Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
1100
1110
1120
1130
1140
1150
1160
1170
1180
1190
1200
1210
1220
1230
1240
1250
4
3
2
1
0
-1
-2
-3
-4


Elevation Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
1250
1260
1270
1280
1290
1300
1310
1320
1330
1340
1350
1360
1370
1380
1390
1400
4
3
2
1
0
-1
-2
-3
-4

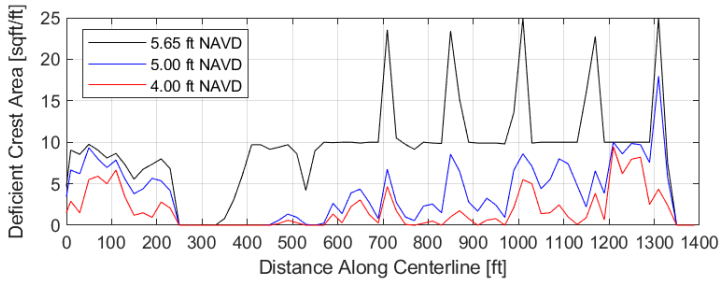
JETTY ELEVATION COMPARISONS

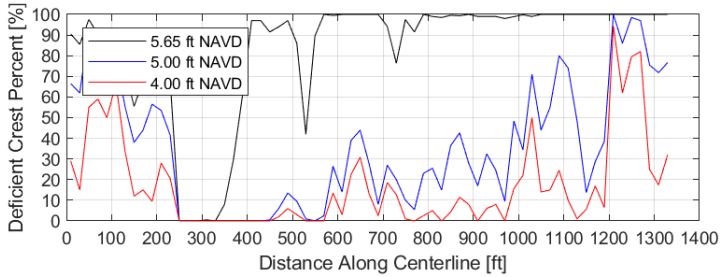


› Crest Elevation Deficiency (sqft)

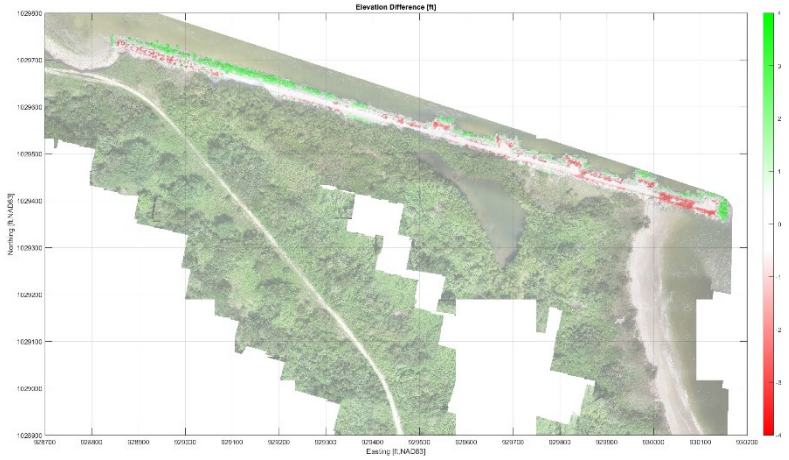
Quantity	< 5.65	< 5.00	< 4.00
Area	12,890	5,420	2,530
Percent	85%	6.1%	2.9%

› Elevation deficiencies were calculated for each 20-foot segment along the jetty crest.

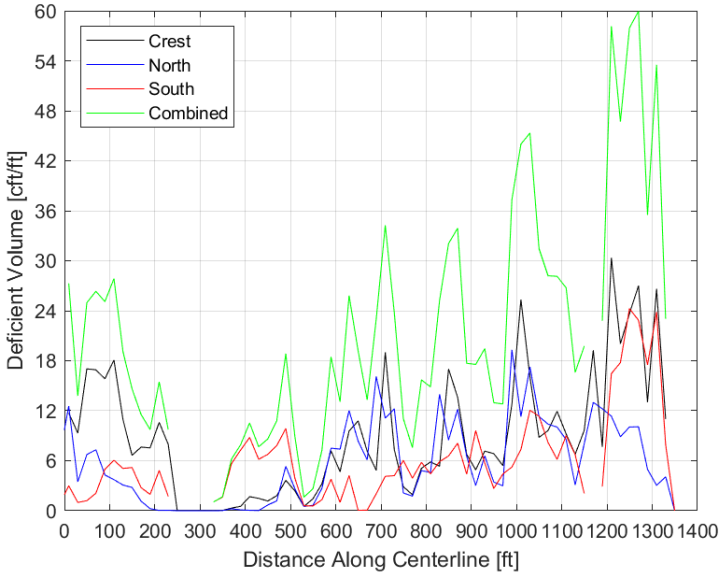




JETTY VOLUME COMPARISONS

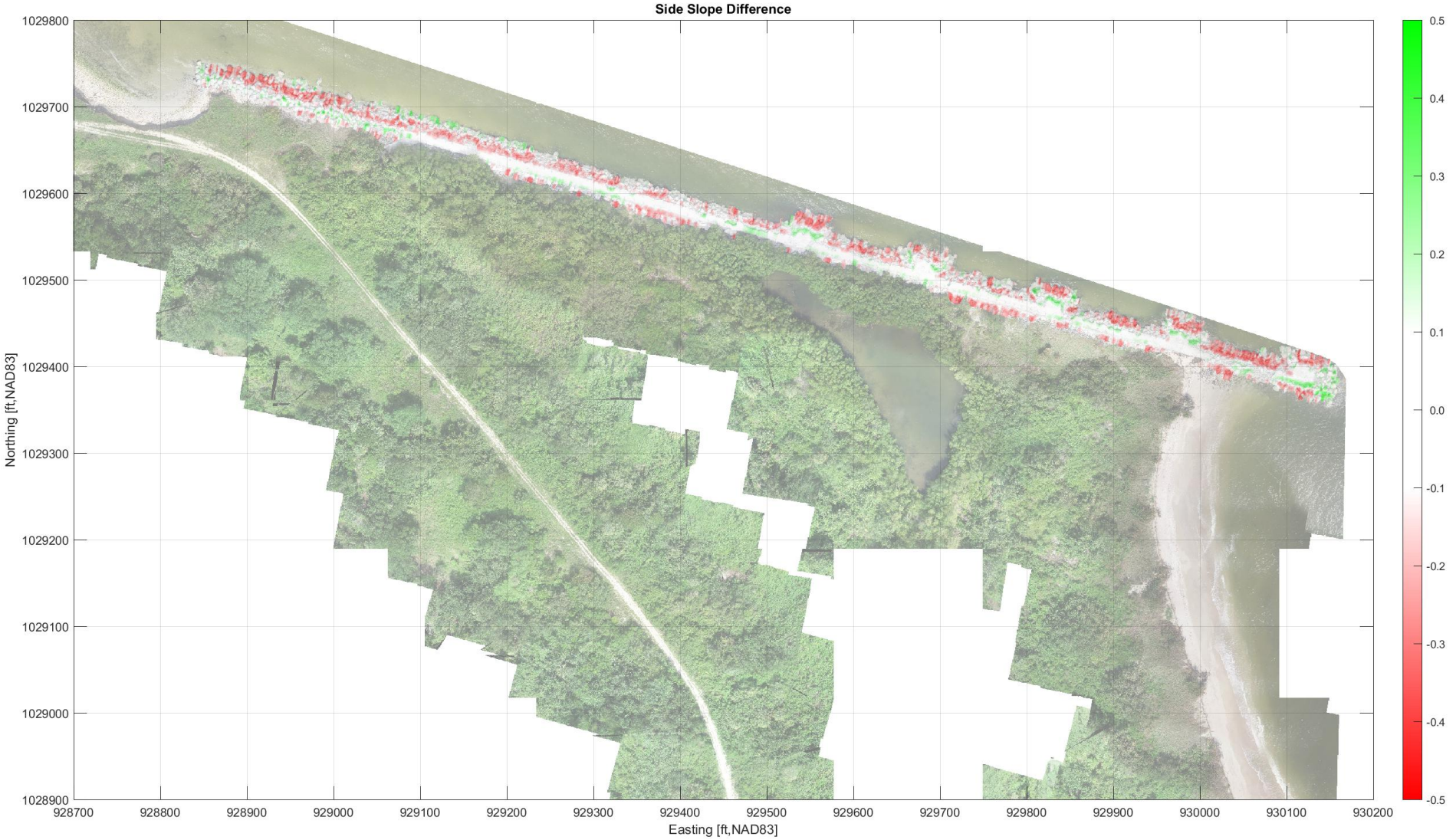


- Volumetric requirements were calculated for each 20-foot segment along the jetty.



Stone Placement Requirements

Face	Volume (cft)	Weight (tons)
Crest	12,450	1,030
North	7,940	650
South	8,480	700
Total	**28,870**	**2,380**


Side Slope Difference
Northing [ft,NAD83]
1029800
1029700
1029600
1029500
1029400
1029300
1029200
1029100
1029000
1028900
Easting [ft,NAD83]
928700
928800
928900
929000
929100
929200
929300
929400
929500
929600
929700
929800
929900
930000
930100
930200
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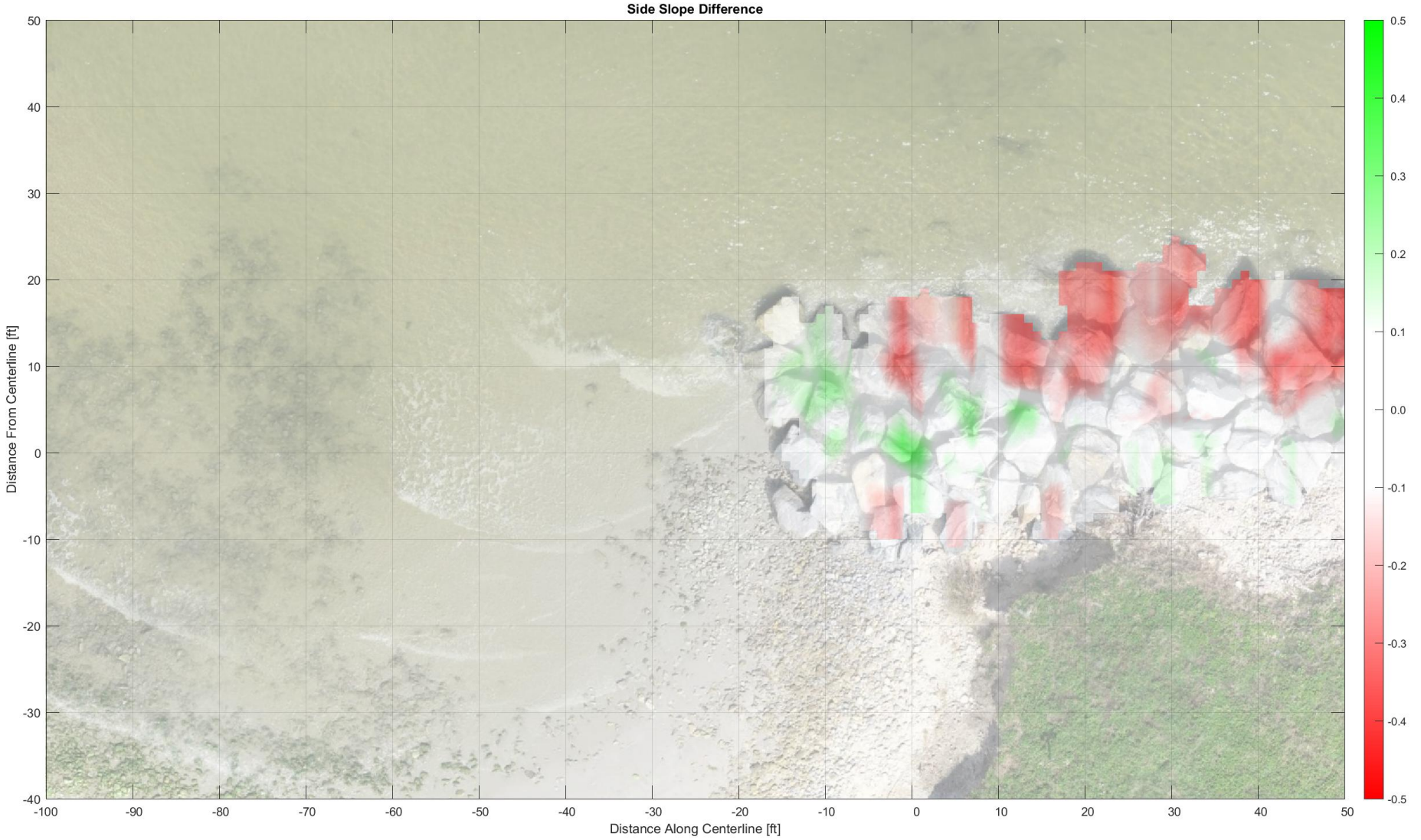
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5


Side Slope Difference
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
0.5
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0.2
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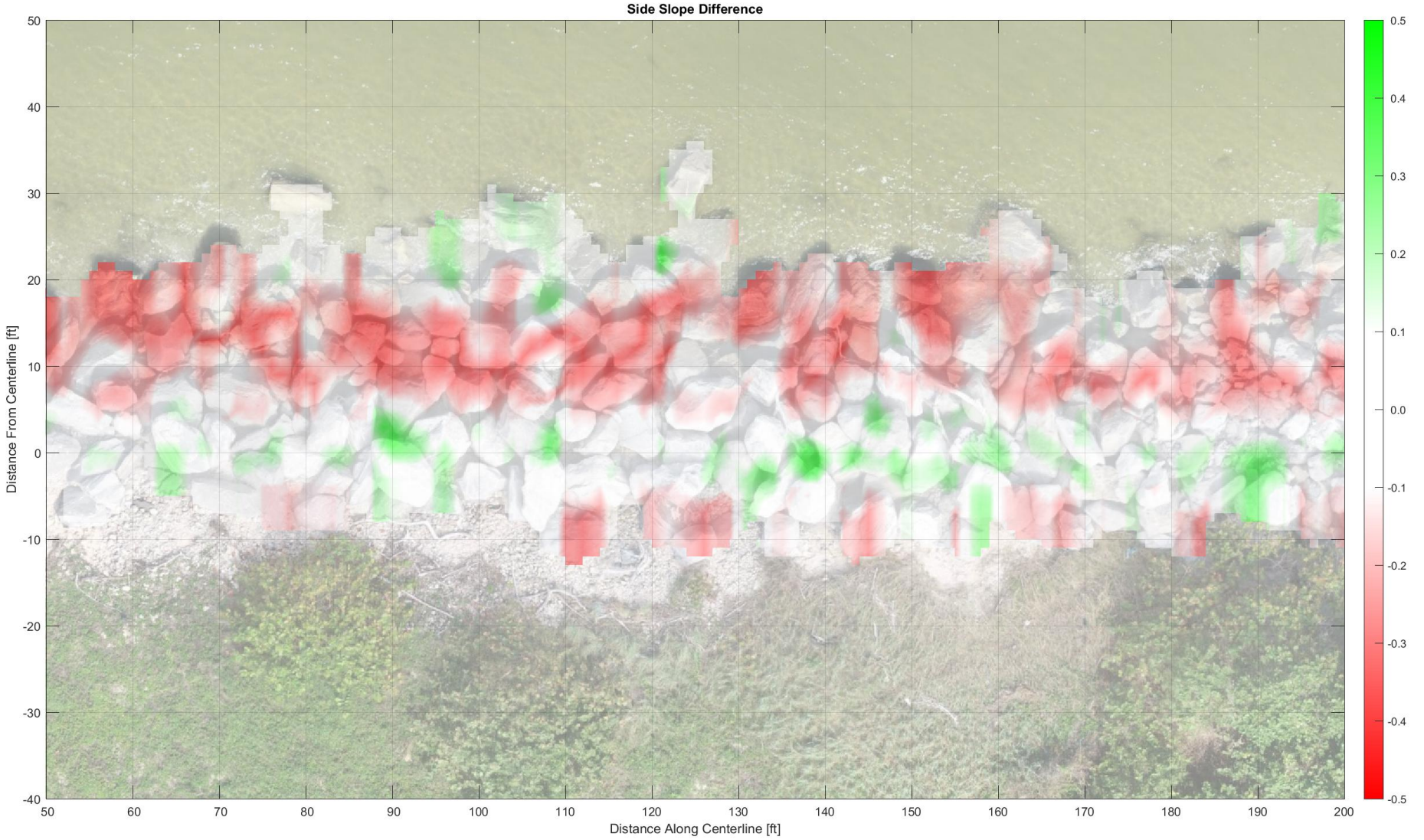
-0.2
-0.3
-0.4
-0.5


Side Slope Difference
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
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0.2
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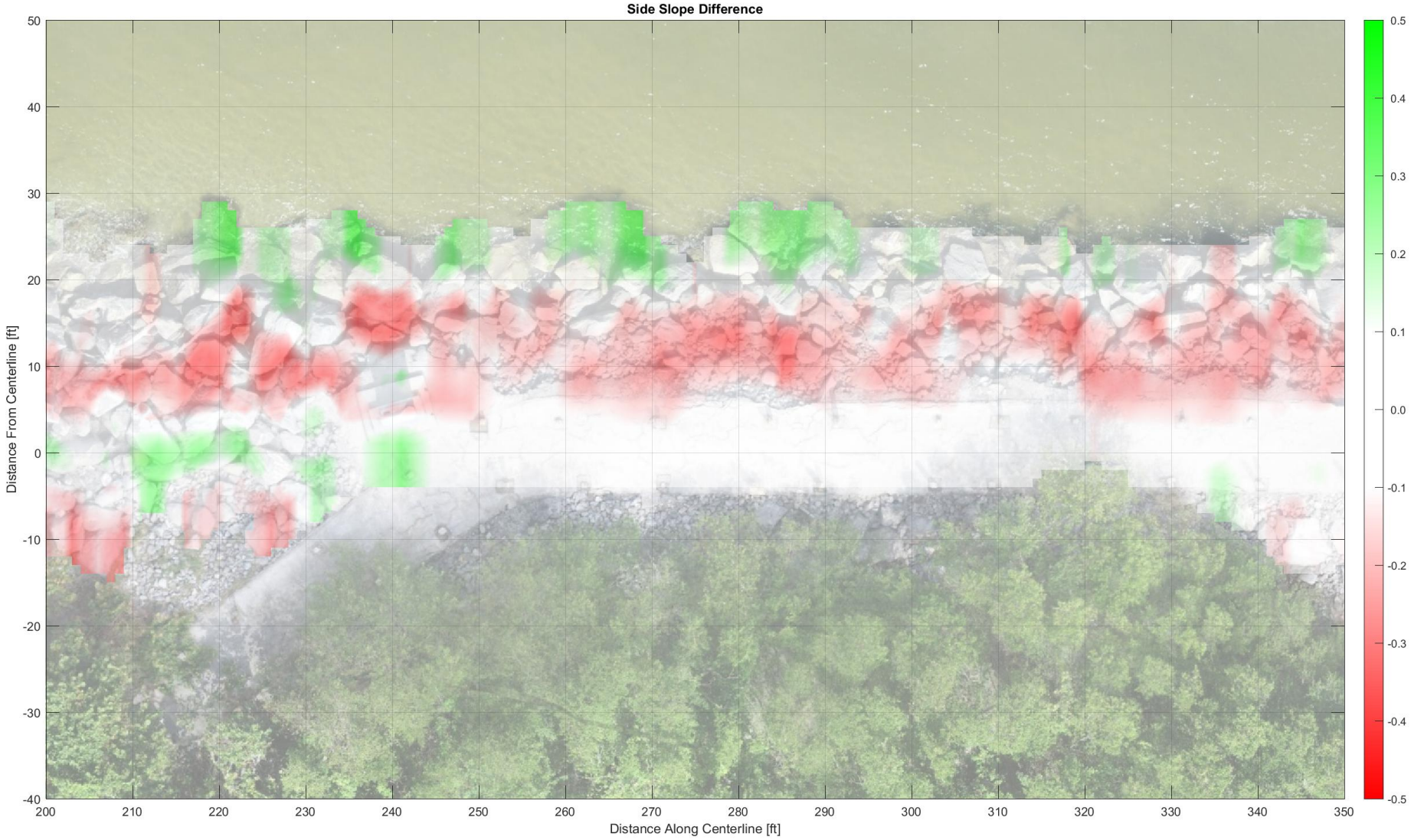
-0.2
-0.3
-0.4
-0.5


Side Slope Difference
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
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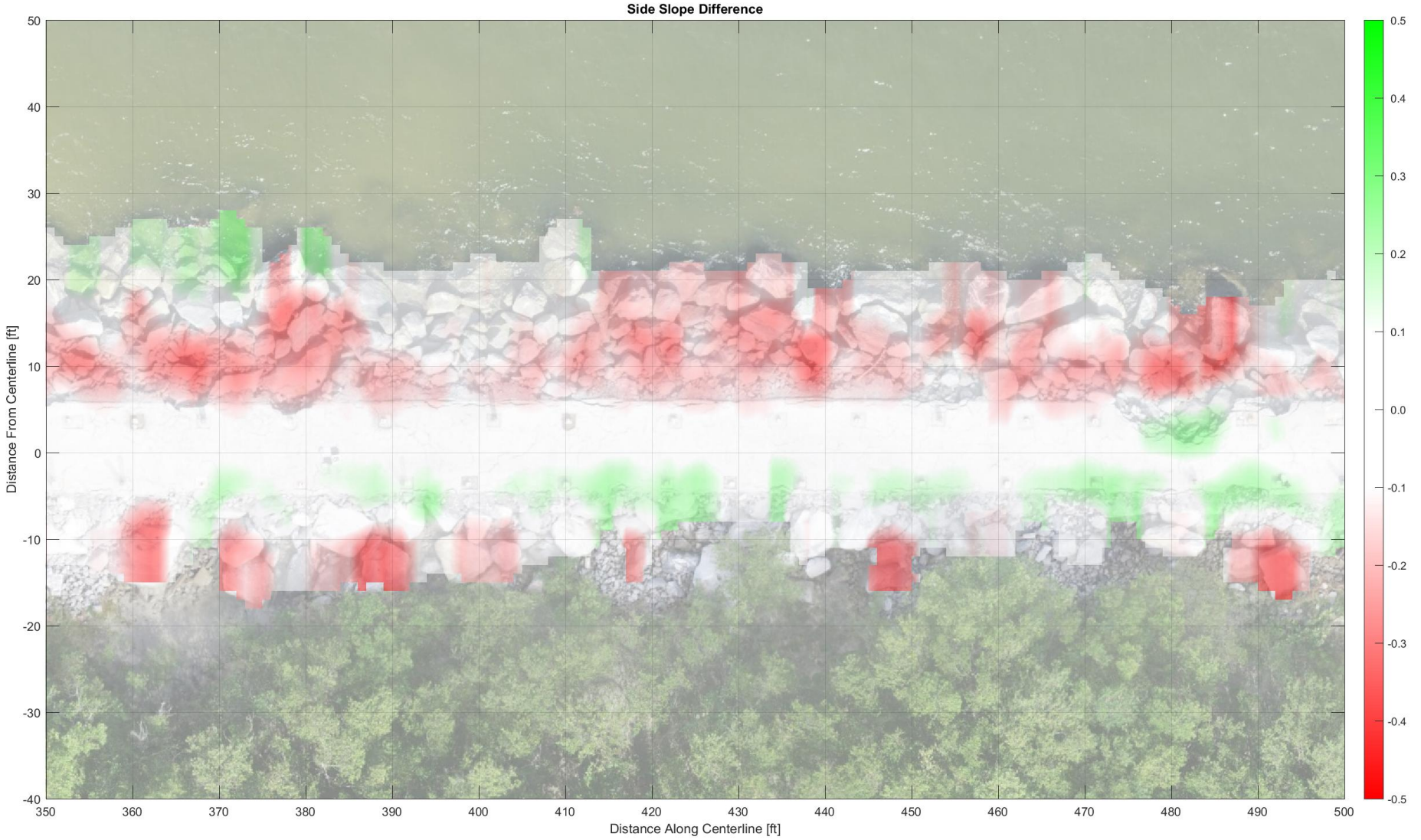
Side Slope Difference
Distance From Centerline [ft]
Distance Along Centerline [ft]
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40
30
20
10
0
-10
-20
-30
-40
350
360
370
380
390
400
410
420
430
440
450
460
470
480
490
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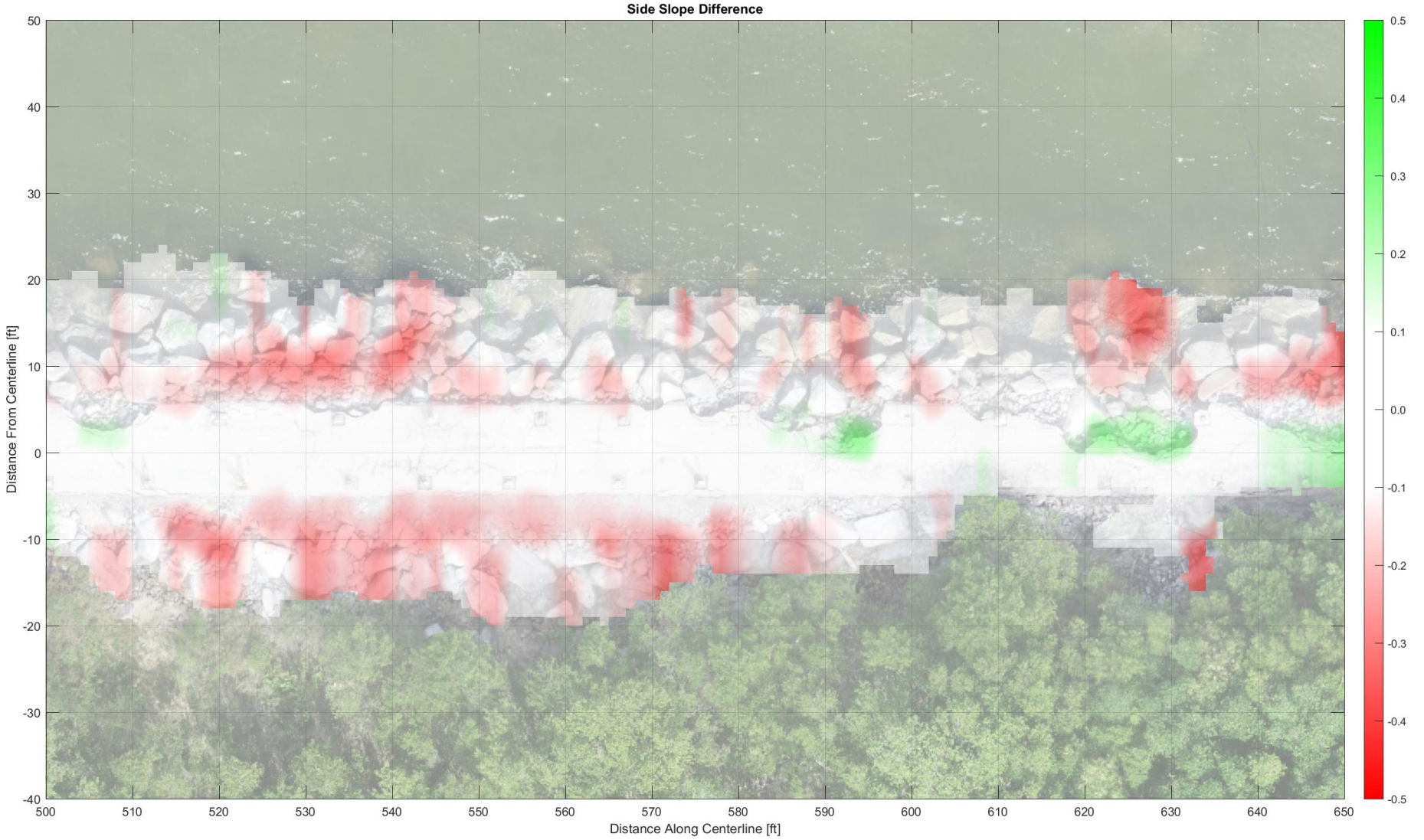
Side Slope Difference
Distance From Centerline [ft]
Distance Along Centerline [ft]
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30
20
10
0
-10
-20
-30
-40
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510
520
530
540
550
560
570
580
590
600
610
620
630
640
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0.2
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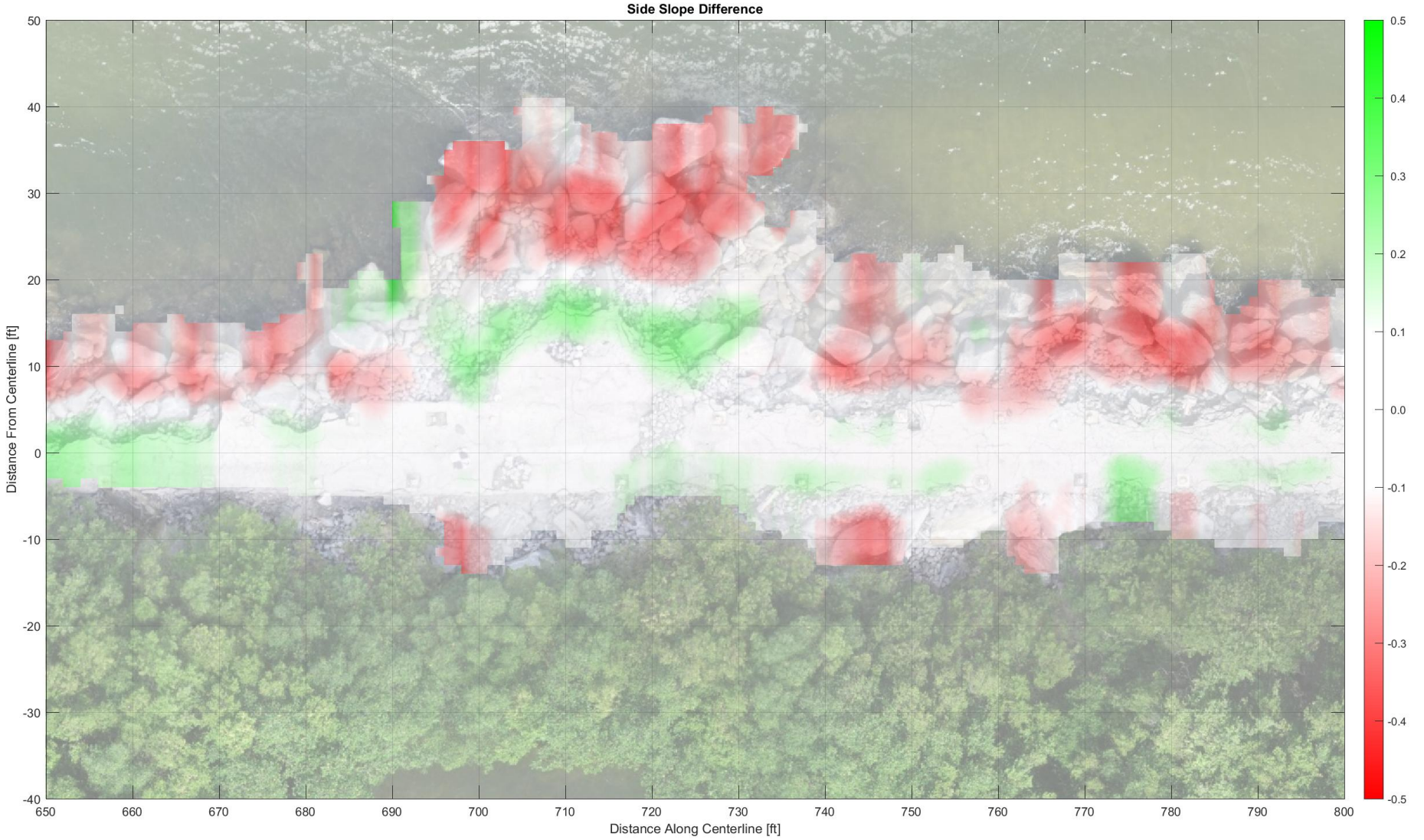
-0.4
-0.5


Side Slope Difference
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
650
660
670
680
690
700
710
720
730
740
750
760
770
780
790
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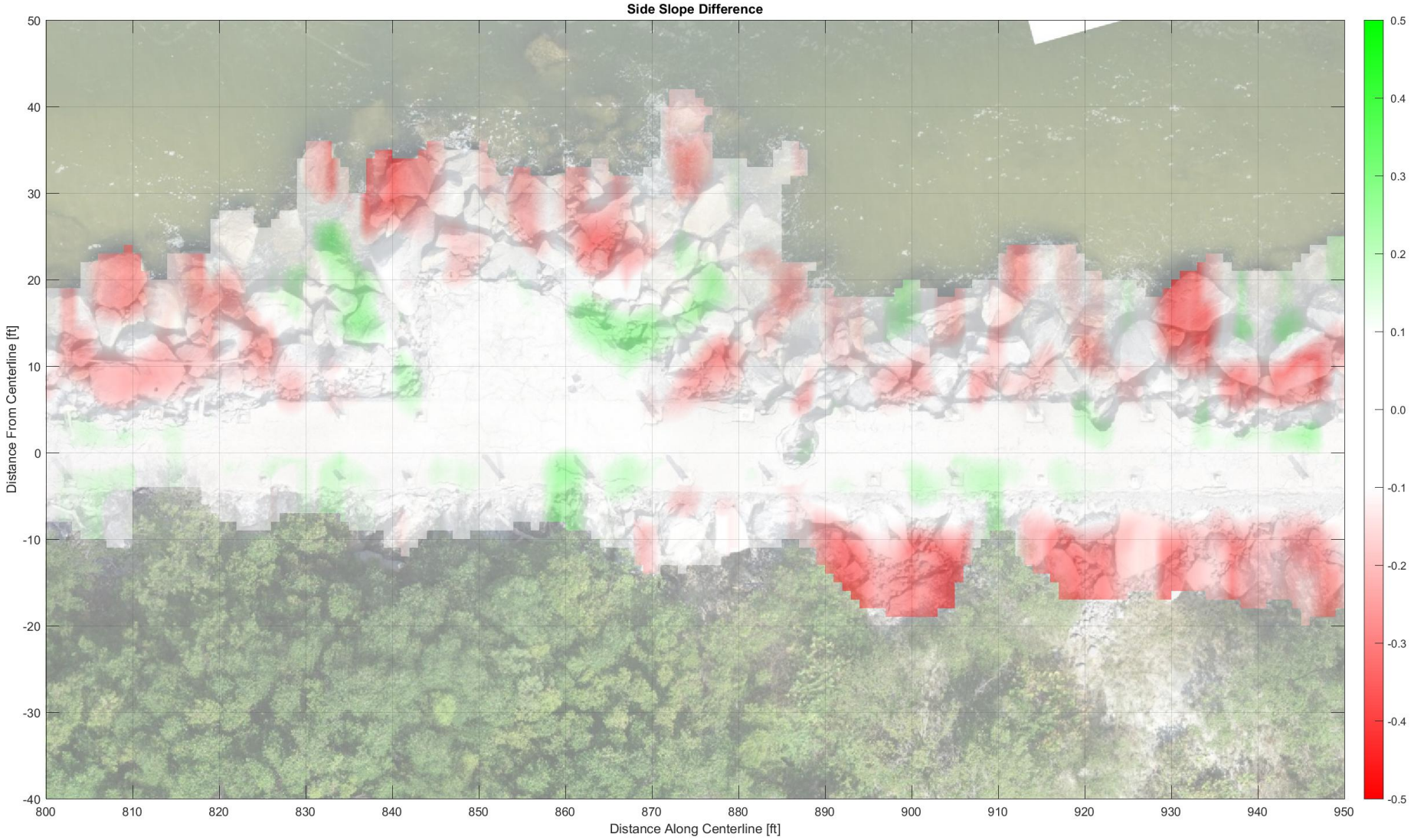
-0.4
-0.5


Side Slope Difference
Distance From Centerline [ft]
Distance Along Centerline [ft]
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40
30
20
10
0
-10
-20
-30
-40
800
810
820
830
840
850
860
870
880
890
900
910
920
930
940
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-0.2
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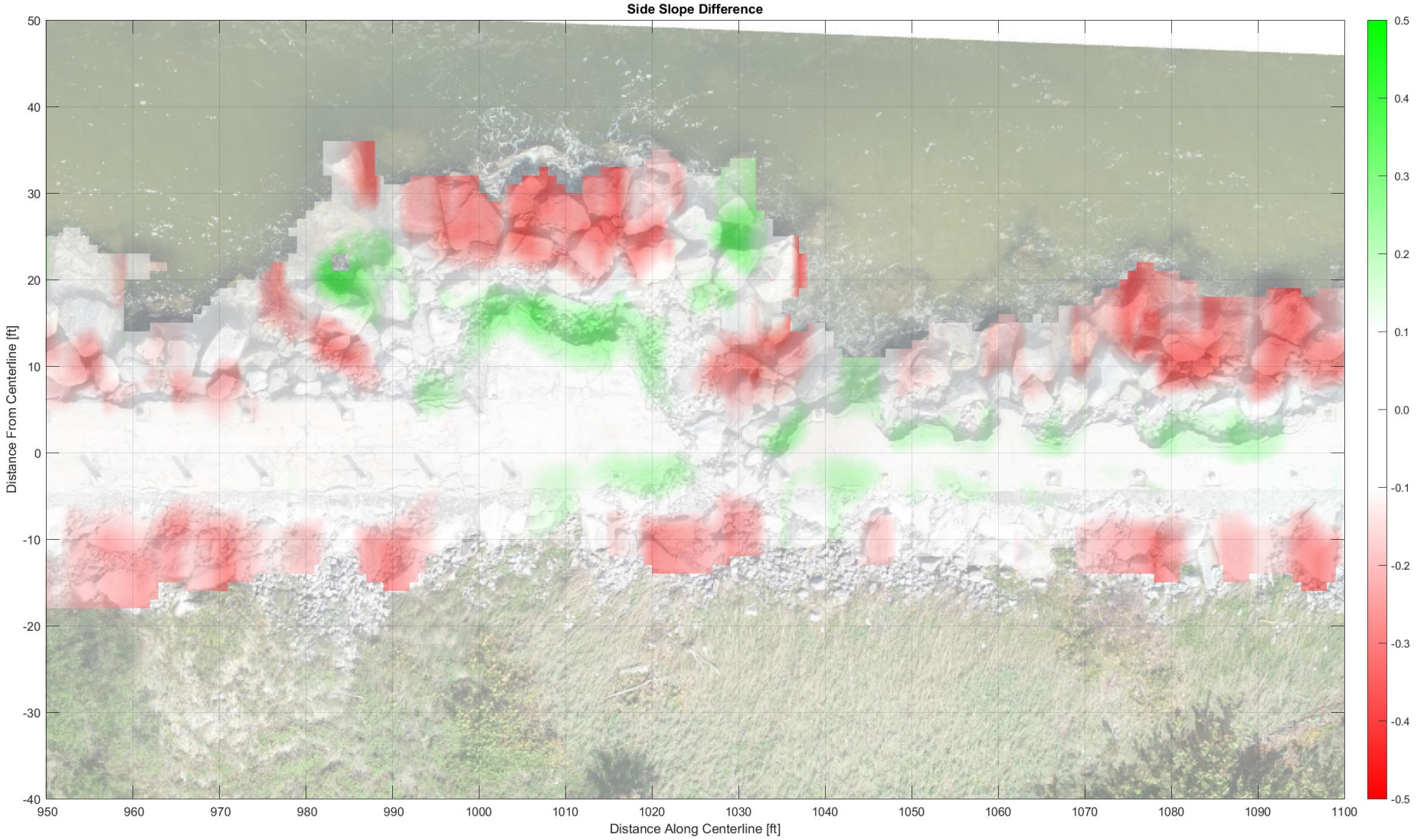
Side Slope Difference
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
950
960
970
980
990
1000
1010
1020
1030
1040
1050
1060
1070
1080
1090
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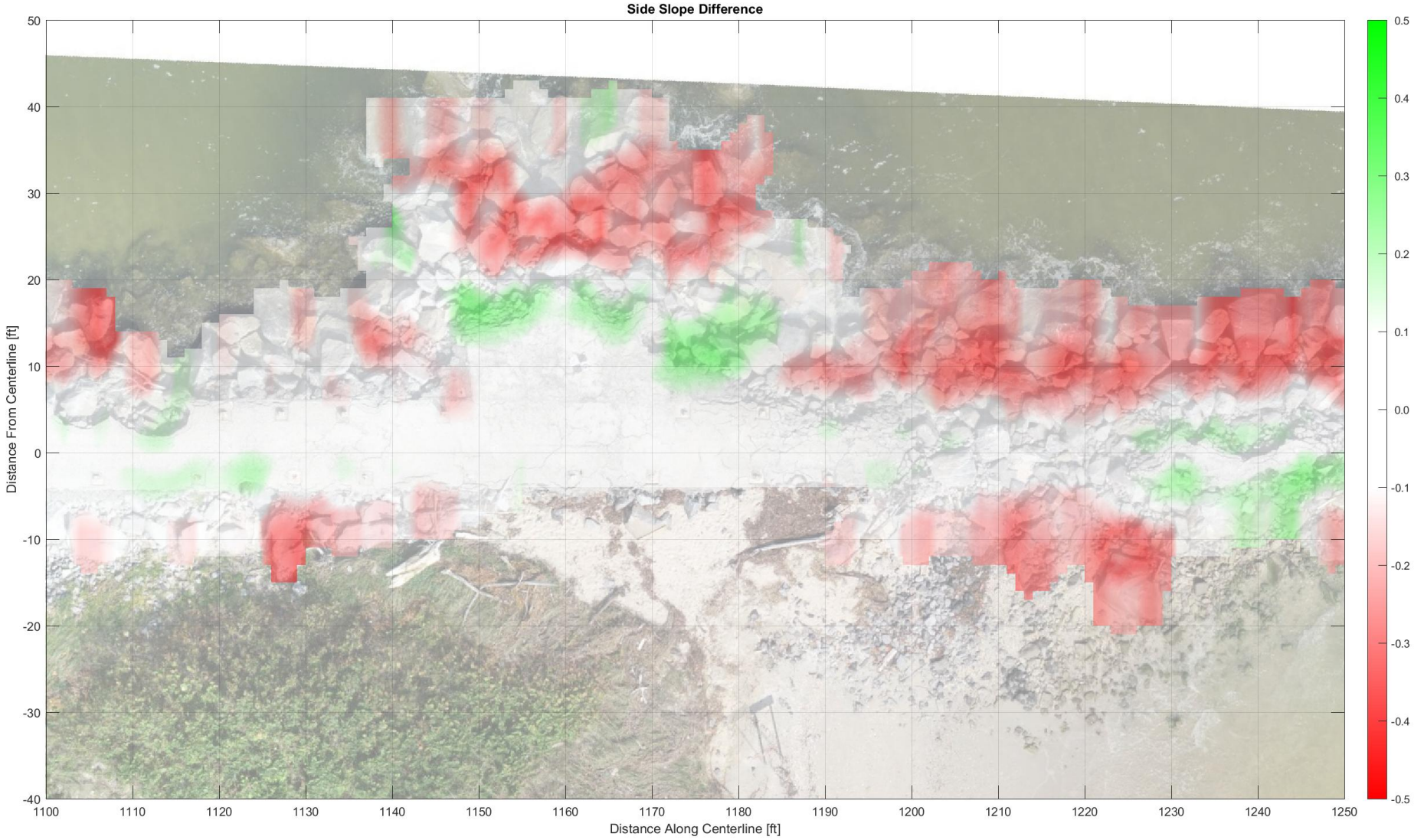
Side Slope Difference
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
1100
1110
1120
1130
1140
1150
1160
1170
1180
1190
1200
1210
1220
1230
1240
1250
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0.0
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-0.2
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-0.4
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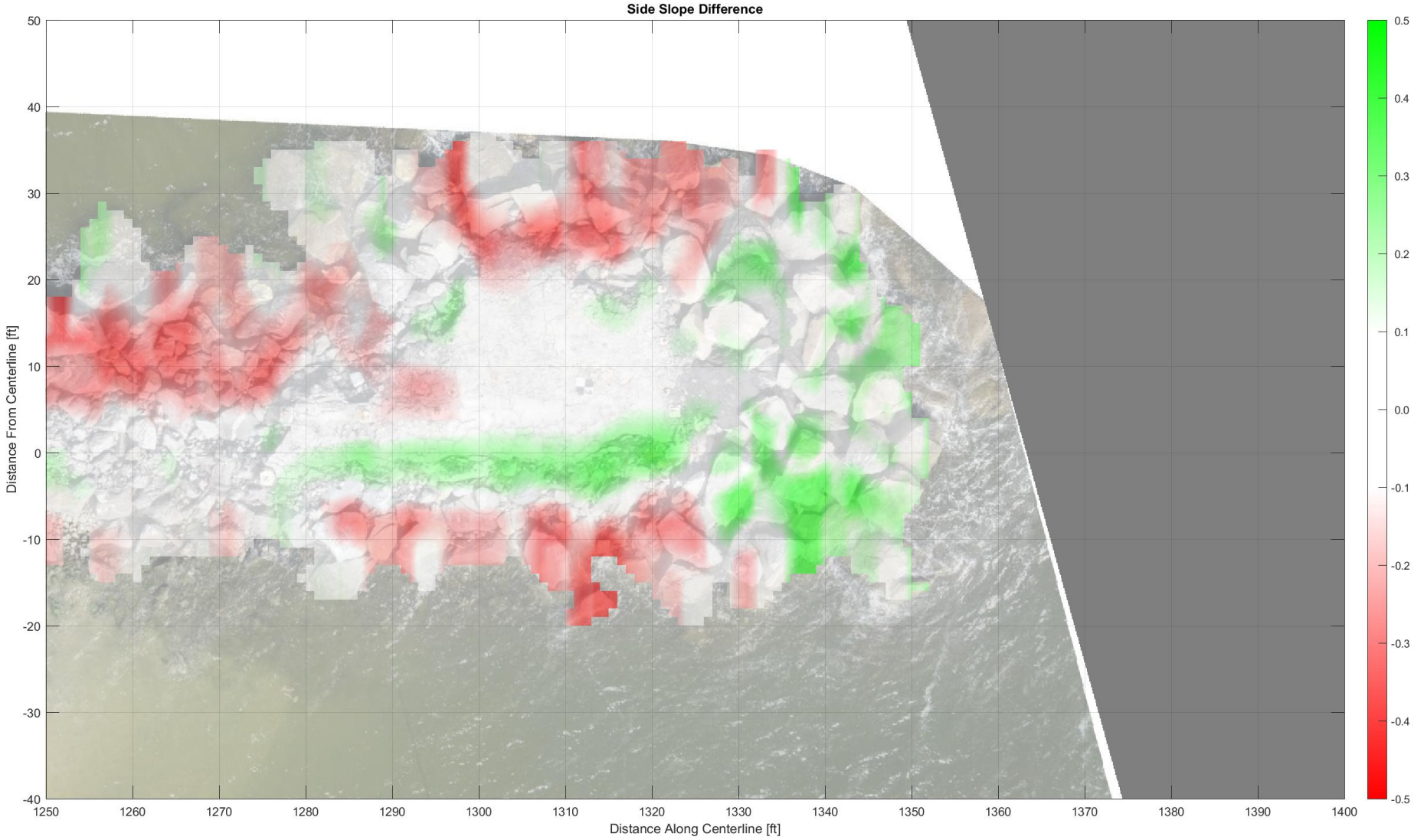
Side Slope Difference
Distance From Centerline [ft]
Distance Along Centerline [ft]
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40
30
20
10
0
-10
-20
-30
-40
1250
1260
1270
1280
1290
1300
1310
1320
1330
1340
1350
1360
1370
1380
1390
1400
0.5
0.4
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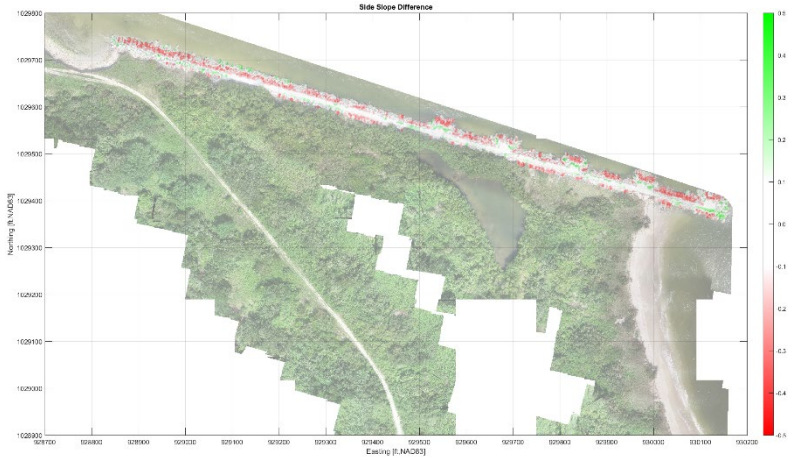
-0.4
-0.5

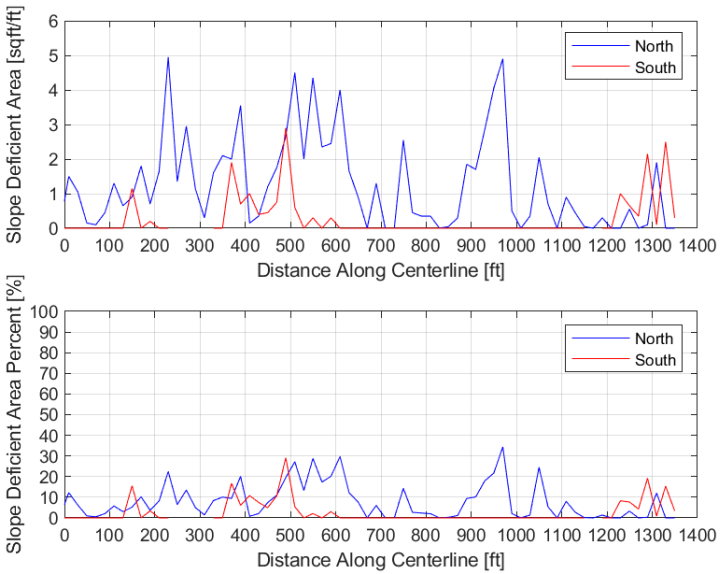
JETTY SLOPE COMPARISONS

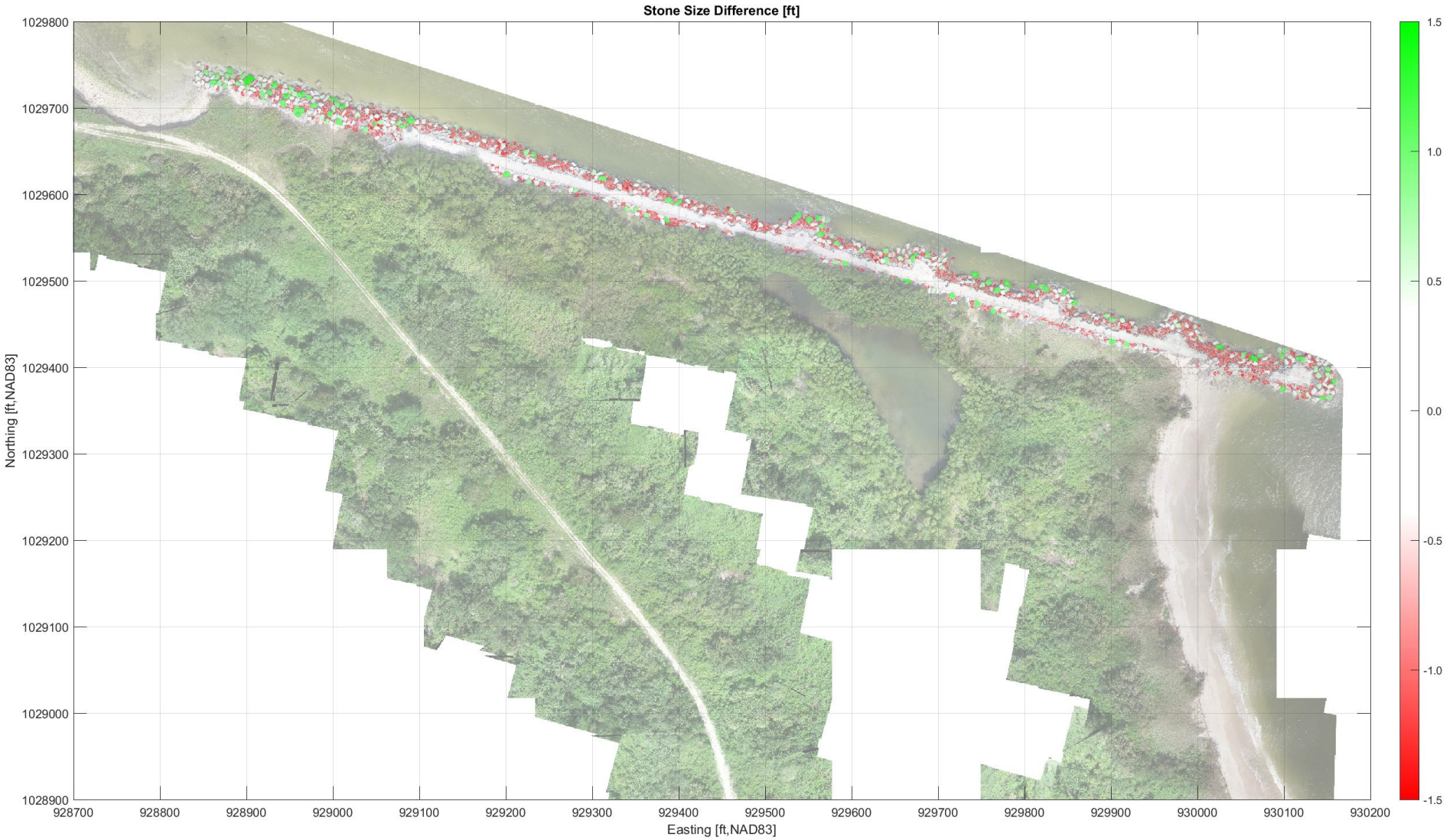


- Side slope deficiencies were calculated for each 20-foot segment along the north and south jetty faces.

Side Slope Deficiency (sqft)

Face	Analyzed	Deficient	Percent
North	24,970	1,750	7%
South	9,780	384	4%
Total	**34,750**	**2,134**	**6%**




Stone Size Difference [ft]
Northing [ft,NAD83]
1029800
1029700
1029600
1029500
1029400
1029300
1029200
1029100
1029000
1028900
Easting [ft,NAD83]
928700
928800
928900
929000
929100
929200
929300
929400
929500
929600
929700
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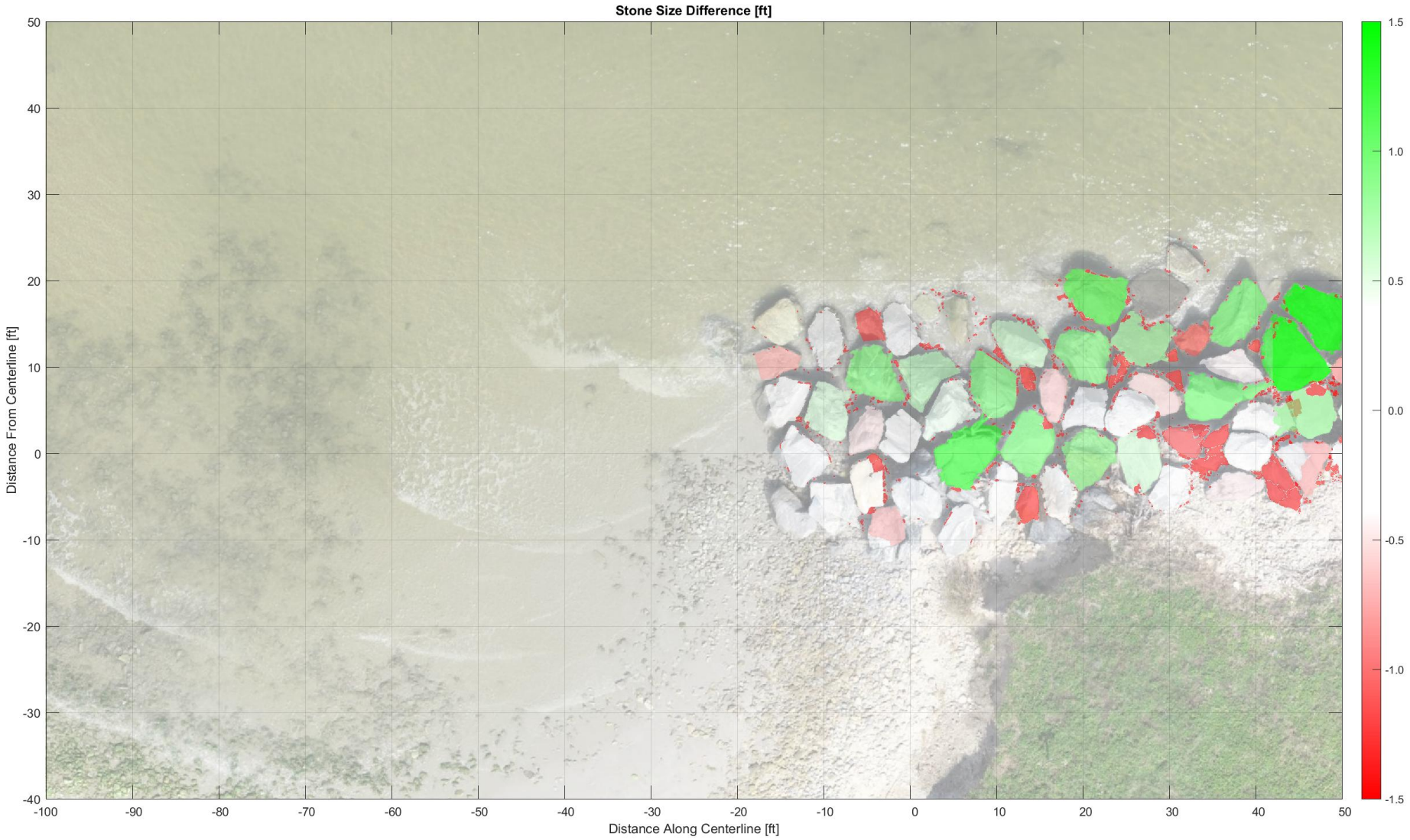
Stone Size Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
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40
30
20
10
0
-10
-20
-30
-40
-100
-90
-80
-70
-60
-50
-40
-30
-20
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40
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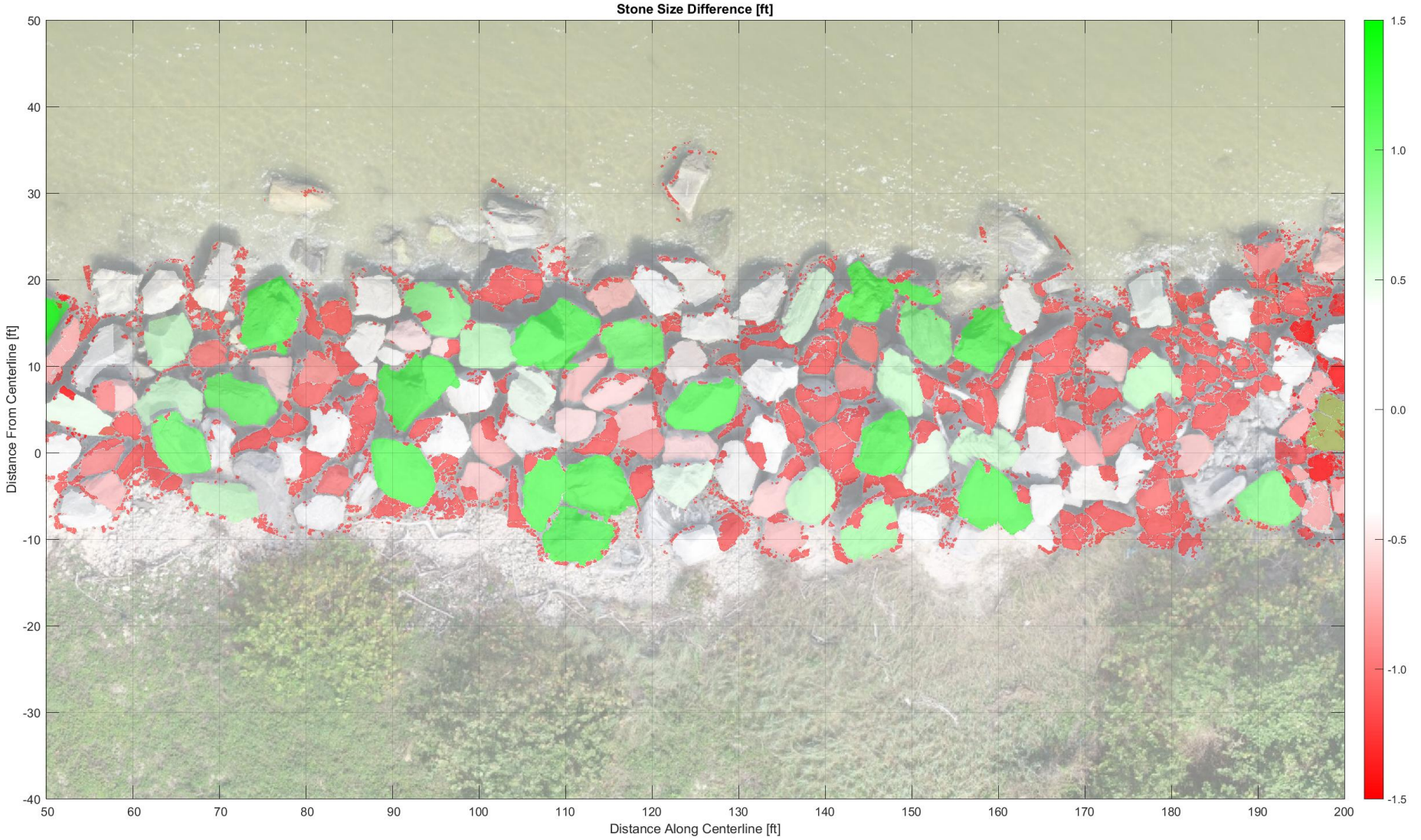
-1.5


Stone Size Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
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-40
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60
70
80
90
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120
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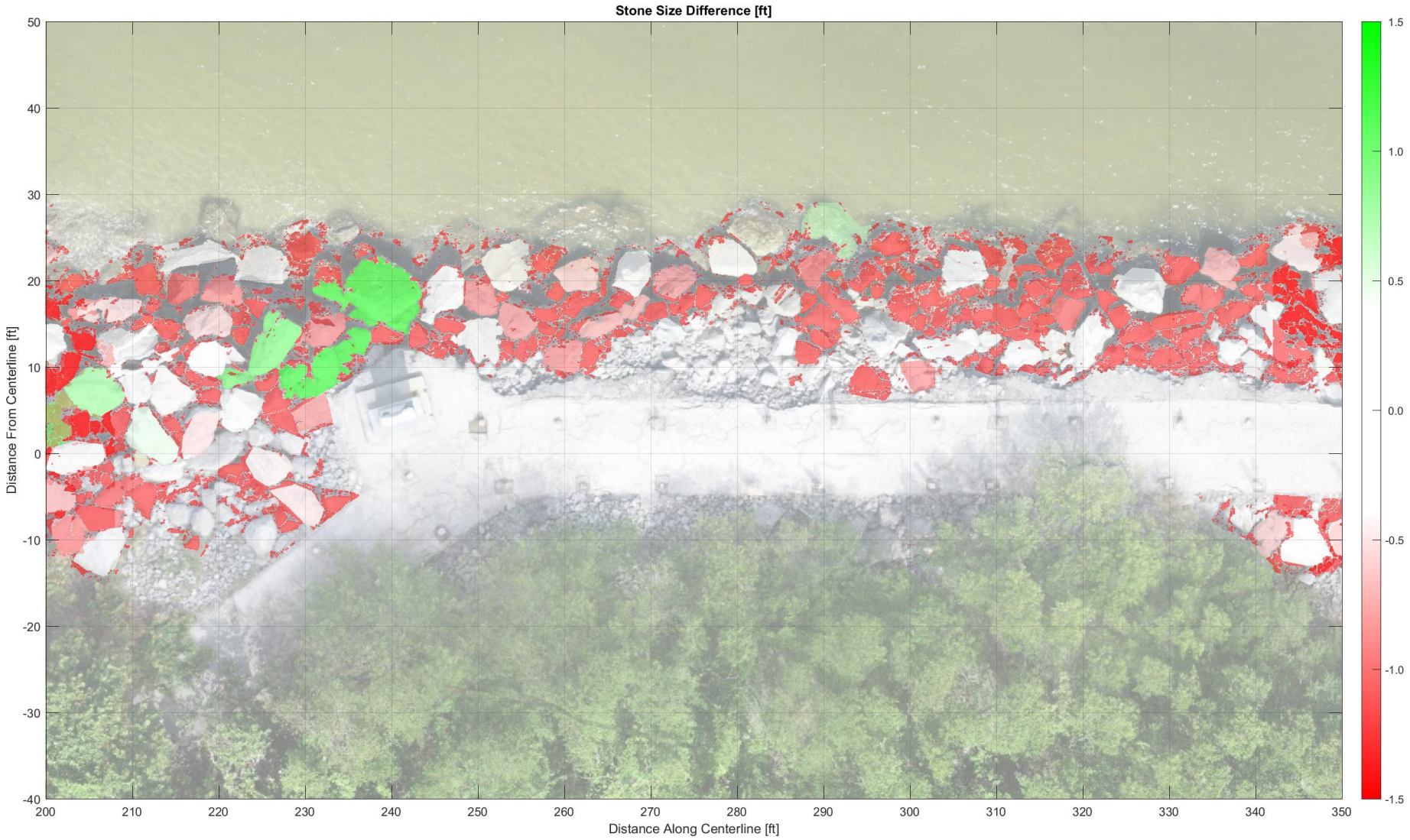
Stone Size Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
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40
30
20
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0
-10
-20
-30
-40
200
210
220
230
240
250
260
270
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300
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330
340
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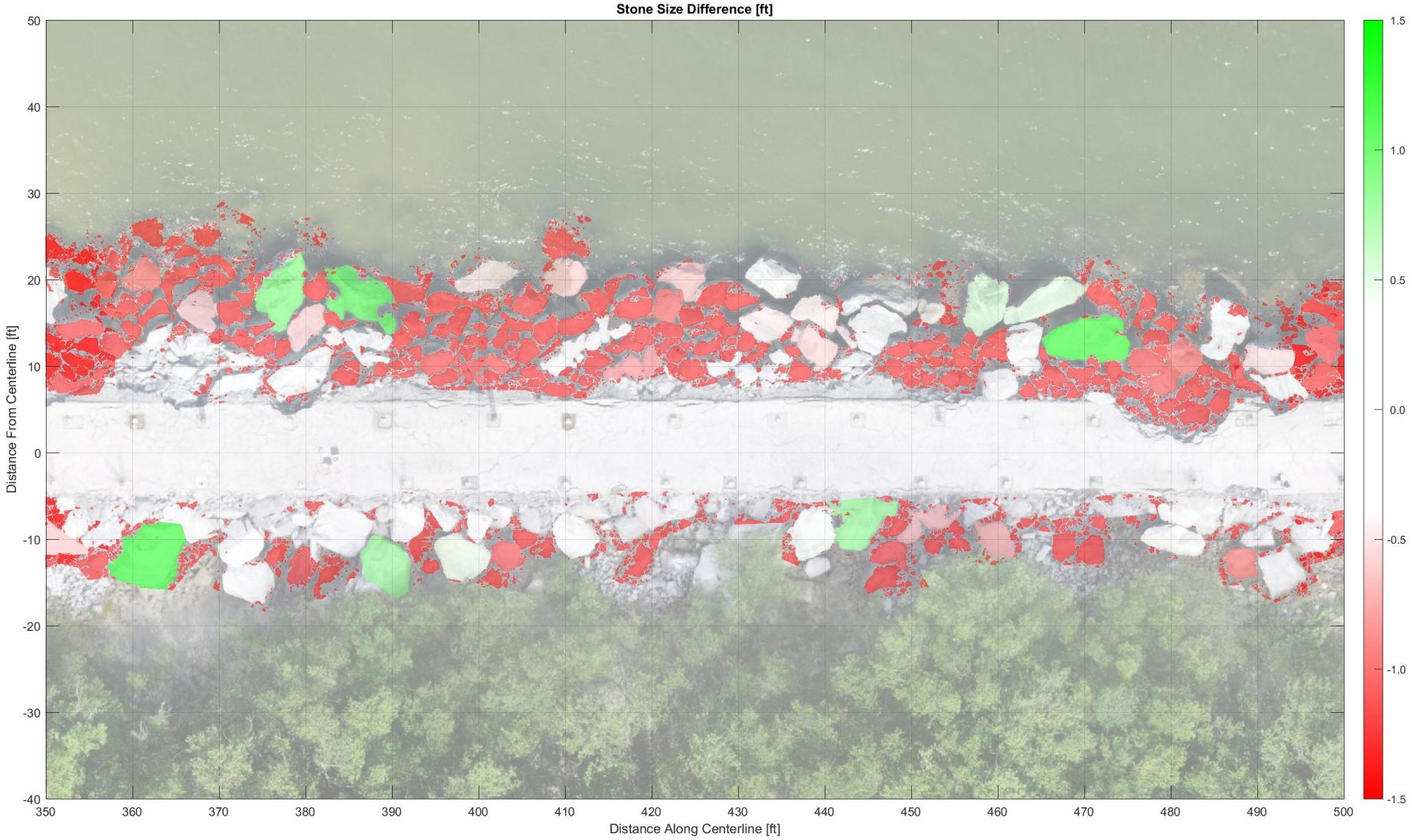
-1.0
-1.5


Stone Size Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
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20
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-20
-30
-40
350
360
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380
390
400
410
420
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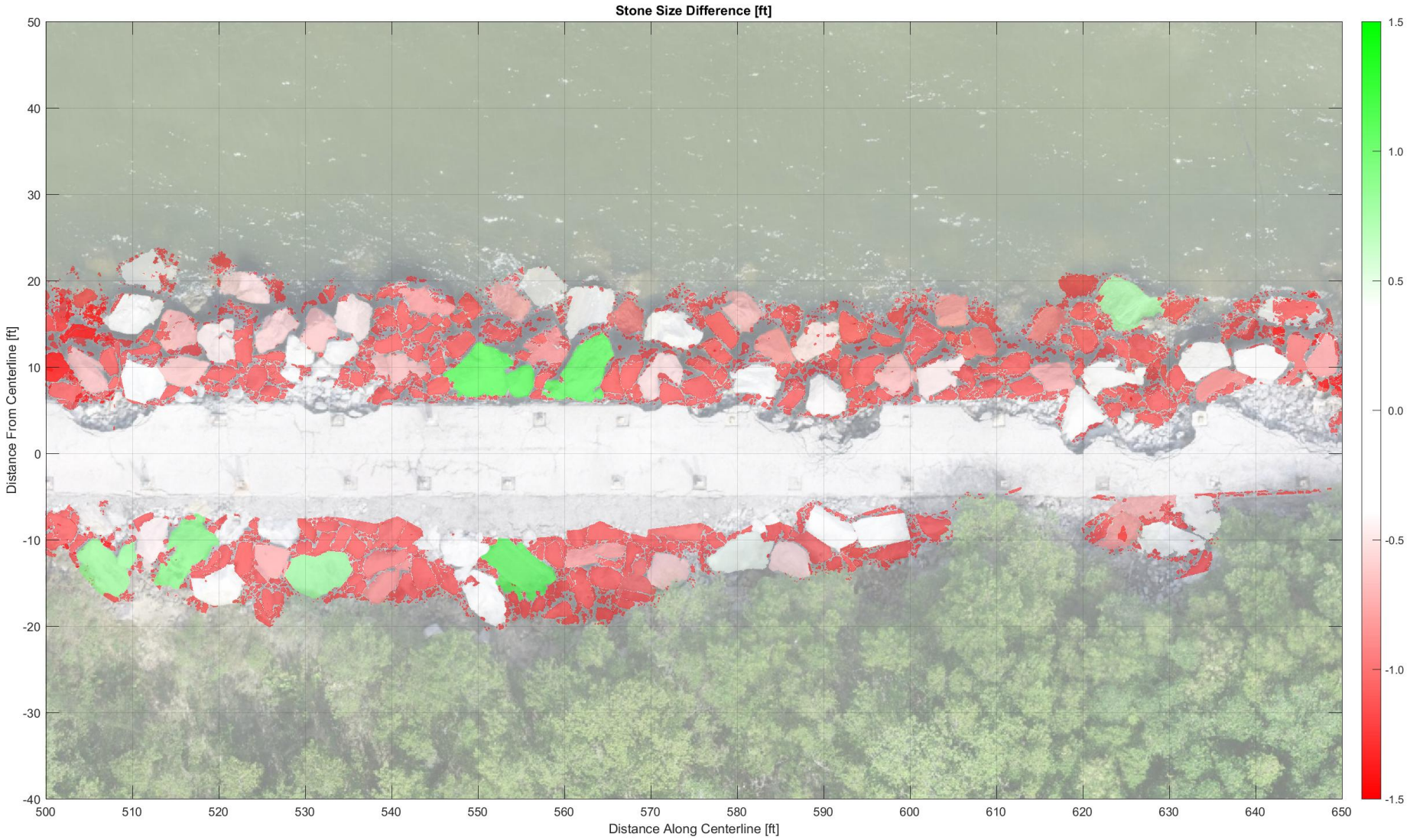
-0.5
-1.0
-1.5


Stone Size Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
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40
30
20
10
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-10
-20
-30
-40
500
510
520
530
540
550
560
570
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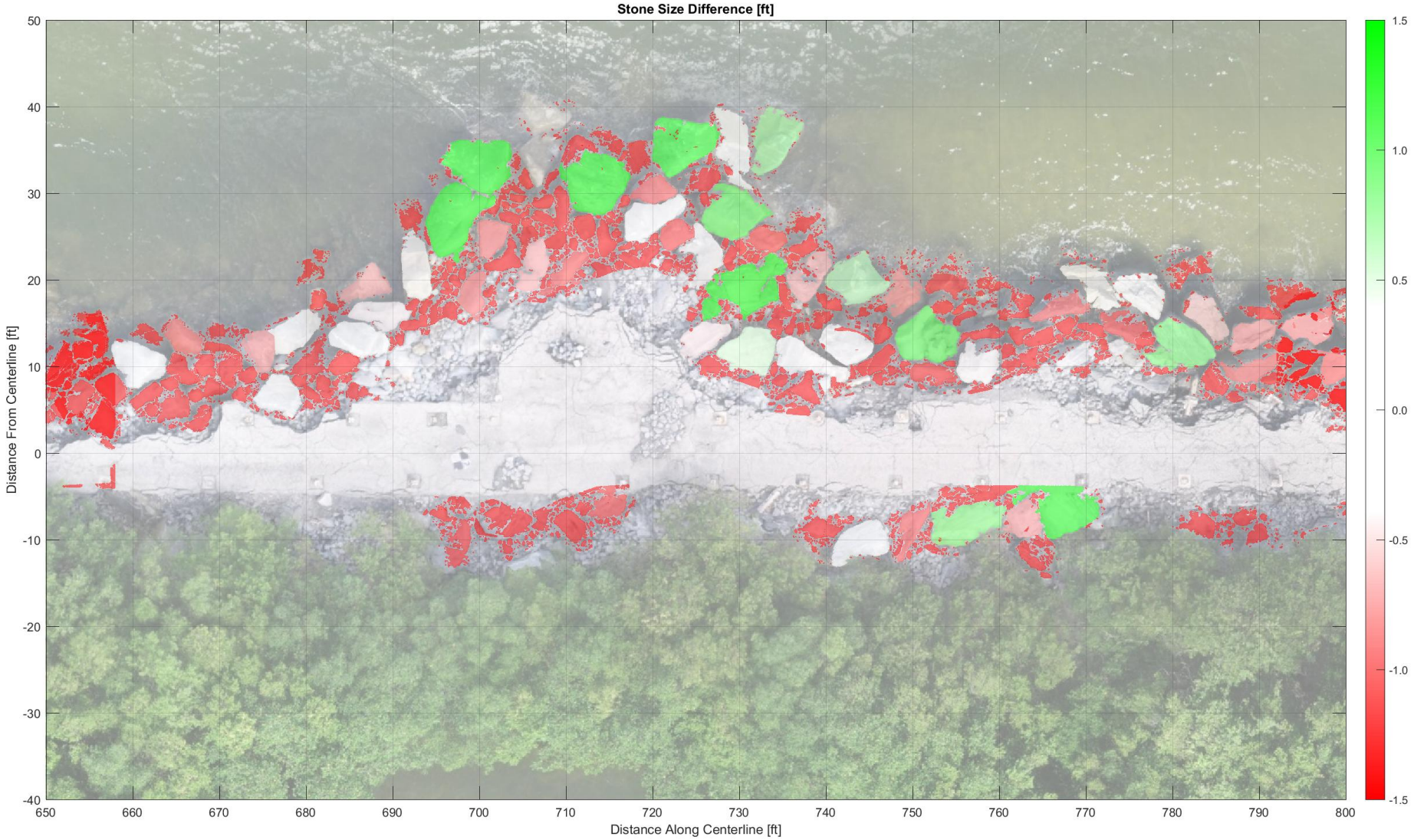
Stone Size Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
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40
30
20
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-10
-20
-30
-40
650
660
670
680
690
700
710
720
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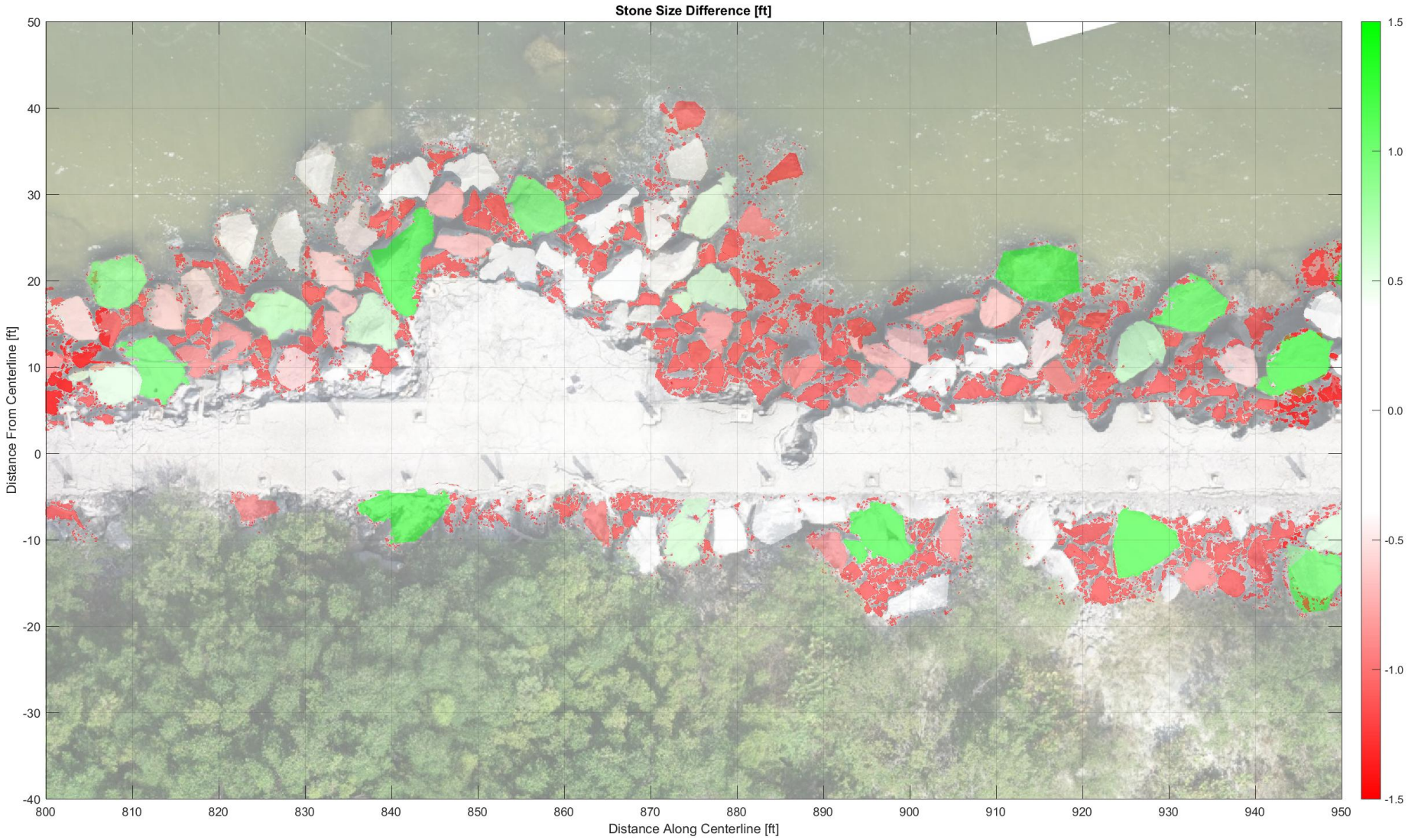
Stone Size Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
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-10
-20
-30
-40
800
810
820
830
840
850
860
870
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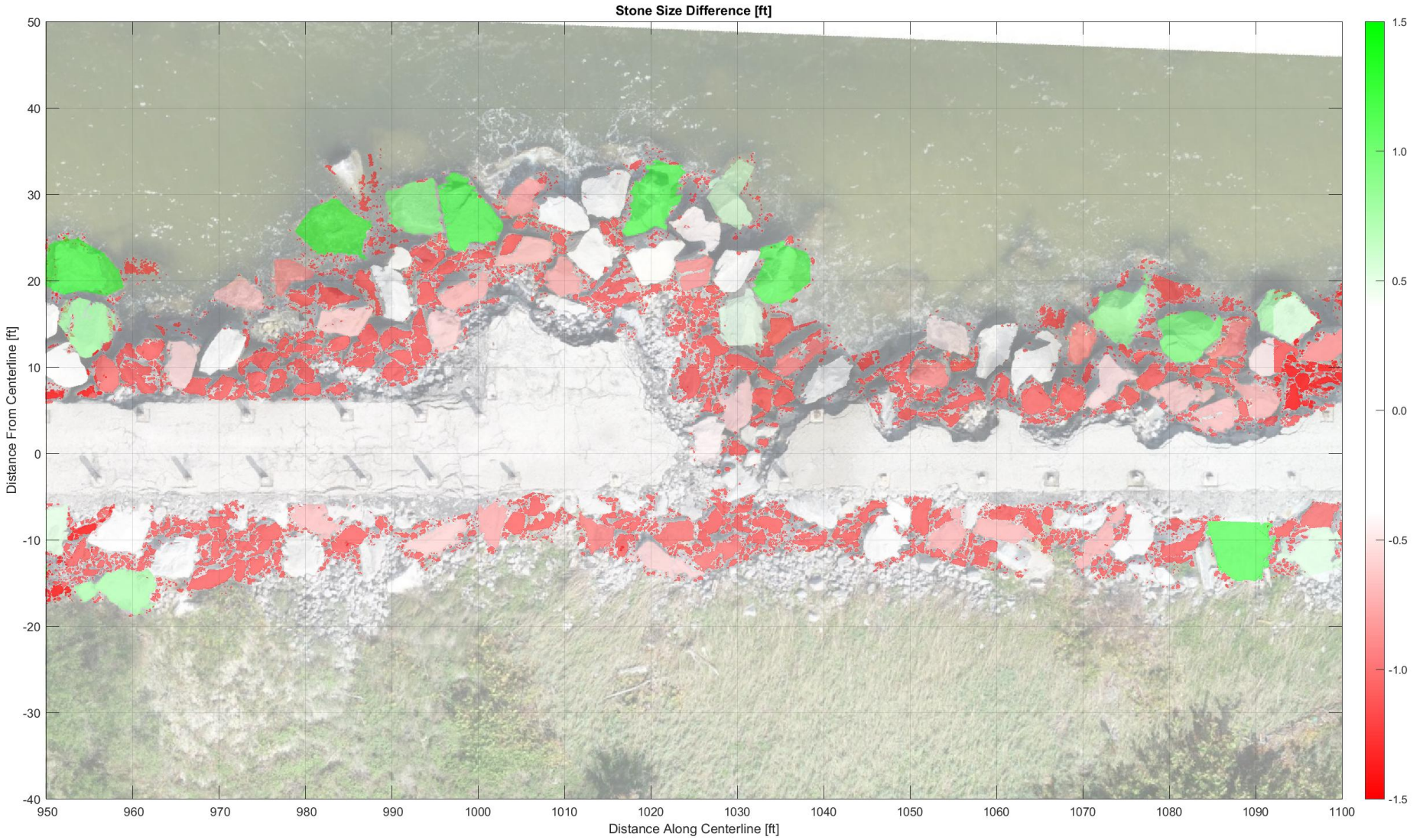
Stone Size Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
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40
30
20
10
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-10
-20
-30
-40
950
960
970
980
990
1000
1010
1020
1030
1040
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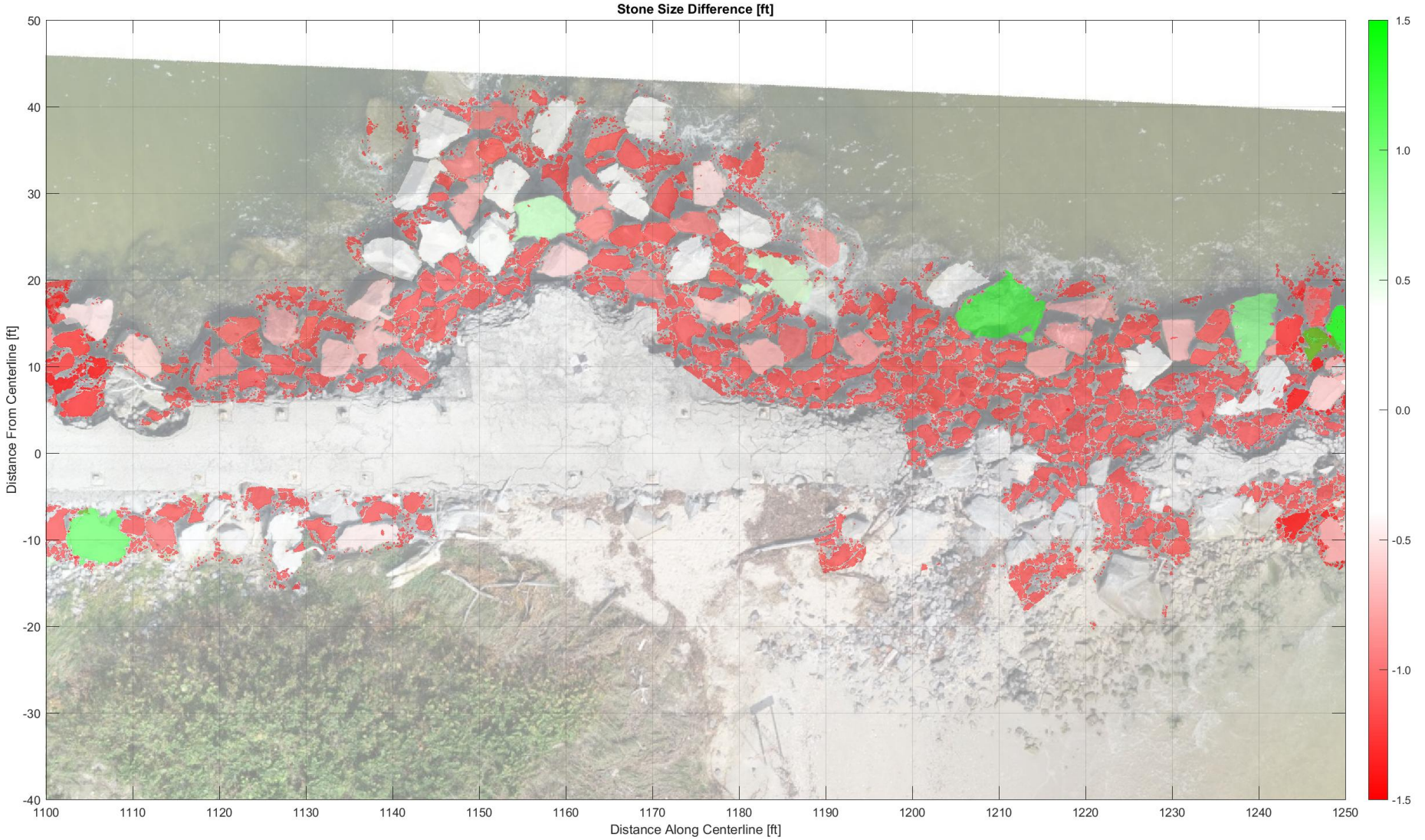
Stone Size Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
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40
30
20
10
0
-10
-20
-30
-40
1100
1110
1120
1130
1140
1150
1160
1170
1180
1190
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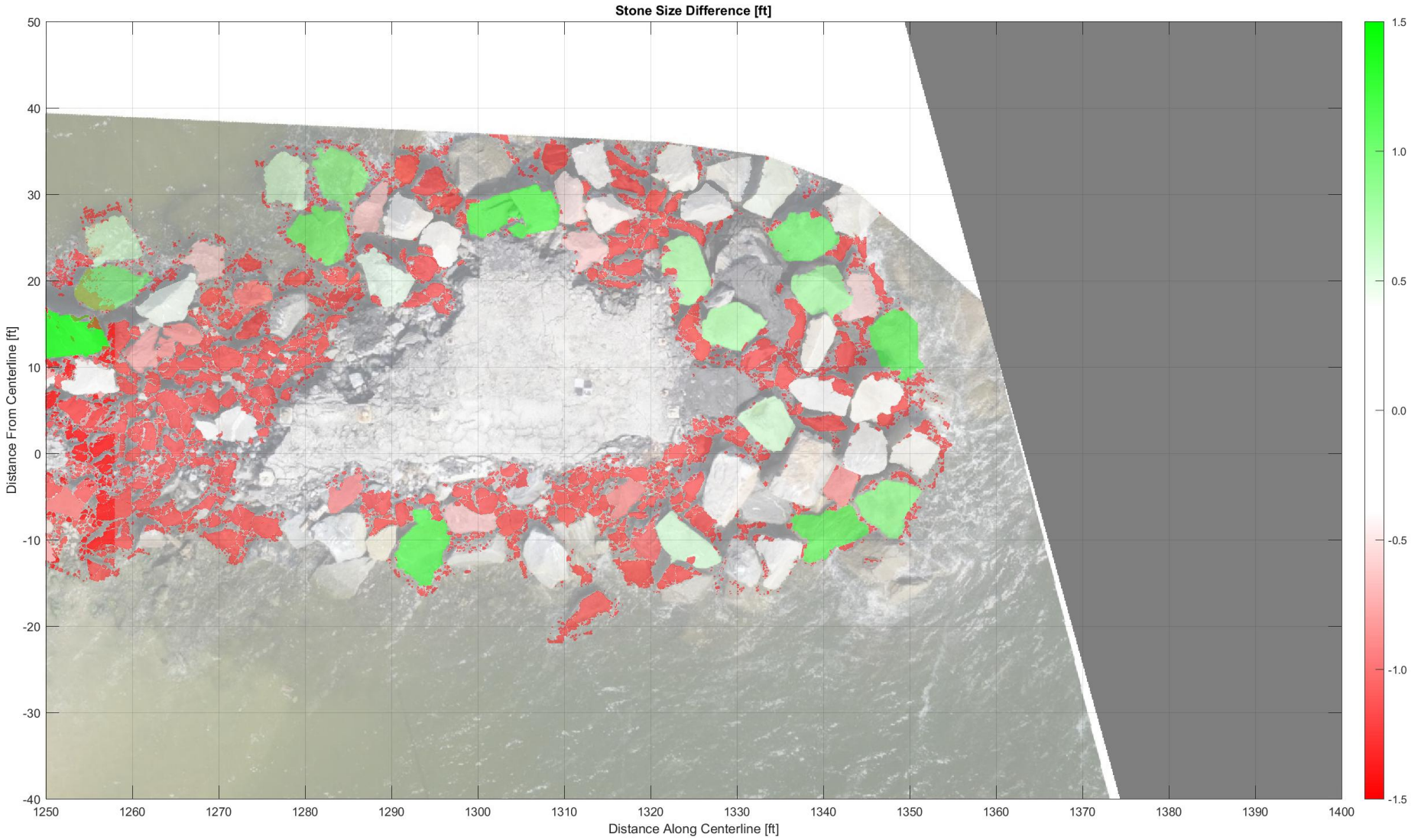
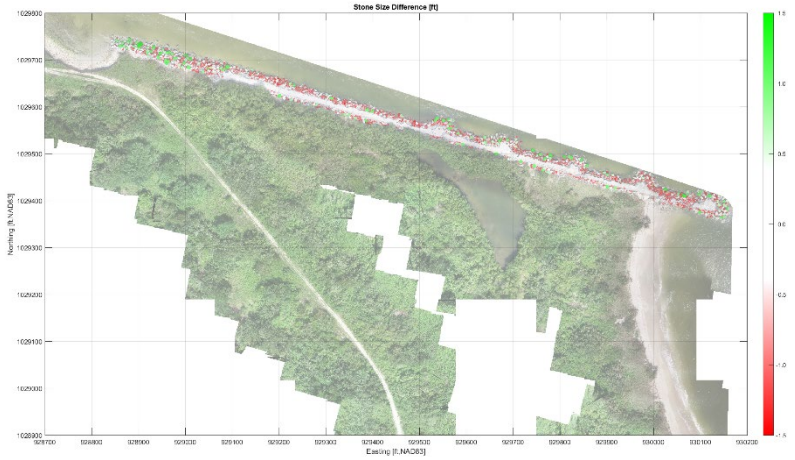

Stone Size Difference [ft]
Distance From Centerline [ft]
Distance Along Centerline [ft]
50
40
30
20
10
0
-10
-20
-30
-40
1250
1260
1270
1280
1290
1300
1310
1320
1330
1340
1350
1360
1370
1380
1390
1400
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5

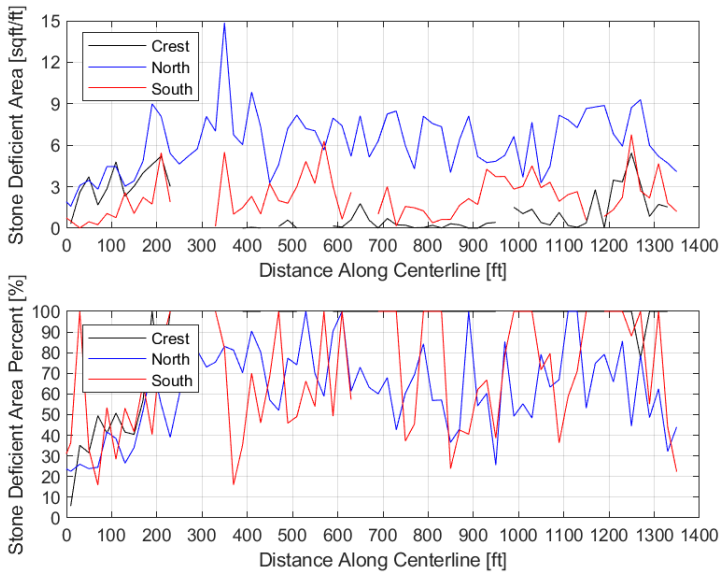
JETTY STONE COMPARISONS



› Stone Size Deficiency (sqft)

Face	Analyzed	Deficient	Percent
Crest	2,350	1,750	50%
North	14,350	8,850	62%
South	5,740	3,470	60%
Total	**22,440**	**8,950**	**60%**

› Armor stone size deficiencies were calculated for each 20-foot segment along the jetty crest and north and south jetty faces.



SUMMARY OF EXISTING CONDITIONS

- Key Observations
  - Large breach is present on seaward end
  - 85% of jetty crest is below design elevation
  - 60% of existing armor stone is undersized
  - Maintenance road has deteriorated
  - Side slopes have flattened

- Conclusions
  - Findings confirm that the structure has been damaged and is need of repair.
  - Damage may be due to structural settlement, storm forces, or a combination of the two.

CONCLUSIONS

- Improves qualitative assessment while decreasing field time.
- Potential use during construction for QA/QC.
- Still need to visit site to evaluate armor interlocking.
- Limited in mapping top-view conditions
  - Cannot be used to evaluate subsurface conditions

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THANK YOU

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